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Determinants of Beijing Residents' Intentions to Take Protective Behaviors against Smog: An Application of the Health Belief Model

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ABSTRACT

Severe smog, a form of air pollution, has become a threat to public health in Beijing, China. To examine Beijing residents' protective behavioral intentions against smog, we proposed a conceptual model, which applies the health belief model (HBM) and specifies the roles of three distal predictors: exposure to news, discussion, and worry. The proposed model was tested in the context of protective behavioral intentions (i.e., intention to wear facemask & intention to use air purifier). Data were collected from Beijing residents during the period from 2/27 to 3/7 in 2017. Structural-equation-modeling (SEM) analyses of valid cases (*N* = 523) found support for the health belief model regarding the positive effects of perceived threat, perceived benefit, and perceived self-efficacy on intention to wear facemask or intention to use air purifier. Perceived barrier has a negative effect on intention to use air purifier, but is *not* related to intention to wear facemask. Neither exposure nor discussion is related to perceived threat. The effect of worry on intention to wear facemaskor intention to use air purifier is mediated by perceived threat. This proposed mediating mechanism is superior to the reverse mechanism (that worry mediates perceived threat). Implications of findings were discussed.

Beijing, China's capital, has experienced severe problems with smog (a form of air pollution) in recent years (Berlinger et al., 2017). For example, Aqistudy.cn (2017), an online monitoring and analysis platform for China's air quality, reported that, in January 2017, six days (19.4%) were classified as "very unhealthy" (or "heavy pollution") and four days (12.9%) were classified as "hazardous" (or "severe pollution").[1] Smog poses a significant threat to public health, as exposure to ambient $PM_{2.5}$ (tiny particles or droplets in the air that are 2.5 microns or less in width; NYS Department of Health, 2018) can increase the risk of numerous diseases, including cardiovascular diseases, respiratory diseases, and lung cancer, and is associated with increased mortality (Fang et al., 2016). An important way to decrease the risk of smog-related health problems is to adopt protective measures, which may include wearing an anti-smog facemask when going outside and using an air purifier when staying indoors (Qian et al., 2016). Though some studies have examined the current situation of air pollution in various Chinese cities (e.g., Sun & Zhou, 2017) and smog-associated health risks (e.g., Fang et al., 2016), only a few studies (e.g., Zhou et al., 2016) have explored potential factors determining protective behaviors/intentions among urban residents. It is essential to identify such factors, as doing so can inform the design and implementation of public health campaigns aiming to reduce smog-related illness.

We have three major purposes in this study. The first is to identify potential factors that may directly determine Beijing residents' protective behavioral intentions, relying upon the health belief model (HBM; Janz & Becker, 1984; Rosenstock et al., 1988), one of the most widely used theoretical models in predicting health behaviors/intentions (Glanz & Bishop, 2010). The second is to investigate the role of communication factors, which are understudied in the HBM literature (Skinner et al., 2015). The third is to explore the influence of affective factors (e.g., worry), which are missing from the HBM, but have received increasing attention from recent studies on health/risk behavior (e.g., Ferrer et al., 2013). Below, we first discuss the HBM and its applications in health-protective behaviors/intentions. Then, we review literature related to the influences of key HBM constructs on health-protective behaviors/intentions, particularly in the context of air pollution. We also propose a theoretical model to guide our data collection process. Finally, we discuss three alternative models and pose questions on comparing alternative models against the proposed model.

Theoretical framework: The Health Belief Model

The present study explored what factors determine Beijing residents' protective behavioral intentions (i.e., intention to wear facemask & intention to use air purifier) when facing the threat of smog. We chose the HBM for the following reasons. First, the HBM was originally developed in the 1950s by a group of social psychologists working for Public Health Services in the U.S. to explain why few people participated in a free tuberculosis screening program (Rosenstock, 1974). It was later used to understand why individuals do or do not implement preventive practices (Prentice-Dunn & Rogers, 1986). It is "an overarching framework on how to promote preventive behaviors" against a health

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threat (Murray-Johnson et al., 2001, p. 324). Second, the HBM (Janz & Becker, 1984) contains components (perceived susceptibility and severity) that have to do with beliefs about negative consequences resulting from a threat, predicting that these are important determinants of protective behaviors/intentions (Noar, 2005). Third, meta-analyses on HBM have demonstrated the predictive power of many of its key constructs (Carpenter, 2010; Harrison et al., 1992). Thus, the HBM appears to be a good choice of theoretical model guiding the present study.

According to the HBM, six constructs predict a health behavior/intention: perceived susceptibility to a disease, perceived severity of that disease, perceived benefits of an action, perceived barriers to that action, perceived self-efficacy of that action, and cues to action (Janz & Becker, 1984; Rosenstock et al., 1988). Perceived susceptibility is defined as belief about the possibility of contracting a disease or a condition; perceived severity is defined as belief about the seriousness of contracting a disease or condition (Janz & Becker, 1984). There has been some contention over how these two constructs function to influence behaviors or behavioral intentions (Weinstein, 2000). Specifically, there is disagreement among researchers on whether it is the *product* of perceived susceptibility and perceived severity or their *sum* that predicts behaviors/intentions.

The present study used the product of perceived susceptibility and severity as a predictor of behavioral intention for three reasons. First, Weinstein (2000) proposed that perceived probability and perceived severity – being two key attributes of health threats – do not act independently on health-protective behaviors/intentions and justified this claim with theoretical reasoning. In a recent review of the HBM, Skinner et al. (2015) echoed this view, arguing that perceived susceptibility and perceived severity should be multiplied to create a product construct called perceived threat, which has a direct impact on behaviors/intentions. Second, a meta-analysis of the effectiveness of HBM variables in predicting behavior reported that susceptibility and severity both have consistently weak effects and recommended that future research should examine the product of susceptibility and severity as a direct predictor, rather than continuing to test their separate direct effects on behavior (Carpenter, 2010). Third, there are empirical data supporting the direct effect of perceived threat (the product of susceptibility and severity) on behavioral outcomes (e.g., Chen, 2018; Weinstein, 2000). In light of these considerations, we treat perceived threat as a product construct in the current study.

Perceived benefits refer to beliefs about positive consequences or advantages of a behavior recommended to decrease the threat; perceived barriers refer to perceived potential obstacles to taking a precautionary action (Janz & Becker, 1984). Benefits and barriers are consistently the stronger predictors of behavior, compared with susceptibility and severity, based on Carpenter's (2010) meta-analysis. Perceived self-efficacy, the belief that one can successfully perform a behavior (Bandura, 1977), was later added to the HBM as a separate construct (Rosenstock et al., 1988). Cues to action refer to factors (either internal or external) that can trigger a precautionary action (Skinner et al., 2015). We did not include cues to action in the present study because cues to action have not been well defined (conceptually or operationally) nor studied systematically (Skinner et al., 2015).

Protective behavioral intentions in the context of smog

There have been several studies on protective behaviors/intentions against smog in China. For example, Qian et al. (2016) reported that protective behaviors taken by residents in Ningbo, China, during hazy weather include staying indoors, using air purifiers, reducing outdoor exercise, and wearing facemasks. Their study focused on percentages of residents holding different attitudes toward the haze and their perceptions of haze-related health risks, as well as percentages of residents taking various protective measures; however, they did not explore the potential influence of HBM constructs (e.g., perceived health risk) on those protective behaviors. Zhou et al. (2016) found that self-efficacy of using a facemask and risk perception of developing respiratory diseases (operationalized as perceived probability) were both positively associated with intentions to wear a facemask, while outcome expectancies of wearing a facemask (operationalized as perceived benefits) were not related to intentions. In their study, they did not explore perceived severity or perceived barriers, which are also key constructs in the HBM. Cheng et al. (2017) found that risk perception – computed by averaging items for perception of smog's adverse effects and items for worry about the potential damage caused by smog – is positively related to a measure of self-protective actions (i.e., wearing mask, staying at home, using air filter, changing diet) in response to city smog. As such, their study is unable to detect the unique impact on protective actions of feelings, distinct from cognitive beliefs.

It appears that no existing study has applied the HBM to systematically investigate theoretical mechanisms accounting for protective behaviors/intentions in the context of smog. Relying on the health belief model and empirical studies on smog-related protective behaviors/intentions, we pose the following hypotheses:

H1: In terms of wearing facemask, (a) perceived threat of smog-related diseases positively, (b) perceived benefit positively, (c) perceived barrier negatively, and (d) perceived self-efficacy positively predict intention to wear facemask.

H2: In terms of using air purifier, (a) perceived threat of smog-related diseases positively, (b) perceived benefit positively, (c) perceived barrier negatively, and (d) perceived self-efficacy positively predict intention to use air purifier.

The roles of exposure, discussion, and worry

HBM is categorized as a social cognition model (Sutton, 2001). Such models have two key assumptions: (1) only a small number of factors are the proximal predictors of behaviors/intentions; (2) many other factors are the distal predictors of behaviors/intentions and "the effects of distal factors are largely or completely mediated by the proximal factors" (Sutton, 2001, p. 2). One of the defects in the HBM is that the model does not specify how distal factors may influence beliefs or indirectly affect health behaviors/intentions (Skinner et al., 2015). Strecher and Rosenstock (1997) suggested that communication factors (e.g., media exposure) and feelings influence behaviors/intentions mainly through *perceived threat*, but this mechanism has not been well tested. Recently, Yang (2015) explored attention to news related to the H1N1 flu and interpersonal discussion about it as two additional predictors in the HBM model; the study found that only interpersonal discussion was significantly related to behavioral intention to get the H1N1 vaccine, but did not explore the mediating role of perceived threat. Chen (2018) found that exposure to prevention messages increases perceived threat (called "risk perception" in the study) of binge drinking, but is not related to binge-drinking behavior. Cheng et al. (2017) found that participants who preferred to receive smog information from *peers* had higher risk perception and were more likely to adopt self-protective behaviors, while these effects were not significant among those who relied more on *media* for smog information. We included exposure to news related to smog and interpersonal discussion about smog as two communication factors, as these two are common sources of risk information (Lindell et al., 2016).

In addition to exposure to news and interpersonal discussion, negative feelings (e.g., worry; Keogh & Reidy, 2000) about the potential negative consequences of an event may also be a distal factor of taking preventive actions to reduce the threat. Specifically, in the context of a health threat, negative feelings are more likely to be triggered, which may augment perceived threat and, accordingly, motivate a protective behavior/intention. There is partial support for such a mechanism in the extant literature. Peipins et al. (2015) showed that worry about ovarian cancer had a moderate impact on perceived risk of getting ovarian cancer among women in a managed care organization. Chen and Yang (2017) reported that, among current smokers, worry positively predicts cancer risk perception (a construct similar to perceived threat), but the effect of worry on quitting intention is not mediated by cancer risk perception. We include worry as another distal factor, as it represents an internal feeling, which may account for additional effects on behaviors/intentions beyond media exposure and interpersonal discussion.

Adding worry to the HBM is valuable for two reasons. First, it has the potential to advance the theoretical development of the HBM as, historically, the HBM and other social cognition models (e.g., theory of reasoned action [TRA]; theory of planned behavior [TPB]) have been criticized for being too cognitive and failing to include feelings as an anticipatory factor of behaviors/intentions (Loewenstein et al., 2001). Adding worry to the HBM addresses this deficiency by highlighting the important role of feelings in predicting behaviors/decision making. Second, with few exceptions, affect (i.e., feelings) has seldom been considered a distal factor in the adoption of health/risk behaviors in the extant HBM literature (e.g., Hilyard et al., 2014). Previous studies on HBM often ignored the role of feelings and only observed interpersonal- and mass-communication factors as distal predictors (e.g., Yang, 2015). Including worry as another distal predictor provides a more comprehensive of distal predictors in the HBM and may improve the overall explanatory capability of the model.

Social cognition models (e.g., HBM, Sutton, 2001) suggest that cognitive beliefs are proximal predictors of behavioral outcomes and serve as mediational pathways connecting distal factors with those outcomes. While the original HBM does not specify the mediating role of perceived threat, Strecher and Rosenstock (1997) advanced the HBM by articulating a theoretical assumption that communication factors and feelings operate primarily through perceived threat. Some studies have supported this assumption (e.g., Jones et al., 2015; Kouchaki & Desai, 2015), while others have not (e.g., Chen, 2018; Chen & Yang, 2015). Among those which supported it, Jones et al. (2015) found a significant indirect effect of flu-vaccine campaign exposure on vaccination behavior through perceived threat. Kouchaki and Desai (2015) reported that "anxiety increases threat perception, which, in turn, results in self-interested unethical behaviors" (p. 360). To our knowledge, no study has systematically explored the mediating role of perceived threat in the relationship between smog-related distal predictors and protective behaviors/intentions against smog. Thus, we pose the following research questions:

RQ1: Do (a) increased *exposure* to smog news, (b) increased *discussion* about smog, and (c) increased *worry* about smog-related diseases lead to increased *perceived threat* of smog-related diseases, which subsequently leads to increased *intention to wear facemask*?

RQ2: Do (a) increased *exposure* to smog news, (b) increased *discussion* about smog, and (c) increased *worry* about smog-related diseases lead to increased *perceived threat* of smog-related diseases, which subsequently leads to increased *intention to use air purifier*?

Figure 1 shows the proposed model (Model 1) predicting intention to wear facemask and intention to use air purifier. Specifically, perceived threat and three HBM constructs related to wearing facemask predict intention to wear facemask; perceived threat and three HBM constructs related to using air purifier predict intention to use air purifier; perceived threat is a mediator connecting distal factors (e.g., worry) with intention to wear facemask/intention to use air purifier.

Alternative models

We consider the proposed model to be the most plausible explanation for intention to wear facemask/intention to use air purifier but, in the present study, we compare this model with three possible alternatives. One such model treats threat as the additive combination of susceptibility and severity, as some previous HBM studies have done (e.g., Bishop et al., 2015; Jones et al., 2015).

Following Weinstein's (2000) theoretical reasoning and Carpenter's (2010) recommendation, we posed the following research question:

RQ3: Is the proposed model (Model 1) that considers threat as the multiplicative combination of susceptibility and severity more appropriate than the model that considers threat as the

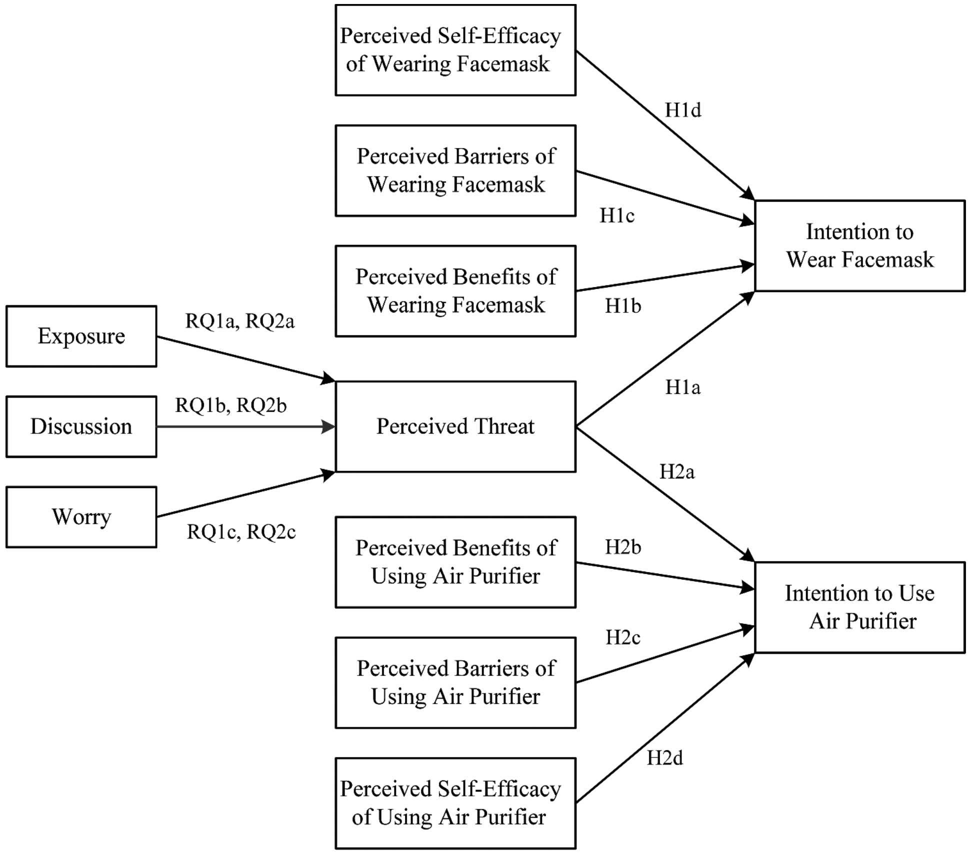

Figure 1. Model 1 (the proposed model) and Model 2. *Note*. Exposure = Exposure to smog-related news; Discussion = Discussion of smog-related topics; Worry = Worry about getting smog-related disease; Perceived Threat = Perceived threat of contracting smog-related diseases. In Model 1 (the proposed model), Perceived Threat is the multiplicative combination of Susceptibility and Severity; in Model 2, Perceived Threat is the additive combination of Susceptibility and Severity.

additive combination of susceptibility and severity (Model 2, see Figure 1)?

Although social cognition models (e.g., HBM, Sutton, 2001) suggest that cognitive beliefs mediate the relationship between distal factors (e.g., exposure, worry) and behavioral outcomes, other theoretical models, such as cognitive appraisal theory (Lazarus, 1991, 2001), suggest a different mediational mechanism: cognitive appraisals precede emotions, which, in turn, can lead to coping strategies (e.g., protective behaviors/intentions, emotional adjustment). This competing mediational mechanism has found support in some studies (e.g., So et al., 2016). For example, So et al. (2016) found that fear and anxiety about meningitis are two significant mediators in the relationship between threat appraisal and intention to obtain meningococcal vaccination. Based on cognitive appraisal theory (Lazarus, 2001) and relevant empirical evidence, we posed the following research questions:

RQ4: Is the proposed model that considers threat as a mediator more appropriate than the model that considers worry as a mediator (Model 3; threat as the multiplicative combination of susceptibility and severity)?

RQ5: Is the proposed model that considers threat as a mediator more appropriate than the model that considers worry as a mediator (Model 4; threat as the additive combination of susceptibility and severity)?

Figure 2 shows Models 3 and 4 with worry as the mediator connecting distal factors (e.g., perceived threat) and intention to wear facemask/intention to use air purifier.

Method

Survey design and procedure

An online survey in English was first designed measuring all major variables in the proposed model, as well as demographic factors including gender, age, ethnicity, education, income, marital status, and health status. The measures in the survey were taken or adapted from established scales in English, and they are described below. The original English survey was translated into Chinese using the back-translation method (Brislin, 1970) to ensure accuracy and clarity in translation.[2]

After the study received IRB approval, we used Questionnaire Star, currently the largest online survey platform in China, to host the final Chinese version of the survey and to collect data. Questionnaire Star has users from various provinces/municipalities in China. Each user registers for a unique account with the Questionnaire Star website and participates in online surveys in exchange for credits from

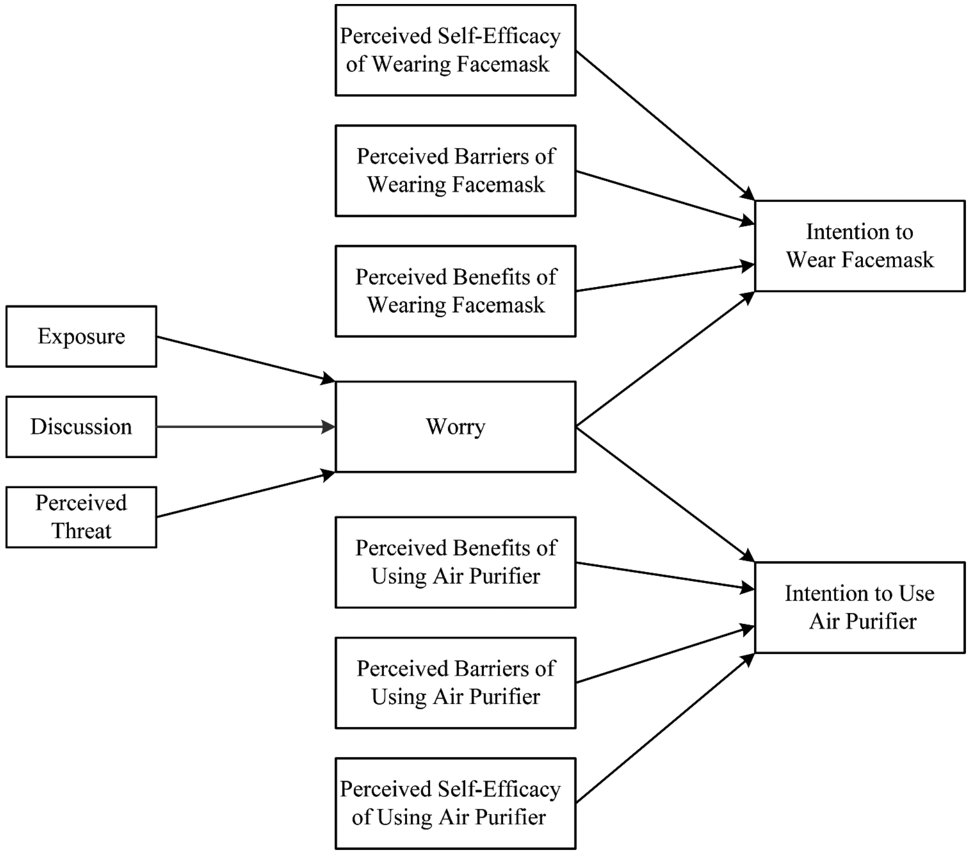

Figure 2. Model 3 and Model 4. *Note*. Exposure = Exposure to smog-related news; Discussion = Discussion of smog-related topics; Worry = Worry about getting smog-related disease; Perceived Threat = Perceived threat of contracting smog-related diseases. In Model 3, Perceived Threat is the multiplicative combination of Susceptibility and Severity; in Model 4, Perceived Threat is the additive combination of Susceptibility and Severity.

various websites, which can be used for shopping, gaming, watching online movies/TV shows, and other expenditures.

Participants

As Beijing is one of the largest cities in China and has been experiencing a severe public health threat due to smog, it is important to understand Beijing residents' protective behavioral intentions in the face of this threat. Thus, the current study targets Beijing residents. Questionnaire Star sent the online Chinese survey we designed to users who were registered as Beijing residents. We limited our survey to individuals aged 18 and older, as some questions in the survey may not be fully comprehensible to teenagers, due to their level of literacy. It should be noted that the current study's recruitment strategy excluded Beijing residents who rarely use the Internet.

We set the valid sample size at 500; when the number of responses for a specific survey reaches the target size, Questionnaire Star stops collecting responses. A total of 8,258 surveys were sent out during 2/27-3/7 in 2017, a time when Beijing had experienced severe smog several times and more were anticipated. A total of 589 users responded (a response rate of 7.13%).

Measures

Individual characteristics including gender, age, ethnicity, education, income, marital status, and health status were measured. Health status was assessed by a single question: How would you describe your health status? The response scale ranged from 1 = very *poor* to 7 = *excellent*.

Intentions to take protective behaviors. We assessed two protective behavioral intentions including (1) intention to wear anti-smog facemask, which was measured by a single item: "When smog happens, I will wear an anti-smog facemask when I go out;" (2) intention to use air purifier, which was measured by a single item: "When smog happens, I will use an air purifier when I stay indoors." These two items were adapted from Cheng et al. (2017). The response scale for both measures ranged from 1 = *Strongly Disagree* to 7 = *Strongly Agree*.

Perceived susceptibility was measured by an item which was adapted from Yang et al. (2010) and stated: What do you think is the probability that you would contract smog-related diseases in the future? Please use a scale from 0 to 100, where 0 means zero probability and 100 means 100% probability. Perceived severity was measured by an item which was adapted from Yang et al. (2010) and stated: If you contracted smog-related diseases in the future, how severe do you think it would be? Please use a scale from 0 to 100, where 0 means not severe at all and 100 means extremely severe. A new variable was calculated by multiplying *perceived susceptibility* and *perceived Severity;* then a square root transformation was performed on this new variable that resulted in a measure of perceived threat of contracting smog-related diseases on a scale from 0 to 100. This procedure has been applied by some previous researchers (e.g., De Zwart et al., 2009).

Perceived benefit of wearing anti-smog facemask was measured by a stem item, "When smog happens, wearing an anti-smog facemask when I go out will . . ." followed by: (1) decrease my chances of getting smog-related diseases; (2) prevent me from getting smog-related diseases; (3) help me resist smog-related diseases. This measure was adapted from Champion et al. (2008). The response scales ranged from 1 = *Strongly Disagree* to 7 = *Strongly Agree*. Items were averaged to create this measure (α = .71). Perceived benefit of using air purifier was measured by a stem item, "When smog happens, using an air purifier when I stay indoors will . . ." followed by the same three items above measuring perceived benefit of wearing an anti-smog facemask. The response scales ranged from 1 = *Strongly Agree* to 7 = *Strongly Agree*. Items were averaged to create this measure (α = .76).

Perceived barrier of wearing anti-smog facemask was measured by four items: (1) Anti-smog facemasks are expensive for me; (2) It is difficult to get anti-smog facemasks that fit me; (3) Wearing an anti-smog facemask is uncomfortable for me; (4) Anti-smog facemasks are difficult for me to wear. This measure was adapted from Yang (2015). The response scales ranged from 1 = *Strongly Disagree* to 7 = *Strongly Agree*. Items were averaged to create this measure (α = .80). Perceived barrier of using air purifier was measured by four items similar to those above measuring perceived barrier of wearing anti-smog facemasks with "anti-smog facemask" replaced with "air purifier" and "wear" replaced with "use." The response scales ranged from 1 = *Strongly Disagree* to 7 = *Strongly Agree*. Items were averaged to create this measure (α = .81).

Perceived self-efficacy of wearing anti-smog facemask was measured by six items: (1) I know how to get anti-smog facemasks; (2) I know what to do to get anti-smog facemasks; (3) I am confident in my ability to get anti-smog facemasks; (4) I know how to wear an anti-smog facemask; (5) I know what to do to wear an anti-smog facemask; (6) I am confident in my ability to wear an anti-smog facemask. This measure was adapted from Umphrey (2004) and Yang (2015). The response scales ranged from 1 = *Strongly Disagree* to 7 = *Strongly Agree*. Items were averaged to create this measure (α = .93). Perceived self-efficacy of using air purifier was measured by six items similar to those above measuring perceived self-efficacy of wearing anti-smog facemask with "anti-smog facemask" replaced with "air purifier" and "wear" replaced with "use." The response scales ranged from 1 = *Strongly Disagree* to 7 = *Strongly Agree*. Items were averaged to create this measure (α = .94).

Exposure to smog-related news was measured by a stem item, "In the past 6 months, how often have you seen or heard smog-related news in the following media?" followed by: (1) print media (e.g., newspaper, journal); (2) electronic media (e.g., radio, TV); (3) Internet, excluding social media (e.g., qq.com, sina.com.cn, 163.com); (4) social media (e.g., Weibo, WeChat). This measure was adapted from two previous studies (Chen & Feeley, 2018; Yang, 2015). The response scales ranged from 1 = *Never* to 7 = *All the time*. Items were averaged to create this measure (α = .71).

Discussion of smog-related topics was measured by a stem item, "In the past 6 months, how often have you discussed smog in the following contexts?" followed by: (1) face-to-face communication with family; (2) face-to-face communication with friends; (3) face-to-face communication with strangers; (4) online communication with family; (5) online communication with friends; (6) online communication with strangers; (7) phone communication with family; (8) phone communication with friends; (9) phone communication with strangers. This measure was adapted from two previous studies (Chen & Feeley, 2018; Yang, 2015). The response scales ranged from 1 = *Never* to 7 = *All the time*. Items were averaged to create this measure (α = .87).

Worry about getting smog-related disease was measured by four items adapted from Ferrer et al. (2013) and Jensen et al. (2015): (1) How often have you worried about getting smog-related diseases sometime in the future? The response scale for this item ranged from 1 = *Never* to 7 = *All the time*. (2) How worried are you about getting smog-related diseases sometime in the future? The response scale for this item ranged from 1 = *Not worried at all* to 7 = *Extremely worried*. (3) How anxious are you about getting smog-related diseases sometime in the future? The response scale for this item ranged from 1 = *Not anxious at all* to 7 = *Extremely anxious*. (4) How nervous are you about getting smog-related diseases sometime in the future? The response scale for this item ranged from 1 = *Not nervous at all* to 7 = *Extremely nervous*. Items were averaged to create this measure (α = .93).

Analysis plan

We conducted SEM analyses to test all models (Models 1, 2, 3 & 4) using AMOS 21.0. Bootstrapping procedures were performed with the number of bootstrap samples set to 1000, in order to test the significance of mediational paths. The advantage of bootstrapping is that it does not impose distributional assumptions (Shrout & Bolger, 2002). The bias-corrected 95% confidence intervals for each mediational path were obtained, and statistical inferences were made based on those confidence intervals (Preacher & Hayes, 2008).

Results

Sample characteristics, descriptive statistics, and correlations

After data cleaning, we determined that, among the 589 respondents, a total of 523 participants were valid cases for data analyses. Those 523 participants range from 18 to 72 years of age (M = 33.37, SD = 9.97). A total of 234 participants (44.7%) are male and 497 participants (95%) are of the Han ethnicity. Their education ranges from 1 = *junior high school*, 2 = *senior high school*, 3 = *college and bachelor's degree*, to 4 = *master's degree and above*. A total of 2 participants (0.4%) had junior high school education, 30 participants (5.7%) had senior high school education, 402 participants (76.9%) had college or a bachelor's degree, and 89 participants (17%) had a master's degree or above. Their monthly income ranges from 0 to 122,222 Chinese Yuan (M = 8,174, SD = 9,463). A total of 323 participants (61.8%) are married. Their health status ranges from 1 = very *poor* to 7 = *excellent* (M = 5.21, SD = 1.11). Table 1

Table 1. Descriptive statistics of study variables.

Variable	Minimum	Maximum	Mean	SD
1. Exposure	1	7	5.15	1.04
2. Discussion	1	7	4.43	1.17
3. Worry	1	7	4.79	1.30
4. Perceived threat	0	100	65.01	22.60
5. Perceived benefit (wearing facemask)	1	7	4.93	1.09
6. Perceived barrier (wearing facemask)	1	7	4.39	1.22
7. Perceived self-efficacy (wearing facemask)	1	7	5.33	1.09
8. Intention (wearing facemask)	1	7	5.74	1.21
9. Perceived Benefit (using air purifier)	1	7	5.25	1.07
10. Perceived barrier (using air purifier)	1	7	3.98	1.26
11. Perceived self-efficacy (using air purifier)	1	7	5.41	1.09
12. Intention (using air purifier)	1	7	5.60	1.34

Exposure = Exposure to smog-related news; Discussion = Discussion of smog-related topics; Worry = Worry about getting smog-related disease; Perceived threat = Perceived threat of contracting smog-related diseases.

shows descriptive statistics, and Table 2 shows a zero-order correlation matrix.

Model specification

For all models tested in this study (Models 1, 2, 3, & 4), we correlated each pair of exogenous (i.e., independent) variables. We did not correlate any of the three endogenous variables (i.e., the two dependent variables as well as the mediator) with any other variable, since this is invalid in SEM analysis. We did correlate the error variables of the three endogenous variables with one another.[3]

Model-selection criteria

We used two model selection criteria (*R*-squared & chi-square) to choose the best model.

R-squared (R^2)

R^2 is a statistical measure that determines the amount of variance in the dependent variable that can be explained by the independent variables. A larger R^2 generally indicates a better model fit to the data (Cohen et al., 2002).

Chi-square (χ^2)

We used χ^2 as another criterion for model comparison, since χ^2 is currently the best test available for detecting problems within the model itself (Hayduk, 2014; Ropovik, 2015). A significant χ^2 means that "the fit function was unable to find a set of parameters that would fit the data sufficiently well" (Ropovik, 2015, p. 5). If the *p*-value of χ^2 of a tested model is significant (i.e., smaller than .05), this suggests that the model departs from the observed data (Kline, 1998). Thus, that model is not likely to be the best-fitting model.

Model comparison and choosing the best model

We tested all four models, obtaining their R^2 and fit indices. Table 3 lists all of these values.

As shown in Table 3, Model 1 accounted for 16.8% of the variance in intention to wear facemask (R^2 = .168), and 28.0% of the variance in intention to use air purifier (R^2 = .280). Model 2 accounted for 16.5% of the variance in intention to wear facemask (R^2 = .165), and 27.7% of the variance in intention to use air purifier (R^2 = .277). Thus, both models explained similar variance in the two outcome variables. The *p*-value of χ^2 is .107 for Model 1 and .083 for Model 2, indicating that both models are consistent with the observed data. Taken together, Model 1 is neither superior nor inferior to Model 2, answering RQ3.

As shown in Table 3, the *p*-value of χ^2 is .002 for Model 3 and .002 for Model 4, indicating that both models do not fit the data well and should be rejected (Kline, 1998). Recall Model 1 is consistent with the observed data (the *p*-value of χ^2 is .107). Thus, Model 1 is more likely to be the best of the three,

Table 2. Zero-order correlation matrix of study variables.

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Exposure	–	.628**	.290**	.273**	.231**	.059	.326**	.286**	.293**	.062	.299**	.292**
2. Discussion		–	.406**	.319**	.185**	.155**	.230**	.264**	.252**	.146**	.173**	.247**
3. Worry			–	.677**	−.004	.271**	−.019	.185**	.100*	.241**	−.097*	.151**
4. Perceived threat				–	−.039	.260**	.010	.154**	.101*	.184**	−.043	.160**
5. Perceived benefit (wearing facemask)					–	−.089*	.331**	.310**	.633**	−.066	.324**	.274**
6. Perceived barrier (wearing facemask)						–	−.196**	−.067	−.026	.668**	−.167**	−.073
7. Perceived self-efficacy (wearing facemask)							–	.357**	.333**	−.195**	.650**	.302**
8. Intention (wearing facemask)								–	.306**	−.056	.336**	.560**
9. Perceived Benefit (using air purifier)									–	−.125**	.373**	.423**
10. Perceived barrier (using air purifier)										–	−.324**	−.217**
11. Perceived self-efficacy (using air purifier)											–	.465**
12. Intention (using air purifier)												–

Exposure = Exposure to smog-related news; Discussion = Discussion of smog-related topics; Worry = Worry about getting smog-related disease; Perceived threat = Perceived threat of contracting smog-related diseases. *$p < 0.05$, **$p < 0.01$.

Table 3. Fit indices and R^2 of all four models.

Model name	The relationship between Worry and Perceived Threat	Assessment of Perceived Threat	χ^2 (df = 12)	χ^2/df	p	CFI	TLI	RMSEA	R^2 (intention to wear facemask)	R^2 (intention to use air purifier)
Model 1 (the proposed model; see Figure 1)	Worry predicts Perceived Threat	The multiplicative combination of Susceptibility and Severity	18.30	1.53	0.107	0.997	0.985	0.032	0.168	0.280
Model 2 (see Figure 1)	Worry predicts Perceived Threat	The additive combination of Susceptibility and Severity	19.26	1.61	0.083	0.997	0.983	0.034	0.165	0.277
Model 3 (see Figure 2)	Perceived Threat predicts Worry	The multiplicative combination of Susceptibility and Severity	30.73	2.56	0.002	0.992	0.956	0.055	0.204	0.296
Model 4 (see Figure 2)	Perceived Threat predicts Worry	The additive combination of Susceptibility and Severity	30.64	2.55	0.002	0.992	0.956	0.055	0.192	0.296

answering both RQ4 and RQ5: it is more appropriate to hypothesize threat as a mediator of worry rather than worry as a mediator of threat.

Although Model 1 is neither superior nor inferior to Model 2, theoretical reasoning justifies the assessment of perceived threat as the product of probability and severity (Weinstein, 2000). Thus, we chose Model 1 as the final model.

Examining alternative fit indices and path coefficients of model 1 (The proposed model)

We used several alternative fit indices to assess model fit of the final model. Those alternative fit indices include comparative fit index (CFI), the Tucker–Lewis index (TLI), and the root mean square error of approximation (RMSEA). Kline (1998) suggested that CFI- and TLI-values larger than .90 and .95 are considered an acceptable and an excellent fit, respectively. McDonald and Ho (2002) suggested that RMSEA-values smaller than .05 and .08 are considered a close and a reasonable fit, respectively.

Results of path analyses indicated that the proposed model provided an excellent fit to the data. As shown in Table 3, chi-square was non-significant at χ^2 (12) = 18.30, p = .107, and χ^2/df = 1.53; CFI = .997, TLI = .985, and RMSEA = .032. The path coefficients of direct effects and indirect effects are presented below.

Perceived threat of smog (β = .335, p < .001), perceived benefit of wearing facemask (β = .213, p < .001), and perceived self-efficacy of wearing facemask (β = .267, p < .001) are all significantly associated with intention to wear facemask and the directions of the associations are all consistent with our hypotheses. However, perceived barrier of wearing facemask (β = −.086, p > .05) was *not* associated with intention to wear facemask. Thus, H1a, H1b, and H1d were all supported, but H1c was *not*.

Perceived threat of smog (β = .299, p < .001), perceived benefit of using air purifier (β = .247, p < .001), perceived barrier of using air purifier (β = −.149, p < .001), and perceived self-efficacy of using air purifier (β = .303, p < .001) are all significantly associated with intention to use air purifier and the directions of the associations are all consistent with our hypotheses. Thus, H2a, H2b, H2c, and H2d were all supported.

Worry about smog (β = .641, p < .001) is significantly associated with perceived threat of smog; however, neither exposure to smog-related news (β = .091, p > .05) nor discussion about smog (β = .018, p > .05) is significantly related to perceived threat of smog. Thus, there is not a significant indirect effect of exposure or of discussion on intention to wear facemask/use air purifier through perceived threat, answering RQ1a, RQ1b, RQ2a, and RQ2b. The bootstrap mediation analyses found that worry has a significant indirect effect on intention to wear facemask through perceived threat (B = .199, 95% CI: [.096, .303]), and on intention to use air purifier through perceived threat (B = .194, 95% CI: [.106, .280]), answering RQ1c and RQ2c. Figure 3 shows standard path coefficients of Model 1 (The proposed model).

Discussion

In recent years, Beijing has experienced severe smog on many occasions, which has become a major threat to public health. To examine Beijing residents' protective behavioral intentions when smog occurs, we proposed a conceptual model, which applies the HBM and assumes perceived threat as a theoretical mechanism accounting for the influences of three distal factors (exposure, discussion, & worry) on intention to wear facemask/intention to use air purifier. Data were collected from Beijing residents from Feb 27 to March 7 in 2017, a time when Beijing had experienced severe smog lasting for several days on numerous occasions, with more such occasions anticipated. Our analyses of valid cases (N = 523) generally supported the proposed model: increased perceived threat of smog-related diseases, perceived benefit of wearing facemask, and perceived self-efficacy of wearing facemask are associated with increased intention to wear facemask; perceived barrier of wearing facemask is *not* related to intention to wear facemask; increased perceived threat of smog-related diseases, perceived benefit of using air purifier, perceived self-efficacy of using air purifier, and decreased perceived barrier of using air purifier are associated with increased intention to use air purifier. Neither exposure to smog-related news nor discussion about smog is related to perceived threat of smog-related diseases. Worry has an indirect effect on intention to wear facemask/intention to use air purifier through perceived threat.

Our proposed model treated threat as the product of susceptibility and severity, based on Weinstein's (2000) theoretical reasoning about the nature of threat and Carpenter's (2010) recommendation in his meta-analysis of the HBM studies. However, some previous HBM studies have treated threat as the sum of susceptibility and severity (e.g., Bishop et al., 2015;

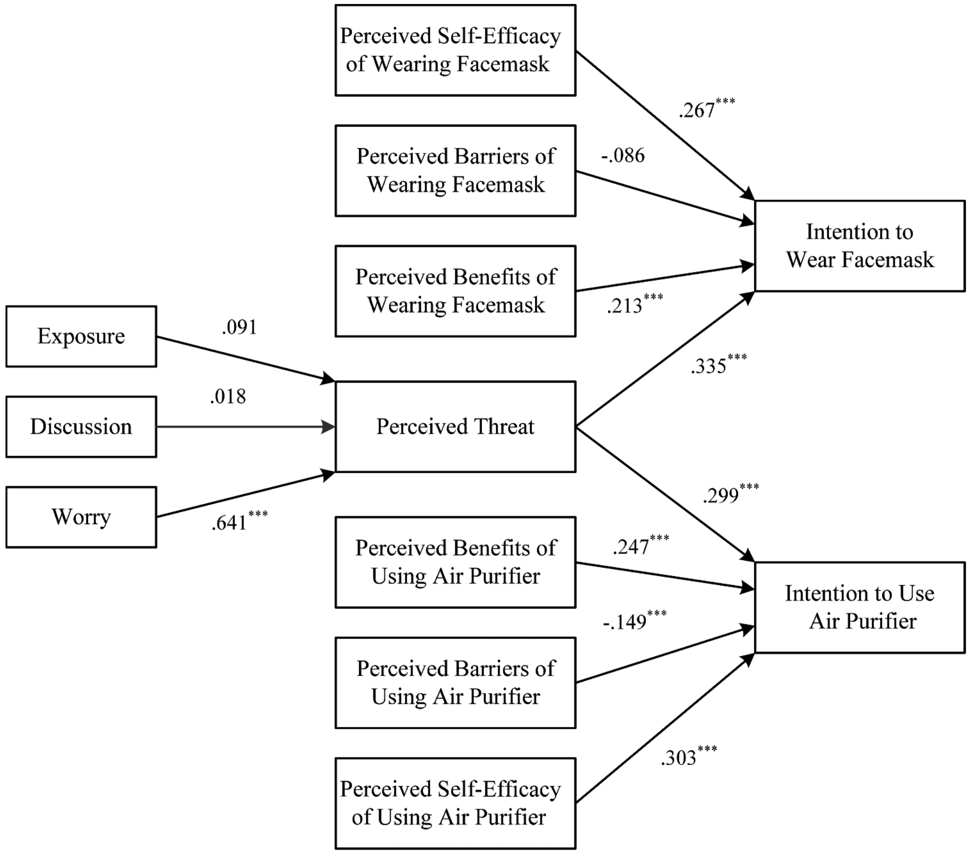

Figure 3. Standard Path Coefficients of Model 1 (The Final model). *Note*. Exposure = Exposure to smog-related news; Discussion = Discussion of smog-related topics; Worry = Worry about getting smog-related disease; Perceived threat = Perceived threat of contracting smog-related diseases. ***$p < .001$.

Jones et al., 2015). We considered the latter practice as an alternative model (Model 2) and tested it in our study. Comparing our proposed model with this alternative model, we found that the former is *not* superior.

Additionally, our proposed model treated threat as a mediator of distal factors (e.g., worry), based on social cognition models (Sutton, 2001) and some empirical evidence (e.g., Jones et al., 2015). However, cognitive appraisal theory (Lazarus, 2001) and some studies (e.g., So et al., 2016) suggest that negative emotions can be mediators of threat. We considered the latter practice as two additional alternative models (Model 3 and Model 4) and tested them in our study too. Comparing our proposed model with these two alternative models, we found that the former *is* superior. Below, we discuss the implications of our findings.

The HBM has been used to examine various protective behaviors/intentions such as healthy eating (Deshpande et al., 2009), cancer screening (e.g., Rawl et al., 2012), or intention to take the H1N1 vaccine (Yang, 2015). According to our findings, all HBM key constructs directly predict behavioral intentions, except perceived barrier of wearing facemask, which is *not* related to intention to wear facemask. These findings suggest that the HBM is a useful model for predicting anti-smog health-protective behavioral intentions in Beijing residents, thus applying the HBM to a new behavioral domain and a new, non-western population that has been seldom explored in HBM studies.

One important finding of our study is that perceived threat shows a strong relationship with intention to wear facemask/intention to use air purifier. Some HBM studies have assumed that perceived susceptibility and perceived severity have additive effects on behaviors/intentions and treated them as two independent predictors (e.g., Deshpande et al., 2009; Yang, 2015). This may explain why Carpenter's (2010) meta-analysis found that perceived susceptibility and perceived severity both have weak relationships with behaviors, as either construct only assesses *one of the two aspects* of perceived threat. However, our finding is consistent with Chen's (2018) findings, which suggested that increased risk perception (the product of perceived susceptibility and perceived severity) of binge drinking is associated with decreased binge drinking, a preventive behavior. In line with Chen's (2018) results, our finding suggests that perceived susceptibility and perceived severity may have a multiplicative effect on behaviors/intentions. That is, the influence of each construct on behaviors/intentions may be contingent on the other. In the context of smog, people may not be willing to take protective actions when either perceived susceptibility or perceived severity of contracting smog-related diseases is low; people may only plan to take protective actions when smog seems very likely to pose a severe threat to their health/well-being (i.e., the product of perceived susceptibility and perceived severity is large). Although treating threat as the product of susceptibility and severity reflects a theory-driven approach, while treating it as the sum of those two components does not, our comparison in model fit indices shows that the former (i.e., the proposed model) is *not* superior to the latter. Perhaps, in SEM analyses with a large sample size and with many predictors (as in the present study), treating threat as the sum of susceptibility and severity is also an acceptable practice, as it is at least inclusive of both components of threat.

A second important finding is that perceived self-efficacy appears to be a strong predictor of intention to wear facemask/intention to use air purifier. The original HBM does not recognize the impact of perceived self-efficacy (Janz & Becker, 1984); it was added to the model later (Rosenstock et al., 1988). Carpenter's (2010) meta-analysis did not analyze the impact of perceived self-efficacy because the number of HBM studies that have examined self-efficacy is insufficient. Based on our finding, perceived self-efficacy adds unique variance for predicting behavioral intention, even after the influences of perceived threat, benefit, and barrier are taken out. In other words, individuals' self-efficacy (i.e., confidence in their own abilities) to adopt a behavior is critical to the actual/intended performance of that behavior and is as important as other constructs proposed in the original HBM (Janz & Becker, 1984). As such, it appears that the revised HBM, with the addition of self-efficacy (Rosenstock et al., 1988), has a higher predictive ability than the original model. After recognizing the important role of self-efficacy, and after incorporating the product of perceived susceptibility and perceived severity, the influences of perceived benefit and perceived barrier may diminish and, as a result, may not be consistently the strongest predictors of behaviors, as reported by Carpenter's (2010) meta-analysis.

A third important finding is that, in the context of smog, perceived barrier is the weakest among the HBM predictors, while perceived threat of smog-related diseases, as well as perceived benefit and efficacy of using protective actions, carry more weight in the decision-making process. This might be because individuals who perceive smog to be a serious threat are willing to do whatever it takes to overcome any barriers to adopting preventive behaviors. It's also possible that individuals perceive the barriers to adopting these protective behaviors to be relatively small.

A fourth important finding of this study is that worry has an indirect effect on intention to wear facemask/intention to use air purifier through perceived threat. Perhaps, when facing the threat posed by smog, worry serves as a constant reminder to Beijing residents that the threat is high, thus triggering them to plan for preventive approaches to reduce such threat. In other words, worry likely affects intention by first increasing perceived threat of smog, which subsequently promotes the intentions of protective behaviors against smog. This indirect effect suggests that perceived threat serves as a theoretical mechanism accounting for the impact of internal feelings on protective behaviors/intentions. This finding is also consistent with the assumption of social cognition models (Sutton, 2001), which argues that the effects of distal factors on behaviors/intentions are mediated through proximal predictors. In contrast to our finding, the mediating role of perceived threat (called *risk perception*) in the link between worry and intention of quitting smoking was not observed in Chen and Yang (2017) study, possibly due to the fact that the perceived-threat measure in their study only evaluated perceived susceptibility of getting cancer, but did not consider perceived severity of getting cancer. Thus, their perceived-threat measure might not have had sufficient validity to capture its conceptual definition and, accordingly, was unable to detect the significant mediating role of this construct.

Finally, contrary to findings from previous studies, our findings suggest that neither exposure to smog-related news nor discussion of smog-related topics is related to perceived threat. One possible reason is that exposure is a composite measure involving the use of various information sources, including print media, electronic media, and the Internet (including social media). Similarly, discussion is a composite measure involving the use of different communication channels with various network members. Perhaps a more refined measure of exposure/discussion which differentiates information sources, communication channels, or network members would be more likely to detect the impact of exposure/discussion. Another possible reason is that exposure and discussion both represent communication with the external environment and their influences on behaviors/intentions may be weaker than internal feelings; thus, such influences fade into the background when an internal feeling (e.g., worry about potential negative consequences of smog) comes into play. This might explain why some previous studies found positive effects on behaviors/intentions of communication factors, such as interpersonal discussion about H1N1 vaccine (Yang, 2015) and smog information from peers (Cheng et al., 2017), but we did not: those studies did not investigate the role of internal feelings in addition to communication factors.

Theoretical implications

This study has three important theoretical implications. First, as the proposed model has an excellent fit to the data, and as perceived threat is significantly related to intentions to take protective behaviors, this suggests that it is appropriate for the HBM to incorporate the product of perceived susceptibility and perceived severity as a major construct predicting behaviors/intentions. Although the proposed model is *not* superior to Model 2, an alternative model, it is worth noting that operationalizing threat as the product of susceptibility and severity represents a theory-driven approach; in contrast, operationalizing threat as the sum of those two components is simply a convenient practice, which does not comply with the conceptualization of threat and lacks theoretical rigor.

Second, as perceived self-efficacy exhibits a strong relationship with intentions to take protective behaviors and adds unique variance to the model, this suggests that self-efficacy is an indispensable factor in the HBM, and that its addition would improve the predictive ability of the model. Taken together, it appears that a parallel four-construct model including perceived threat, perceived benefit, perceived barrier, and perceived self-efficacy would be superior to the original HBM model.

Third, as worry produces an indirect effect on intention to wear facemask/intention to use air purifier through perceived threat, it appears necessary for the HBM to take account of the influences of affective factors, which have been absent since the HBM was proposed. Including affective factors (e.g., worry) to the HBM addresses a long-standing criticism of social cognition models (Sutton, 2001) that they are too cognitive/rational and fail to consider the functions of affective factors (Loewenstein et al., 2001), which might impede the understanding of decision-making processes mainly/partially driven by feelings.

Fourth, as the proposed model is superior to Model 3 and Model 4 (two additional alternative models), this suggests that, in the context of protective behavioral intentions against smog, it is more likely that the effect of worry on intention is mediated by threat rather than that the effect of threat on intention is mediated by worry. This finding is inconsistent with cognitive appraisal theory (Lazarus, 2001), which assumes a direct effect of emotion on coping strategies, including adjustment of behaviors/intentions. However, this finding is in line with the extended parallel process model (EPPM; Witte, 1992), which suggests that fear indirectly influences adaptive responses (e.g., protective intentions/behaviors) through cognitive appraisal (Popova, 2012). Perhaps this is because maladaptive responses (e.g., simply denying the threat) may be effortless, while adaptive responses (such as wearing a facemask or using an air purifier), are behaviors that demand deliberate effort. Such protective behaviors will likely be initiated by a three-step process: first, individuals facing the threat need to experience negative emotions (e.g., worry), making the threat a salient issue in their mind; second, negative emotions prompt individuals to engage in deep thoughts (i.e., cognitive appraisals of the threat's probability and severity) on whether it is worth one's effort to take protective actions; third, those deep thoughts facilitate adoptions of protective behaviors. In sum, the theoretical mechanism of "negative emotion – cognitive appraisal" better explains the decision-making process of taking adaptive behaviors and should therefore supersede the reverse mechanism when studying protective behaviors.

Practical implications

In practice, that the proposed model has excellent fit indices promotes the methodological practice of operationalizing threat as the multiplicative combination of susceptibility and severity, as it reflects a strict compliance with the conceptualization of threat (Weinstein, 2000). That Model 2 (an alternative model) is *not* inferior to the proposed model suggests that, in SEM analyses with large sample sizes and many predictors, operationalizing threat as the additive combination of susceptibility and severity is possibly also an acceptable practice for the purpose of statistical testing, although this practice is not grounded in theoretical reasoning (Weinstein, 2000).

Additionally, our findings suggest that public health campaigns in Beijing aiming to promote anti-smog protective behaviors should focus on educating residents on the threat of smog and increasing perceived benefits of adopting protective behaviors. Residents should be informed of the health risks associated with direct exposure to smog (Fang et al., 2016), be warned in advance when smog occurs, and be encouraged to take preventive actions to reduce those risks along with explanations of the benefits of doing so. Government agencies in Beijing might want to implement policies/regulations to make anti-smog devices more accessible and affordable (e.g., researching consumer demand, producing more high-quality products, & controlling prices), thereby reducing the barriers to using those devices. It is equally important to teach residents how to effectively use facemasks/air purifiers with public service announcements through various communication channels, thus boosting residents' efficacy beliefs about wearing facemasks/using air purifiers.

Although worry is considered a negative affect (Keogh & Reidy, 2000) and excessive worries can be harmful to health and well-being (Davey et al., 1996), public health professionals in Beijing might want to weave affective components into smog-related PSAs to stimulate a *reasonable* amount of negative feelings about smog. Such negative feelings may well serve as effective reminders to facilitate the formation of perceived threat of smog, which may subsequently prompt the adoption of preventive actions to reduce the threat.

Limitations

This study is not without limitations. First, all constructs were measured based on self-report. Some participants might over-report or under-report scores to some questions due to social desirability or poor recall. However, the questions asked in our survey were very relevant to participants' experiences and not very sensitive, thus it is likely that many participants would have provided honest answers. Second, participants in our study are Beijing residents who are Internet-savvy and have registered with the Questionnaire Star website. While our survey reached out to 8,258 Beijing residents, the response rate (7.13%) was low, and the final sample might not be representative of the Beijing population. Third, although we relied upon the HBM and adopted a theory-driven approach, the cross-sectional nature of our study constrains the causal inferences of our findings. Fourth, besides wearing a facemask and using an air purifier, there are certainly other possible protective behaviors in the smog context, such as simply staying indoors with all windows/doors closed, consuming foods or beverages that are believed to be able to help clear dust from the lungs, etc., which were not examined in our study. We used wearing facemask and using air purifier as examples of protective behaviors in the smog context because these two are common behaviors people take when facing a smog/air pollution threat. Future research may want to examine more smog-related protective behaviors/intentions, in addition to the two examined in the current study and compare the likelihoods to adopt all possible behaviors/intentions.

Conclusion

Despite the limitations mentioned above, this study represents an initial effort to apply the HBM in the context of anti-smog behavioral intentions and test the model with a non-western population. Our findings suggest that the parallel four-construct model consisting of perceived threat, benefit, barrier, and self-efficacy, with worry as a distal factor mediated through perceived threat, is superior to the original HBM. The study contributes to the health communication literature by justifying that treating perceived threat as the product of perceived susceptibility and perceived severity, or as the sum of those two components, are both *acceptable* practices for the purpose of statistical model testing. However, only the former practice complies with the conceptualization of threat and represents a theory-driven approach. A second contribution of our study is recognizing the essential role of perceived self-efficacy, which was missing from the original HBM. Finally, we specified perceived threat as a potential theoretical mechanism accounting for the effects of worry on anti-smog behavioral intentions and demonstrated that this proposed mechanism is superior to the reverse mechanism that assumes worry as a mediator of threat. Future research might want to test this modified HBM model with residents in other cities with smog problems, explore whether there are interaction effects between HBM constructs, and employ a longitudinal design when studying the relationships between HBM constructs and anti-smog behavioral outcomes.

Notes

1. It is considered "Very Unhealthy" when the 24-hour average level of $PM_{2.5}$ (tiny particles or droplets in the air that are 2.5 microns or less in width; NYS Department of Health, 2018) is over 150 μg/m^3; it is considered "Hazardous" when the 24-hour average level of $PM_{2.5}$ is over 250 μg/m^3 (Aqicn.org, 2013).
2. A bilingual researcher translated the original English questionnaire into Chinese. Then the second bilingual researcher translated the Chinese version back into English, without having access to the original English version. Both English versions were compared, then the first researcher modified the Chinese and the second researcher translated the modified Chinese back into English again. This procedure was repeated until no inconsistency was found in the meaning between the two versions.
3. It is plausible that any two of the variables in this study are correlated with each other, although some correlations may be stronger than others. Methodologically, SEM analysis only allows exogenous (i.e., independent) variables to be correlated with each other; SEM analysis does not allow an endogenous (i.e., dependent) variable to be correlated with any other variable (either exogenous or endogenous; Pitblado, 2013). However, the error variable of an endogenous variable (which is itself exogenous) is allowed to be correlated with any exogenous variable.

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