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Huang, P.-C. orcid.org/0000-0002-2047-2246, Chen, I.-H., Barlassina, L. et al. (8 more authors) (2023) Expanding Protection Motivation Theory to explain vaccine uptake among United Kingdom and Taiwan populations. *Human Vaccines & Immunotherapeutics*, 19 (1). 2211319. ISSN 2164-5515

<https://doi.org/10.1080/21645515.2023.2211319>

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To cite this article: Po-Ching Huang, I-Hua Chen, Luca Barlassina, James R. Turner, Felipe Carvalho, Alvaro Martinez-Perez, Jilly Gibson-Miller, Miklós Kürthy, Kuo-Hsin Lee, Mark D. Griffiths & Chung-Ying Lin (2023): Expanding Protection Motivation Theory to explain vaccine uptake among United Kingdom and Taiwan populations, Human Vaccines & Immunotherapeutics, DOI: [10.1080/21645515.2023.2211319](https://doi.org/10.1080/21645515.2023.2211319)

To link to this article: <https://doi.org/10.1080/21645515.2023.2211319>



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Expanding Protection Motivation Theory to explain vaccine uptake among United Kingdom and Taiwan populations

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ABSTRACT

Vaccination can sufficiently ameliorate the coronavirus disease-2019 (COVID-19). Investigating what factors influence vaccine uptake may benefit ongoing vaccination efforts (e.g. booster injections, annual vaccination). The present study expanded Protection Motivation Theory with possible factors including perceived knowledge, adaptive responses, and maladaptive responses to develop a proposed model investigating vaccine uptake among United Kingdom (UK) and Taiwan (TW) populations. An online survey collected responses from UK ($n = 751$) and TW ($n = 1052$) participants (August to September, 2022). The results of structural equation modeling (SEM) showed that perceived knowledge was significantly associated with coping appraisal in both samples (standardized coefficient $[\beta] = 0.941$ and 0.898 ; $p < .001$). Coping appraisal was correlated with vaccine uptake only in the TW sample ($\beta = 0.319$, $p < .05$). Multigroup analysis showed there were significant differences between the path coefficients of perceived knowledge to coping and threat appraisals ($p < .001$), coping appraisal to adaptive and maladaptive responses ($p < .001$), as well as threat appraisal to adaptive response ($p < .001$). Such knowledge may improve vaccine uptake in Taiwan. The potential factors for the UK population require further investigation.

ARTICLE HISTORY

Received 14 February 2023
Revised 17 April 2023
Accepted 2 May 2023

KEYWORDS

COVID-19; coping appraisal; knowledge; Protection Motivation Theory; vaccination

Introduction

The coronavirus disease 2019 (COVID-19) global pandemic has lasted for three years¹ and has caused almost seven million deaths worldwide.² Vaccination is considered to be one of the most effective strategies because it can reduce disease severity as well as suppressing the infectiousness by alleviating the symptoms that may spread the viruses (i.e., coughing and sneezing).³ However, vaccine hesitancy derived from vaccination beliefs or attitudes toward the pandemic^{4,5} may prevent individuals with such hesitancy from receiving the COVID-19 vaccination.⁶ Moreover, the mutated virus variants as well as the fading of natural immunity effect have forced the scientists to investigate the necessity for additional immunization to maintain the vaccine efficacy and effectiveness.⁷ If routine COVID-19 vaccination is needed in the future, it is important to investigate the factors that may affect the public's willingness for booster doses.

Protection Motivation Theory (PMT) is a social cognitive theory that is used to describe individuals' responses toward

perceived threats.^{8,9} More specifically, the theory proposes that coping and threat appraisal derived from fear appeal may affect individuals' motivations to take self-protection action.^{8,10} A previous study¹¹ used PMT as a framework and added several possible factors (i.e., perceived knowledge, adaptive response, and maladaptive response) to develop a proposed model investigating the intention to uptake COVID-19 vaccination among Taiwanese university students. PMT with perceived knowledge, adaptive responses, and maladaptive response (hereafter, extended PMT) was supported because perceived knowledge was interpreted as the information that individuals received from either formal or informal resources.¹² Such information may influence the formation of coping or threat appraisal through evaluation involving self-efficacy, response efficacy, vulnerability and threat severity.¹³ Consequently, individuals' attitudes toward the behavior could be altered.¹⁴ Studies have shown that such knowledge may determine individuals' adherence to COVID-19-related policies such as social restrictions.^{15,16} This knowledge could

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 Supplemental data for this article can be accessed on the publisher's website at <https://doi.org/10.1080/21645515.2023.2211319>

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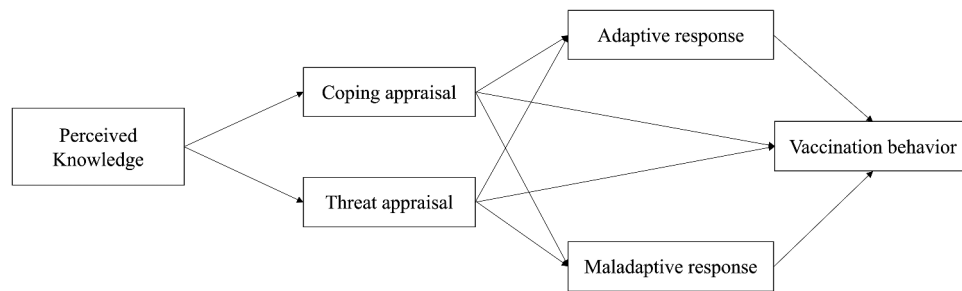


Figure 1. Proposed model illustrated using the protection motivation theory (PMT) to explain the COVID-19 vaccination behavior (vaccine uptake).

positively influence vaccination intention,¹⁷ and lack of knowledge could predict lower vaccination willingness.^{18,19}

Moreover, both coping and threat appraisal may further prompt individuals' adaptive or maladaptive responses.^{20–22} Adaptive response is when individuals take appropriate precautionary action toward the stressful event for self-protection. Maladaptive response is when inadequate action may hurt individuals' own self-interests.²³ Appraisals may prompt adaptive responses such as self-responsibility or maladaptive responses such as optimistic bias,²⁴ and distinct appraisals work mutually to determine individuals' response toward the stressful event.²² One study showed that appropriate information may prompt the implementation of adaptive responses and facilitate protective behavior of individuals.²² However, the lack of fear, as well as coping and threat appraisal, may provoke maladaptive responses and result in dangerous behavior.²⁵ Another study reported that avoidance as a coping appraisal and low perception of COVID-19 as a threat fostered individuals' vaccine hesitancy as a maladaptive response. However, behaviors such as information-seeking or help-seeking may act as coping behaviors and be a response to threat appraisal to adaptively reduce vaccine hesitancy.²⁶

Given that cultural differences or a government's health policy may affect the associations between studied variables, the United Kingdom (UK) and Taiwan (TW) were chosen as two different sample groups for comparison. Compared to the UK population who tend more toward individualism,²⁷ the TW population tend more toward collectivism.^{27,28} The different regional characteristics and cultural features possessed by these two different populations may demonstrate the disparate associations regarding vaccination behavior among Western and Eastern populations. At the time of writing (May 2023), approximately 36.5% of total UK population had contracted COVID-19 with the mortality rate of 0.9%.² The proportions of individuals who had received the first, second or third (booster) doses were 93.9%, 88.8%, and 70.1% of the population aged 12 years and over, respectively.²⁹ There are eight vaccines that have been approved for use in the UK: *Moderna* (Spikevax and Spikevax Bivalent Original/Omicron BA.1), *Pfizer/BioNTech* (Comirnaty and Comirnaty Bivalent Original/Omicron BA.1), *Novavax* (Nuvaxovid), *AstraZeneca* (Vaxzevria), *Janssen* (Johnson & Johnson), and *Valneva* (Valneva).³⁰ Similarly (by May 2023), in Taiwan, approximately 43.45% of total population had contracted COVID-19 with the mortality rate of 0.1% (data accessed on 2023 May 7).³¹ The proportions of individuals who had received the

first, second or third (booster) dose were 94.3%, 89.5% and 74.3% of population aged 12 years and over, respectively.³¹ There are six vaccines that have been approved for use in TW: *Moderna* (Spikevax and Spikevax Bivalent Original/Omicron BA.1), *Pfizer/BioNTech* (Comirnaty), *Novavax* (Nuvaxovid), *AstraZeneca* (Vaxzevria) and *Medigen* (MVC-COV1901).³² With different severity levels of COVID-19 and different policies regarding vaccine uptake, it is unclear if the aforementioned extended PMT performs similarly across different countries and cultures. In order to maximize the utility of the extended PMT, it is important to use different country samples to cross-validate the theory.

Therefore, the purpose of the present study was to investigate the critical factors regarding COVID-19 vaccine uptake among UK and TW populations. PMT was used as the theoretical framework with added possible factors including perceived knowledge, adaptive responses, and maladaptive responses, along with the vaccination behavior (i.e., vaccine uptake), to develop the proposed model (Figure 1) in order to examine the interaction between factors. Moreover, the study examined the differences between the two studied samples to determine the factors that may affect vaccination behavior in different cultural populations.

Methods

Participants and procedure

The present study was a cross-sectional study conducted using internet-based self-administered snowball sampling to collect data. An online survey created by *Survey Monkey* (for TW data collection) and *Prolific* (for UK data collection) was distributed through social networking platforms (e.g., *LINE* and *Twitter*) and individuals were also asked to send the link of the survey to other individuals. The survey took place between August and September 2022. Participants who had lived in the UK or Taiwan for more than six months at the time of the survey took place were eligible to participate. Individuals who wanted to participate in the survey had to provide their (electronic) informed consent. Participants gave their consent by clicking the "yes" button. E-mail addresses and telephone numbers were collected in the survey because participants who completed the survey could receive the equivalent of 3–4 US\$ reimbursement. Therefore, the e-mail addresses and telephone numbers were used to contact the participants regarding the financial payment. However, individuals could decline to participate if they had any concerns. One of the research assistants

screened the e-mail addresses and telephone numbers to identify if there were any duplicate responses. After cleaning the data to ensure no duplicate responses, the research assistant deleted the personal private information from the data and forwarded the anonymized dataset to the data managers of the present study. The data storage, electronic link circulation, data retrieval, and data management were controlled by Dr. Barlassina (for the UK data) and Dr. Lin (for the TW data). The study protocol was approved by the ethics committee at the University of Sheffield (Reference Number 047221).

There were 751 responses collected in the UK population and 1052 responses collected in the TW population with no missing data. In brief, participants in the UK population had an average age of 41.2 years (SD = 14.0) with approximately even numbers of males and females. In the TW population, the participants had an average age of 37.5 years (SD = 15.1) with slightly more females ($n = 540$, 51.3%).

Measures

Perceived knowledge was defined as individuals' knowledge regarding the COVID-19 vaccination. Three items rated on a seven-point Likert-like scale (1 = strongly disagree; 7 = strongly agree) were used for the assessment. A higher score indicates a higher knowledge level regarding the COVID-19 vaccination. Cronbach's alpha was 0.843 in the UK sample and 0.816 in the TW sample. Items are provided in the supplementary materials.

Coping appraisal was defined as the positive perception of COVID-19 vaccination as a disease preventive strategy. Four items rated on a seven-point Likert-like scale (1 = strongly disagree; 7 = strongly agree) were used for the assessment. A higher score indicates a higher agreement of perceiving vaccination as a self-protection strategy against COVID-19. Cronbach's alpha was 0.909 in the UK sample and 0.830 in the TW sample. Items are provided in supplementary materials.

Threat appraisal was defined as the strategies used to evaluate the risk of COVID-19 pandemics. Therefore, the Fear of COVID-19 Scale (FCV-19S)³³ was used to assess threat appraisal. The FCV-19S has seven items rated on a five-point Likert-like scale (1 = strongly disagree; 5 = strongly agree). The score was summed to generate a total score ranging from 5 to 35. A higher score indicates a higher level of perceived fear of COVID-19. The psychometric properties of the FCV-19S have been verified and found satisfactory in prior research on both TW and UK samples.^{34,35} Cronbach's alpha was 0.899 in the UK sample and 0.925 in the TW sample. Items are provided in supplementary materials.

Adaptive response was defined as positive thoughts regarding COVID-19 vaccination. An item rated on a seven-point Likert-like scale (1 = strongly disagree; 7 = strongly agree) was used for the assessment. A higher score indicates a higher agreement of the COVID-19 vaccination to improve individuals' wellbeing. The item is provided in the supplementary materials.

Maladaptive response was defined as negative thoughts regarding COVID-19 vaccination. An item rated on a seven-point Likert-like scale (1 = strongly disagree; 7 = strongly agree) was used for the assessment. A higher score indicates

a higher agreement that the COVID-19 vaccination may harm individuals' health. The item is provided in the supplementary materials.

Vaccination behavior concerned the receiving of the COVID-19 booster vaccination. The booster dose was defined as an extra vaccine administration after an earlier or primer dose.³⁶ Information regarding individuals' booster dose injection was recorded for statistical analysis.

For tool validation, variables using non-standardized measures (i.e., perceived knowledge, coping appraisal, threat appraisal, adaptive response and maladaptive response) underwent forward translation, back translation, reconciliation, and committee review.

Statistical analysis

Descriptive analysis for continuous variables (i.e., age and the scores of all the studied variables) and chi-square tests for categorical variables (i.e., gender and vaccine uptake) were used to summarize and compare participants' characteristics between the UK and TW groups. Pearson's correlation was used to calculate the correlation coefficients between the studied variables. Structural equation modeling (SEM) with the estimator of diagonally weighted least squares was set to test if the collected data fit well with the proposed model (Figure 1). Four indices including comparative fit index (CFI), Tucker – Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR)³⁷ were used to examine if the proposed model was supported. The path coefficients of SEM were further inspected if the fit indices were found to be satisfactory. That is, both CFI and TLI should higher than 0.95; and both RMSEA and SRMR should lower than 0.08.³⁷ Multigroup analysis in the confirmatory factor analysis was used to test if the path coefficients differed between the two groups (i.e., UK and TW). The differences of path coefficients between the two groups were examined using chi-square tests. The *lavaan* package in R software³⁸ was used to perform the SEM and multigroup analysis.³⁹ SPSS 26.0 (IBM, Corp., NY: Armonk) was used to perform the remaining data analyses. The significance level was set at $p < .05$.

Results

The scores of all the studied variables as well as the frequency of responses are reported in Tables 1 and 2. Briefly, the scores of all the studied variables were significantly different between the two populations (p -values ≤ 0.001). The bivariate associations between the studied variables among both UK and TW populations are separately reported in Tables 3 and 4.

In the UK population, all the variables were significantly correlated with each other, except for the correlation between threat appraisal and maladaptive response. In the TW population, perceived knowledge and coping appraisal were significantly correlated with all the other variables, except for threat appraisal. Threat appraisal was significantly correlated with maladaptive response ($r = -0.172$, p -value $< .001$), and adaptive response was significantly correlated with vaccination behavior ($r = 0.291$, p -value $< .001$).

Table 1. Participants' characteristics.

	United Kingdom population (n = 751)	Taiwanese population (n = 1052)	p-value
Age (years)	41.17 ± 14.01	37.45 ± 15.05	< .001
Gender			.163
Male	372 (49.5)	489 (46.5)	
Female	370 (49.3)	540 (51.3)	
Prefer to self-define	9 (1.2)	23 (2.2)	
Perceived knowledge (score range: 1–7)	5.32 ± 1.39	4.97 ± 1.15	< .001
Coping appraisal (score range: 1–7)	6.17 ± 1.62	4.88 ± 1.18	< .001
Threat appraisal (score range: 5–35)	12.63 ± 5.36	17.83 ± 6.77	< .001
Adaptive response (score range: 1–7)	5.19 ± 1.80	4.94 ± 1.25	.001
Maladaptive response (score range: 1–7)	4.45 ± 1.92	4.06 ± 1.66	< .001
Vaccination behavior (received booster shot)	526 (70)	879 (83.6)	< .001

Data are presented with mean ± SD or n (%).

Table 2. Frequency response of study variables.

Item	Response; the UK, TW						
	1	2	3	4	5	6	7
<i>Perceived Knowledge</i>							
I know very well how vaccination protects me from COVID-19.	24 (3.2), 41 (3.9)	30 (4.0), 40 (3.8)	22 (2.9), 84 (8.0)	92 (12.3), 223 (21.2)	145 (19.3), 282 (26.8)	266 (35.4), 268 (25.5)	172 (22.9), 114 (10.8)
I understand how the COVID-19 jab helps fight the virus	20 (2.7), 21 (2.0)	33 (4.4), 23 (2.2)	25 (3.3), 58 (5.5)	68 (9.1), 173 (16.4)	187 (24.9), 319 (30.3)	242 (32.2), 329 (31.3)	176 (23.4), 129 (12.3)
The contribution of the COVID-19 jab to my health is very important	55 (7.3), 9 (0.9)	37 (4.9), 33 (3.1)	36 (4.8), 76 (7.2)	76 (10.1), 242 (23.0)	126 (16.8), 323 (30.7)	223 (29.7), 269 (25.6)	198 (26.4), 100 (9.5)
<i>Coping appraisal</i>							
Vaccination is an effective way to protect me.	42 (5.6), 69 (6.6)	32 (4.3), 69 (6.6)	22 (2.9), 101 (9.6)	58 (7.7), 163 (15.5)	78 (10.4), 274 (26.0)	249 (33.2), 274 (26.0)	270 (36.0), 102 (9.7)
It is important that I get the COVID-19 jab	59 (7.9), 28 (2.7)	31 (4.1), 16 (1.5)	19 (2.5), 46 (4.4)	51 (6.8), 168 (16.0)	69 (9.2), 253 (24.0)	194 (25.8), 364 (34.6)	328 (43.7), 177 (16.8)
Vaccination greatly reduces my risk of catching COVID-19.	67 (8.9), 47 (4.5)	79 (10.5), 51 (4.8)	68 (9.1), 94 (8.9)	73 (9.7), 194 (18.4)	135 (18.0), 270 (25.7)	159 (21.2), 282 (26.8)	170 (22.6), 114 (10.8)
Getting the COVID-19 jab has positive influence on my health.	56 (7.5), 11 (1.0)	47 (6.3), 34 (3.2)	34 (4.5), 81 (7.7)	167 (22.2), 292 (27.8)	115 (15.3), 301 (28.6)	196 (26.1), 252 (24.0)	136 (18.1), 81 (7.7)
<i>Threat appraisal</i>							
I am most afraid of COVID-19	266 (35.4), 141 (13.4)	274 (36.5), 287 (27.3)	104 (13.8), 285 (27.1)	90 (12.0), 265 (25.2)	17 (2.3), 74 (7.0)	–	–
It makes me uncomfortable to think about COVID-19	235 (31.3), 158 (15.0)	254 (33.8), 246 (23.4)	96 (12.8), 275 (26.1)	151 (20.1), 302 (28.7)	15 (2.0), 71 (6.7)	–	–
My hands become clammy when I think about COVID-19	492 (65.5), 371 (35.3)	207 (27.6), 332 (31.6)	33 (4.4), 221 (20.1)	16 (2.1), 93 (8.8)	3 (0.4), 45 (4.3)	–	–
I am afraid of losing my life because of COVID-19	355 (47.3), 200 (19.0)	207 (27.6), 246 (23.4)	85 (11.3), 225 (21.4)	84 (11.2), 306 (29.1)	20 (2.7), 75 (7.1)	–	–
When watching news and stories about COVID-19 on social media, I become nervous or anxious.	296 (39.4), 221 (21.0)	223 (29.7), 271 (25.8)	95 (12.6), 280 (26.6)	116 (15.4), 218 (20.7)	21 (2.8), 62 (5.9)	–	–
I cannot sleep because I'm worry about getting COVID-19	542 (72.2), 346 (32.9)	175 (23.3), 326 (31.0)	24 (3.2), 213 (20.2)	8 (1.1), 128 (12.2)	2 (0.3), 29 (3.7)	–	–
My heart races or palpitates when I think about getting COVID-19	519 (69.1), 344 (32.7)	179 (23.8), 201 (28.6)	33 (4.4), 244 (23.2)	16 (2.1), 132 (12.5)	4 (0.5), 31 (2.9)	–	–
<i>Adaptive response</i>							
The COVID-19 jab plays an important role in protecting my life and others	55 (7.3), 9 (0.9)	37 (4.9), 33 (3.1)	36 (4.8), 76 (7.2)	76 (10.1), 242 (23.0)	126 (16.8), 323 (30.7)	223 (29.7), 269 (25.6)	198 (26.4), 100 (9.5)
<i>Maladaptive response</i>							
I feel under pressure to get the COVID-19 jab	48 (6.4), 50 (4.8)	90 (12.0), 153 (14.5)	147 (19.6), 207 (19.7)	93 (12.4), 166 (25.3)	76 (10.1), 128 (12.2)	156 (20.8), 143 (13.6)	141 (18.8), 105 (10.0)

Data are presented as n (%).

The results of SEM are shown in Figure 2. The model fitted well in both the UK and TW populations, as supported by all fit indices (CFI = 1.000 and 0.996, TLI = 1.005 and 0.989, RMSEA = 0.000 and 0.028, SRMR = 0.018 and 0.029), except for the significant χ^2 tests (p -value < .001). In the UK population, the SEM model showed that perceived knowledge was significantly associated with coping appraisal and threat appraisal (standardized coefficient [β] = 0.898 and 0.158). Coping appraisal and threat appraisal were significantly associated

with adaptive response (β = 0.887 and 0.104) and maladaptive response (β = 0.378 and –0.083), respectively. In the TW population, the SEM model showed that perceived knowledge was significantly associated with coping appraisal and threat appraisal (β = 0.941 and –0.022). Coping appraisal and threat appraisal were significantly associated with adaptive response (β = 0.813 and 0.013) and maladaptive response (β = –0.073 and –0.173). Additionally, coping appraisal was significantly associated with vaccination behavior (β = 0.319).

Table 3. Correlations between studied variables in a United Kingdom population (n = 751).

	1	2	3	4	5	6
1 Perceived knowledge	–					
2 Coping appraisal	0.840 (<0.001)	–				
3 Threat appraisal	0.154 (<0.001)	0.144 (<0.001)	–			
4 Adaptive response	0.851 (<0.001)	0.841 (<0.001)	0.230 (<0.001)	–		
5 Maladaptive response	0.326 (<0.001)	0.351 (<0.001)	–0.030 (0.410)	0.328 (<0.001)	–	
6 Vaccination behavior	0.511 (<0.001)	0.558 (<0.001)	0.086 (0.019)	0.541 (<0.001)	0.241 (<0.001)	–

Table 4. Correlations between studied variables in a Taiwanese population (n = 1052).

	1	2	3	4	5	6
1 Perceived knowledge	–					
2 Coping appraisal	0.850 (<0.001)	–				
3 Threat appraisal	–0.042 (0.174)	–0.005 (0.862)	–			
4 Adaptive response	0.829 (<0.001)	0.732 (<0.001)	0.001 (0.963)	–		
5 Maladaptive response	– 0.097 (0.002)	– 0.070 (0.023)	– 0.172 (<0.001)	–0.022 (0.476)	–	
6 Vaccination behavior	0.318 (<0.001)	0.340 (<0.001)	–0.057 (0.065)	0.291 (<0.001)	0.034 (0.275)	–

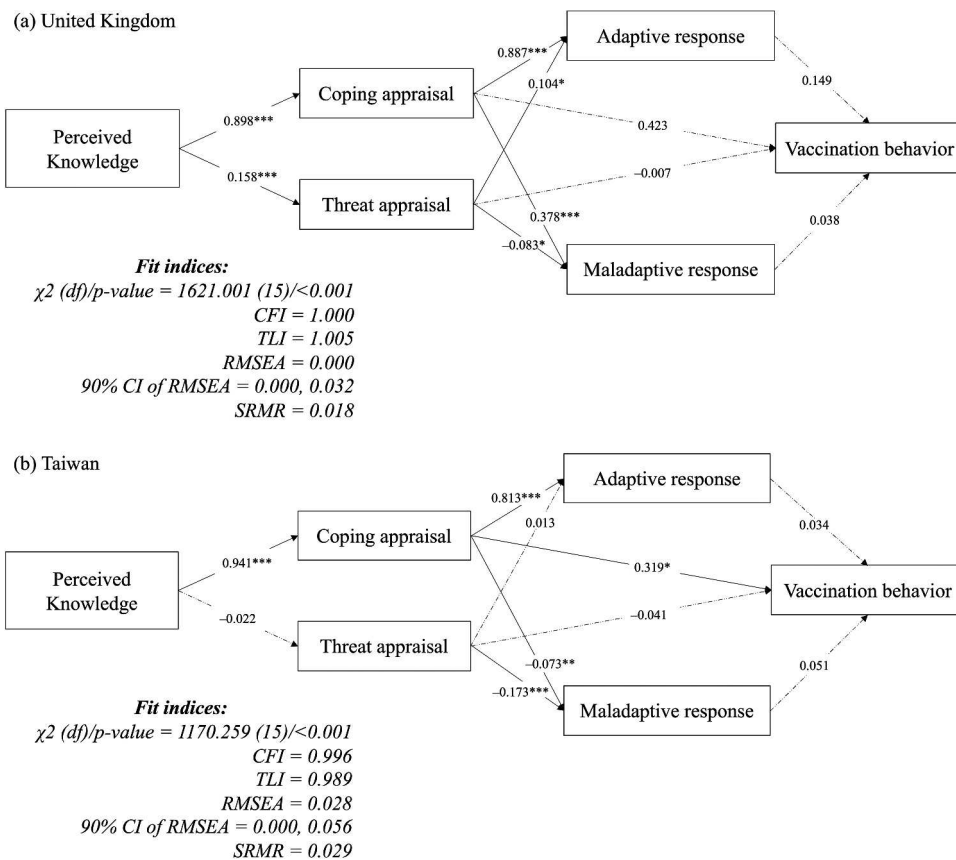


Figure 2. Confirmed model in explaining the COVID-19 vaccination behavior (vaccine uptake) among the (a) UK population and (b) Taiwanese population. Coefficients are presented using standardized coefficients. Solid lines indicate significant pathways while dashed lines indicate non-significant pathways. * $p < .05$; ** $p < .01$; *** $p < .001$; CFI = Comparative fit index; TLI = Tucker – Lewis index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

Table 5. Results of multigroup analysis.

	Unstandardized coefficient (SE)		Chi-square difference (df difference)	<i>p</i> -value (>chi-square)
	UK	TW		
Perceived knowledge (coping appraisal)	1.026 (0.078)	0.940 (0.064)	13.205 (1)	< .001
Perceived knowledge (threat appraisal)	0.061 (0.010)	-0.013 (0.015)	13.516 (1)	< .001
Coping appraisal (adaptive response)	1.004 (0.058)	0.889 (0.049)	19.898 (1)	< .001
Coping appraisal (maladaptive response)	0.456 (0.037)	-0.106 (0.036)	78.976 (1)	< .001
Threat appraisal (adaptive response)	0.348 (0.139)	0.024 (0.073)	22.488 (1)	< .001
Threat appraisal (maladaptive response)	-0.297 (0.147)	-0.426 (0.092)	0.818 (1)	.366
Coping appraisal (vaccination behavior)	0.122 (0.085)	0.103 (0.043)	0.207 (1)	.649

The results of multigroup analysis are shown in Table 5. Significant differences in the path coefficients between the two populations were found in the correlations of perceived knowledge with coping appraisal and threat appraisal ($\Delta\chi^2(\Delta df) = 13.205 (1)$ and $13.516 (1)$, all p -value < .001), the associations of coping appraisal and threat appraisal with adaptive response ($\Delta\chi^2(\Delta df) = 19.898 (1)$ and $22.488 (1)$, all p -value < .001), as well as the association between coping appraisal and maladaptive response ($\Delta\chi^2(\Delta df) = 78.976 (1)$, p -value < .001).

Discussion

The present study investigated the potential factors associated to the vaccination behavior between UK and TW populations. The results from the UK sample showed that perceived knowledge was significantly correlated with coping and threat appraisals. Coping and threat appraisals were respectively associated with adaptive and maladaptive responses. However, none of the factors were associated with vaccination behavior. The results from the TW sample showed that perceived knowledge was significantly correlated with coping appraisal. Coping appraisal was significantly associated with adaptive and maladaptive responses, while threat appraisal was only significantly associated with maladaptive response. However, coping appraisal was associated with vaccination behavior in the TW sample, forming a significant pathway from perceived knowledge to explain the vaccination behavior. In addition, the results from the multigroup analysis showed significant differences in the correlations between (i) perceived knowledge and coping and threat appraisal, (ii) coping appraisal and adaptive and maladaptive responses, and (iii) threat appraisal and adaptive response. Regarding the present findings, the cultural differences between the UK and TW might be crucial in determining the willingness of vaccine uptake. Such cultural differences might explain the different results between the two countries.

The significant correlations between perceived knowledge and coping appraisal as well as coping appraisal and vaccination behavior demonstrated a possible mechanism to explain COVID-19 vaccination behavior in the TW population. Knowledge has been found to be one of the effective

factors in controlling the spread of viruses in pandemics⁴⁰ because knowledge may affect the individuals' attitude,^{41,42} increase self-efficacy⁴³ and response efficacy⁴⁴ to facilitate (even enhance) the adoption of coping strategies as self-protection measures.^{11,40} Previous research has found response efficacy to be the most influential psychosocial predictor^{44,45} that dominates the willingness to get vaccinated. One study showed that the information regarding the COVID-19 vaccine efficacy may prompt individuals' response efficacy and further strengthen vaccination intention.⁴⁵ Accordingly, studies investigating the factors associated with COVID-19 vaccination report that perceived knowledge is usually a pro-vaccination factor.^{11,41,42,46} More specifically, perceived knowledge influences individuals' attitude toward the COVID-19 vaccine.⁴² With perceived response efficacy⁴⁵ and self-efficacy to vaccination,^{9,45} individuals tend to develop vaccination intention and acceptance^{11,42,46} to cope with the COVID-19 pandemic.

However, the findings from the TW sample were somewhat different from the those in the UK sample. The SEM results demonstrated a significant correlation between perceived knowledge and coping appraisal, but the correlation did not extend to vaccination behavior. The multi-group analysis further corroborated the findings that several path coefficients were found to be different between the two studied groups. Literature indicates that the correctness of knowledge may play an important role in deciding the public perception to the COVID-19 vaccine.⁴⁷ It appears that UK participants had lowered their trust toward the British government early in the pandemic because of perceived misinformation⁴⁷ and conspiracy beliefs.^{48,49} One study reported that misinformation regarding COVID-19 may confuse the public and cause psychological distress, therefore contributing to vaccine hesitancy.⁴⁷ In addition, the individuals who believed in conspiracy theories may be misguided⁴⁹ and resulted in distrust with government and authorities,⁵⁰ which may have been a factor in suppressing their willingness to get vaccinated.⁵⁰ Moreover, compared to Taiwan, which embraces a collectivism culture,^{27,28} the individualistic culture of UK society²⁷ may imperceptibly cause the spread of COVID-19.⁵¹ Individualistic societies may be more vulnerable to

infectious diseases^{52,53} because compared to collective cultures which put the group benefits over self, individualistic cultures value the freedom and personal rights.⁵³ Therefore, misinformation and the increase in COVID-19-related conspiracies may interfere with the knowledge perceived by the UK public.^{47,54} This, alongside living in an individualistic cultural orientation, UK citizens would be more hesitant to obey social restraint regulations (e.g., staying at home, avoiding social interaction, etc.)⁵² or COVID-19 preventive strategy (e.g., COVID-19 vaccination),^{48,55} resulting in the delay of essential responses and very high death tolls.^{51,52}

The present study provides informative knowledge regarding COVID-19 vaccine uptake in the UK and TW populations. The findings showed a clear path from perceived knowledge to vaccination behavior in the TW sample, suggesting that knowledge may be a potential facilitator in enhancing COVID-19 preventive strategy. Fear or concern regarding injection, as well as a lack of knowledge regarding COVID-19 vaccine, were reported to be the potential barriers to prevent the vaccine uptake in TW.⁵⁶ In the UK sample, the investigated variables failed to demonstrate a significant pathway in explaining vaccine uptake and the present study provides some possible insights considering sociological characteristics of UK residents. Studies suggest that effective communication strategies⁴⁶ as well as valid and reliable information⁵⁰ may help restore the potential influence of knowledge, reduce the negative attitude toward COVID-19 vaccination,⁴⁷ and facilitate vaccine uptake among individuals in the UK population. In addition, several studies have reported that misinformation may be a potential barrier for the UK population.^{47,57} Therefore, governmental action is needed to help overcome this problem in order to promote the vaccine uptake.

The present study has several limitations. First, the study adopted a cross-sectional study design. The lack of temporal measures restricts the evidence regarding causal relationships between the studied variables. Second, the self-reported data may result in bias and misrepresentation. For example, participants may have social desirability biases and provided responses that were more pro-vaccination. Third, the present study was conducted using snowball sampling (resulting in a modest sample size for each country). Therefore, the samples were unlikely to be representative and lack generalizability. Fourth, a few variables in the present study were assessed using a single item which may have limited the accuracy in assessing these specific variables. Fifth, there may have been some selection bias given that not everybody uses social media platforms. More specifically, it has been reported that 84.3% of the UK population⁵⁸ and 89.4% of the TW population⁵⁹ use social media platforms. Therefore, individuals who do not use social media platform could not participate which impacts on the generalizability of the present findings. Sixth, the response rate in the present study was unknown because it was conducted using snowball sampling. Therefore, it is not known how many individuals were sent the link to participate in the survey.

Conclusion

The present study expanded the PMT with several potential factors including perceived knowledge, adaptive responses, and maladaptive responses to develop a proposed model investigating vaccination behavior among UK and Taiwanese populations. The SEM results showed that perceived knowledge was significantly associated to coping appraisal in both groups. However, the association between coping appraisal and vaccination behavior was only observed in the TW group. Therefore, vaccination behavior among Taiwanese individuals can be improved by providing reliable knowledge regarding COVID-19 vaccination. As for the UK, the potential facilitators for vaccination behavior require further investigation. Moreover, health communication and information clarification may help rebuild some of the public's trust toward authority that helps inhibit the spread of COVID-19.

Acknowledgments

We thank all the participants who responded to the online survey.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The present study was supported in part by a research grant from the Ministry of Science and Technology, Taiwan (MOST109-2327-B-006-005; MOST111-2321-B-006-009), the National Science and Technology Council, Taiwan (NSTC 112-2321-B-006-008-), the WUN Research Development Fund (RDF) 2021 and the Higher Education Sprout Project, the Ministry of Education at the Headquarters of University Advancement at the National Cheng Kung University (NCKU).

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