

# Population Behavior Patterns in Response to the Risk of Influenza A(H7N9) in Hong Kong, December 2013–February 2014

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## Abstract

**Background** A novel avian influenza A(H7N9) virus, first identified in Mainland China in February and March 2013, caused an outbreak in humans in April and May, 2013. Closure of live poultry markets in some affected cities dramatically reduced numbers of cases during summer of 2013, but the epidemic resurged during the winter 2013–14, increasing reported cases to 393 in Mainland China as of 30 March 2014. **Purpose** The study aimed to explore population behavior patterns responding to an epidemic of influenza A(H7N9) virus. **Method** Three cross-sectional surveys were conducted among 1000, 680, and 1011 respondents in December 2013, January 2014, and February 2014, with response rates of 68.0, 64.4, and 66.6 %, respectively, in Hong Kong. Adults were recruited and interviewed using random digit-dialing telephone survey. Latent class analysis was employed to explore heterogeneity in protective behavior patterns across the three surveys. Multinomial regression models were developed to determine factors associated with latent class membership. **Results** Three comparable latent classes were identified across the three surveys: Moderate hygiene compliance (Class 1), High hygiene compliance (Class 2), and Vigilance (Class 3). The prevalence of Class 1 was 48–52 % across the three surveys while Class 3 prevalence increased significantly from 13 % in the Dec-2013 survey to 20 % in the Feb-2014 survey. Compared with Class 1, Class 3 were more likely to be female, older, better educated, married, perceive higher susceptibility to H7N9, attribute greater severity to H7N9, report higher current worry, and anticipated worry about H7N9 infection.

**Conclusion** The three classes reflect different levels of adoption of protection and thereby may have different levels of vulnerability toward contracting H7N9 infection. It appears that as the epidemic intensifies, Class 2 (Good hygiene compliance) members are likely to transfer to Class 3 (Vigilance) while Class 1 (Moderate hygiene compliance) could be unchanged. The young, mostly single males and those with lower educational achievement represent a group for whom public health messages need to be targeted.

**Keywords** Influenza A(H7N9) · Protective behaviors · Risk perception · Latent class analysis

## Introduction

A novel avian influenza A(H7N9) virus, first identified in Mainland China in February and March 2013 [1], caused an outbreak in humans in April and May, 2013 [2, 3]. Closure of live poultry markets in some affected cities dramatically reduced numbers of cases during summer of 2013 [4], but the epidemic resurged during the winter 2013–14, increasing reported cases to 393 in Mainland China as of 30 March 2014 [5]. The winter 2013–14 outbreak was mainly focused in Zhejiang Province in eastern China near Shanghai and Guangdong province in southern China adjacent to Hong Kong [6]. Guangdong's proximity sees considerable daily cross-border movement of people and poultry into Hong Kong. Ten confirmed human cases of H7N9 infection have been reported in Hong Kong since the winter 2013–2014 outbreak, each of which had a recent history of exposure to live poultry in Guangdong [7].

Although a local epidemic has yet to occur in Hong Kong, the behavioral responses among the public in the early stages of an infectious disease epidemic are important for determining the patterns of population contacts. Population behavior

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can significantly modify the basic reproductive number,  $R_0$ , and thereby the daily number of newly emerging cases, influencing the epidemic's trajectory and final size [8–10]. A few studies have tried to measure the patterns of social contacts to provide some empirical parameters for mathematical models to assess the dynamics of transmission during epidemics [9, 10]. These studies mainly focused on patterns of daily individual contacts, and they treated behavior in the population as homogenous, without considering the potential heterogeneity in population behavior in response to infectious disease outbreaks [9, 10]. Latent class analysis (LCA), a statistical approach that captures population heterogeneity and classifies the observed population into a certain number of groups who answer a set of categorical variables in similar ways [11], has been widely used to analyze patterns of behaviors in relation to non-communicable diseases such as alcohol drinking [12, 13]. However, we are not aware of previous studies that attempted to classify population behavioral patterns in response to a new infectious disease. To address this knowledge gap, the first objective of this study was to explore population behavior patterns in response to newly emerging infection diseases, using H7N9 infection as an example. We also examined whether patterns of behavioral responses would change as the H7N9 epidemic grew in Mainland China and more imported H7N9 human cases were reported in Hong Kong.

Accounting for variation in adoption of personal protective behaviors is an important task that has so far not been well addressed. Population behaviors toward a threat are inherently heterogeneous because of individual variation in perceived personal risk to any given threat which serves to motivate responses to the threat [14]. Prevailing cognitive behavioral models [15, 16] propose that higher perceived personal susceptibility to disease and higher perceived threat severity motivates greater adoption of protective behaviors. A recent literature review [14] showed that most empirical studies have consistently reported a positive association between perceived personal risk (including perceived personal susceptibility to and perceived severity of the disease, and worry about the infection) and adoption of both hygiene practices and avoidance behaviors during the 2003 outbreak of severe acute respiratory syndrome and the 2009 influenza A/H1N1 pandemic.

People with different demographics are likely to vary in their perceived personal risk to a common threat. Older people are more likely to view themselves as more susceptible to a disease [17], and thereby they were more likely to adopt hygiene practices [18–20] and avoid public places during epidemics [21, 22]. Reports suggest that females perceive themselves to be more vulnerable to a threat and to worry more about diseases [23]. Women report better hygiene and more avoidance behaviors during epidemics [18, 19, 24]. The association between educational attainment and adoption of

protective behaviors is less conclusive in the literature [14]. Better educated individuals may be more aware of the risk related to the threat but may also have more confidence to control the threat [25], and so might be expected to be more variable in their responses to a new infectious disease. Therefore, the second objective of this study involved examining how patterns of behavioral responses among the public differed by their demographics and risk perception relating to H7N9 infection.

## Methods

### Timing of the Population Surveys

Three independent cross-sectional surveys were conducted among the Hong Kong general public in 4–8 December 2013 (Dec-2013 survey), 23–28 January 2014 (Jan-2014 survey), and 12–17 February 2014 (Feb-2014 survey), respectively. The Dec-2013 survey was conducted after two imported cases were reported in Hong Kong and before the winter 2013–2014 outbreak had started, while the Jan-2014 and Feb-2014 surveys were conducted during the peak of the winter 2013–2014 outbreak. The Feb-2014 survey was also conducted after H7N9 virus was first identified from samples of live chickens imported from Mainland China and the government closed all live poultry markets in Hong Kong accordingly [26]. Three more imported cases were confirmed in Hong Kong between the Jan-2014 and the Feb-2014 surveys.

### Participants

Penetration of landlines among Hong Kong households was around 100 % [27]. Over 90 % of the Hong Kong population were Chinese ethnicity and able to communicate using Cantonese or Mandarin. All three surveys recruited subjects who were of Chinese ethnicity, aged 18 years or above, and able to speak Cantonese or Mandarin. To recruit subjects, households were first selected using random-digit dialed telephone numbers. Then within each household, one eligible subject was randomly selected using Kish grid methods and invited to complete a telephone interview based on a standardized questionnaire. This has been demonstrated to be a valid method to recruit a sample representative of the population in Hong Kong in previous studies [19, 28]. All calls were made by an experienced polling institution that had demonstrated good performance in similar population surveys [28]. All interviews were conducted during non-working hours to avoid oversampling of unemployed subjects. Up to four additional calls were made for unanswered numbers or if the selected subjects were not available. All respondents gave verbal consent before participating in the study. The study obtained ethics

approval from the Institutional Review Board of The University of Hong Kong/Hospital Authority Hong Kong West Cluster.

A total of 1000, 680, and 1011 respondents completed the Dec-2013, Jan-2014, and Feb-2014 surveys, with response rates of 68.0, 64.4, and 66.6 %, respectively.

### Study Measures

The questionnaires used for the three surveys were similar to those used in our previous surveys related to severe acute respiratory syndrome (SARS) [19], A/H5N1 in 2004 and 2005 [29, 30], and the 2009 influenza A/H1N1 pandemic [28]. Each questionnaire required on average 15 min to complete by telephone interview. This paper focuses on respondents' adoption of protective measures and their associations with perception of H7N9 risk and demographics. All the following measures were assessed using identical items for the three surveys.

*Adoption of Protective Measures* A total of 14 items were used to measure respondents' adoption of protective measures including hygiene practices, avoidance behaviors, and wearing face masks. Specifically, respondents were asked how frequent they had adopted the following seven practices 3 days prior to the survey: washing hands after sneezing or coughing, washing hands after returning home, using liquid soap when washing hands, using serving utensils when dining with others, avoiding touching common objects such as door knobs and lift buttons, washing hands after touching common objects, and wearing face masks. Responses for all these items were dichotomized as "1=always/usually" and "0=sometimes/never" except for of the item "wearing face masks" which was dichotomized as "1=always/usually/sometimes" and "0=never" because it is unlikely that most respondents will routinely wear face masks in their daily life. Respondents were also asked whether they had adopted any of the following practices in the 7 days prior to the survey: avoiding eating out, avoiding using public transport, avoiding going to crowded places, rescheduling travel plans, cleaning or disinfecting household more often, avoiding visiting live poultry market, and avoiding eating poultry. All these items were dichotomized as "1=yes" and "0=no" for subsequent data analysis.

*Perceived Susceptibility to H7N9 Infection* Respondents were asked about their perceived personal likelihood of being infected with H7N9 over the next 1 month. Responses for this item were seven-point Likert scale ranged from "never" to "certain."

*Perceived Severity of H7N9* One item each addressed respondents' perception of H7N9 severity relative to SARS and

A/H5N1, respectively. Responses for these two items were on five-point categorical scales that ranged from "Much lower" to "much higher."

*Worry About H7N9 Infection* One item addressed respondents' anticipated level of worry about developing flu-like symptoms the next day. Responses for this item were on a seven-point categorical scale ranging from "not at all worried" to "extremely worried." Another item asking respondents to rate their current level of worry about H7N9 infection on a scale from "1" to "10", with 1 indicating "very mild" and 10 indicating "very severe."

*Demographics* Age, gender, education attainment, place of birth, and marital status were collected at the end of the questionnaire.

### Data Analysis

Proportions of adopting different protective behaviors across surveys were first calculated and weighted by age, gender, and educational achievement within the Hong Kong general population. Then, LCA was employed to explore latent classes regarding adoption of protective behavior among the respondents across the three surveys. To perform the LCA, all items on protective measures which had been dichotomized as described above were entered into Mplus 6.0 for data analysis. Mplus employs full information maximum likelihood (FIML) methods to handle missing data. Hence, all cases can be used for data analysis except for cases with data missing in all analyzed items [31]. To determine how many latent classes can best fit to our data, LCA was performed in an exploratory way starting with a single-class model. The model with " $n+1$ " classes was compared against model with " $n$ " classes in terms of major model fit statistics including Akaike information criterion (AIC), Bayesian information criterion (BIC), sample size adjusted BIC (aBIC), and entropy value. Models with smaller values of AIC, BIC, and aBIC and greater entropy values were preferred. The simulation study suggested that BIC index was more accurate in determining the true number of classes in LCA based on large sample size ( $N=1000$ ) compared with AIC and aBIC [32]. Entropy has a value range from 0 to 1 with higher values indicating better quality of classification of the model [31]. Except for the model fit statistics, the principle of parsimony and model interpretability are another two critical criteria for determining the optimal number of latent classes [33]. Parsimony means that when other conditions are equal, model selection should favor the model with fewer freely estimated parameters. That is, the model with fewer latent classes should be selected. For multigroup models, model selection should also privilege models in which all groups have the same number of latent classes if the data can be easily interpreted based on the same model

[33]. Using the above criteria, the optimal number of latent class was determined for each sample. LCA estimates both the item-response probabilities for each latent class and the class probabilities (latent class prevalence) within each sample.

If the number of latent classes is the same for the three samples based on the above procedure, multigroup LCA will be conducted to determine the equivalence in behavior patterns across samples, that is, the equivalence test of item-response probabilities for each latent class across the three samples while number of latent classes is set equal across samples. To do this, we compare the unconstrained model (M1) in which all item-response probabilities and class probabilities across the three samples were set free and a nested model (M2) in which item-response probabilities were set equal across samples but class probabilities were allowed to vary across samples. Then M1 and M2 will be compared for their likelihood ratio chi-square ( $G^2$ ) and values of AIC and BIC. An insignificant  $p$  value ( $p > 0.05$ ) associated with the difference  $G^2$  statistics and smaller values of AIC and BIC suggest that the more restrictive model fits as well as the less restrictive model, then for the principle of parsimony, the more restrictive model will be selected [33]. If item-response probabilities could be constrained equal across samples, equivalence in class probabilities will then be tested by comparing M2 with a further nested model (M3) in which item-response probabilities and class probabilities across samples were set equal.

If item-response probabilities could be constrained equal across samples, the three samples will be combined into one to rerun the LCA to determine individual class memberships. The prevalence of latent classes across the three samples will then be compared using multinomial logistic regression model adjusted by sample age, gender, and educational attainment. Multinomial logistic regression models were also performed to determine factors associated with patterns of protective behavioral responses (latent class membership). The odds ratios (OR) of respondents with certain characteristic belonging to a particular class relative to belonging to the reference class and their corresponding 95 % confidence interval (CI) were estimated.  $p$  values of less than 0.05 were considered as statistically significant for all analysis.

## Results

The characteristics of the respondents were generally comparable across the three surveys except that the second surveys comprised more respondents aged 34–55 years (Appendix Table). Adoption of the 14 preventive measures among the respondents across the three surveys is shown in Table 1. Generally, compliance to hand hygiene was high among respondents with more than 60 % across the three surveys. The prevalence of avoidance behaviors was generally low, but

around one third of the respondents reported avoiding crowded places and avoiding markets where live poultry were sold.

### Behavioral Patterns Regarding Adoption of Preventive Measures Across the Three Surveys

Table 2 shows that BIC values were lowest for the three-class model across all three surveys. Additionally, the entropy value was also highest for the three-class model in both the Dec-2013 and Jan-2014 surveys (Table 2). Although the values of AIC or aBIC continued to decline as the four-class model and the five-class model were tried, based on the principle of parsimony and model interpretation, the model with fewer latent classes that is easier to interpret and, for multiple groups, the model in which all groups can hold the same number of latent classes are preferred [33]. Therefore, according to the value of BIC, parsimony, and model interpretation, the three-class model was determined to be optimal in all three surveys.

*The profiles of the three latent classes* across the three surveys were indicated by the estimated response probabilities on each preventive measure (item-response probabilities) for members within each latent class. A higher positive item-response probability indicated a higher chance a respondent would adopt a particular preventive measure. Figure 1 shows the positive response probabilities for each preventive measure in each latent class across the three surveys. It shows that the conditional item-response probabilities in each latent class only vary slightly across the three surveys, indicating that the profiles of three latent classes are comparable across the three surveys (Fig. 1). In all three surveys, Class 1 was characterized by a moderate probability of adopting basic hygiene practices including washing hands after sneezing or coughing, washing hands after returning home, and using liquid soap when washing hands. The probability of adopting other preventive measures in Class 1 was low. Therefore, we named this class “Moderate hygiene compliance” group. Class 2 had high compliance with most routine hygiene practices but low probabilities of adopting avoidance behaviors. Class 2 was labeled “Good hygiene compliance.” Class 3 was characterized by both high probabilities of adopting hygiene practices and relatively higher probabilities of avoidance behaviors relative to Classes 1 and 2. It indicates that this group of people may have heightened sensitivity toward threat signals in the environment, one manifestation of which is enhanced vigilance [34, 35]. Class 3 was labeled “Vigilance.”

Although item-response probabilities in each latent class across surveys were generally comparable, there was an obvious declining trend of adopting washing hands after sneezing and coughing for members of Class 1 across the three surveys while members of Class 3 apparently increased adoption of wearing face mask in the Jan-2014 survey but reduced that in the Feb-2014 survey (Fig. 1). Members of Class 3 also

**Table 1** Adoption of protective behaviors across the three surveys, Hong Kong, December 2013–February 2014

Behaviors	Dec-2013 survey (%)	Jan-2014 survey (%)	Feb-2014 survey (%)
Wash hands after sneezing, coughing <sup>a</sup>	69.9 (66.4–73.4)	71.7 (67.3–76.0)	62.8 (58.9–66.8)
Wash hands after returning home <sup>a</sup>	80.1 (77.2–83.0)	82.4 (79.1–85.8)	78.7 (75.6–81.7)
Use liquid soap when washing hands <sup>a</sup>	68.5 (65.1–72.0)	68.7 (64.6–72.7)	70.5 (67.2–73.9)
Use serving utensils when dining with others <sup>a</sup>	44.0 (40.3–47.8)	50.1 (45.6–54.7)	43.3 (39.5–47.0)
Wash hands after touching common objects <sup>a</sup>	35.6 (32.3–39.0)	37.0 (32.9–41.2)	37.1 (33.6–40.5)
Clean and disinfect household <sup>b</sup>	25.8 (22.5–29.0)	33.2 (29.0–37.4)	25.6 (22.3–28.8)
Wear face mask <sup>c</sup>	12.1 (9.6–14.6)	17.5 (14.3–20.8)	15.7 (13.1–18.3)
Avoid touching common objects <sup>a</sup>	10.0 (7.8–12.1)	11.4 (8.7–14.1)	7.7 (5.9–9.5)
Avoid eating out <sup>b</sup>	8.1 (6.0–10.1)	11.2 (8.5–13.9)	8.6 (6.7–10.5)
Avoid using public transport <sup>b</sup>	3.5 (2.2–4.9)	4.4 (2.5–6.4)	4.9 (3.4–6.3)
Avoid going to crowded places <sup>b</sup>	29.8 (26.4–33.1)	30.6 (26.7–34.6)	27.2 (24.0–30.5)
Reschedule travel plan <sup>b</sup>	6.8 (5.0–8.6)	10.3 (7.7–12.9)	8.4 (6.5–10.3)
Avoid visiting markets <sup>b</sup>	30.5 (27.2–33.8)	38.2 (34.0–42.4)	38.4 (34.9–42.0)
Avoid eating poultry <sup>b</sup>	15.0 (12.6–17.5)	18.3 (15.0–21.6)	18.6 (15.9–21.4)

All percentages were weighted by population age, gender, and educational attainment. Percentages in the parentheses were 95 % confidence interval

<sup>a</sup> Response scales for the items were “never,” “sometimes,” “usually” and “always.” Proportions were for those who answered either always or usually

<sup>b</sup> Response scales for the items were “yes” and “no.” Proportions were for those who answered yes

<sup>c</sup> Response scales for the items were “never,” “sometimes,” “usually,” and “always.” Proportions were for those who answered either always, usually, or “sometimes”

reduced their adoption of cleaning and disinfecting household, avoiding eating out, avoiding visiting live poultry markets, and avoiding eating poultry in the Feb-2014 survey (Fig. 1).

*Multigroup LCA* was further conducted to test equivalence in behavior patterns across samples. Table 3 shows the fit

**Table 2** Model fit indices to compare different models across the three surveys

Model	AIC	BIC	aBIC	Entropy
The Dec-2013 survey				
Two classes	12,505.87	12,648.17	12,556.06	0.66
Three classes	12,328.74	12,544.64 <sup>a</sup>	12,404.89	0.69
Four classes	12,285.16	12,574.66	12,387.27 <sup>a</sup>	0.66
Five classes	12,264.13 <sup>a</sup>	12,627.23	12,392.20	0.65
The Jan-2014 survey				
Two classes	8874.77	9005.39	8913.32	0.68
Three classes	8736.41	8934.60 <sup>a</sup>	8794.90	0.69
Four classes	8683.92	8949.67	8762.34	0.68
Five classes	8663.34 <sup>a</sup>	8996.66	8761.71 <sup>a</sup>	0.66
The Feb-2014 survey				
Two classes	13,308.85	13,451.49	13,359.39	0.64
Three classes	13,178.71	13,395.14 <sup>a</sup>	13,255.39	0.62
Four classes	13,110.37	13,400.57	13,213.18 <sup>a</sup>	0.65
Five classes	13,088.32 <sup>a</sup>	13,452.30	13,217.27	0.69

AIC Akaike information criterion, BIC Bayesian information criterion, aBIC sample size adjusted Bayesian information criterion

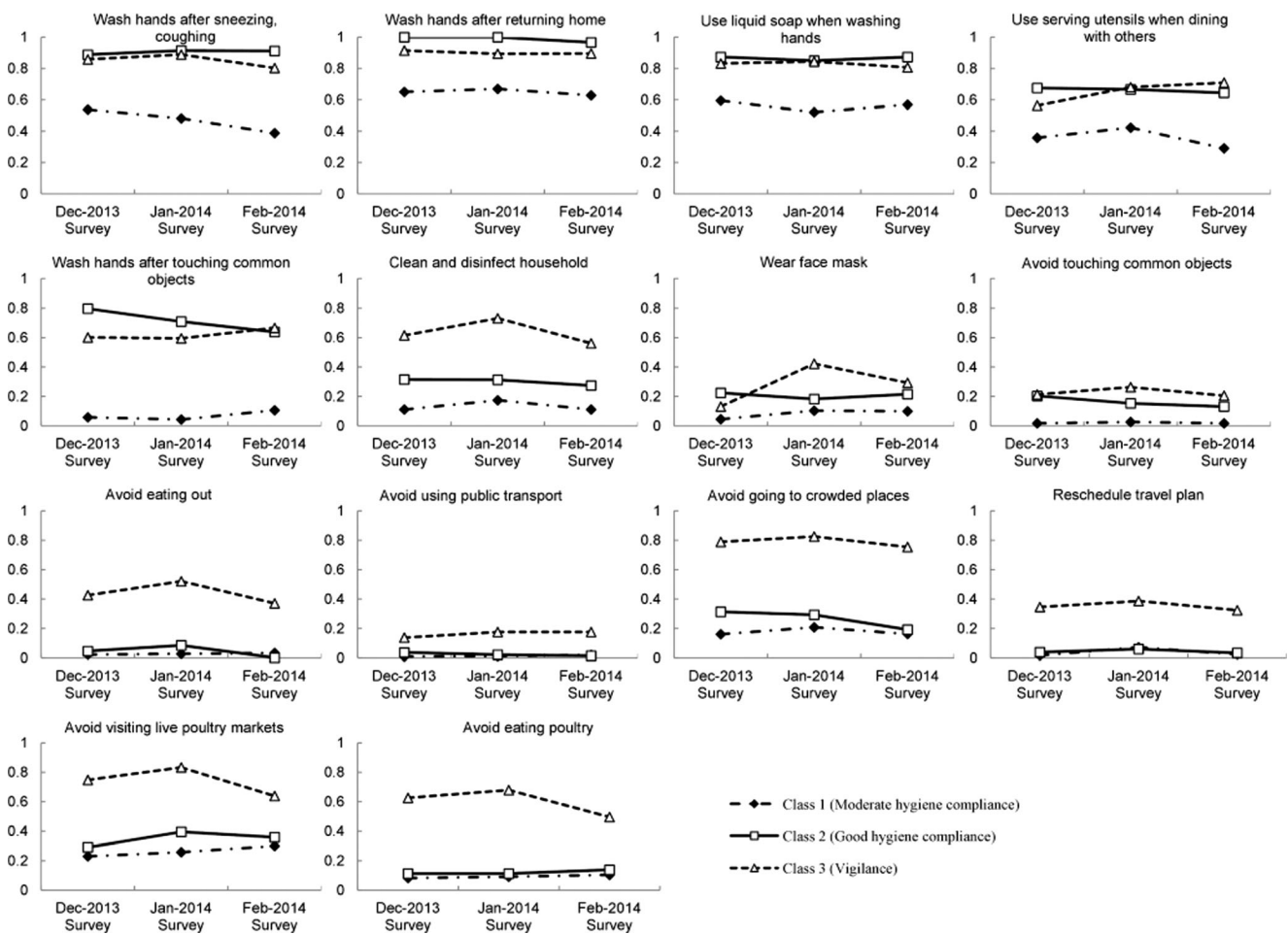
<sup>a</sup> The lowest values across different models

statistics for sets of nested models. The difference of  $G^2$  between M2 (the more constrained model) and M1 (the unconstrained model) was statistically significant, indicating that M2 did not fit as well as M1. However, the large number of degree of freedom difference between these two models ( $\Delta df = 86$ ) raised a question about whether  $G^2$  differences ( $\Delta G^2$ ) could distribute approximately well by chi-square [33]. Furthermore, the lower values of AIC and BIC for M2 indicated that the more parsimonious M2 should be selected. Taking into account the comparable item-response probabilities within each latent class across samples (Fig. 1), we determined that item-response probabilities across samples could be equally constrained. Comparing M3 (the complete constrained model) with M2, the  $\Delta G^2$  indicated that M3 did not fit as well as M2. The higher value of AIC for M3 than for M2 also indicated that class probabilities were not equivalent across the three samples.

The prevalence of latent classes across the three surveys, after adjustment for sample age, gender, and educational attainment using a multinomial logistic regression model, indicated that only prevalence of Class 2 and Class 3 varied across surveys with prevalence of Class 2 being significantly lower while prevalence of Class 3 significantly increased in the Feb-2014 survey (Fig. 2).

#### Factors Associated with Response Patterns

Since item-response probabilities can be set equal across the three surveys, indicating structure invariance of behavior



**Fig. 1** Positive item-response probabilities of the preventive measures for members within each latent class across the three cross-sectional surveys. See footnote to Table 1 for interpretation of positive responses

patterns across samples, the three samples were subsequently treated as one sample for the purposes of examining factors associated with latent class membership. Table 4 shows comparisons of the characteristics and perceptions of H7N9 risk by the three latent classes. The three classes differed significantly in most characteristics including gender, age, educational achievement, place of birth, and marital status. Compared with the other two classes, respondents in Class 1 (moderate hygiene compliance) were more likely to be male, single, young respondents with higher educational attainment and born in Hong Kong. The three classes also differed in perceived personal susceptibility; perceived severity of H7N9 compared with A/H5N1; anticipated worry about developing flu-like symptoms; current worry about H7N9, with respondents in Class 3 (Vigilance) reporting the highest levels of perceived susceptibility; perceived severity; and anticipated worry and current worry toward H7N9 (Table 4).

Multinomial logistic regression model was conducted to examine factors associated with patterns of behavioral responses adjusted by study waves. The results (Table 5) indicated that compared with Class 1 (moderate hygiene

compliance), Class 2 (High hygiene compliance), and Class 3 (Vigilance) were more likely to be female, older, better educated, perceived higher susceptibility, and had higher level of current worry toward H7N9. Furthermore, compared with Class 1 (moderate hygiene compliance), Class 3 members (Vigilance) were also more likely to be married or formerly married, perceive greater severity for H7N9 relative to A/H5N1, and report higher anticipated worry (Table 5).

### Discussion

We believe this to be the first study that quantifies and characterizes population patterns of preventive behavior in the pre-epidemic stage. Across the three samples, we identified three comparable major patterns (classes) in preventive behavior: the moderate hygiene compliance, Good hygiene compliance, and Vigilance. This suggests that, currently within the context of repeated epidemic influenza irruptions from South China, the Hong Kong population may retain relative stable patterns of behavioral responses to a new infectious disease in the early

**Table 3** Multigroup latent class analysis to compare model fit statistics of nested models

Model	Model description	AIC	BIC	$\Delta G^2$	$\Delta d_f$	<i>p</i> value
M1	All item-response probabilities and class probabilities are allowed to vary across samples	40,043.97	40,833.61	–	–	–
M2	Item-response probabilities were set equal across samples but class probabilities are allowed to vary across samples	40,018.17	40,312.81	157.26 <sup>a</sup>	86	<0.05
M3	All item-response probabilities and class probabilities were set equal across samples	40,024.08	40,295.15	10.60 <sup>b</sup>	4	<0.05

*AIC* Akaike information criterion, *BIC* Bayesian information criterion,  $G^2$  likelihood ratio chi-square,  $d_f$  degree of freedom

<sup>a</sup> Compared with  $G^2$  in M1

<sup>b</sup> Compared with  $G^2$  in M20

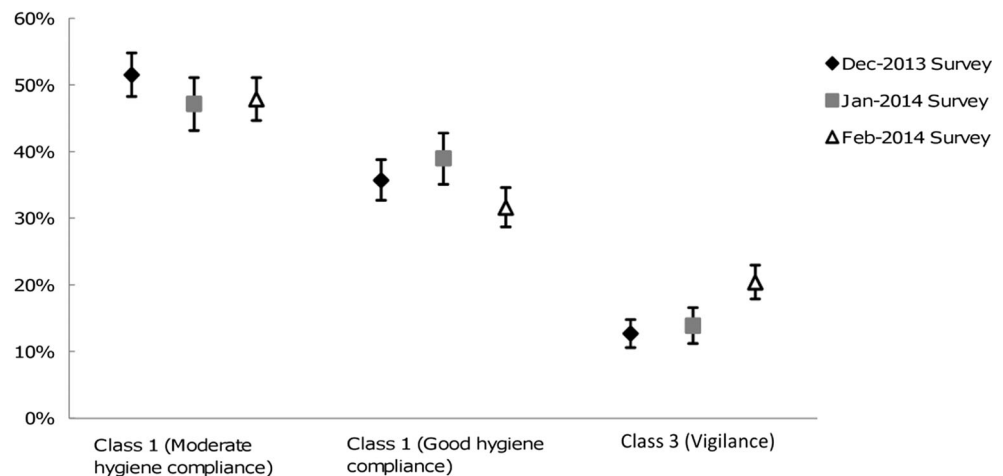
stages, even as more confirmed cases of human infection were reported and the epidemic progressed [6]. The generally consistent item-response probabilities of a particular latent class across the three surveys further suggest structural invariance in behavior patterns [33] though it is possible that members of particular classes also change certain behaviors. For example, the Moderate hygiene compliance group reduced hand-washing after coughing or sneezing as the epidemic progressed but might have demonstrated an increase if the epidemic had significantly intensified. Moderate hygiene compliance defined the most prevalent group and its prevalence was comparable across the three surveys. Members in the Moderate hygiene compliance class may be quite resistant to changing their existing pattern of practices even if a potential epidemic is indicated but might change if significant increases in threat level are indicated. However, there were significant changes in prevalence of Class 2 (Good hygiene compliance) and Class 3 (Vigilance) in the third survey (Feb-2014 survey), suggesting that as the H7N9 epidemic became more severe in Mainland China and more imported H7N9 human cases were reported in Hong Kong; members of Class 2 may become more vigilant to the threat and thereby increase adoption of avoidance behaviors subsequently. However, this speculation awaits confirmation in future cohort surveys.

The Moderate hygiene compliance class accounted for around half of the respondents, who adopted only the most basic

hand hygiene practices at a moderate level. Since it is unlikely that people will reduce their prevention practices in response to a growing epidemic threat, this pattern of practices is very likely to be habitual or even increased over the usual level seen in the absence of any epidemic activity. This class may contribute to transmitting infections such as seasonal influenza in their daily life or they might be late-stage responders who intensify protective behaviors only when risk is perceived to be imminent. Compared with the characteristics of the other two classes, respondents in this class were more likely to be male, younger, and less educated. This is consistent with previous studies conducted during SARS and the 2009 influenza A/H1N1 pandemic in Hong Kong [18, 19, 28], suggesting that these subpopulations should be considered for targeted public health interventions to control future outbreaks of infectious diseases.

The Good hygiene compliance class, which captured around one third of respondents, was characterized by greater hygiene practices relative to Class 1 but few avoidance behaviors. However, members of this group perceived generally comparable levels of threat from H7N9 to members of Moderate hygiene compliance except that members in Good hygiene compliance reported slightly higher perceived susceptibility and level of current worry about H7N9. The comparable risk perception patterns to those seen in Moderate hygiene compliance members suggest that habitual preventive practices dominate in this

**Fig. 2** Prevalence of latent class memberships across the three surveys. The *error bars* represent the 95 % confidence for each class probability estimated using multinomial logistic regression models



**Table 4** Comparison of the characteristics, risk perception, and anxiety state among the three latent classes

Characteristics	Moderate hygiene compliance (N=1287) (%)	Good hygiene compliance (N=950) (%)	Vigilance (N=441) (%)	Differences
<b>Gender</b>				
Male	46.9	32.3	28.2	<0.001
Female	53.1	67.7	71.7	
<b>Age group</b>				
18–34 years	29.1	16.2	12.3	<0.001
35–54 years	34.5	37.0	35.3	
≥55 years	36.4	46.8	52.4	
<b>Education</b>				
Primary or below	18.2	19.7	16.8	<0.001
Secondary	44.0	47.0	57.1	
Tertiary or above	37.7	33.3	26.0	
<b>Place of birth</b>				
Hong Kong	65.6	62.3	56.3	<0.001
Other places	34.4	37.7	43.7	
<b>Marital status</b>				
Single	32.2	21.9	14.2	<0.001
Married/formerly married	67.8	78.1	85.7	
<b>Perceived susceptibility</b>				
Never/very unlikely/unlikely/evens	91.1	88.5	85.1	0.002
Likely/very likely/certain	8.9	11.5	14.9	
<b>Perceived severity of H7N9 compared with SARS</b>				
Much lower/a bit lower/same	90.9	88.3	87.6	0.064
A bit higher/much higher	9.1	11.7	12.4	
<b>Perceived severity of H7N9 compared with H5N1</b>				
Much lower/a bit lower/same	64.4	61.0	50.4	<0.001
A bit higher/much higher	35.6	39.0	49.6	
<b>Anticipated worry if to develop flu-like symptoms</b>				
Not at all/less/the same as normal	65.6	61.3	45.7	<0.001
More/much more/extremely worry	34.4	38.7	54.2	
<b>Current feeling of worry</b>				
Score of 1–5	79.8	76.6	66.1	<0.001
Score of 6–10	20.2	23.4	33.9	

class also. The occasional avoidance behavior characterizing the behavior pattern of members in Good hygiene compliance suggests that they may have greater propensity toward modifying behavior should threat increase, through adopting greater avoidance and intensification of prevention.

Previous mathematical models concluded that early behavioral change in response to an epidemic is small and should have little impact on the development of the epidemic [36]. However, the present study suggests that even in the early pre-epidemic stage, when there is little evidence for human-to-human transmission of H7N9 and no locally acquired cases, around 13–20 % of the respondents had reported high compliance to most hygiene practices and avoidance behaviors, indicating high vigilance to the threat. Except for high compliance to hygiene practices, this group also adopted more avoidance behaviors that were recommended by the

government of Hong Kong, suggesting that this group had high compliance to government recommendation in the prevention of H7N9. The odds of an individual being assigned to this group were positively associated with greater perceived threat from H7N9 relative to members in the other two classes. Female, older, married, and better educated individuals were more likely to belong to Class 3 compared to the other two classes. This was also consistent with previous studies conducted during SARS [14, 19].

Previous studies have indicated that humans are inherently heterogeneous in their attention to threat, which is closely linked to personality characteristics such as neuroticism and trait anxiety [34, 35, 37]. For example, people who are generally more anxious would be expected to show high vigilance for potential threat information [34, 35]. Variation in these personality characteristics generates variable attentional bias



**Table 5** Factors associated with patterns of behavioral responses regarding the prevention of influenza H7N9

Demographics	Association (OR, 95 %CI) <sup>a</sup>	
	Class 2 (Good hygiene compliance)	Class 3 (Vigilance)
Gender		
Male	1.00	1.00
Female	1.80 (1.46–2.21)***	2.21 (1.67–2.93)***
Age group		
18–34 years	1.00	1.00
35–54 years	1.75 (1.27–2.40)**	1.69 (1.07–2.66)*
≥55 years	2.61 (1.85–3.68)***	3.33 (2.07–5.34)***
Education		
Primary or below	1.00	1.00
Secondary	1.18 (0.87–1.60)	1.77 (1.19–2.64)**
Tertiary or above	1.42 (1.01–2.01)*	1.82 (1.15–2.86)*
Place of birth		
Hong Kong	1.00	1.00
Other places	1.11 (0.90–1.38)	1.26 (0.96–1.66)
Marital status		
Single	1.00	1.00
Married/formerly married	1.27 (0.95–1.69)	2.15 (1.42–3.26)***
Perceived susceptibility		
Never/very unlikely/unlikely/evens	1.00	1.00
Likely/very likely/certain	1.39 (1.00–1.94)*	1.65 (1.11–2.45)*
Perceived severity of H7N9 compared with SARS		
Much lower/a bit lower/same	1.00	1.00
A bit higher/much higher	1.32 (0.94–1.86)	1.12 (0.73–1.73)
Perceived severity of H7N9 compared with H5N1		
Much lower/a bit lower/same	1.00	1.00
A bit higher/much higher	0.97 (0.79–1.20)	1.54 (1.18–2.01)**
Anticipated worry if to develop flu-like symptoms		
Not at all/less/the same as normal	1.00	1.00
More/much more/extremely worry	1.18 (0.96–1.46)	1.89 (1.44–2.48)***
Current feeling of worry related to H7N9 (1–10)*		
Score of 1–5	1.00	1.00
Score of 6–10	1.28 (1.00–1.63)*	2.03 (1.52–2.73)***

OR odds ratios relative to the reference group, 95 %CI 95 % confidence interval

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$

<sup>a</sup> The reference group was Class 1 (Moderate hygiene compliance)

in information processing and, coupled with cognitive style manifests as enhanced, or blunted vigilance toward threat-

related information [38, 39]. This might help to explain the spectrum of active and passive behaviors seen when different individuals face a common threat signal. However, we did not measure neuroticism or trait anxiety among the respondents and thereby cannot conclude whether the heterogeneity in behavioral responses to this new infectious diseases was due to variation in these personality characteristics or not. However, the significant difference in perceived threat of H7N9 among the three classes suggests that variation in perceived vulnerability at least partially explained the behavioral heterogeneity across classes. Such variability has long been described with younger males particularly poor at risk estimates and overconfident in their abilities to control risk impacts [23, 40], so this may reflect a developmental state.

This study had some limitations. First, although the three independent cross-sectional surveys enable observing the change in profiles and prevalence of each behavior pattern, the actual growth and decay of preventive behaviors in these three classes within the evolution of an epidemic remain unknown. Longitudinal studies should be conducted throughout future epidemics to more precisely investigate these research questions. Second, sampling errors may be a reason for the variation in prevalence of behavior patterns across surveys. However, the three cross-sectional surveys were conducted using the same sampling methods, and the demographics of the three samples were generally comparable. We had further adjusted the difference in the prevalence of behavioral patterns by sampling age, gender, and education to minimize the influence of sampling errors on behavioral variation across samples. Third, our measure of perceived personal susceptibility to H7N9 was not conditional on “not taking any prevention.” This may lead to underestimation of the true association between perceived personal susceptibility and adoption of prevention if some respondents estimated their personal susceptibility to be low because they had taken the preventive behaviors [41]. Furthermore, although LCA provides significant insights in guiding public health practices, how to determine the optimal number of classes using LCA can be as much an art as a science [31]. Here, we determined the final number of latent classes based on BIC, entropy value, the principle of parsimony, and the model interpretation, factors which have been suggested to be more important over other model fit indices in simulation studies [31–33]. Finally, since all behaviors were measured relying on self-reported data, the results may be subject to social desirability bias. As a result, the actual size of the second and the third classes may be overestimated.

In conclusion, Hong Kong’s population may evidence three major protective behavior response classes in the face of preliminary threat from H7N9, tentatively named: Moderate hygiene compliance, Good hygiene compliance, and Vigilance. These three classes reflect different levels of adoption of protection which may translate to different levels of vulnerability toward contracting and spreading H7N9 infection or

instead may be a reflection of generalized compliance behavior. It appears that as epidemic threat increases, more people in Good hygiene compliance may transfer to the Vigilance group while that of Moderate hygiene compliance may remain unchanged. However, it remains unknown how the trajectories of change in these behavioral practices will unfold as the threat level evolves throughout an epidemic. Given the present limited data, young, mostly single males and those with lower educational achievement represent a group for whom public health messages need to be targeted.

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**Conflict of Interest** BJC reports receipt of research funding from MedImmune Inc. and Sanofi Pasteur for studies of influenza vaccines and consulted for Crucell NV. The authors declare no other potential conflict of interest.

## Appendix

**Table 6** Characteristics of respondents in the surveys conducted in 2014

	Dec-2013 survey (%)	Jan-2014 survey (%)	Feb-2014 survey (%)	Differences ( <i>p</i> ) <sup>b</sup>
<b>Sex</b>				
Female	62.6	61.0	60.1	0.521
Male	37.4	39.0	39.9	
<b>Age group (years)</b>				
18–34	23.5	19.4	21.9	0.006
35–54	35.1	40.8	32.4	
≥55	41.4	39.3	45.7	
<b>Education</b>				
Primary or below	18.6	16.8	19.5	0.073
Secondary	45.0	47.1	49.4	
Tertiary or above	36.4	36.1	31.0	
<b>Place of birth<sup>a</sup></b>				
Hong Kong	64.0	60.0	65.7	0.473
Other places	36.0	40.0	34.3	
<b>Marital status<sup>a</sup></b>				
Single	26.4	28.8	27.3	0.988
Married/formerly married	73.6	71.1	72.7	

<sup>a</sup> Proportions were weighted by the age, gender, and educational attainment of the general population in Hong Kong

<sup>b</sup> Differences were examined based on Pearson chi-square test

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