Risk perception as a double-edged sword in policy compliance in COVID-19 pandemic? A two-phase evaluation from Hong Kong

Ricci P.H. Yue^{a*}, Bobo H.B. Lau^{b*}, Cecilia L. W. Chan^c, Siu-Man Ng^c

^aDepartment of Geography, University of Hong Kong, Hong Kong
Tel.: +852 6018 2370.

E-mail address: ricciyue@connect.hku.hk

^bDepartment of Counselling and Psychology, Hong Kong Shue Yan University, Hong Kong
Tel.: +852 2570 7110.

E-mail address: hplau@hksyu.edu

^cDepartment of Social Work and Social Administration, University of Hong Kong

* Corresponding authors.

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Abstract

The emphasis of risk has been recognized as a crucial component to effective and successful policy compliance amidst a crisis. Yet, during the COVID-19 pandemic, when the impact of risk may fluctuate with the severity of the prolonged pandemic, and that the public consider not only public health factors when they choose whether to follow a COVID-19 related policy, perceived risk may not always lead to policy compliance. Two cross-sectional online surveys (during almost zero case period in late April to May, 2020 (Wave 2) and during the biggest outbreak in July, 2020 (Wave 3)) with convenient sampling were conducted to examine the dichotomous role of perceived severity and perceived susceptibility in influencing policy compliance in Hong Kong. A total of 1816 responses from local adults were collected (Wave 2: N=564; Female %=69.7%; Mean age=39.4; Wave 3: N=1252; Female %=68.8%; Mean age=40.2). Although policy compliance is found to increase with the scale of the outbreak, results from path analyses showed that perceived susceptibility and perceived severity have an indirect role in policy complying behaviour when the objective risk is low. Risk variables, including attitude, knowledge, benefit and trust, have directly shaped policy compliance. More importantly, perceived severity boosts policy compliance but perceived susceptibility was associated with disobedience to public health policies. Meanwhile, Hong Kong citizens have a selective and conscious preference regarding the stringency of public health policy: They welcome more law and order, with increasing magnitude of penalty, but reject lockdown measures such as a curfew. Regression results implied that demography had a mild contribution to the acceptance of public health policies, with only the female gender being statistically related to higher policy acceptance. The findings of this study imply that boosting attitude, knowledge, benefit and trust would come more directly helpful in promoting public health policy compliance than emphasizing on risks alone. This study calls for further reflection on the traditional role of risk, especially perceived susceptibility, in mobilizing policy compliance to COVID-19 related measures.

Introduction

The COVID-19 pandemic has created novel challenges for global governments in terms of nonpharmaceutical public health containment strategies and risk communication. In the absence of vaccination and effective treatment at the initial stage of the pandemic, governments have relied heavily on travel restriction, social distancing, quarantine, curfew or even city lockdown to halt the spread of the virus. In addition, individual acts such as wearing face-masks, washing hands and avoiding mass gatherings are advocated as self precautionary public health measures. The effectiveness of these stringent public health measures and precautionary behaviours are, indeed, largely dependent on whether the citizens are willing to comply, which, in turn, is commonly related to the level of threat people perceive during the pandemic.

Traditional studies on epidemics suggest that the adoption of protective measures is related to the levels of fear/worry/perceived risk (Chapman & Coups, 2006; Brewer *et al.*, 2007; Seale *et al.*, 2010) and the adherence to the recommendation of the governments (Bults *et al.*, 2011). A recent study by Harper *et al.* (2020) reported that fear of COVID-19 was the dominant predictor of positive public health compliance. Similar studies in Italy (Motta Zanin *et al.*, 2020) and Qatar (Abdelrahman, 2020) support the role of perceived risk in compliance to public health measures. However, the frequency of protests against stringent COVID-19 related public health measures are surging in many parts of the world, hinting that perceived risk alone might not always lead to compliance with policy.

According to the classic Health Belief Model (Champion & Skinner, 2008), people's beliefs on the threats of the epidemic and the effectiveness of the preventive measures determine whether they would adopt the preventive measures. Several groups of factors, including demographic variables, as well as health and risk perceptions, are in play in determining compliance with public health measures. Indeed, Allcott *et al.* (2020) recently found that partisan rifts differentiate social distancing behavior and the belief about COVID-19 risk. Barrios and Hochberg (2020) asserted the concept that COVID-19 risk is embedded in the individual-related interpretations of the risk, which may vary based on political affiliations and beliefs. Perceptions of threats are often captured by perceived severity and perceived susceptibility. The former may be understood as an extrinsic dimension of risks informed by often the incidence or prevalence of the infection in a defined space and/or time. The latter is usually conceptualized as an intrinsic dimension pertaining to an individual's idiosyncratic evaluation of his/her chance of infection. However, Wise *et al.* (2020) reported that engagement in public health measures could be predicted by the perceived susceptibility of an individual, instead of the severity of the pandemic. As new findings emerge, the traditional idea of 'risk-generates-compliance' could be sinking into the sea of unknowns in the face of COVID-19 pandemic. Risk variables such as trust in government policy, knowledge, benefits and attitudes may contribute to one's evaluation of whether the recommended preventive measures are effective. Dryhurst *et al.* (2020) reported that trust in government policy, knowledge of public health strategy and attitude to individualistic and prosocial values were significantly associated with risk perception and public health behaviour in 10 surveyed countries. In Singapore, Wong and Jensen (2020) described public trust as 'a double edged sword', meaning that in the case of pandemic, trust in the government's competence may in fact lead people to underestimate the risk of a pandemic and thus

reduce their motivation to adopt protective measures. The studies mentioned above prompt evidences alerting us to rethink the role of risk in promoting COVID-19 policy. What the literatures found seems to indicate that risk variables have a direct role in determining policy compliance, but it is unclear that the influence of perceived risk or perceived susceptibility on policy compliance is mediated by risk variables indirectly.

Another question behind public health policy compliance is whether the public can persist in complying with stringent protective measures. Research studies on the initial stage of COVID-19 indicated that the level of risk surges quickly in the first week of outbreak (Kwok *et al.*, 2020; Wise *et al.*, 2020). Yet, as the pandemic continues, 'dread factors' may fade out in most people's perception, especially when knowledge is built up to facilitate risk communication on one hand but unnecessary optimism on the other (Wong & Jensen, 2020). During the H1N1 pandemic in Germany in 2009/10, Walter *et al.* (2012) recorded a sharp decrease in risk perception shortly after the pandemic hit its peak, which led to loosening of public compliance to vaccination afterwards. However, the problem of the ongoing COVID-19 pandemic is that this virus is going to hit most countries in multiple waves. For instance, over the two springs in 2020 and 2021, Europe has experienced an upsurge of COVID-19 cases in March to April 2020 (First Outbreak), October to December 2020 (Second Outbreak), and another one starting in March 2021(Third Outbreak). Likewise, Hong Kong has experienced its first local outbreak in March to April 2020; the second outbreak in July to August 2020, and the third outbreak between November 2020 and February 2021(Dong *et al.*, 2020). Questions remain of how risk perception, and risk variables, change during the pandemic with the severity of outbreaks.

In this paper, we use data from two cross-sectional surveys, conducted during a period without local infection (Wave 2: late-April to May, 2020) and a period of the biggest outbreak (Wave 3: July, 2020), to explore how the intrinsic and the extrinsic dimensions of risk interact with risk variables (attitude, knowledge, benefit and trust) to influence public health policy compliance in Hong Kong. Hong Kong is distinguished by its relatively successful experience in mitigating the transmission at the early stage of the COVID-19 pandemic (Kwok *et al.*, 2020), suppressing the spread of the virus at a low level compared with nearby regions (See Figure 1 which shows the incidence of COVID-19 from January to July, 2020). Hong Kong has been the epicentre of SARS in 2003. Hence, most adult citizens are not foreign to respiratory pandemic and the use of face-masks and hand-sanitizers as preventive measures. A local study conducted in April 2020 found that 87.9% respondents considered COVID-19 as more serious than SARS (Lau *et al.*, 2020).

Unlike most other parts of the world, Hong Kong was relatively unscathed during the first outbreak of the COVID-19 pandemic in Spring 2020. The epidemic curve is mostly flattened in the first half year of the pandemic, as the city beat back the resurgence of imported case to avoid a major local outbreak. The first wave of data used in this study was conducted between April 24 to May 12 (Wave 2), which corresponds to a situation at the trough of the first outbreak with an average of one case per day during our survey period. Despite the suspension of schools and most public services since the end of January and the closure of most borders by early February in 2020, the government had stepped up public health orders in late March 2020, when Wave 1 data collection was conducted (March 12 to April 8), by banning gatherings, mandating the closure of high-risk premises and businesses (e.g., cinemas, sport fields, bars, amusement parks, game

centres, bathhouses, fitness centres, party-rooms, beauty parlours, massage parlours), and restricting restaurants to cater up to only half capacity with adjacent tables at 1.5m apart. By the time Wave 2 data collection was conducted, public health measures were progressively lifted or relaxed.

The second wave of data used in this study was collected during the peak of the second major local outbreak in Summer 2020 (Wave 3). In early July, an imported case rolled into a local outbreak that brought Hong Kong over 2000 new cases in a month. Between 15 to 22 July when the data was collected, there were an average of 70 cases per day. Unlike in Spring 2020, a majority of cases in this summer outbreak were accountable to local infection clusters. The government reintroduced public health restrictions, including prohibition on public gatherings and compulsory closure of high-risk businesses and premises, and banned evening catering (after 6pm) for the first time on 16th July (HKSAR Government, 2020).

The case of Hong Kong between April and July 2020 exemplifies a transition for the public to experience an elevating infection risk and offers a rare opportunity to study policy compliance in COVID-19 at different objective risk environments, namely a trough of the previous wave (Wave 2) versus the next peak (Wave 3). The study therefore has the following research questions:

- (i) To what extent do perceived susceptibility, perceived severity, trust, benefits, attitude and knowledge contribute to public health policy compliance?
Hypothesis 1: Perceived severity, perceived susceptibility, trust, benefits, attitude and knowledge will be positively related to policy compliance.
However, due to the lack of research on how different risk variables relate to public health policy compliance during the peak and the trough of an outbreak, we have no a priori hypothesis regarding the relative strength of associations between risk variables and policy compliance at Wave 2 and 3 respectively.
- (ii) Does risk variables (attitude, knowledge, benefit and trust) mediate the effects of risk perception (perceived severity and perceived severity) on policy compliance?
Hypothesis 2: Risk variables mediate the effects of risk perceptions on policy compliance.
According to Health Belief Model, risk perceptions indirectly affect policy compliance through the moderation by risk variables. However, it remains unclear how such mediation effect works, and whether risk perceptions exert direct influence on policy compliance.
- (iii) How do risk perception and policy compliance change with the alteration in the objective severity of the pandemic?
Hypothesis 3: Perceived severity, perceived susceptibility and policy compliance will be higher in Wave 3 (i.e., peak of next wave) compared to Wave 2 (i.e., trough of previous wave).
No a prior prediction has been postulated for risk variables (attitude, trust, benefits and knowledge).
- (iv) What demographic characteristics – gender, age, education, income, presence of a chronic illness and co-residence with an individual vulnerable to a severe course of illness in case of COVID-19 infection – are related to shifting risk perceptions according to the changing objective severity of the pandemic?

These demographic variables have been commonly used demographic items in the latest COVID-19 study in psychology and risk perception (Yue *et al.*, 2020). However, due to the lack of studies regarding the factors on the flexibility of threat appraisals in the case of COVID-19 pandemic, no a priori hypothesis has been proposed for this research question.

Materials and methods

Recruitment and study procedure

This study is a part of a research project that contains three waves of data collection, and the current study utilized the data of Wave 2 collected in late April to May 2020 and Wave 3 collected in July 2020 (See Figure 1), while Wave 1 (Lau *et al.*, 2020) included no questions on risk variables and compliance to public health policies. Eligible participants were adults aged 17 or older residing in Hong Kong at the time of data collection. The lower end of the age range was set at 17 to cater for participants who have entered university but yet to had their 18th birthday by the time of data collection. The two waves included responses from 1,816 (Wave 2: N=564; Wave 3: N=1252) Hong Kong adults. Sample characteristics are provided in Table 1. Sample characteristics were not significantly different across the two surveys. Participants were recruited via convenience sampling. The advertisements invited the participants to take part in a study related to how Hong Kong citizens adjust and cope in the COVID-19 pandemic, and the survey links were attached with the advertisements. The advertisements have been sent through WhatsApp groups, Facebook pages, Telegram groups and institutional email lists. Participants were also invited to snowball the advertisements to their friends and relatives. Participants were not overlapped in these two waves of data. Due to the versatility of the pandemic, convenience sampling was commonly used as a low-cost but quick response to COVID-19-related issues (Lau *et al.*, 2020). The two surveys asked for participants' risk perceptions and policy compliance regarding the pandemic. The surveys were hosted on Qualtrics. Participants were reimbursed \$50HKD worth of supermarket coupons upon completion of each survey.

Questionnaire design

The questionnaire for both surveys was identical, being designed based on Huang *et al.* (2013) psychometric approach on risk perception and policy acceptance and health belief model (Champion & Skinner, 2008), with modification following Lohiniva *et al.* (2020) and Dryhurst *et al.* (2020) risk perception analytic framework on COVID-19 to fit the context. 'COVID-19 risk perception' was delineated in terms of perceived severity of the pandemic at the city level (questions 1) and perceived susceptibility at the individual level (questions 2). Perceived severity was measured on a single item running from 1(not at all) to 10 (very severe) with reference to the severity of the outbreak at the time of data collection. Perceived susceptibility was measured by asking the participants how likely they think they will contract SAR-CoV-2 on a scale running from 1 (impossible) to 10 (must contract). The questionnaire also includes key constructs to measure their acceptance of local governments' public health policies (policy compliance; questions 14-17), their attitude towards the perceived impact they believe the pandemic has brought to society (attitude; questions 3-4), knowledge of the pandemic and its prevention (knowledge' questions 5-8), perception of benefits and costs of public health policies (benefits; questions 9-12) and their trust in the government policies and interventions

(trust; questions 13). Policy compliance, attitude, knowledge, benefits and trust were evaluated on a 7-point Likert scale running from 1 (strongly disagree) to 7 (strongly agree). (The items were provided as Supplementary material Table S1). The Cronbach alphas ranged from .68 (attitude) to .84 (benefits). The scale scores for each key construct were derived by adding up the corresponding items. Demographic variables, including gender, age, educational attainment, income, presence of chronic illness including psychiatric disorders, and co-residence with an individual vulnerable to a severe course of illness if infected (including toddlers, children, elderly, persons with chronic illness or disability), were also documented.

Statistical analysis

Path analysis

Path analysis allows for controlling the strengths of paths toward multiple endogenous variables simultaneously. All hypothetical pathways being tested in the path analysis are shown in Figure S1. We also decomposed the overall correlation between dependent variables and predictors into direct effects of one on the others, and indirect effects when an exogenous variable has a correlation on the dependent variable through the mediating effect of other variables. Mathematically speaking, the total effect of a pathway between a predictor and a response variable is the sum of direct effect and all indirect effects mediated by the constructs. In other words, path analysis assumes that all effects are additive and unidirectional. The goal of applying path analysis was to (i) compare the relative importance of risk perception and risk constructs on policy compliance, (ii) decide whether perceived severity and/or perceived susceptibility has any influence on policy compliance and, (iii) compare and contrast the pathways between risk perception and policy compliance between the two waves of surveys, which correspond to different phases of the COVID-19 pandemic.

The path analyses were tested by PROCESS macro (version 3.0) of SPSS (Hayes, 2019), with policy compliance as the outcome variable, perceived severity and perceived susceptibility as the predictor variables, and attitude, knowledge, benefits and trust as parallel mediators. All variables were manifest variables. The indirect effects were estimated by 5,000 bootstrapped samples. If the lower and upper 95% confidence intervals of an effect exclude a zero, the effect is statistically significant at $p < .05$.

Testing inter-wave differences

Inter-wave differences on the compliance of government policies and risk perceptions were compared by independent sample t-tests with effect sizes indicated by Cohen's d . The differences in the proportion of disagreement-neutral-agreement stances on items of policy acceptance were explored by Chi-square tests of associations.

We also explored the effects of demographic variables and the interaction between wave (Wave 2 vs Wave 3) and predictors by linear multiple regressions. To test for the robustness of the model, we combine data from the two waves to check the correlations between policy compliance and different predictor variables. A dichotomous variable (Wave 2 = 0, Wave 3 = 1) was introduced to measure the effect of July's outbreak on policy

compliance, in the presence of predictor variables and demographic factors. Missing values were not imputed, therefore listwise deletion was applied to handle missing values. The calculations in this part were conducted with JASP (version 0.13.0.0; 2020), except for the mediation models which were computed by SPSS (version 25.0).

Results

Associations among risk perceptions, risk variables and policy compliance in Wave 2 and 3

We first tested the relationships between risk perceptions, risk variables and compliance to public health policies through a saturated model with path analysis to answer Research Questions (i) and (ii). In the path analysis, the causal relationships between variables are specified and assumed explicitly (Fig S1). Indirect effects were calculated to evaluate the extent to which attitude, knowledge, benefit and trust mediate the associations between risk perceptions and compliance.

The unstandardized coefficients of the paths are presented in Figure 2. We also provide the standard errors of each path in Table S2. In both waves, respondents with higher perceived susceptibility viewed the public health policies as less beneficial ($B_{Wave2} = -0.46$, $B_{Wave3} = -0.35$) and the preventive measures as less trust-worthy ($B_{Wave2} = -0.15$, $B_{Wave3} = -0.15$). In Wave 2, higher susceptibility was related to stronger attitude ($B = 0.17$), but not in Wave 3. Also, respondents in Wave 3 with higher susceptibility rated their knowledge as lower ($B = -0.33$), but not among those in Wave 2. In general, perceived susceptibility has a negative relationship with risk variables, and we detect no direct relationship between perceived susceptibility and policy compliance. On the other hand, perceived severity was associated with stronger attitude ($B_{Wave2} = 0.27$, $B_{Wave3} = 0.35$) and knowledge ($B_{Wave2} = 0.16$, $B_{Wave3} = 0.32$) in both waves, as well as greater benefits ($B = 0.26$) in Wave 3. Perceived severity also mobilized stronger policy compliance behaviour in Wave 3 ($B = 0.51$). It should be noted that perceived severity, as a whole, has a positive relationship with risk variables. Significant direct correlation between perceived severity and policy compliance was also absent in Wave 3. In the second half of the model, it is showed that higher attitudes ($B_{Wave2} = 0.31$, $B_{Wave3} = 0.36$), knowledge ($B_{Wave2} = 0.15$, $B_{Wave3} = 0.15$), benefits ($B_{Wave2} = 0.41$, $B_{Wave3} = 0.38$), and trust ($B_{Wave2} = 0.43$, $B_{Wave3} = 0.31$) were all related to greater compliance with public health policies in both waves.

The results of the indirect effects are provided in Table S2. In both waves, benefits and trust mediated the negative association between perceived susceptibility and policy compliance. In Wave 2, perceived susceptibility was also related to higher compliance through perceiving stronger attitude, whereas in Wave 3 the negative susceptibility-compliance link was further explained by dampened knowledge. In Wave 2, perceived severity influenced policy compliance through inducing stronger attitude. In Wave 3, perceived severity was related to greater knowledge and benefits, in addition to increased attitude, which in turn were conducive to complying with the policies. Collectively, the predictors and the mediators together explained 35.6% and 39.3% of the variance of compliance in Wave 2 and 3 respectively, meaning that the efficiency of risk perception and risk variables increased slightly when Hong Kong faced the peak of the summer outbreak in July.

Differences in risk perceptions, risk variables and policy compliance in Wave 2 and 3

Table 2 provides the results of the between-subject t-tests for comparing the levels of risk perceptions, risk variables and policy compliance across Wave 2 and 3 that answers Research Question (iii). Results show participants at time of the peak of an outbreak (Wave 3) had significantly higher compliance scores than those before outbreak (Wave 2), yet the effect was mild. Also, participants in Wave 3 perceived higher severity and susceptibility than those in Wave 2, with moderate effect sizes. However, there was no significant difference in attitude, knowledge, benefits and trust.

According to Nivette *et al.* (2020), public compliance to some public health measures, such as social distancing, is relatively lower than the others. We asked further in this study, whether, and how, policy compliances to different measures change between the trough of a preceding wave and the peak of the subsequent wave of the pandemic. Figure 2 provides the frequencies of disagreement, neutral, and agreement across the four compliance items in the two waves. They represent, in descending order in the figure, frequency of laws and orders, city lockdown (in the case of Hong Kong curfew is more likely to happen than total lockdown), magnitude of laws and orders, and duration of stringent public health policy. Results of the chi-square tests show significantly different proportions of stances across the two waves for items '*We should introduce more public health-related laws and orders to control disease from spreading*' (Agreement % Wave 2 vs 3 = 65.1% VS 72.5%; $X^2(2)=10.54$, $p=.005$) and '*We should increase the punishments to those who violate public health-related laws and orders*' (Agreement % Wave 2 vs 3 = 66.3% VS 75.6%; $X^2(2)=17.18$, $p<.001$), which indicates more support for frequency and magnitude of laws and orders after the COVID-19 outbreak in July. People's perceptions on curfew and future adherence to preventive measures were not significantly different after the July outbreak in Hong Kong. Yet, from Figure 2 we can observe that fewer people supported curfew in Wave 3. It should be noted that the definition of 'public health related laws and orders' is embedded in the context when the surveys were conducted, rather than a quantification of the stringency of public health policy.

Interactions between wave and predictors of policy compliance

Table 3 illustrates the findings of a regression model testing how policy compliance varies by risk perception, risk variables and demographic variables, and whether such variation differs by waves by introducing interaction terms (variables x wave), in other words, research question (iv). Only gender and two interaction terms (wave x perceived severity, wave x gender) were significant. Female participants were more likely to endorse the government policies ($B=1.69$) regardless of the timing of data collection. To deconstruct the interaction effects, we conducted separate linear regressions with the perceptions, risk variables and demographic variables by wave. Compliance was predicted by higher severity only in Wave 3 ($B=0.51$) and female gender only in Wave 2 ($B=0.78$). However, the inclusion of the demographic variables and the interaction terms in general did not remarkably increase the explanatory power in all three models ($R^2_{\text{Wave2\&3}} = 0.39$; $R^2_{\text{Wave2}} = 0.37$; $R^2_{\text{Wave3}} = 0.40$).

Discussion

A key milestone to controlling the spread of infectious disease focuses on promoting compliance to public health measures, with the goal of identifying factors that facilitate risk communication at different phases of a pandemic. In this study, we compared the risk communication process when the COVID-19 pandemic was transiting into elevated severity in Hong Kong between late-April and May to July, 2020. We investigated whether risk perceptions (perceived severity and perceived susceptibility) and risk variables (benefits, trust, attitude and knowledge) contribute to public acceptance of stringent public health policies and whether these predictors behave differentially under different levels of objective pandemic severity (i.e., at the trough of a previous outbreak in late-April to May 2020 vs a peak of the next outbreak in July 2020). Our findings show that perceived severity and perceived susceptibility are not equivalent in COVID-19 risk communication and that the choices of which public health policy Hong Kong citizens comply depends on the stage of the pandemic, risk variables, and the characters of the public health measure in the particular temporal setting.

Before the local outbreak in July 2020, the perceived risk of COVID-19 appeared to be dropping in Hong Kong. A survey in February indicated a very high level of perceived severity (97%) and perceived susceptibility (89%) to COVID-19 in Hong Kong (Kwok *et al.*, 2020). The Wave 1 of this research project was conducted at the peak of the Spring outbreak in mid-March (Lau *et al.*, 2020), and a median perceived severity of 8.0 and median perceived susceptibility of 5.0 were documented. Such vigilance could have been the result of the city's previous exposure to SARS in 2003. By comparison, people in our late-April / May survey (i.e., Wave 2) had a perceived severity score of 6.8 and perceived susceptibility score of 3.9, which both fell into the neutral category. Results from the path analysis show that neither perceived severity nor perceived susceptibility influence policy compliance directly in Wave 2, suggesting that risk alone cannot stimulate policy compliance without invoking other variables covarying with risk. This pattern changes when the subsequent summer outbreak arrived in July 2020 (i.e., Wave 3) and boosted perceived susceptibility and perceived severity to 4.7 and 7.8, reaching levels comparable with those of the Spring outbreak. The model in Wave 3 shows that perceived severity now can affect policy compliance directly, and the perceived severity and perceived susceptibility both affect policy compliance indirectly through risk variables.

The fact that risk is mainly linked to policy compliance indirectly may challenge the foundations of conventional risk communication approaches in many governments. There are numerous studies that demonstrate a consistent pattern that the perception of risk could eventually boost public compliance to policy during a pandemic (Ibuka *et al.*, 2010; Poletti *et al.*, 2011; Geana, 2020). Yet, our findings support a scenario that boosting attitude, knowledge, benefit and trust at a time of low/medium risk environment might be more helpful in increasing public compliance to policy. The emphasis of risk and severity of the pandemic might only play a central and direct role in spreading compliance when the objective risk is high. In this bind, given that our results make the applicability of past studies involving risk perception seem problematic, government should carefully deal with risk communication by valuing risk determinants instead of stressing on 'risk' itself, in order to better achieve policy compliance to public health policy.

In addition, our results suggest that perceived severity enhances risk variables, while perceived susceptibility mainly demotes risk variables. The independent, or sometimes even dichotomous, effect of perceived severity and perceived susceptibility is not uncommon in other health hazards (Iriyama *et al.*, 2007; Bonar & Bohnert, 2016) but it is found for the first time in risk perception towards COVID-19. Interestingly, our findings show that if one perceived oneself to have a high chance of being infected, that could challenge knowledge, benefit and trust in government policy, further reducing the level of compliance to public health policy. On the other hand, if a person perceives COVID-19 as a severe issue in Hong Kong, they tend to develop stronger attitude, knowledge and benefit, which promotes their interest in following public health policy. As such, the over-emphasis of risk, in the case of Hong Kong, may not always serve the purpose of stimulating policy compliance, but rather it drives those who feel themselves susceptible to disobey public health policy. It might have helped explain why sometimes protests against public health orders were more prevalent at times when the pandemic reached its peak.

In our study, we also found that public compliance slightly increased from Wave 2 (19.81) to Wave 3 (20.57), meaning that more people were willing to follow public health orders at the time of COVID-19 outbreak. As shown in Figure 1, respondents are selective and conscious in their compliance behaviour, if they have a choice. They prefer more laws and orders, with increasing magnitude in punishment, but refuse to accept lockdown measures such as a curfew. As Nivette *et al.* (2020) hypothesized, different COVID-19 measures are in part driven by different mechanisms. For example, laws and orders, or magnitude of punishment were associated with authority. Adoption of such public health measures might first require trust and belief that the authorities are effective in implementing restrictive rules (Nivette *et al.*, 2020). On the other hand, compliance with city lockdown or curfew will involve direct and drastic consequences in social and economic well-being (Bonaccorsi *et al.*, 2020; Brodeur *et al.*, 2020). According to Sibley *et al.* (2020), the presumption of successful lockdown is the high level of trust in science, politicians and patriotism. A significant fiscal effort and community support are needed to sustain fragile individuals and to mitigate the poverty and inequality intensified by the lockdown (Bonaccorsi *et al.*, 2020). This indicates that public preference for public health orders is embedded in a complex mechanism and is subjected to change over time and space, and thus, provides important insights for public health policies and campaigns that aim to motivate compliance with COVID-19 related measures.

People from different backgrounds may have different opinions towards the same catastrophic event. Yet, in this study we demonstrate that demographic factors have little effect on policy compliance to COVID-19, regardless of the time of survey. Of the demographic factors we investigated, only the female gender is associated with greater compliance to public health policy. It could be the case that men tend to perceive situations as less risky than women when a crisis breaks out (Finucane *et al.*, 2000). Another recent study also showed that females could perceive significantly higher levels of COVID-19 related emotional risk than males (Yıldırım & Güler, 2020), although an Asian study has suggested that COVID-19 related stress and gender are statistically irrelevant to each other in Hong Kong (Yue *et al.*, 2020).

Despite being a two-stage evaluation where data from the trough of one wave and the peak of another wave were collected for contrast, this study has limitations on several

fronts. First, there are limitations regarding the sampling, as the study was conducted as a swift response to the versatile pandemic. The non-random sample may have under-representation from participants of the male gender and lower socio-economic status. The reliance on online survey for data collection may have also excluded a population who is not comfortable with using the internet or with no convenient access to the internet, notably those who are old and of low socio-economic status (SES). As the entire surveys, which included other questionnaires unrelated to the current inquiry, took about 15-20 minutes to finish, an incentive was included to boost participation. The incentive could have attracted a group of participants of lower SES (Simmons & Wilmot, 2004), but this was not the case in this study. Instead, our sample was biased toward the higher end of SES. As such, we do not have enough data to speculate the impacts of the incentive on responses related to risk perceptions and policy compliance at present. The second front of limitations pertains to the measurements. The constructs were also evaluated with items specifically created for the situations in Hong Kong by a team of experts in pandemic risk perceptions, health psychology, mental health and medical social work. In spite of the favourable psychometric properties with the current sample, the applicability of these items to other contexts awaits further testing. Besides, we did not take account the potential effect of pandemic fatigue in this study considering the difficulty and uncertainty of measuring and quantifying this variable. Latest studies argue that behavioural fatigue is a naïve construct or a myth arising from policy design aiming at tackling COVID-19 crisis {Harvey, 2020 #38}. Yet, no consensus has been made in academia whether pandemic fatigue changes people's behavior and perception. Lastly, the two surveys were cross-sectional in nature, and causal inferences were precluded. The respondents surveyed in the two waves were not the same. However, considering the survey method and the survey questions between waves are kept unchanged, sample characteristics were not significantly different across the two surveys.

Extrapolating a local study to any conclusion requires great caution: Hong Kong had a unique background during the COVID-19 pandemic. Massive social unrest broke out in 2019, tearing trust apart within sectors in the society and between the citizens and the government, as well as compressing community capacity to respond to crisis (Hartley & Jarvis, 2020). A 10-year cohort study in Hong Kong showed that the depression and post-traumatic stress levels had an 8-fold increase after the social movement, which has translated into an urgent mental health burden at the time of the COVID-19 pandemic (Ni *et al.*, 2020). More generally, Hong Kong is close to China, where the first case of COVID-19 has been identified, and people here have experienced numerous pandemics, such as SARS and H1N1, in the past. Overall COVID-19 related mortality was lower in Hong Kong, and the factors that might affect risk perception, risk variables and policy compliance are not the same in each study area. More studies and more comparisons in both longitudinal and cross-sectional dimensions need to be collated to understand the full picture of policy compliance and risk. We also suggest future studies to collect responses on different COVID-19 related public health policies to enable our hypothesis of risk-related policy compliance to be tested thoroughly.

That said, our conclusions, from the example of Hong Kong, are alarming for ongoing pandemic planning efforts worldwide that emphasize the role of risk in motivating policy compliance to COVID-19 related public health measures. The differential roles and mechanisms of perceived severity and perceived susceptibility in determining policy compliance are sobering to COVID-19 related policy decisions. We thus urge

530 governments to consider more about risk variables in the decision-making and modelling
531 of COVID-19 related public health policy, so that policy compliance can continue after a
532 wave of outbreak to delay the time of the next wave of outbreak.
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Contributors

RPHY, BHBL, CLWH, and SMN contributed to study concept and design. RPHY, BHBL, CLWH, and SMN contributed to acquisition of data. RPHY and BHBL contributed to data analysis and initial drafting of the manuscript. All authors contributed to interpretation of data and critical revision of the report. RPHY, BHBL, CLWH, and SMN contributed to study supervision.

Declaration of interests

All authors declare no competing interests.

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Figure 1. COVID-19 cases in Hong Kong from early January to late July, 2020. The shaded areas indicate the two survey periods in late April to May 2020 (Wave 2) and July 2020 (Wave 3).

(a)

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Figure 2. Path diagram for (a) survey done in May 2020 (Wave 2); (b) survey done in July 2020 (Wave 3), for the effects of risk perception (perceived severity and perceived susceptibility) on policy compliance via risk variables (attitude, knowledge, benefit and trust). The associations between predictor variables and outcome variable were indicated as either direct or indirect effects. The residual variables represent the unmeasured variance affecting each outcome variables. The correlations are assumed to be unidirectional as indicated by the single arrow. Unstandardized path coefficients (B) were shown next to each significant correlation. Insignificant correlations are not shown in this figure.

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Table 1. Sample characteristics				
		Wave 2 (N=564)	Wave 3 (N=1252)	
		N (%) / M (SD)	N (%) / M (SD)	p-value
Gender				0.233
	Female	393 (69.7%)	862 (68.8%)	
	Male	154 (27.3%)	294 (23.5%)	
	Missing	17 (3.0%)	96 (7.7%)	
Age		39.44 (13.76)	40.21 (14.48)	0.289
	Educational attainment			0.088
	Secondary or less	126 (22.3%)	313 (25.0%)	
	Higher diploma / associate degree	70 (12.4%)	164 (13.1%)	
	Undergraduate	203 (36.0%)	422 (33.7%)	
	Postgraduate	148 (26.3%)	257 (20.5%)	
	Missing	17 (3.0%)	96 (7.7%)	
Monthly household income				0.118
	Less than 20,000HKD	124 (22.0%)	270 (21.5%)	
	20,000-39,999HKD	152 (27.0%)	392 (31.3%)	
	40,000 or above	275 (48.8%)	553 (44.2%)	
	Missing	13 (2.2%)	37 (3.0%)	
Presence of chronic illness				0.524
	Yes	137 (24.3%)	316 (25.2%)	
	No	417 (73.9%)	892 (71.2%)	
	Missing	10 (1.8%)	44 (3.5%)	
Co-residence with a vulnerable individual				0.293
	Yes	254 (45.0%)	590 (47.1%)	
	No	297 (52.7%)	619 (49.4%)	
	Missing	13 (2.3%)	43 (3.4%)	

Note. P-value was calculated by Chi-square tests of association, except for age which was indicated by an independent samples t-test.

Note. 17 and 96 individuals did not provide information about their age in Wave 2 and 3, respectively.

Table 2. Descriptive of risk perceptions, risk variables and policy compliance across waves.

	Wave May (N=564) M (SD)	Wave July (N=1252) M (SD)	Difference t-value	Effect size Cohen's d
Policy compliance	19.8 (4.14)	20.6 (4.05)	-3.68***	0.187
Perceived susceptibility	3.93 (1.76)	4.65 (1.94)	-7.54***	0.383
Perceived severity	6.80 (2.15)	7.81 (1.58)	-11.2***	0.566
Attitude	10.05 (2.78)	10.04 (2.72)	0.053	0.003
Knowledge	20.2 (3.65)	19.8 (4.07)	1.95	0.099
Benefits	18.6 (5.14)	18.3 (5.29)	1.08	0.055
Trust	4.17 (1.76)	4.27 (1.76)	1.22	0.062

Note. *p<.05, **p<.01, ***p<.001.

Table 3. Linear regressions of risk perceptions and demographic variables on policy compliance

	Wave May & July B (SE)	Wave May B (SE)	Wave July B (SE)
Perceived susceptibility	0.245 (0.217)	0.140 (0.107)	0.034 (0.063)
Perceived severity	-0.221 (0.188)	0.143 (0.088)	0.507 (0.076)***
Attitude	0.274 (0.133)*	0.311 (0.064)***	0.348 (0.045)***
Knowledge	0.145 (0.101)	0.153 (0.050)***	0.161 (0.030)***
Benefit	0.401 (0.094)***	0.394 (0.046)***	0.387 (0.029)***
Trust	0.635 (0.283)*	0.517 (0.138)***	0.399 (0.088)***
Gender	1.694 (0.795)*	0.783 (0.386)*	-0.127 (0.263)
Age	-0.016 (0.029)	-0.030 (0.014)*	-0.044 (0.010)***
Education	-0.415 (0.341)	-0.295 (0.166)	-0.176 (0.108)
Income	0.108 (0.130)	0.042 (0.063)	-0.023 (0.045)
Chronic illness	-0.681 (0.847)	-0.172 (0.412)	0.336 (0.275)
Co-residence with vulnerable individual	0.394 (0.707)	0.320 (0.344)	0.247 (0.228)
Wave	-0.730 (1.770)		
Perceived susceptibility X Wave	-0.106 (0.122)		
Perceived severity X Wave	0.364 (0.115)**		
Attitude X Wave	0.037 (0.077)		
Knowledge X Wave	0.008 (0.057)		
Benefit X Wave	-0.007 (0.053)		
Trust X Wave	-0.118 (0.161)		
Gender X Wave	-0.911 (0.460)*		
Age X Wave	-0.014 (0.017)		
Education X Wave	0.120 (0.195)		
Income X Wave	-0.066 (0.076)		
Chronic illness X Wave	0.509 (0.488)		
Co-residence with vulnerable individual X Wave	-0.074 (0.406)		
Model summary			
N	1703	547	1156
F-value	43.694***	25.996***	64.031***
R-square	.394	.369	.402

Note. *p<.05, **p<.01, ***p<.001.

Appendix

List of supplementary figures and tables

Figure S1. Schematic path of the theoretical framework applied in this study.

Table S1. List of questions and the formulation of key constructs used in this study

Table S2. Direct and indirect effects of the path analysis models

Figure S1. All hypothetical paths for the schematic framework applied in this study. Perceived susceptibility and perceived severity donate to the concept of risk perception; attitude, knowledge, benefit and trust are the risk variables; outcome variable of the framework is policy compliance to the public health measures in Hong Kong.

No.	Question	Risk construct	Cronbach alpha
1	How severe do you think COVID-19 epidemic is on a scale from 1 (not at all) to 10 (very severe)	Perceived severity	N/A
2	How likely do you think you will contract COVID-19 on a scale from 1 (not possible) to 10 (must be contracted)?	Perceived susceptibility	N/A
3	COVID-19 is going to generate irreversible impact to our global economy	Attitude	.68
4	COVID-19 would promote instability to at least one country in the world	Attitude	
5	I am familiar with the symptoms and health consequences of COVID-19	Knowledge	.75
6	I am competent in understanding information about COVID-19	Knowledge	
7	I understand how to avoid getting infected by COVID-19 as much as I can in my daily life	Knowledge	
8	I can distinguish the filtering efficiency of different kinds of facemasks	Knowledge	
9	Although the public health measures adopted have led to a considerate degree of economic recession, I still think that the measures are beneficial considering the outcomes of the measures	Benefit	.84
10	The current public health measures have been doing the least harm to our economy	Benefit	
11	Although the public health measures adopted have limited my personal liberty, I still think that measures are beneficial considering the outcomes of the measures	Benefit	
12	The current public health measures have been doing the least harm to personal liberty	Benefit	
13	Citizens should support the interventions and policies of the government.	Trust	N/A
14	We should introduce more public health related laws and orders to control disease spreading	Policy compliance	.78
15	If the outbreak escalates, a curfew should be used to control COVID-19	Policy compliance	
16	We should increase the punishments to those who violate public health-related laws and orders	Policy compliance	
17	If the current level of preventive measures is going to be in place for another 3 months, I will still strictly follow them	Policy compliance	

Table S1. List of questions and the formulation of key constructs used in this study

Table S2. Direct and indirect effects of the path analysis models		
	Model 1 - May	Model 2 - July
	Direct effect B(SE)	
Susceptibility → Attitude	0.1708 (0.0682)*	0.0592 (0.0398)
Susceptibility → Knowledge	-0.0600 (0.0925)	-0.3298 (0.0601)***
Susceptibility → Benefits	-0.4563 (0.1294)***	-0.3508 (0.0786)***
Susceptibility → Trust	-0.1523 (0.0442)***	-0.1537 (0.0260)***
Severity → Attitude	0.2705 (0.0559)***	0.3544 (0.0490)***
Severity → Knowledge	0.1612 (0.0757)*	0.3163 (0.0739)***
Severity → Benefits	0.1161 (0.1060)	0.2560 (0.0967)**
Severity → Trust	0.0099 (0.0362)	-0.0114 (0.0320)
Attitude → Compliance	0.3053 (0.0638)***	0.3631 (0.0427)***
Knowledge → Compliance	0.1480 (0.0477)**	0.1538 (0.0287)***
Benefits → Compliance	0.4074 (0.0449)***	0.3748 (0.0278)***
Trust → Compliance	0.4290 (0.1305)**	0.3129 (0.0827)***
Susceptibility → Compliance	0.1395 (0.1033)	0.0711 (0.0593)
Severity → Compliance	0.1404 (0.0851)	0.5028 (0.0728)***
	Indirect effect [Bootstrapped 95% LLCI , ULCI]	
Susceptibility → Attitude → Compliance	[0.0069, 0.1091]	[-0.0105, 0.0549]
Susceptibility → Knowledge → Compliance	[-0.0485, 0.0281]	[-0.0831, -0.0241]
Susceptibility → Benefits → Compliance	[-0.3064, -0.0713]	[-0.1968, -0.0669]
Susceptibility → Trust → Compliance	[-0.1330, -0.0145]	[-0.0826, -0.0189]
Severity → Attitude → Compliance	[0.0354, 0.1433]	[0.0801, 0.1860]
Severity → Knowledge → Compliance	[-0.0015, 0.0636]	[0.0187, 0.0875]
Severity → Benefits → Compliance	[-0.0502, 0.1532]	[0.0123, 0.1864]
Severity → Trust → Compliance	[-0.0329, 0.0393]	[-0.0272, 0.0183]

Note. *p<.05, **p<.01, ***p<.001; B= Unstandardized coefficients (B); SE = standard errors (SE)