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Profiling vaccine believers and skeptics in nurses: A latent profile analysis

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ABSTRACT

Background: A tailored immunization program is deemed more successful in encouraging vaccination. Understanding the profiles of vaccine hesitancy constructs in nurses can help policymakers in devising such programs. Encouraging vaccination in nurses is an important step in building public confidence in the upcoming COVID-19 and influenza vaccination campaigns.
Objectives: Using a person-centered approach, this study aimed to reveal the profiles of the 5C psychological constructs of vaccine hesitancy (confidence, complacency, constraints, calculation, and collective responsibility) among Hong Kong nurses.
Design: Cross-sectional online survey.
Settings: With the promotion of a professional nursing organization, we invited Hong Kong nurses to complete an online survey between mid-March and late April 2020 during the COVID-19 outbreak.
Participants: 1,193 eligible nurses (mean age = 40.82, *SD* = 10.49; with 90.0% being female) were included in the analyses.
Methods: In the online survey, we asked the invited nurses to report their demographics, COVID-19-related work demands (including the supply of personal protective equipment, work stress, and attitudes towards workplace infection control policies), the 5C vaccine hesitancy components, seasonal influenza vaccine uptake history, and the COVID-19 vaccine uptake intention. Latent profile analysis was employed to identify distinct vaccine hesitancy antecedent subgroups.
Results: Results revealed five profiles, including "believers" (31%; high confidence, collective responsibility; low complacency, constraint), "skeptics" (11%; opposite to the believers), "outsiders" (14%; low calculation, collective responsibility), "contradictors" (4%; high in all 5C constructs), and "middlers" (40%; middle in all 5C constructs). Believers were less educated, reported more long-term illnesses, greater work stress, higher perceived personal protective equipment sufficiency, and stronger trust in government than skeptics. They were older and had higher perceived personal protective equipment sufficiency than middlers. Also, believers were older and had greater work stress than outsiders. From the highest to the lowest on vaccination uptake and intention were believers and contradictors, then middlers and outsiders, and finally skeptics.
Conclusion: Different immunization programs can be devised based on the vaccine hesitancy profiles and their predictors. Despite both profiles being low in vaccination uptake and intention, our results distinguished between outsiders and skeptics regarding their different levels of information-seeking engage-

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ment. The profile structure reveals the possibilities in devising tailored interventions based on their 5C characteristics. The current data could serve as the reference for the identification of individual profile membership and future profiling studies. Future endeavor is needed to examine the generalizability of the profile structure in other populations and across different study sites.

Tweetable abstract: Covid-19 vaccine hesitancy profiles of Hong Kong nurses (believers, sceptics, outsiders, contradictors and middlers) highlight the importance of tailored vaccine campaigns.

What is already known

- The 5C psychological constructs of vaccine hesitancy predict the vaccination intention of COVID-19 and seasonal influenza vaccines.
- The intention to take COVID-19 and seasonal influenza vaccines were 63% and 50%, respectively, among nurses in Hong Kong in 2020.
- Vaccine believers and skeptics are common vaccine hesitancy profiles in the literature.

What the paper adds

- The current study reveals five distinctive vaccine hesitancy profiles based on the 5C constructs. On top of believers and skeptics, we found three new profiles, namely outsiders, middlers, and contradictors.
- Our result demonstrates that outsiders were qualitatively different from skeptics in their lack of interest in the pandemic, which warrants different interventions in enhancing their vaccine acceptance.
- Our result reveals that individuals with more negative attitudes toward governmental control policies were more likely to be skeptics.

1. Introduction

One primary focus of the current coronavirus disease 2019 (COVID-19) epidemiology development is vaccination. Recent studies suggest that vaccination is very effective in driving down the transmission of the disease (Baden et al., 2021; Voysey et al., 2021), but there are also uncertainties about the effectiveness of current vaccines to current and future variants. Vaccination is an essential pathway to safely achieve herd immunity against COVID-19 (World Health Organization, 2020a), but the herd immunity equation may be affected with the emergence of variants (Kwok et al., 2021a) and vaccine breakthrough infections (Hacisuleyman et al., 2021). Latest results suggests that COVID-19 vaccination is still considered as effective for protection against moderate to severe disease and deaths from the current variants of concerns such as Alpha and Delta (Lopez Bernal et al., 2021). Effort to expanded the vaccination program and to maximize vaccine uptake rate is urged, especially for countries with relatively low vaccine uptake rate and substantial degree of vaccine hesitancy (Tang et al., 2021).

1.1. Vaccine hesitancy among healthcare workers

Vaccine hesitancy, defined as the delay in acceptance or refusal in administering vaccines despite available services (MacDonald, 2015), has been recognized by the World Health Organization as a top threat to global health in 2019 (World Health Organization, 2019). Prior studies have indicated a significant prevalence of vaccine hesitancy among healthcare workers. Studies have indicated low acceptance rate of influenza vaccine in France (54%, Wilson et al., 2020), and Hong Kong (30%, Kwok et al., 2019; 49%, Kwok et al., 2020a). The intention to administer the COVID-19 vaccine among nurses was also alarming based on results of studies from Turkey (68.6%, Kose et al., 2021), Israel (61%, Dror et al., 2020) and Hong Kong (63%, Kwok et al., 2020a). These rates of vaccination intention are relatively low compared to the global average of 74% among adults in the general population from 27 countries (Dai, 2020).

Issues of vaccine hesitancy among healthcare workers is particularly influential. Healthcare workers is one of the highest risk group during the pandemic. Protecting healthcare workers from infection is vital in the battle to the pandemic. Protecting healthcare workers from infection through vaccination also reduces the risk of nosocomial transmission (Kwok et al., 2007). In addition, healthcare workers are usually the frontline for patients to convey benefits and address concerns about novel vaccines (Danchin et al., 2020). Healthcare workers have been playing a crucial role in building public confidence in vaccines (European Centre for Disease Prevention and Control, 2015; World Health Organization, 2020b).

Vaccine hesitancy is a complex and dynamic phenomenon. The traditional one-size-fit-all approach does not appear to be effective in conveying the message for vaccination to the versatile psychological profiles. Prior studies showed that a tailored intervention program targeting specific subpopulation enhances the acceptance and uptake rate of vaccination (Kopsidas et al., 2020; Neufeind et al., 2020). Prior studies have also categorized people into vaccine believers and skeptics based on their confidence in vaccines (e.g., Chen et al., 2021; Lee and Sibley, 2020; Murphy et al., 2021). In our current study, we adopted the 5C psychological antecedents of vaccination (Betsch et al., 2018) as the theoretical premise for understanding the psychological factors underlying nurses' vaccine hesitancy, which includes confidence, constraints, complacency, calculation, and collective responsibility. We further applied the outcome for the prediction of vaccination intentions as the distal outcomes. The results would be useful for tailoring different vaccination campaigns for nurses based on different vaccine hesitancy profiles.

1.2. Research questions

In this study, we aimed to explore the psychological antecedents of vaccine hesitancy for nurses in Hong Kong, one of the most densely populated cities with frequent social connectivity among citizens (Kwok et al., 2018) under the threat of COVID-19 pandemic (Kwok et al., 2021b), using latent profile analysis (RQ1). We also investigated the predictors of the profiles (RQ2) and examined how nurses in these profiles would differ in their intention to be vaccinated against COVID-19 and their actual behavior of taking influenza vaccine in the past (RQ3).

2. Methodology

2.1. Design and procedure

The current study was a secondary analysis using the database from a self-administered online survey study on influenza vac-

cine uptake, COVID-19 vaccination intention, and vaccine hesitancy among nurses in Hong Kong (Kwok et al., 2020b). The participants were recruited through a collaborating party, the Association of Hong Kong Nursing Staff. Their participation was completely voluntary. Before the participation and access to the survey items, the participants provided informed consent on the online survey platform. The participants were given a coupon of HKD 25 as compensation upon completing the self-administered survey. The recruitment period was from 16 March to 29 April 2020. The study was approved by the Survey and Behaviour Research Ethics Committee of The Chinese University of Hong Kong (reference number: SBRE-19–251).

2.2. Participants

The members of the Association of Hong Kong Nursing Staff are registered nurses, enrolled nurses, and nursing trainees in public or private medical facilities. The current sample was representative, as over 60% of the 50,000 registered or enrolled nurses in Hong Kong were members of the association (i.e., around 30,000 nurses were invited). Nursing trainees and retired nurses were excluded in the subsequent analyses (for their risk exposure was not comparable to full-time nurses). An analysis was conducted in Kwok et al., 2020a's study to examine the extent to which the sample might deviate from the population.

2.3. Materials

The self-administered online survey was developed by the research team and comprised four sections and 79 main questions with follow-up items. Only a selection of questions and scales that were relevant to our study aims and hypotheses was included in the current study. The items tapped on demographics, including the year of birth, biological sex, education level, and the presence of chronic diseases. Variables related to their workplace included the supply of personal protective equipment, work stress, and attitudes towards workplace infection control policies. Other sections included the 5C vaccine hesitancy components, seasonal influenza vaccine uptake history, and the COVID-19 vaccine uptake intention. Scales and items included were either well-validated or used in our previous studies (e.g., Kwok et al., 2019; Kwok et al., 2020b).

2.3.1. Psychological antecedents of vaccine hesitancy

We adopted a 15-item scale for measuring the 5C psychological antecedents to vaccination (Betsch et al., 2018). The five constructs (the 5C) include confidence, complacency, constraints, calculation, and collective responsibility. The first three factors are originated from the 3C model (MacDonald, 2015), including the lack of trust in and the fear towards the vaccine (*confidence*), the perception that the diseases are of low risk and the vaccination is not necessary (*complacency*), and the difficulties in accessing the vaccines (*constraints*), which are identified by the Strategic Advisory Group of Experts on Immunization of the World Health Organization (European Commission, 2012; Larson et al., 2014). The fourth antecedent is *calculation*, which depicts the engagement in extensive information searching, as an additional factor (Betsch et al., 2015). The construct of calculation is also pertinent to the individual differences in need for elaboration, information searching, and questioning vaccination. The last antecedent identified is *collective responsibility*, inspired by the concept of awareness about the social benefits of vaccination (for example, the herd immunity brought by the majority of immune individuals can protect unvaccinated individuals) (Thomson et al., 2016). Conceptually, confidence and collective responsibility should positively predict the intention and the actual behavior of vaccination, while constraints, complacency, and calculation should do the opposite.

They were measured by three items on a 7-point Likert scale (1 = *strongly disagree*; 7 = *strongly agree*). Higher mean scores of the domain indicating stronger agreement of that domain. We removed the only reverse item tapping collective responsibility for its inability to converge with the other two items in the sub-scale (Kwok et al., 2020a). The scale has shown good concurrent validity as all five constructs were significantly associated with actual vaccination behavior and future vaccination intention (Betsch et al., 2018). Good construct validities were also established for the five constructs (e.g., high *confidence* associated with a positive attitude and lower perceived risk of vaccines; high *constraints* associated with low behavioral control).

2.3.2. Workplace-related variables

We measured the perceived insufficiency of the supply of personal protective equipment by asking the participants to report the shortage of seven types of personal protective equipment on yes-or-no items (1 = *yes*; 0 = *no*). A higher summed score indicated more insufficiency in the supply of personal protective equipment. We assessed work stress using a single item asking the participants to rate their work stress level during the COVID-19 pandemic on an 11-point Likert scale (0 = *no stress at all*; 10 = *the maximum stress*). There was a single item asking whether the participants' job duties included work in an infection isolation room (1 = *yes*; 0 = *no*). Another three items measured the attitudes towards workplace infection control policies on timeliness, sufficiency, and effectiveness on a 5-point Likert scale (1 = *strongly disagree*; 5 = *strongly agree*).

2.3.3. Vaccination uptake history and intention

The participants reported whether or not they administered the seasonal influenza vaccine in 2019–20 (1 = *yes*; 0 = *no*) and revealed their intention in taking the vaccine in the influenza season in 2020–21 on items used in the previous studies (e.g., Kwok et al., 2019) on a 5-point Likert scale (1 = *definitely not*; 5 = *definitely yes*). They also reported their intention in taking the COVID-19 vaccine when available on an item used in our recent study of the general population (i.e., Kwok et al., 2021c) on an 11-point Likert scale (0 = *definitely not*; 10 = *definitely yes*). The scale ranges were kept as the same as the previous studies to allow comparison across studies.

2.4. Statistical analysis

2.4.1. Advantages of the person-centered approach

In our attempt to look for the profiles of vaccine hesitancy antecedents, person-centered analyses would be a category of statistical techniques that best suit the purpose (Li, 2013). Statistical analyses, including cluster analysis, latent class analysis, and latent profile analyses, are typical techniques that fall into this category. Individuals are regarded as the functioning whole instead of the sum of the parts in a person-centered analysis (Bergman and Magnusson, 1997), and it serves several advantages in its usage. First, it enables us to identify the profiles among individuals, thus provides distinctive insight into the heterogeneity of the target population. Second, it simplifies the otherwise complex higher-order interactions among variables in the variable-centered analyses into a brief and simple representation (see Lanza et al., 2010; Muthén and Muthén, 2002). Lastly, tailored-made interventions for sub-populations become possible to suit their needs better (Roeser et al., 1998). Person-centered analyses have been used in health behavior studies, for example, examining the profiles of outcome expectancies on physical activity (Li, 2013), symptoms pattern of posttraumatic stress disorder (Bondjers et al., 2018), and investing relationship between parent prevention communication profiles and adolescent substance use (Choi et al., 2017).

2.4.2. Latent profile analysis

We used latent profile analysis (McLachlan and Peel, 2000) in examining the number of unobserved classes (i.e., the categorical latent profiles of vaccine hesitancy), describing the characteristics of the classes, and estimating the probabilities of class memberships for each individual. We adopted the three-step approach to examine the relationship between the latent categorical variable (i.e., the class memberships) and the predictors as well as distal outcome variables (Asparouhov and Muthén, 2009).

Analyses were done using Mplus version 7.4 (Muthén and Muthén, 1998-2015). In the latent profile analyses, we have the five constructs in the 5C model as the indicator variables of the latent class variable. Individuals that share a similar pattern or characteristics of the indicator variables would be classified into the same 5C profiles. We used the R3STEP command in Mplus to model the predictors of the latent categorical variable (Asparouhov and Muthén, 2014; Vermunt, 2010). These predictors included the demographics (including age, sex, chronic diseases, education level), working environment-related variables (including working in public hospitals, patient contact frequency, work stress, insufficiency in personal protective equipment supply, involvement in isolated rooms), and attitudes toward control policies. The R3STEP command generated the probability for an individual to be classified in a particular class over another class. Following Lanza et al. (2013), we separately modeled the distal outcome variables, including the intention to be vaccinated against COVID-19 when the vaccine is available, the intention to be vaccinated against seasonal influenza in 2021 season, and the actual uptake of seasonal influenza vaccine in the 2020 season, using the DCON command in Mplus. The analysis compares among the profiles and determines if each profile is significantly different from others in predicting the distal outcome variable.

In making the decision on the number of classes retained, we relied on a combination of statistical indexes and substantive interpretation in comparing competing models with different numbers of classes (Lanza et al., 2003; Tofighi and Enders, 2007). We used the Lo-Mendell-Rubin likelihood ratio test (LMRT; Lo et al., 2001) and bootstrapped likelihood ratio test (BLRT, McLachlan and Peel, 2000) as significance tests to compare models with a different number of classes. A significant LMRT or BLRT (with $p < .05$) would indicate that the more complex model (*k* class model) outperformed the simpler model (*k-1* class model) with the increased model fit (Nylund et al., 2007). We considered a combination of indexes in aiding the decision on model selection, including Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), sample size adjusted Bayesian Information Criterion (sBIC), and entropy. The model with lower AIC, BIC, and sBIC would indicate a better fit (Tofighi and Enders, 2007), while the model with the entropy value approaching 1 would indicate a clear delineation of the classes constructed in the model (Celeux and Soromenho, 1996). The interpretability and meaning of the groupings of individuals represented by the profiles would also be considered in the decision-making process of the number of profiles to be retained (Marsh et al., 2004, 2009).

Unlike a recent study using the latent profile analysis with the motivation of vaccination and preventive behaviors as the indicators of latent profiles (Chen et al., 2021), the use of the 5C constructs of vaccine hesitancy as indicators of profiles allowed us to derive more practical implications from the distinctive combinations of the 5C constructs in each profile. Furthermore, the three-step approach enabled us to examine the relationship between the class membership, demographic and work-setting predictors, as well as the vaccination intention outcomes with less error and better precision (Asparouhov and Muthén, 2014; Berlin et al., 2014; Vermunt, 2010).

Table 1
Means, standard derivations, and correlations of all variables ($N = 1193$).

	M /%	*SD*	Possible Range	Age	Women	LTI	EDU	PUBH	Contact	Stress	iPPE	ISO	GOV	CONF	COMP	CONS	CALC	COLL	CVAC	FVYN	FVAC
Age	40.82	10.49	>18	—																	
Women	90.0%		0-1	.043	—																
LTI	12.8%		0-1	.281 ***	.002	—															
EDU	67.4%		0-1	.397 ***	.055	.138 ***															
PUBH	56.6%		0-1	.027	-.122 ***	.027	-.029	—													
Contact	4.23	1.24	1-5	-.179 ***	-.047	.012	-.029	.238 ***	—												
Stress	7.38	2.05	0-10	-.099 ***	-.047	.013	-.035	.104 ***	.114 ***	—											
iPPE	2.79	1.86	0-8	-.237 ***	-.096 ***	.001	-.088 **	.214 ***	.189 ***	.233 ***	—										
ISO	32.8%		0-1	-.063 *	-.048	-.011	-.063 *	.208 ***	.214 ***	.125 ***	.135 ***	—									
GOV	2.56	1.05	1-5	.434 ***	.055	.132 ***	.165 ***	-.030	-.128 ***	-.210 ***	-.344 ***	-.018	—								
CONF	4.93	1.20	1-7	.144 ***	.020	.109 ***	-.021	-.033	-.036	.017	-.160 ***	-.024	.253 ***	—							
COMP	3.63	1.21	1-7	-.011	-.004	-.114 ***	.067 *	-.012	.025	-.071 *	.008	.050	.037	-.302 ***	—						
CONS	3.13	1.25	1-7	-.180 ***	-.083 **	-.114 ***	-.105 ***	.025	.024	.107 ***	.092 **	.074 *	-.082 **	-.215 ***	.410 ***	—					
CALC	5.62	0.86	1-7	.056	.008	.044	.002	.013	-.019	.070 *	.062 *	.004	-.067 *	.088 **	-.062 *	-.097 ***	—				
COLL	5.28	1.14	1-7	.041	-.010	.044	-.062 *	-.012	-.023	.074 *	-.024	.008	.053	.581 ***	-.309 ***	-.134 ***	.244 ***	—			
CVAC	6.51	2.83	0-10	-.034	-.021	.002	-.059 *	-.026	.012	.200 ***	.041	-.033	-.032	.373 ***	-.218 ***	-.080 **	.108 ***	.326 ***	—		
FVYN	49.5%		0-1	.059 *	-.006	.072 *	-.038	.055	-.010	.052	-.040	-.005	.067 *	.518 ***	-.337 ***	-.241 ***	.008	.420 ***	.247 ***	—	
FVAC	2.78	1.26	1-5	.188 ***	.005	.120 ***	.033	.045	-.058 *	-.026	-.028	.029	.101 ***	.253 ***	-.215 ***	-.253 ***	.082 **	.212 ***	.066 *	.452 ***	—

Notes. LTI = reported having long-term illnesses; EDU = with a bachelor's degree of above; PUBH = working in public hospital; Contact = patient contact frequency; Stress = perceived work stress; iPPE = perceived insufficiency of personal protective equipment; ISO = involvement in isolated rooms; GOV = attitudes toward governmental control policies;.
CONF = confidence; COMP = complacency;.
CONS = constraints; CALC = calculation; COLL = collective responsibility; CVAC = intention of taking the COVID-19 vaccine when available; FVYN = have taken the flu vaccine in 2020 flu season; FVAC = intention of taking the flu vaccine in 2021 flu season.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 2
Fit Statistics for Profile Structures (N = 1193).

Number of profiles	LL	FP	AIC	BIC	sBIC	LMR (p)	BLRT (p)	Entropy	Smallest class%
1	−9156.879	10	18,333.759	18,384.601	18,352.837	NA	NA	NA	NA
2	−8804.689	16	17,641.377	17,722.725	17,671.903	<0.0000	<0.0000	0.744	37.47%
3	−8645.755	22	17,335.511	17,447.364	17,377.483	<0.0000	<0.0000	0.699	32.02%
4	−8529.173	28	17,114.346	17,256.704	17,167.766	0.0011	<0.0000	0.743	13.41%
5	**−8457.944**	**34**	**16,983.888**	**17,156.752**	**17,048.755**	**0.0255**	**<0.0000**	**0.765**	**3.94%**
6	−8393.237	40	16,866.473	17,069.842	16,942.787	0.0803	<0.0000	0.789	1.76%
7	**−8349.737**	**46**	**16,791.474**	**17,025.349**	**16,879.235**	**0.0416**	**<0.0000**	**0.815**	**1.68%**
8	−8313.517	52	16,731.034	16,995.414	16,830.242	0.0905	<0.0000	0.819	0.67%
9	−8286.044	58	16,688.089	16,982.974	16,798.744	0.8051	<0.0000	0.824	1.34%
10	−8256.309	64	16,640.618	16,966.009	16,762.720	0.3965	<0.0000	0.844	0.67%
11	−8227.605	70	16,595.209	16,951.105	16,728.759	0.1969	<0.0000	0.786	1.34%
12	−8197.032	76	16,546.064	16,932.465	16,691.060	0.5954	<0.0000	0.793	1.17%
13	−8170.717	82	16,505.435	16,922.341	16,661.878	0.2389	<0.0000	0.792	0.67%
14	−8140.886	88	16,457.772	16,905.184	16,625.663	0.2852	<0.0000	0.808	0.59%
15	−8108.441	94	16,404.881	16,882.799	16,584.219	0.4825	<0.0000	0.820	0.59%
16	−8082.757	100	16,365.514	16,873.937	16,556.299	0.7520	<0.0000	0.822	0.50%
17	−8067.024	106	16,346.048	16,884.976	16,548.280	0.7336	<0.0000	0.824	0.34%
18	−8041.560	112	16,307.120	16,876.553	16,520.799	0.2375	<0.0000	0.822	0.34%
19	−8030.688	118	16,297.377	16,897.316	16,522.503	0.8391	0.3333	0.813	0.34%

Notes. LL = log-likelihood; FP = free parameters; AIC = Akaike information criteria; BIC = Bayesian information criteria; sBIC = sample-size- adjusted BIC; LMR = Lo et al. (2001) test; BLRT = bootstrapped likelihood ratio tests.

3. Results

3.1. Participants and correlations among variables

The online survey system has recorded 1660 attempts of answering the survey. Responses from retired nurses (n = 37), full-time nursing students (n = 95), and incomplete responses (n = 323) were excluded. The representativeness of the current sample was described in an earlier paper (Kwok et al., 2020a). Since response set bias could distort the profile structure (e.g., Geiser et al., 2014) and given the 5C constructs are theoretically different in their prediction on vaccine intention, we screened responses with repeating answers in the 5C items at the extreme ends. Responses with repeated 1 (n = 2), 2 (n = 0), 6 (n = 7), or 7 (n = 3) in all 15 items of the 5C scales (including one reverse item) were discarded. We have retained 1193 cases for subsequent analyses.

The mean scores, standard deviation, and correlations of the studied variables, including demographics, COVID-19-related work demands, the 5C vaccine hesitancy components, seasonal influenza vaccine uptake history, and the COVID-19 vaccine uptake intention variables, are shown in Table 1. On a 7-point scale, the participants had relatively high scores in confidence (M = 4.93, SD = 1.20), calculation (M = 5.62, SD = 0.86), and collective responsibility (M = 5.28, SD = 1.14), and low in complacency (M = 3.63, SD = 1.21) and constraints (M = 3.13, SD = 1.25). As expected, all of the 5C factors were intercorrelated, and they were all significantly correlated with the vaccination intention. However, calculation was positively correlated with the vaccination intention (r = 0.108 p < .001), which was contrary to the hypothesis. The same patterns can be observed for the actual flu vaccination in the 2020 season and the intention of taking flu vaccine in the 2021 season with the 5C construct, except that calculation was not correlated with the actual flu vaccination in the 2020 season (r = 0.008, p = .780).

3.2. Model selection

Fit statistics for different latent profile structures were shown in Table 2. With a greater number of profiles, the solutions provided lower LL, AIC, BIC, sBIC, and significant BLRT until the number reached 19. We chose the five-profile solution, as it provided lower LL, AIC, BIC, and sBIC than the solutions with a smaller number of profiles, with significant LMR and BLRT values, indicating a significant improvement in fit indexes comparing to the *k-1* solution (i.e., four-profile solution). The six-profile solution had slightly better fit indexes in terms of LL, AIC, BIC, sBIC, and entropy with a significant BLRT value; its BLRT value was insignificant compared to the five-profile solution. For a solution with six profiles or more, there were small profiles with less than 5% of the total sample with a profile size less than 30. Considering profiles with this size may be spurious (Ferguson et al., 2020; Marsh et al., 2009), we did not further examine solutions with six profiles or more and retained the five-profile solution (see Fig. 1). The seven-profile solution also yielded a significant LMR over the six-profile solution. We have looked into the profile structure, and its details are presented in the supplementary materials.

3.3. RQ1: Profile characteristics

The estimated means and the 95% confidence intervals of the 5C indicators are shown in Table 3. We labelled the profile with high complacency (M = 4.33) and calculation (M = 6.12) and low confidence (M = 3.23) and collective responsibility (M = 3.45) as *skeptics* (10.98%). Skeptics are of the lowest chance to take the vaccine, do not think the disease is severe, extensively search for more information about the vaccine, do not believe that the vaccine is effective and can protect the public, and have constraints in taking vaccine even if it is available.

Individuals with high confidence (M = 5.78), collective responsibility (M = 6.14) and calculation (M = 5.78), and low complacency (M = 2.44) and constraints (M = 2.29) were labelled as *believers* (30.68%). Believers are of the highest chance to take the vaccine, would do research on the vaccine, believe that the disease is an issue, and believe that the vaccine is effective and can protect the public. They reported low constraints in taking the vaccine.

We labelled the profile with high complacency (M = 3.97) and constraints (M = 3.66) and low in other indicators ($M_{\text{Confidence}}$ = 4.30, $M_{\text{Calculation}}$ = 4.19, $M_{\text{Collective}}$ = 4.28) as *outsiders* (14.08%). They are less involved in the information search and do not believe that the vaccine is effective and can protect the public. They do not think that the disease is severe and have a concern about the constraints in taking the vaccine.

The profile with the smallest portion is the *contradictor* (3.94%). They are high in all 5C indicators ($M_{\text{Confidence}}$ = 5.98, $M_{\text{Complacency}}$ = 5.59, $M_{\text{Constraints}}$ = 4.94, $M_{\text{Calculation}}$ = 6.07, $M_{\text{CollectiveResponsibility}}$ = 6.12). Contradictors do not think the disease

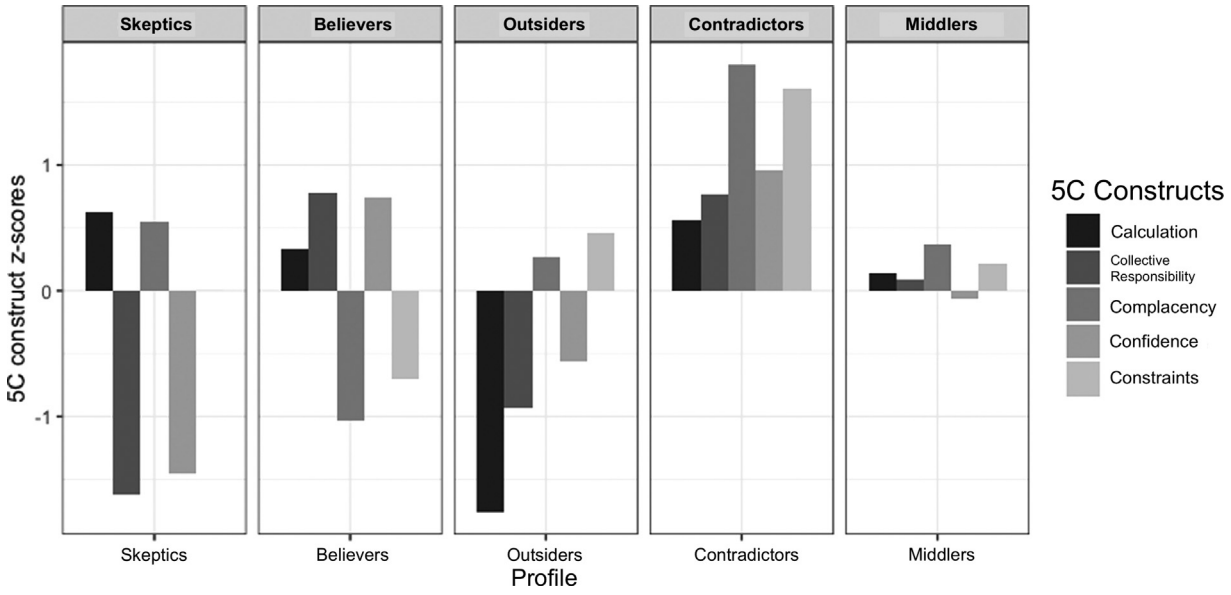

Fig. 1. Latent profiles for the 5C indicators.

Table 3
Descriptive information per latent profile ($N = 1193$).

Profiles	*n*	% of sample	CONF		COMP		CONS		CALC		COLL	
			M	95% CI	*M*	95% CI	*M*	95% CI	*M*	95% CI	*M*	95% CI
C1: Skeptic	131	10.98%	3.23	[2.71, 3.75]	4.33	[3.99, 4.67]	3.15	[2.89, 3.41]	6.12	[5.96, 6.29]	3.45	[3.07, 3.83]
C2: Believer	366	30.68%	5.78	[5.67, 5.89]	2.44	[2.28, 2.59]	2.29	[2.14, 2.44]	5.89	[5.81, 5.98]	6.14	[6.05, 6.22]
C3: Outsider	168	14.08%	4.30	[4.11, 4.48]	3.97	[3.84, 4.10]	3.66	[3.49, 3.83]	4.19	[4.04, 4.35]	4.28	[4.14, 4.43]
C4: Contradictor	47	3.94%	5.98	[5.48, 6.48]	5.59	[4.94, 6.23]	4.94	[4.10, 5.77]	6.07	[5.81, 6.34]	6.12	[5.85, 6.39]
C5: Middler	481	40.32%	4.86	[4.62, 5.10]	4.01	[3.83, 4.18]	3.36	[3.16, 3.56]	5.75	[5.67, 5.82]	5.39	[5.14, 5.64]

Notes. M = mean; CI = confidence interval; CONF = confidence; COMP = complacency; CONS = constraints; CALC = calculation; COLL = collective responsibility.

is as severe as claimed and may be reluctant to take the vaccine because of the constraints, yet they believe in the efficacy of the vaccine and somehow believe that it can be protective to the public.

The last profile is labeled as *middlers* (40.32%), which was the profile of the largest portion. They are higher in complacency ($M = 4.01$) and constraints ($M = 3.36$), with other indicators around the sample means ($M_{\text{Confidence}} = 4.86$, $M_{\text{Calculation}} = 5.75$, $M_{\text{CollectiveResponsibility}} = 5.39$). Being ambiguous in their attitudes about the vaccine efficacy and disease severity, middlers would somehow look for information and have some constraints in taking the vaccine.

3.4. RQ2: Predictors

The three-step result for the predictors is shown in Table 4. We observed that believers reported more long-term illnesses, lower education levels, greater work stress, lower perceived personal protective equipment insufficiency, and higher trust in government than skeptics. Believers were older and reported less involvement in isolated rooms than middlers, and they were older and claimed more work stress than outsiders. Skeptics were older, reported higher perceived personal protective equipment insufficiency, and less trust in government than outsiders; skeptics were also older and more educated than middlers, and with less trust in government than contradictors. Besides, outsiders reported more contact than middlers. No significant difference between believers and contradictors was observed in terms of the predictors.

3.5. RQ3: Outcomes

For the intention of taking the COVID-19 vaccine when available (see Table 5), believers ($M = 7.77$) and contradictors ($M = 7.89$) reported the highest intention, and they were not significantly different from each other. Skeptics were having a significantly lower intention of taking the COVID-19 vaccine when available than all other classes ($M = 4.10$). Similar patterns can be observed for the intention of taking the flu vaccine in the 2021 flu season and the actual flu vaccination in the 2020 flu season. Believers report a significantly higher intention among all profiles in ($M = 3.58$), and 92% of them claimed they had taken the flu vaccine in the 2020 flu season. Contradictors came second in both the intention of taking the flu vaccine in the 2021 flu season ($M = 3.08$) and the actual flu vaccination in the 2020 flu season (76%). Interestingly, only 3% of the skeptics have taken the flu vaccine in the 2020 flu season, which was the lowest among all profiles. Nevertheless, their reported intention of taking the flu vaccine in 2021 was significantly higher than outsiders and middlers.

4. Discussion

To our knowledge, this is the first study examining the profiles of 5C constructs of vaccine hesitancy among nurses. Our results revealed five distinct profiles constituted by the different combinations of constructs. For RQ1, as expected, we observed a profile characterized with high confidence and collective responsibility with low constraints and complacency (*believers*) and another profile with the exact opposite characteristics (*skeptics*). There was a profile representing “laid-back” individuals (*outsiders*), with them

Table 4
Three-step results for antecedents (R3STEP).

	Antecedents																	
Profile comparison	Age		Women		LTI		EDU		PUBH		Contact		Stress		iPPE		ISO		GOV	
C1 vs C5	0.04	*	0.01		-0.27		0.72	*	-0.04		0.13		-0.08		0.08		-0.31		-0.28	
C2 vs C5	0.03	*	-0.10		0.55		-0.36		0.01		0.08		0.06		-0.08		-0.47	*	0.18	
C3 vs C5	-0.00		-0.36		-0.08		0.14		-0.12		0.21	*	-0.09		-0.14		-0.19		0.24	
C4 vs C5	0.03		-1.12		0.13		0.18		-0.75		0.55		0.34		-0.18		0.26		0.77	
C2 vs C1	-0.01		-0.10		0.82	*	-1.08	**	0.05		-0.05		0.14	*	-0.17	*	-0.16		0.46	**
C3 vs C1	-0.04	*	-0.37		0.19		-0.58		-0.08		0.08		-0.00		-0.22	*	0.12		0.52	**
C4 vs C1	-0.01		-1.12		0.40		-0.54		-0.71		0.42		0.43		-0.26		0.57		1.05	*
C3 vs C2	-0.04	**	-0.26		-0.63		0.50		-0.13		0.13		-0.15	**	-0.06		0.28		0.07	
C4 vs C2	-0.00		-1.02		-0.43		0.54		-0.76		0.47		0.28		-0.10		0.73		0.60	
C4 vs C3	0.03		-0.76		0.21		0.03		-0.63		0.34		0.43		-0.04		0.45		0.53	

Notes. Values in the table are estimates from the R3STEP logistic regression analyses using Mplus. Positive values indicate that the particular antecedent makes an individual more likely to be classified as the first latent profile than the second latent profile; negative values indicate the opposite. LTI = reported having long-term illnesses; EDU = with a bachelor's degree of above; PUBH = working in public hospital; Contact = patient contact frequency; Stress = perceived work stress; iPPE = perceived insufficient of personal protective equipment; ISO = involvement in isolated rooms; GOV = attitudes toward governmental control policies; C1 = skeptic, C2 = believer, C3 = outsider, C4 = contradictor, C5 = middler.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 5
Three-step results for outcomes (DCON) and pairwise comparisons between profiles.

Outcomes (score range)	Profiles						Difference between profiles
	C1	C2	C3	C4	C5	Chi-square	
CVAC (0–10)	$4.10^{2,3,4,5}$	$7.77^{1,3,5}$	$5.32^{1,2,4,5}$	$7.89^{1,3,5}$	$6.41^{1,2,3,4}$	250.15***	2 = 4 > 5 > 3 > 1
FVAC (1–5)	$3.08^{2,3,5}$	$3.58^{1,3,4,5}$	$2.47^{1,2,4,5}$	$3.08^{2,3,5}$	$2.02^{1,2,3,4}$	502.61***	2 > 4 = 1 > 3 > 5
FVYN (0–1)	$0.03^{2,3,4,5}$	$0.92^{1,3,4,5}$	$0.35^{1,2,4}$	$0.76^{1,2,3,5}$	$0.29^{1,2,4}$	2056.30***	2 > 4 > 3 = 5 > 1

Notes. Values in the table are means for CVAC and FVAC, and percentages for FVYN. Superscripts besides the mean values indicate significant differences in means with that particular profiles. Analyses were conducted using DCON command in Mplus. C1 = skeptic, C2 = believer, C3 = outsider, C4 = contradictor, C5 = middler.
CVAC = intention of taking the COVID-19 vaccine when available; FVYN = have taken the flu vaccine in 2020 flu season; FVAC = intention of taking the flu vaccine in 2021 flu season.
* $p < .05$, ** $p < .01$, *** $p < .001$.

having low calculation, confidence, and collective responsibility, and high constraints and complacency. We also found two quantitatively different profiles with individuals having all 5C constructs around the mean (*middlers*) and all at high levels (*contradictors*), respectively. For RQ2, we observed differences in terms of predictors between the profiles. Regarding RQ3, the profiles revealed differences in their intention and actual vaccination uptake.

4.1. Relation between calculation and vaccination intention

In the individuals with high calculation, Betsch et al. (2018) expected the high engagement in cost-benefit calculations might bring more exposure to vaccine-critical information sources, risk-aversion, and a more deliberative cognitive style of decision-making. These would, in turn, decrease vaccination intention. However, our results contradicted such a proposition. The alternative argument suggested that information seeking can be a way to provide cognitive closure for people to make a behavioral decision (Griffin et al., 1999). People who have been effortfully engaging in information seeking may also be more likely to form a stable behavior in taking vaccines. Some evidence suggested that people who seek more vaccine-related information have shown a stronger tendency to be vaccinated (see Lu et al., 2020 for review). The media in which people look for information may also moderate the relationship between information seeking and vaccination intention (e.g., H. O. Lee and Kim, 2015). The calculation-vaccination relationship is more equivocal than we expected, and investigation about the plausible moderators is warranted in future studies.

4.2. Implication of plausible tailored interventions for the five profiles

The most significant implication of this study is to provide tailored-made health communication interventions for different profiles based on their patterns of vaccine hesitancy constructs. It seems that confidence and collective responsibility are more important determinants of vaccination intention, as we can see from the high vaccination rates in both believers and contradictors. The high complacency and constraints in the contradictors may explain the lower vaccination intention in the contradictors as compared to the believers. Providing flexible hours and more easily accessible points in administering the vaccine (i.e., lowering the constraints; e.g., Yamin and Gavious, 2013) and stressing the severity of the disease (i.e., lowering the complacency; Chamberlain et al., 2015) may further secure the high vaccination rate in these profiles.

Outsiders and middlers are less actively engaging in information search about the vaccines, as compared to other profiles. These may imply their inattention, unawareness, or lack of interest in the progress of the outbreak or passivity in receiving health information (Grasso and Bell, 2015; Ramanadhan and Viswanath, 2006). Providing more easily accessible health information and communicating the risk of contracting the disease would be particularly important in persuading these individuals to take vaccines (e.g., Chamberlain et al., 2015; Ma et al., 2019). Interestingly, outsiders and middlers were reporting lower intention than skeptics in taking the seasonal influenza vaccine, although their vaccination rates of seasonal influenza were much higher than skeptics (35% for outsiders and 29% for middlers, versus 3% for skeptics). There could be other unique factors for particular vaccine-preventable diseases governing the intention-vaccination linkage, such as the moral norms embedded in the actual vaccination against a particular disease (Godin et al., 2005), or the stigma attached to certain diseases, like COVID-19 (Bagcchi, 2020), that creates social pressure for one to be vaccinated. These postulations, together with other plausible moderating factors, would warrant further investigation.

Skeptics could be the hardest to increase their vaccination intention given their active participation in the information search, and they may have already formed a stable attitude about vaccines (Griffin et al., 1999). The negative attitudes toward the governmental control policies predicted a higher likelihood for an individual to be classified as a skeptic. This echoes the proposition that distrust in health authorities is associated with low vaccination intention (Hartley and Jarvis, 2020; Jamison et al., 2019). The re-establishment of trust and bonding between the health authorities and these healthcare workers at the frontline would be the foremost important in enhancing the acceptance rate of the vaccines in these individuals (e.g., Schoch-Spana et al., 2020). Our data suggested skeptics were more educated. They may be more critical and reflective in evaluating the scientific basis of the information they received (ten Kate et al., 2021) and have a tendency to overestimate the rare adverse events (LaCour and Davis, 2020). More transparent information would have to be supplied to these individuals to enhance the trustworthiness of the vaccine (e.g., Mannan and Farhana, 2020).

With these in mind, we can design tailored health communication materials for different profiles. For example, we can tie the 5C measure in training modules for healthcare workers and provide them with tailored vaccine information.

4.3. Other public health implications

This study has other important public health implications. First, we expect a similar profile structure can be found in the general public. Except for calculation, we observed the same associations between the other 4C constructs, vaccination intention, and the actual behavior as suggested in Betsch et al. (2018)'s study in a general public sample. Tailored immunization campaigns can be possible in the general public when future studies examine the antecedent profile in the general public.

Second, persuading certain subgroups, for example, skeptics who hold a stable negative attitude towards vaccines could be particularly difficult. Besides encouraging the uptake of the vaccine, providing adequate training for nurses (regarding the use of personal protective equipment, personal hygiene, and management of occupational exposure) and sufficient personal protective equipment are important to protect nurses in the pandemic (Huang et al., 2020).

Third, vaccine skeptics are often described as having lower confidence in the vaccines and being self-centered (e.g., Lee and Sibley, 2020; Shim et al., 2012). Our result disagreed with this proposition and suggested that there may be diligent information seekers who formed unfavorable attitudes on the vaccine. We also revealed the existence of outsiders who were more "laid-back" and concerned more about the constraints in taking the vaccine. Despite to low intention of vaccination in both groups, the differences between skeptics and outsiders remind the policymakers to carefully look into the vaccine hesitancy profiles for effective interventions.

Fourth, the current study was conducted at the peak of the second wave of the COVID-19 outbreak in Hong Kong. One possible impact would be the extensive exposure of the pandemic-related information from different media, which may bring excessive stress and increase disproportionate information-seeking and help-seeking behavior in response to the threat (Garfin et al., 2020; Sousa-Pinto et al., 2020). This may also increase the reported intention of taking the COVID-19 vaccine in general. The emergence of the *contradictor* may reflect the conflict between the internalized social pressure and self-interest. Studies using a person-centered approach at different time-point of a pandemic can help to reveal the impact of the pandemic.

Fifth, given the uniqueness of the current data set, we can use the current data as training data in machine learning for the identification of the profile membership of an individual. The profile structure revealed can serve as a reference for future studies, and we can integrate the future data to revise the profile structure.

Sixth, the adoption of person-centered analyses using latent profile analysis or alike statistical strategies is increasingly popular in nursing field in the recent decade. Studied outcomes included commitment (Gellatly et al., 2014), work demands (Jenull and Wiedermann, 2015), moral sensitivity (Zhang et al., 2020), fatigue (Drake and Steege, 2016; Watanabe and Yamauchi, 2019), mental workload (Shan et al., 2021), and risky lifestyle (Macedo et al., 2020). Many stopped at mere classification without further predicting distal outcomes. The current study is among the few of them, if any, using psychological indicators in classification and predicting health behavioral outcomes in nursing studies. We believe that person-centered analyses would be important to the nursing field for the benefits of devising tailored intervention as mentioned above and would advocate this approach in future nursing studies.

4.4. Limitation

Despite the practical implications, the generalizability of the result suffered from several limitations. First, the interpretation about the *contradictors* would need special caution, given its small profile size (3.94% of the sample). Replication of the profile structures would be needed to verify the genuineness and stability of this profile. Second, convenience sampling in this study may bring potentially biased estimates. Third, there may be recall bias regarding vaccination history. Fourth, participants may answer the items in a socially desirable manner that bias the results. Fifth, there are some other components explaining vaccine hesitancy not addressed in the 5C framework. Psychological reactance and conspiratorial belief (e.g., Hornsey et al., 2018; Murphy et al., 2021), for example, are good candidates that can be added in future studies.

5. Conclusion

As Betsch et al. (2015) suggested, it is crucial for policymakers to consider psychological constructs and behavioral insights in devising more promising and effective immunization strategies. The five vaccine hesitancy profiles revealed in this study shed light on the possibility of tailored communication and intervention programs regarding the 5C profile of the target audiences. Future endeavors are warranted to replicate and generalize the profile patterns in nurses and other populations.

Declaration of Competing Interest

None.

CRediT authorship contribution statement

Cyrus Lap Kwan Leung: Formal analysis, Writing – original draft, Visualization. **Kin-Kit Li:** Conceptualization, Methodology, Formal analysis, Writing – original draft. **Vivian Wan In Wei:** Data curation, Writing – review & editing, Project administration. **Arthur Tang:** Writing – review & editing. **Samuel Yeung Shan Wong:** Resources, Writing – review & editing, Supervision. **Shui Shan Lee:** Conceptualization, Investigation. **Kin On Kwok:** Conceptualization, Methodology, Writing – review & editing.

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Supplementary materials

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