Covid-19 Vaccination and Mental Stress within Diverse Socio-demographic Groups

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Abstract: In this study, we surveyed over 600 participants to determine: a) major causes to mental stress during the pandemic and its future impacts, and b) diversity in public perception and acceptance (specifically for children) of Covid-19 vaccination. Statistical results and intelligent clustering outcomes indicate significant relationships between sociodemographic diversity, mental stress causes, vaccination perception, and Covid-19 infections. For instance, statistical results indicate significant dependence between mental stress due to Covid-19 and gender ($p = 1.7e\text{-}05$). Over 25% of males indicated work related stress comparing 35% in females however, females indicated more stressed (17%) due to relationships comparing to males (12%). Around 30% of Asian/Arabic participants don't feel vaccination being safe as compared to 8% of white-British and 22% of white-European indicating significant dependence ($p = 1.8e\text{-}08$) with ethnicity. More specifically, vaccination acceptance for children is significantly dependent to ethnicity ($p = 3.7e\text{-}05$) where only 47% participants show willingness towards children's vaccination. Primary dataset in this study along with experimental outcomes identifying sociodemographic information diversity with respect to public perception and acceptance of vaccination to children and potential stress factors might be useful for public and policy makers to be better prepared for future epidemics as well as working globally to combat mental health issues and running more effective vaccination campaigns.

Keywords: Mental stress Covid-19; Covid-19 vaccine dataset; Vaccine sociodemographic; Vaccine acceptance rate; Vaccine perception

1. Introduction

Coronavirus disease which resulted to 2019 pandemic and hence the name Covid-19, has infected more than 4.5 million people in the UK and more than 175 million worldwide as of June 2021 causing around 3 779 000 deaths [1].   Majority of the people experience mild symptoms, however there is large number of patients who develop severe symptoms related to respiratory issues and required hospitalization [2].

Covid -19 also known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and is a new strain of coronavirus that has not been known to humans previously [3]. During 2020, Covid -19 caused significant interference to daily life because of unavailability of required vaccine or known treatment strategies. Governments around the world have been introducing and depending upon various policies such as quarantine measures and social distancing to control the infection and hence support healthcare systems [4].

Deterioration of economy as well as the isolation as results of the pandemic have inevitably increased stress among populations [5]. Due to the living with fear of being infected and death because of SARS-CoV-2 among people, researchers have indicated that many psychological problems are likely to be increased including depression, panic, and anxiety [6] [7] [8]. In addition, changes in people's work pattern, environments, and lifestyle have significant effects on mental health [9] and could have negative effects such as reduced work abilities [10]. As such Covid-19 could be linked with various stress responses known as Covid Stress Syndrome in which Covid Stress Scales (CSS) has been

utilised to measure its severity and was introduced by Taylor et al. [11]. The authors assured its validity and reliability using USA and Canadian data samples. This measure defined in five factors including fears of socioeconomic consequences, danger and contamination fears, compulsive checking and reassurance seeking, traumatic stress symptoms, and xenophobia. The authors concluded that with the end of this pandemic, various mental health requirements will be emerged within the society.

While the long-term solution for an effective reduction in the number of cases and deaths due to SARS-CoV-2 is to provide globally accessible Covid-19 vaccination programme [12]. It should be noted that such solution can only be effective when it is widely used and accepted allowing global immune protection. Studies have been reporting the vaccination hesitancy which causes major issue to the successfulness of the governments' vaccination programs. Hesitancy of being vaccinated and its effects on people acceptance have identified various factors in this respecting including demographic, socioeconomic, and religious beliefs [13]. There are various studies investigating the acceptability of the Covid-19 vaccination. Reiter et al., [14] [15] indicated that most of the participants are willing to take the vaccination while Malik et al., [16] indicated differences in the acceptance of vaccination as a result of the demographics and geography diversity. Similar outcomes are also reported by Antoinette et al., [13] from US as well as Kumari et al., [17] from India, while Maraqa et al., [18] survey on healthcare workers in Palestine indicated that only 37% of the participants are intending to take the vaccination.

Another important aspect related to vaccination is its perception in public. Studies have found that those who consider Covid-19 as a threat, engaged more with the efforts to prevent being affected by the disease including social distancing, handwashing and wearing masks [19]. Malik et al. [16] investigated the relationship between the risks of disease perceived by individual and willingness to take the vaccination. Their analysis indicated that those who rate the disease as having high risks are most likely accepting to take the vaccination. Likewise, Glöckner et al. [20] on a surveyed German population reported that those who consider high likeliness of being infected by Covid-19, are most likely to be vaccinated. Similar work is carried out by Adams et al. [21] who surveyed 5082 young adults in the age range of 18 to 25 with the intention to receive Covid 19 vaccination. Their results indicated that majority of unvaccinated participants indicated willingness to be vaccinated, while those who rejected to be vaccinated reported various causes for rejection such as desire to wait and monitor vaccination safety, concerned due to side effects, and the thoughts of others could need the vaccination more. However, it would be useful to further investigate the demographical distributions of vaccination acceptance and perception specifically, its acceptance for the children which is lacking in the existing works.

Studies have also been reporting variety of side effects due to Coivd-19 vaccination mainly including tiredness, pain in muscle, fever, fatigue, headache, tenderness, and chills [22]. Quiroga et al. [23] investigated the side effects of Covid-19 vaccination with 708 nephrologist participants. The major side effects reported were included local reaction, myalgia, tiredness, and headache (represents 34%). Likewise, several works have also been addressing the mental stress and mental health issues due to the pandemic on children. For instance, a report published by the Unisef in 2020 indicated that there are possible implications of indirect and mental health issues as a result of closing the schools during the pandemic [24]. Similarly, several studies indicated that young children revert to the extensive use of electronic gadgets, sleep pattern disorder, unhealthy and poor diets which could lead to post traumatic stress disorder [25] [26] [27]. Recent study by Agarwal [28] reported the impact and stress of Covid-19 in the Indian society. The author indicated that the healthcare workers including nurses and doctors are on a continues frontline fight by mass testing, care to patients admitted to hospitals and the extra unpaid working hours. While students face stressful and anxiety measures due to the worries about completing their degrees and online examinations. The author also reported that farmers are the most hit by the pandemic since the ongoing lockdown measures knowing showed difficulties

to transport their harvest crops to the local markets and hence their saving is constantly shrinking.

While the existing studies have been investigating various aspects related to Covid-19 impacts, pandemic, vaccination perception, its acceptability and side effects, there are several limitations with these studies particularly, publicly available responses (i.e., dataset) covering multiple aspects of sociodemographic diversity, mental stress causes with respect to demographic diversity, vaccination perception and acceptance, and other social and psychological aspects which are addressed in this study and dataset we produced. We furthermore conduct experiments using intelligent clustering algorithms and statistical tools to investigate the following research questions (RQ):

RQ₁: What are the major causes of mental stress during Covid-19 period and how they affected people within diverse sociodemographic backgrounds? *RQ₂: How vaccination is perceived and accepted for family and children in public with diverse sociodemographic attributes?*

Major contributions of the proposed works include: a) Primary dataset comprising variety of aspects mainly related to major causes to mental stress due to Coivd-19 vaccination, its acceptability and perception within the diverse sociodemographic groups, b) Multi-attribute analysis to investigate dependence between sociodemographic factors, vaccination types, acceptability for children, and mental stress causes, c) Utilization of intelligent visualizations beyond the conventional statistical tools to investigate the complex relationships within multi-attribute dataset.

2. Materials and Methods

The proposed research mainly focuses the mental stress analysis, perceptual and social aspects (specifically, vaccination acceptance for children) with respect to Covid-19, pandemic, and vaccination while utilising a primary dataset comprising sociodemographic diversity within the UK. We deploy statistical tools and machine intelligence for effective visualization and investigation of outlined research aspects described in the following sections.

2.1. Primary Dataset Acquisition

We present a primary dataset collected from 600 participants using online survey. The information is collected following the ethical approval form the Liverpool John Moores University (*Ethical approval reference:21/CMP/002*). Participants are approached using random sampling via online platforms and social networks. Figure 1 demonstrates the sequential workflow of data collection in the proposed study in which, following the ethical approval, participants were invited via social and academic networks. All participants were agreed to informed consent before proceeding to survey questions. The survey questions are structured following the recommendations of clinical experts and academic researchers. The questionnaire comprises four major aspects that include information about sociodemographic aspects, Covid-19, pandemic, and vaccination. The aim is to collect information form randomly selected adult participants in relation to major causes to mental stress and social challenges due to Covid-19, pandemic, and vaccination while considering the sociodemographic diversity. 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 are collected including mental stress recovery, social activities, social media interaction, online shopping, and safety measures etc., which might be useful for the related community and global policy makers. The survey data is stored on LJMU secure data repository.
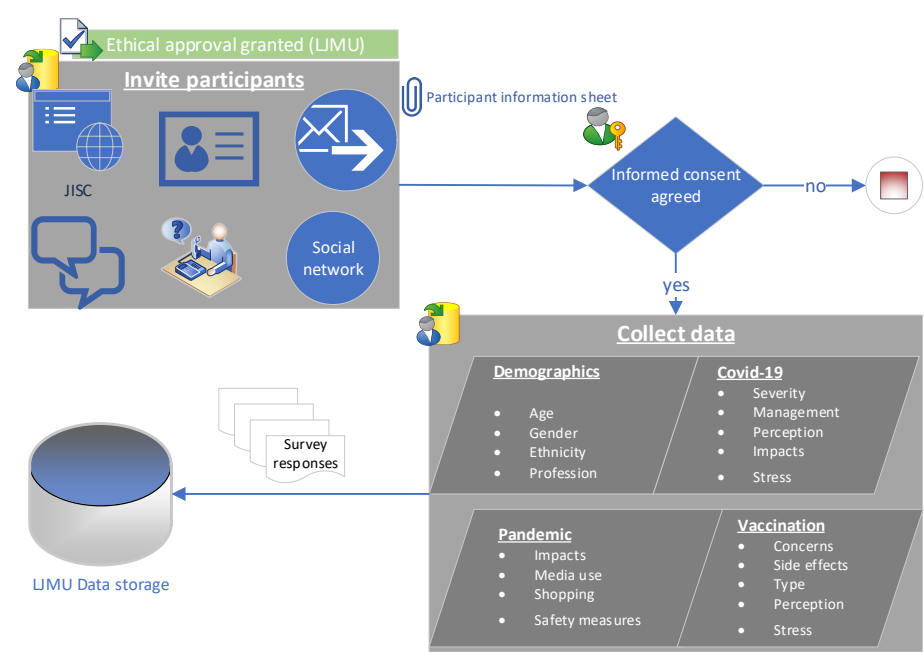
Figure 1. Sequential procedure for primary data collection, ethical process, survey contents, and information storage.

Table 1 summarises the distributions of responses for the major survey questions in relation to sociodemographic, vaccination, pandemic, and Covid-19. Complete set of questions and histograms of corresponding responses are presented in Supplementary S2 while dataset (in CSV format) is presented in Supplementary S3. The collected dataset contains 600 unique responses comprising sufficient representations for gender, profession, ethnicity, and normally distributed age groups. Over 67% participants feel they are being stressed due to Covid-19 impacts on various aspects of their routine life. The major causes to mental stress reported include work, pandemic, Covid-19 infection, childcare & school closures, and negative impact on relationships. On the other hand, common activities reported to control the stress level include speaking to family and friends, watching TV and movies, engagement in hobbies, sports activities and use of social media. While 47% participants think that vaccination reduced their mental stress, 33% reported no reduction while 20% do not know about this. It is also important to note that most of the participants responded positive to vaccine acceptance for themselves and family (75% and 80% respectively), however, the acceptance rate reduced substantially to 47% for the children while 5% indicate no acceptance at all. The common vaccination side effects include tiredness, muscle pain or swelling, headache, aches or chills, fever, and nausea. Furthermore, we asked for additional information (i.e., survey questions) that include social interactions, future safety measures, previous illnesses, online shopping, Covid-19 severity, and management. The variations in responses presented in Table 1 and complex relationships between different aspects including sociodemographic diversity, vaccination and Covid-19 attributes is needed to be further investigated as outlined in the proposed RQs.

Table 1. Distribution of public responses (i.e., attributes) to outlined survey questions. Detailed visualisations of attribute distributions are presented in Supplementary S2

Attribute	n(%)	Attribute	n(%)	Attribute	n(%)
Ethnicity		Profession		age-Group	
- Asian/Arabic	146(24)	- Education	284(47)	- Under 20	12(2)
- white-British	386(64)	- Medical	107(18)	- 21-30	68(11)
- white-EU	51(8)	- Other	209(35)	- 31-40	113(19)
- Other	17(3)			- 41-50	156(26)
safe-Vaccine		stress-reduced		- 51-60	137(23)
- yes	507(84)	- yes	283(47)	- 61-70	81(14)
- no	93(16)	- no	198(33)	- Over 70	33(6)
		- don't know	119(20)		
Gender		stress-Covid		stress-causes	
- male	252(42)	- yes	402(67)	□ Work	203(48)
- female	348(58)	- no	198(33)	□ Pandemic	183(43)
				□ Covid (infection)	152(36)
				□ Childcare/School	105(25)
				□ Relationships	92(22)
type-Vaccine				□ Other	54(12)
- None	123(20)			□ Finance	46(11)
- pFizer-BioNtech	180(30)			□ Studies/perf	42(10)
- Oxford-AstraZeneca	290(48)			□ Vaccine	39(9)
- Other	7(1)				
side-effect-Vaccine		Stress-Manage		shopping-Online	
□ Tired	228(47)	□ Speak to family	242(40)	- yes	396(66)
□ Muscle-Pain/Swell	184(38)	□ Watch TV etc.	203(34)	- no	204(24)
□ Headache	175(36)	□ Engage in hobbies	178(30)		
□ Chill/Aches	166(34)			Social media time	
□ Fever	106(22)	□ No stress	123(20)	- yes	577(96)
□ None	95(20)	□ Sports/games	111(18)	- no	23(4)
□ Strange feeling	52(11)	□ Other	83(14)	stress-Shopping	
□ Nausea	48(10)	□ Social media use	79(13)	- yes	350(58)
□ Dizziness	36(8)			- no	250(42)
accept-Vaccine		concerns-Vaccine	93 (15)	Future SOP	
□ Yourself	451(75)	□ Side effects	70(67)	□ Mask wear	328(55)
□ Children	283(47)	□ Other	33(32)	□ Social distance	291(48)
□ Family	483(80)	□ Personal beliefs	15(14)	□ Tier response	197(33)
□ None	32(5)	□ Allergic	9(8)	□ No restriction	167(28)
□ Don't know	37(6)	□ Needle-phobia	4(4)	□ Lockdown	81(13)

2.2. Data preparation

Public responses per question are transformed to data frames comprising questions as attributes (i.e., columns in Table 1) and user responses as data samples (see the dataset file in Supplementary S3). The dataset contains binary (yes/no), ordinal (e.g., age group), and multi-nominal (e.g., profession) attributes. To employ the statistical and visualization tools effectively, we transformed the dataset into required form specifically, the multi-choice questions such as side effects where user can select more than one option. For this purpose, we employed one-hot key encoding (i.e., dummy coding) to transform the multi-choice and multi-nominal attributes into binary categories where appropriate. For example, stress-Cause in Table 1 comprising 9 categories can be transformed into 9 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, visualisations, and statistical tools, for discrete level investigation of complex patterns within the data, inter-relationships between multiple attributes, and lower dimensional visualizations of relationships that are easily understandable by humans.

2.3. Statistical Analysis and Visualisations

Based on proposed RQs and type of dataset, we employ multi-correspondence analysis (MCA), test of independence (i.e., Chi-square test), and self-organising maps (SOM), to analyse the complex relationships between multiple attributes and visualize the patterns in lower dimensional space. On the other hand, MCA is one the powerful exploratory multivariate tool to visualize the inter-relationships between multiple categorical attributes. Technically, MCA uses the standard correspondence analysis producing proximities in low dimensional map. The eigenvalues generated through single value decomposition can be used to identify the principal components that are used to visualise the attributes' correspondence in lower dimensional map. Further information about mathematical formulation and applications of MCA can be found elsewhere [29].

While the MCA are useful to show the correspondence between multiple attributes, the simultaneous visualisation of all principal components is impractical for humans' visual interpretations. For this purpose, we employ the supervised self-organising maps (SOM) which are established for their powerful visualizations of multidimensional data and complex patterns in lower dimensions (usually, two dimensional) maps. The topological properties of input data are preserved within the competitive learning used by SOM in contrast to error minimization approaches in other types of neural networks. Data samples (i.e., participants' responses in our study) are recursively projected to SOM to determine the best matching unit (i.e., winning neuron) based on the distance from its weights and the input sample (i.e., one row from the dataset). The weight update is performed for a predefined neighborhood radius which results grouping of similar samples within winning neuron and its neighborhood neurons using:

$$w\_j\,(n+1) = w\_j\,(n) + \eta(n)\,h\_{ji}(x)\ \ (n)\ [\![(x(n) - w]\!]\_j\,(n))\,(1)$$

Where, $\eta(n)$ is the learning rate and $h\_{ji}(X)$ (n) is the neighbourhood function around the winner neuron $i(x)$ in equation (1). Both, $\eta(n)$ and $h\_{ji}(X)$ (n) vary dynamically to achieve optimal results. While the dataset is in categorical form, the one-hot encoding of attributes preserve the numerical property of data as required for the competitive learning-based clustering algorithms. Further explanation and mathematical formulation of SOM can be found elsewhere [30].

3. Results and Discussions

Experiments are conducted using the processed dataset, statistical tools, and visualization algorithms to investigate outlined research questions and corresponding hypothesis. It can be notice that the dataset covers variety of other aspects (see Supplementary S2) in addition to attributes presented in Table 1 which are beyond the scope of analysis presented in this study. We mainly focus two major research aspects in this work (see RQs) to investigate the dependence between sociodemographic diversity, major causes to

mental stress, vaccination perception and acceptability. Detailed statistical outcomes and visualisations for each RQs are presented as follows.

3.1. Mental Stress causes

Various causes to mental stress are reported by the participants (see Table 1) mainly including work, pandemic, Covid-19 infection, vaccination, relationships and so on. However, it would be useful investigate the variations within the public responses with respect to sociodemographic diversity. To analyse the variation in stress causes with respect to sociodemographic diversity, we set up following hypothesis:

H_0_1: Sociodemographic *diversity is independent to mental stress causes due to Covid-19 infection and its effects;* **H_1_1:** *Sociodemographic diversity is dependent to stress causes due to Covid-19 infection and its effects*

It can be noticed from Table 1 that work, pandemic, Covid-19 (infections) and school closures are reported as major causes to mental stress within the public responses. However, these might vary with respect to sociodemographic diversity for which, we employed the 'contrib measure' representing the variable categories contributing to each dimension of MCA. A larger 'contrib' value indicates better explaining (or defining) the variability in dataset for that dimension and vice versa.
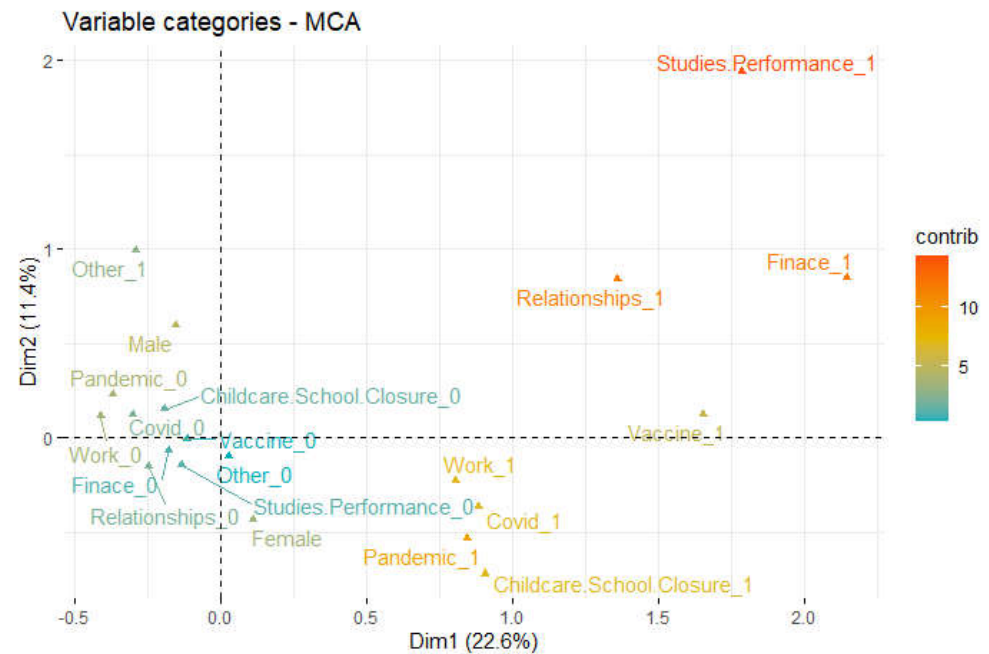

Figure 2. MCA outcomes (1st two dimensions) indicating gender correspondence to major stress causes reported in public responses. Closer the attributes, higher the correspondence and vice versa. Green to red 'contrib' colour scale indicates the contribution level being low to high respectively for corresponding dimension of MCA.

3.1.1.   Gender

Existing studies such as [29] [30] reported the significant differences in Covid-19 infection and mortality rate in cross gender. Males are being more effected as compared to females [30] [31]. However, these works lack the investigation of differences between males and females with respect to major stress causes such as pandemic, Covid-19, and vaccinations effects etc.

Figure 2 shows the first two dimensions of MCA retaining 34% of the total inertia (variation) contained in the data. The variations between males (top left quadrant) and females (bottom right) groups indicate the difference in responses as well as relationships to mental stress causes. For instance, working females indicated more stress due to several factors such as school closures and pandemic, as compared to male participants who

correspond to 'other' factors. It can also be observed that work, Covid-19 (infection), pandemic, and child closure are very close to each other within the plot (Fig. 2) which shows their inter-relationships as well as with correspondence to gender (and mainly females).
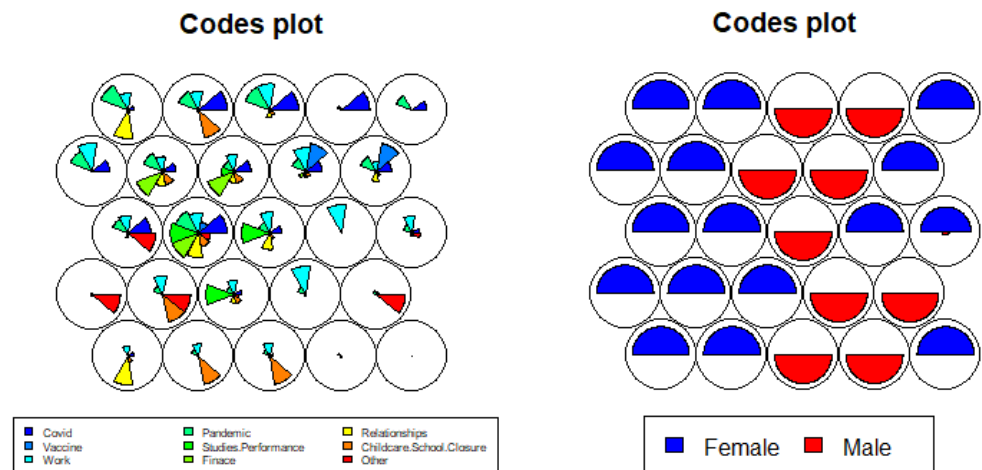

Figure 3. SOM code plot for two-dimensional visualisation of inter-relationships between multipl causes to mental stress (left side plot) within the dataset and participants' gender (right side plot).

Despite MCA outcomes in Fig. 2 provides better visualisations of variables' distributions and correspondence, we require additional dimensions to perfectly represent the data which is impractical with visualisations tools such as MCA. Alternatively, SOM provides an efficient way to represent multiple factors as well as corresponding distributions useful to analyse the inter-relationships and complex patterns as shown in Fig. 3. It can be observed that 'relationships' attribute indicates high occurrences in the female group as compared to males while Covid, pandemic and work appeared regardless of gender. The childcare/school closure indicated high correlation with females comparing males.

Furthermore, SOM heatmap produces individual relationships between these attributes as shown in Supplementary S1 (see Fig.1.S1). It clearly indicates the high appearances of child school closure (left side of heat map) and relationships within females as compared to male groups. On the other hand, both groups indicated similar behaviour for being mentally stressed by Covid, pandemic and work.

3.1.2. Age groups

Similar to different Covid-19 infection rate within different age group reported in a recent study [29], we identified that stress causes reported in Table 1 also varies with respect to age groups. It is important to note in Fig. 4 that older age groups (60 to 70, 70+) and under 20 participants indicate weak relationship with common causes of mental stress in contrast to middle age groups who are grouped together mainly with attributes including pandemic, work, Covid and relationships. This indicates that middle age working class population mentally stressed mainly due to school closure, pandemic, and relationships which is not the case with younger and older age groups. However, young participants (20 to 30) indicate substantial correlation with studies and performance that potentially, represents students. This also algins with the research outcomes reported in [32] indicating the impact of effectiveness of vaccination, and pandemic on students' performance. Specifically, perception of vaccination in students has a positive impact on acceptance of e-learning platforms. Further detailed visualisation for individual age groups is available in Supplementary S1 (Fig.2.S1).
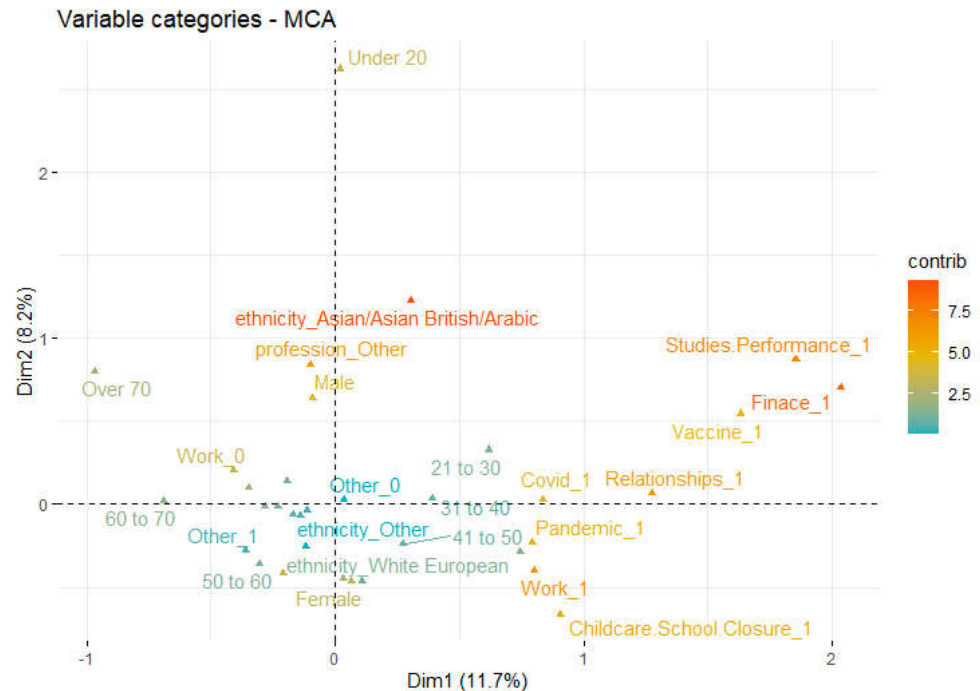
Figure 4. MCA outcomes (1st two dimensions) for the combined visualisation of major stress causes and sociodemographic attributes (ethnicity, profession, gender, and age groups)

The SOM codes plot for relationships between participants' age groups and major stress causes is shown in Fig.3.S1 which clearly indicates a minor representation of mental stress factors for younger and older groups that also aligns with the MCA outcomes in Fig. 4. In contrast, participants with age group 31 to 40 indicate more concerns due to studies performance and work while middle age (41 to 60) are strongly inter-related to Covid, work, school closure & childcare, and pandemic.

3.1.3.   Ethnicity

The dataset comprises substantial representations of diverse ethnic groups listed in Table 1. Figure 4 and Fig.4.S1 (in Supplementary) show the visualisation of first two components (retaining 30% of the variance) for stress causes and ethnicity. Distinguishing responses are noticed from different ethnic groups in relation to stress causes. For instance, the Asian/Arabic group indicates minor stress due to work, pandemic, childcare/school closure as compared to white European and White British population. In contrast, they indicated partial relationship with vaccine and 'other' factors (see dataset).

These outcomes align with the SOM based visualisations shown in Supplementary S1 (Fig.5.S1, Fig.6.S1) indicating independence between Asian/Arabic participants and causes to mental stress due to Covid-19 infection, studies/performance, childcare/school closure, and relationships (*p>0.05*). In contrast, white British and white EU groups indicated strong associations with these factors. On the other hand, both Asian/Arabic and white British groups indicated vaccine as one of the stress causes whereas, substantial proportion of Asian/Arabic population showed finance, vaccine and 'other' factors as major causes of stress.

3.1.4.   Profession

Figure 7.S1 (in Supplementary S1) demonstrates 31% of the variance retained in first two dimensions of MCA. While both groups (i.e., medical and academic professionals) indicated almost similar correspondence to Covid-19 infection, pandemic, and work, people from medical profession indicated comparatively less correspondence to these factors as compared to academic professionals specifically, in case of and childcare/school closure. On the other hand, people in 'other' professions indicated high correspondence to

'other' stress causes as shown in Table 1. These outcomes align with SOM code plots shown in Fig. S8, indicating interrelationships between profession and stress causes. Similar to MCA, it indicates string correlation between academic professionals and childcare/school closures as compared to participants from medical and other professions.

Table 2. Statistical significance of relationships between major causes to mental stress reported in dataset and sociodemographic diversity

	Childcare & School Closure			Work			Vaccine			Pandemic		
	X^2	Df	p-value	X^2	df	p-value	X^2	Df	p-value	X^2	df	p-value
Ethnicity	4.9	3	0.11	5.8	3	0.12	19	3	0.0002	4.5	3	0.21
ageGroup	88	6	2.2e-16	38	6	9.4e-07	11	6	0.08	12	6	0.06
gender	5.3	1	0.02	1.8	1	0.17	0	1	1	5.7	1	0.01
profession	3.6	2	0.12	15.6	2	0.0003	2.3	2	0.3	1.9	2	0.3

	Relationships			Stress_Covid			Finance			Studies/ performance		
Ethnicity	6.9	3	0.07	6.9	3	0.07	18.4	3	0.0003	21	3	0.00001
ageGroup	10.4	6	0.1	16	6	0.01	11.7	6	0.06	45	6	4.2e-08
gender	1.9	1	0.15	21.4	1	3.5e-06	0	1	1	0.8	1	0.3
profession	0.6	2	0.7	17.6	2	0.0001	7.5	2	0.02	2.6	2	0.2

While above MCA and SOM based visualisations are useful to understand the diversity of stress causes with respect to sociodemographic factors, we further employed Chi-square test of independence to analyse the statistical significance between these factors and stress causes. Table 2 shows the detailed statistical outcomes in relation to investigate the inter-dependence and statistical significance of sociodemographic factors and stress causes. These outcomes further support the investigation of hypothesis (**H_0_1, H_1_1**) and therefore, argument set in RQ_1. It can be observed from the statistical outcomes in Table 2 that childcare/school-closure indicates the significant dependence with ageGroup and gender with *p=2.2e-16≈0* and *p=0.02* respectively. This outcome aligns with the SOM and MCA based visualisations and outcomes (as shown in Fig. 2, Fig. 3, Fig. 4) indicating females and middle age populations reporting childcare/school-closure as one of the major causes of mental stress due to Covid-19 and its impacts. On the other hand, ethnicity and profession did not indicate significance (*p>>0.05*) which also aligns with the SOM and MCA based visual analysis.

In relation to work, pandemic, stress_Covid, finance, and studies/performance, several demographic factors indicate significant dependence which also aligns with the SOM and MCA based outcomes. For instance, profession and ageGroup are significantly dependence with work (ageGroup: *p≈0*, profession: *p=0.0003*) while gender indicate significant dependence with pandemic (*p=0.01*). Similarly, stress_Covid is significantly dependent to gender *(i.e., p≈0)*, profession *(p=0.0001)*, and ageGroup *(p=0.01)*; indicating mental stress varies with respect to sociodemographic factors that aligns with the MCA based outcomes in Fig. 4 which indicates discrete level correspondence between sociodemographic and factors to mental stress.

In summary, the aforementioned statistical outcomes with (*p<0.05*) and visualisation patterns clearly validate the rejection of **H_0_1** and indicate significant relationships between sociodemographic diversity and several causes to mental stress as listed in Table 2.

3.2. Vaccination acceptability and perception

Research have been reporting varying public perception in relation to Covid-19 vaccination, acceptability and perception. Authors in [33] reported the significant impact of misinformation on vaccination acceptability in the UK and USA. Several studies indicated children being affected by the Covid-19 and are the potential drivers of Covid-19 spread in general public [34]. Likewise, authors in [35] highlighted the risk of increased vulnerability to vaccine-preventable diseases due to reduction in children vaccination. However, the acceptability of children vaccination at current stage is a major challenge. Some recent studies such as [36] highlighted the arguments addressing the advantages and risks for children vaccination. Authors addressed the existing arguments in support of delaying children vaccination as well opposite, effectiveness indicated by medical experts about children vaccination in previous studies. Likewise, work presented in [37] hypothesised that measles, mumps, and rubella vaccine is effective for children however, these studies are not supported by the experimental analysis or public opinions. Alternatively, we believe that the perception about vaccination specifically, for the children, is highly associated to sociodemographic diversity.

Table 1 and Supplementary S2 (Q13 to Q20) demonstrate overall distribution of public responses regarding vaccination concerns (e.g., feeling safe if vaccinated) as well as acceptability (e.g., acceptance for family, children etc.). Around 15.5% of the total participants (i.e., 93 participants) do not feel safe being vaccinated. Most of them (67.3%) show the side effects as major concern while 31.7% and 14.4% reported 'other' factors and 'personal beliefs' respectively as major concerns regarding the vaccination. Similarly, the acceptability of vaccination varies in public responses. Majority of participants responded acceptance of vaccination for their family and themselves (80.5% and 70.2% respectively) while it reduced to 47.2% only for the children. However, little proportion (32 participants, 5.3%) responded with no acceptance. To investigate the varying distributions of responses in relation to sociodemographic diversity and vaccination perception, following hypothesis is set.

H₀_2: *Sociodemographic diversity is independent to vaccination acceptance in public.* **H₁_2:** *Sociodemographic diversity is significantly dependent to vaccination acceptance in public.*
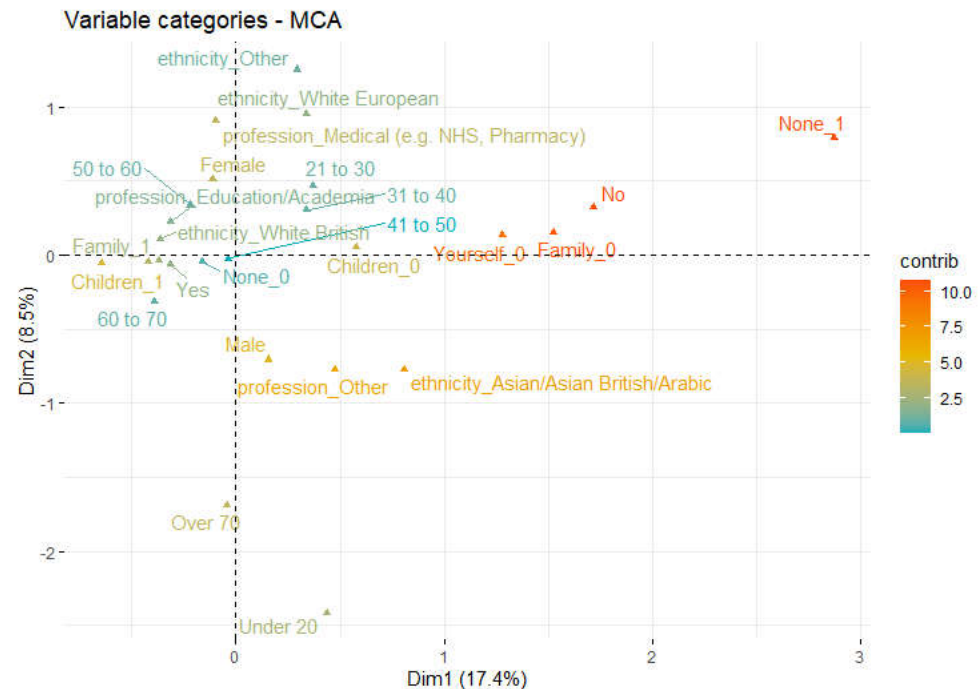

Figure 5. MCA outcomes (1st two dimensions) for the combined visualisation of vaccination acceptance and sociodemographic attributes (ethnicity, profession, gender, and age groups)

Similar to mental stress causes, we employed MCA and SOM for the visual analysis of multi-attribute distributions and identification of complex patterns for vaccination perception and acceptance with respect to sociodemographic attributes. Figure 5 summarises the vaccination acceptability and perception within diverse sociodemographic groups represented by MCA two components retaining 26% variance. It can be noticed that participants representing 'other' profession and Asian/Arabic backgrounds tends towards less acceptance of being vaccinated as compared to white-British from academic and medicine professions. Likewise, males indicate more correspondence to 'no acceptance' as compared to female participants.

Figure 9.S1 and Fig.10.S1 (see Supplementary S1) represent the SOM codes plots indicating the diversity in public responses about feeling safe if being vaccinated. It is important to note that despite most of the participants (84.5%) feel safer being vaccinated, *the acceptance rate for the children being vaccinated is comparatively higher in white-British than Asian/Arabic and 'other' ethnic groups.* Similarly, acceptance to 'None' (i.e., complete rejection of being vaccinated) appears mostly for the Asian/Arabic and white-European ethnic groups which is not the case for majority of white-British group.

Likewise, Fig.11.S1 and Fig.12.S1 (see Supplementary S1) show the distributions of vaccination acceptance with respect to profession. It can be observed that responses from 'other' professions are highly correlated to 'None' (i.e., rejection to being vaccination) as compared to academics and medical professionals. *The acceptance for children is comparatively higher in academic professional than individuals in medical and 'other' professions.* Furthermore, vaccination perceived as 'not safe' is associated with 'other' professionals as compared to people in academia and medical professions.

Table 3. Statistical significance of relationship between sociodemographic attributes, vaccination acceptability, and its perception

	Safe Vaccine		Vaccine Acceptance							
			Yourself		Children		Family		None	
	X^2	p	X^2	p	X^2	p	X^2	p	X^2	p
ageGroup	22	0.0009	10	0.1	23	0.0005	7	0.34	9	0.16
gender	0.01	0.91	13	0.7	0.8	0.35	3.8	0.05	0.1	0.7
profession	12	0.002	20	4e-05	20	3.7e-05	19	6.3e-05	9	0.01
ethnicity	38	1e-08	48	2e-10	35	1.1e-07	31	7.8e-07	17	0.0007

For the statistical significance, we employed Chi-square test of independence between sociodemographic factors and vaccination acceptance in public responses. It can be noticed in Table 3 that dependence between ethnicity and vaccination acceptance is significant ($p<0.05$ in all cases). Similarly, there is a significant dependence between ethnicity and feeling safe (if vaccinated) *(p = 1.8e-08).* On the other hand, gender did not indicate significant dependence with safe vaccine *(p=0.9)* and its acceptability *(p>0.05 in all cases).* Profession indicates significance for both vaccination safety as well as acceptability *(p≈0).* These outcomes align with the MCA and SOM based visualisations in Fig. 5 and Supplementary information S1.

The above findings also align with similar works presented in previous studies. For instance, [33] presented the impact of online misinformation on vaccination acceptability within the UK and USA. They noticed a substantial declined in acceptance rate due to misinformation specifically, among those who were definite intend to accept vaccination before such misinformation. Furthermore, the study reported differences on impact of misinformation on vaccination acceptance between sociodemographic groups. For instance, unemployed individuals in the UK indicated less undecided about vaccination acceptance as compared to employed groups. Likewise, as compared to white ethnicity, 'other' ethnic groups and lower-income individuals were more robust to misinformation in USA. There is also religious factor indicating differences in opinion between Jewish and Christians within the UK. Furthermore, comparative to males in USA, females indicate more likeliness to decrease vaccination acceptance upon exposure to misinformation.

Global survey conducted in [38] reported significant differences in vaccination acceptance across the globe where, respondents mainly trust on government information sources about the vaccination. Many recent studies in both UK and USA have highlighted females as less likely to vaccinate than males [39] [16] [40]. However, our findings indicate independence between gender and vaccination acceptance. This may be due to several factors such as study design, demographics differences, and mainly, time of survey because effective campaigns by policy makers across the globe might have impact on public perception about Covid-19 vaccination as well as help to counter the misinformation.

In summary, the above statistical results and pattern analysis clearly validate the argument that acceptability of vaccination and its perception in public is significantly dependent to several sociodemographic diversity and therefore, **H₀_2** can be rejected. Rate of vaccination acceptance across the globe is insufficient as reported in [38] as well as statistical and visual results from proposed study. These outcomes clearly indicate the need of effective campaigns by policy makers to convince public for the vaccination uptake and compete with misinformation about vaccination.

4.   Conclusions

The proposed study aims to investigate major factors causing the mental stress due to ongoing Covid-19 vaccination and pandemics within the diverse sociodemographic groups in the UK. Detailed analysis is performed using statistical tools and intelligent pattern matching algorithm over a primary dataset acquired from 600 participants from different professions, age groups, ethnic backgrounds, and gender. Our outcomes indicated significant relationships between sociodemographic factors and major stress causes mainly pandemic, work, Covid-19, school closure, and relationships. Majority of participants (40.3%) speaks to family or friend and watch TV shows (34%) to reduce the mental stress. We furthermore observed substantial differences about vaccination perception and its acceptance within different sociodemographic groups which might be helpful understanding the variations in diverse communities. As an example, the vaccination acceptance for the children is comparatively higher in white-British than Asian/Arabic and 'other' ethnic groups. Similarly, acceptance to 'None' (i.e., complete rejection of being vaccinated) is higher in Asian/Arabic and white-European ethnic groups which is not the case for majority of white-British group. Furthermore, vaccination being felt as 'not safe' is significantly associated with 'other' professionals as compared to academic and medical professionals. Despite a substantial proportion of the participants (84.5%) feel 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. The acceptance for children is comparatively higher in academic professional than individuals in medical and 'other' professions.* This clearly indicate the need of potential vaccination campaign for the target audience.

While majority (around 58%) of the participants feel reduction in mental stress level after vaccination, it is not the case for rest of 42% which is a considerable proportion. In addition, primary dataset presented in this study include additional information related to other social factors such as online shopping etc., (see S1 for detailed survey questions and responses). The study outcomes along with primary dataset might be useful for better prepared for future epidemics, policy making as well effective campaigns by policy makers across the globe which might have impact on public perception about Covid-19 vaccination (specifically, vaccination for the children) as well as help to counter the misinformation.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available in [Supplementary S3].

Conflicts of Interest: The authors declare no conflict of interest

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