sustainability

MDPI

Article

Revealing an Integrative Mechanism of Cognition, Emotion, and Heat-Protective Action of Older Adults

Hee Jin Yang [1] and Heeyeun Yoon [2,*]

[1] Incheon Studies Institute, Incheon National University, Incheon 22012, Korea; hjyang@inu.ac.kr
[2] Department of Landscape Architecture and Rural Systems Engineering, College of Agriculture and Life Sciences, Seoul National University, Seoul 08826, Korea
* Correspondence: hyyoon@snu.ac.kr; Tel.: +82-2-880-4876

Abstract: This study aims to provide an in-depth understanding of what motivates older adults to take their adaptive behaviors during extreme heat events. Elaborating the mediating role of emotion in human behaviors, we empirically explore an interrelationship between individuals' cognition, emotion, and heat-protective action in response to heat warning system alarms. Through face-to-face surveys and structural equation modeling, this study reveals that an increased level of cognition about climate change, heat waves, and local policy measures leads to emotional responses such as concern and worry, and consequently encourages people to comply with heat-related public guidelines. Furthermore, we also consider individuals' pre-existing health conditions and their previous experiences of heat-related illnesses together with the emotional factors. The role of emotion in mediating between cognition and heat-protective action is much greater than in mediating between pre-existing health conditions and heat-protective action. We conclude that policy interventions to educate older adults can effectively increase the likelihood of individual compliance with the relevant preventive measures beyond their individual health and experiences.

Keywords: heat wave; climate change; older adults; adaptive behaviors; structural equation models

Citation: Yang, H.J.; Yoon, H. Revealing an Integrative Mechanism of Cognition, Emotion, and Heat-Protective Action of Older Adults. *Sustainability* **2021**, *13*, 3534. https://doi.org/10.3390/su13063534

Academic Editor: Michalis Diakakis

Received: 8 February 2021
Accepted: 17 March 2021
Published: 22 March 2021

1. Introduction

Extreme weather events have gained worldwide attention. Heat waves are predicted to occur more frequently, with greater intensity and duration in the future, creating a global health concern [1,2]. Some previous studies have documented that such increased magnitudes would explain escalating morbidity and mortality from heat-related illnesses, such as heat stroke, heat exhaustion, and heat cramps [3–5]. While all can be affected, the vulnerability to such symptoms differs according to individual characteristics. In particular, the elderly and people with pre-existing illnesses are at higher risk, because they tend to have weaker thermoregulatory systems and be less able to adapt themselves to excess temperature [6–10].

In the fields of public health and preventive medicine, substantial evidence suggests that these heat-related health problems can be prevented by taking appropriate actions, such as avoiding outdoor activities and staying hydrated [11–13]. In contrast to the aforementioned studies, other studies found that the improvement of public warning systems and public education helped reverse the trend of increasing heat-related morbidity and mortality [14,15]. Indeed, a large portion of public policy measures have focused on encouraging people to take appropriate actions in the event of heat waves. Examples include the real-time release of heat wave alarms through public websites and mobiles, educating people on how to minimize heat-related health damage, and making daily visits and phone calls to those who are at particularly high risk. In this regard, studies have revealed the effectiveness of heat warning systems and public guidelines in minimizing adverse health effects in general [16,17].

In the fields of social sciences and psychology, on the other hand, research has been conducted to understand a fundamental mechanism to promote individual behavioral changes [18]. In the decision-making of shifting behaviors toward heat-protective actions, a higher level of cognition of heat wave risk plays an important role [6,19]. For example, those who are well aware of the dangers of heat waves would be more likely to drink plenty of water, reduce outdoor gardening, and use an umbrella and a hat when going outside. Meanwhile, a less emphasized but important factor is the emotional response, such as feelings of threat and concern, to the threat. It takes a mediating role in the individual perceptions of the risk from heat waves [1,20], and it is expected that those who are emotionally engaged in health-threatening circumstances are more likely to engage in health-protective behaviors [21–23]. While those two factors are known to trigger people's behavioral changes in the face of heat-related threat [12], the magnitude of the contributions that each has made has not been revealed. It might be guessed that the characteristics of the people would matter in this respect, and public programs have to be designed differently to cater to each group.

Then what is the behavioral mechanism of the elderly's prevention action, responding to a public warning of a heat event? Older adults are known to have relatively lower cognitive levels and higher emotional concerns for their health than younger adults [10,24]. Does the emotion take a larger part in inducing behavioral change? Then are the current public policies effective in encouraging older adults to adapt to the heat wave risks? While older people are considered at particular risk due to their weaker health conditions and lower awareness of heat-related risks [6], such questions have not been answered. In order to promote heat-protective behaviors of older adults amid the increasing risk of heat waves, it is crucial that scholars and planners understand their willingness to comply with heat-related public measures and guidelines.

Against this backdrop, this research aims to empirically explore an interrelationship between cognition, emotion, and heat-protective behaviors of people over the age of 50, following activation of the heat warning system. Specifically, it addresses the question of how public awareness of and personal emotions about heat waves influence the compliance of the elderly with heat-related public guidelines. We used self-reported levels of awareness of public interventions and the vulnerability felt during heat events as proxies to measure cognition and emotion, respectively. For the purposes of comparison, we considered the respondents' pre-existing health conditions and their previous experience of heat-related illnesses together with emotional factors. People with those conditions and experiences are more prone to engage in heat-protective behaviors [6,11], regardless of their cognitive level.

We employed a two-fold analysis: first, using a questionnaire survey, we gathered the information to produce an indicator—the level of behavioral change after a public warning of an extreme heat event—and the two constructs, cognition and emotion; second, using a structural equation model (SEM), we deciphered the aforementioned mechanism. The rest of this paper is structured as follows: in the upcoming section we describe the analytical design and method, we then provide the empirical results of structural equation modeling, and we conclude the paper by discussing policy implications.

2. Background and Literature Review

2.1. Public Intervention in Response to Heat Waves in Seoul, South Korea

According to the Korea Meteorological Administration, the summer of 2018 was recorded as the hottest since the beginning of observations in 1907. The highest daily temperature in South Korea was recorded as 41 °C. The number of days with an average daily temperature above 33 °C was 32 in that year, followed by 31 in 1994, 22 in 2016, and 19 in 2013. In the case of Seoul, the capital city of South Korea, 2018 was also notorious for high humidity accompanying the heat. During the two months of July and August 2018, the Seoul Automatic Weather System recorded an average daily maximum humidity of 81.8% and an average daily maximum temperature of 33.2 °C.

The Seoul Metropolitan Government (SMG) has introduced various policy measures to address heat-related health threat. One of these is the heat alarm system. This system is activated when it is expected that the daily maximum temperature will be over 33.0 °C for more than two consecutive days. The alarm goes off via cell phone text messages listing precautions against heat: avoiding outdoor activities and drinking plenty of water. In addition, SMG provides public services such as cooling centers, temporary shelters for the homeless, and medical examinations for those susceptible to heat-related hazards. According to the internal report of the Heat Response Task Force of SMG, from 2017 to 2018, publicity activities through electronic signage increased from 29,990 times to 41,545 times, street broadcasting increased by approximately 5 times, from 491 to 24,978, and media exposure also increased from 796 to 1273. Nevertheless, it is unknown whether these public relations activities were effective in promoting heat-protective actions by individuals.

2.2. Preventive Behaviors in Response to Heat Waves

In the study of preventive health behaviors, for decades, the "health belief" model has long been the theoretical framework employed to explain why individuals engage in preventive health behaviors and why they do not [21,22,25,26]. The model highlights the role of individuals' subjective perceptions of risks, in that those who feel threats sensitively and recognize the costs and benefits of preventive health behaviors are more likely to engage with public health programs. This explanation holds true in the case of heat emergencies: a higher level of risk perception related to heat waves triggers heat-protective actions [19,20,27].

Cognition and emotion are recognized as the two factors that make up risk perception, inducing behavioral changes [12]. First, knowledge about heat waves drives behavioral changes [21,22,28]. Some previous studies have assessed whether local health programs or media campaigns improved climate change literacy and promoted public understanding of climate problems [28–30]. In general, advice from health professionals is well understood by people and leads to the alteration of their daily routines. The previous research also emphasized the importance of public communication and educational efforts to raise awareness of the dangers of heat exposure, especially among the vulnerable population, in order to encourage their protective behaviors [28].

Second, emotions also play an imperative role in driving preventive behaviors. The role of emotional responses, such as worry and regret, was revealed in the decision to get an influenza vaccination [31]. Those who were more concerned about heat-related hazards were also more likely to take preventive actions, such as having an air conditioner at home [20]. On the other hand, positive feelings about heat also affected behavioral changes. Those who relish hot weather or enjoy sun exposure are less likely to take heat-protective actions [1]. In addition, such emotions can be built from past experiences or preexisting health conditions. People who have experienced heat-related illnesses or have chronic diseases are more concerned about heat-related risks [11,32].

Recently, a sequential relationship among cognition, emotion, and behavioral changes was established [12]. They systematically reviewed the existing studies on the effectiveness of heat warning systems and explained that the cognition of heat-related dangers triggers emotions upon heat warnings, such as feeling threatened or fearful. Then the cognitive and emotive factors together affect the decision to take preventive action. Although the study synthesized the preexisting discussions on this matter, it did not provide empirical evidence supporting the interrelationship between cognition, emotion, and heat-protective action.

3. Analytical Design and Method

3.1. Study Setting

Our analysis aims to reveal the behavioral mechanism by which older people take preventive actions in response to heat waves. We focus on the magnitude of the influence that cognition and emotion contribute to the behavioral changes: (1) what is the magnitude that cognition of heat waves directly promotes compliance with public guidelines to take heat-protective actions; (2) what is the magnitude that emotional response to heat waves directly promotes compliance with public guidelines to take heat-protective actions; (3) what is the magnitude that cognition indirectly promotes compliance with public guidelines to take heat-protective actions by influencing emotional responses. With this synthesis framework described in Figure 1, we were able to compare the magnitude of indirect influences of cognition with those of an individual's health condition.

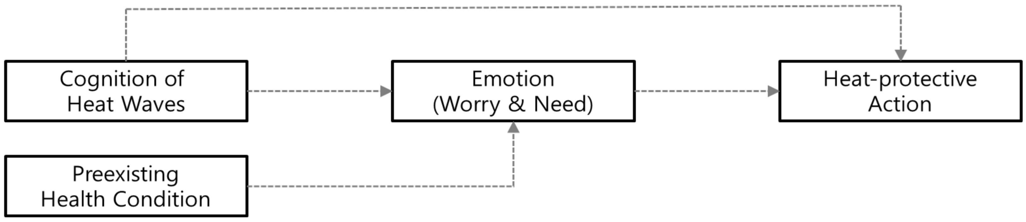


Figure 1. Key research framework.

In order to analyze the integrative mechanism of cognition, emotion, and heat-protective action, this study utilized cross-sectional survey data collected as part of South Korea's national research project on climate change and adaptation policy. The survey was conducted in February 2019 through face-to-face interviews by the professional staff at Gyunggi Research Center. Since the heat wave of 2018 was notable not only for its duration but also for its intensity, the survey participants were asked about their heat-related experiences in that summer and about their general knowledge of climate change and heat waves.

A total of 300 people over the age of 50 participated. Since it is well established that older people tend to have a lower understanding of the health risks of heat waves and are less engaged in taking proper actions [8,10,12], we focused on those over 50 and their behavioral responses to extreme heat events. Among the five regions of Seoul depicted in Figure 2, the city center is characterized by the lowest population density, the highest ratio of people over 50 years old, and the highest employment density. Thus, we recruited survey participants who live or work in the city center of Seoul, which covers three ward-level local governments: *Jungu*, *Jongrogu*, and *Yongsangu*.

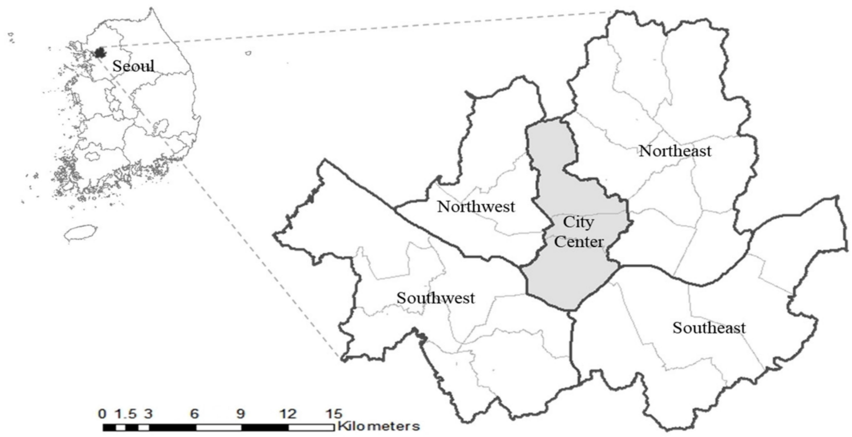


Figure 2. Survey area.

3.2. Questionnaire

In the survey, we asked three groups of questions regarding the three components illustrated in Figure 1; heat-protective actions, cognition, and emotion (See Appendix A for more details). Additionally, we also asked the survey participants about their socioeconomic characteristics and their pre-existing health conditions. First, for the part on heat-protective action, respondents recorded their perceived level of behavioral change in response to the heat alarm. The specific question was, "To what degree do the heat alarm system and the emergency text message affect your behavioral change?" The answer was measured on a 5-point Likert-type scale ranging from 1 = Not influential at all to 5 = Very influential.

To measure the level of cognition, we utilized three questions: How much are you aware of climate change? How much do you know about the adverse health effects of heat waves due to climate change? and How much do you know about local heat action plans to reduce the health effects of heat waves (i.e., cooling shelter, emergency contacts, and health care services)? All three answers were measured on a 5-point Likert-type scale.

Levels of personal emotion were also measured by three questionnaire items: How much do you worry about the impacts of climate change on your life in the future? How much do you worry about the impacts of heat waves on your health in the future? and How much do you feel the necessity for a heat alarm system to reduce adverse health effects such as heat stroke or heat exhaustion? The first two questions are related to the extent of negative emotions about climate change and heat waves, and the third question is related to positive emotions about the public intervention. All three variables were coded on a 5-point Likert-type scale.

The survey also included questions on demographic and socioeconomic characteristics such as gender, age, education, and occupation. Pre-existing health conditions were measured by two dichotomous questions: first, whether the participants had previously experienced heat illness; second, whether they had chronic diseases such as diabetes, hypertension, or cardiovascular disease.

3.3. Structural Equation Model

We employed an SEM to analyze the integrative and sequential mechanisms among cognition, emotion, and compliance with heat-related public guidelines by taking action. SEM is widely applied to analyze survey data in behavioral studies [33] because this methodology has the advantages of taking into account measurement errors of the survey questions, evaluating direct, indirect, and total effects, and testing the overall model's goodness of fit with statistical indicators [34]. By establishing a latent construct from multiple indicators, this technique captures the causal relationships among multiple variables and provides a way to verify theoretical models [35,36].

The SEM analysis followed two steps. First, we made two latent constructs—cognition and emotion—and then we explored the simple bivariate relationship between each construct and the resultant indicator—the perceived level of heat-protective action—one by one. Second, we applied a full SEM to examine the interrelationship between the constructs and the indicator. Since those key constructs include ordinal and dichotomous variables, we applied a robust weighted least square estimator (WLSMV) in Mplus (Muthen & Muthen, Los Angeles, CA, USA) 8.3. WLSMV provides the weighted least square method using a diagonal weight matrix, which has been suggested to be superior to the use of Maximum Likelihood when ordinal data are analyzed [36,37].

To assess the fitness of the structural equation models, we use five different measures. In the first step of measurement models, we use composite reliability (CR) and average variance extracted (AVE) to assess reliability of our latent constructs. CR indicates the internal consistency of the multiple indicators that compose the construct and AVE indicates the ratio of the variance explained by the construct to that by the error. In general, CR is expected to be greater than 0.70 while AVE is expected to be greater than 0.5. In the second step of structural models, we use the comparative fit index (CFI), the Tucker–Lewis Index (TLI) and the root mean square error of approximation (RMSEA) to assess the goodness of fit. It is generally expected that CFI and TLI are greater than 0.9 while RMSEA is lower than 0.06. All results were standardized to compare the effect size of variables regardless of their unit scales.

4. Results

4.1. Descriptive Statistics

The demographic and socioeconomic characteristics of the survey participants are shown in Table 1. Of the 300 survey participants, 161 (53.7%) were female and the rest were male. The average age of the participants was 64. Housing tenure shows the economic stability of the age group studied: 191 (63.7%) owned their own house, 103 (34.3%) were renters, and 6 others lived in the house of a child or acquaintance.

Table 1. Characteristics of survey participants.

Categories		Frequency	Percentage
Gender	female	161	53.7%
	male	139	46.3%
Age	50–59	134	44.7%
	60–69	71	23.7%
	70–79	59	19.7%
	≥80	36	12%
Education	middle school or lower	85	28.3%
	high school	149	49.7%
	university or higher	66	22%
Occupation	white-collar	39	13%
	indoor labor	125	41.7%
	outdoor labor	47	15.7%
	housewife	47	15.7%
	unemployed & retired	42	14%
Housing tenure	own	191	63.7%
	rent	103	34.3%
	others	6	2%
Total		300	100%

In Table 2, the average perceived level of behavioral change equaled 2.873 with a standard deviation of 1.220. This means that 133 (44.3%) gave negative responses such as "not at all" and "not really," while 122 (40.7%) gave positive responses such as "somewhat" and "very much." For the three questions regarding cognition, the survey participants showed the lowest level of awareness about the local heat action plans (mean = 2450), while knowledge of climate change and knowledge of adverse heat wave effects were above the middle (means = 3.400 and 3.307, respectively). This indicates that, on average, survey participants consider themselves to have sufficient knowledge about the danger of extreme heat events due to climate change; however, they have less understanding of what local municipalities offer to the public in response to such events. The emotional levels registered about the three items were roughly similar: worry about climate change (mean = 3.793), worry about adverse heat wave effects (mean = 3.650), and feelings about the level of necessity for a heat alarm system (mean = 3.583) all exhibited means within a narrow range.

As to preexisting health conditions, 201 (67.0%) participants had experienced health issues such as sleep disturbance, fatigue, headache, dyspnea, rash, or heatstroke during the summer of 2018; 115 people (38.3%) currently had a chronic disease that was being treated or medicated. In general, people with heat-illness experience or chronic disease had a higher level of preventive action, cognition, and emotion related to heat wave risks than those without such a history. This corresponds to extant studies in that people with weak health conditions have been found to be more cautious and more involved in preventive actions against heat episodes.

Table 2. Survey responses.

Category		Freq.	Action	Cognition			Emotion		
				v1	v2	v3	v4	v5	v6
Total		300	2.873	3.400	3.307	2.450	3.793	3.650	3.583
			(1.220)	(1.025)	(0.888)	(0.958)	(0.832)	(0.885)	(0.966)
Past heat illness experience	yes	201	2.975	3.597	3.373	2.428	3.935	3.781	3.726
			(1.210)	(0.986)	(0.886)	(0.978)	(0.788)	(0.844)	(0.933)
	no	99	2.667	3.000	3.172	2.495	3.505	3.384	3.293
			(1.221)	(0.990)	(0.881)	(0.919)	(0.850)	(0.911)	(0.972)
Chronic disease	yes	115	3.096	3.417	3.409	2.548	3.887	3.730	3.626
			(1.192)	(1.034)	(0.887)	(0.891)	(0.803)	(0.862)	(0.912)
	no	185	2.735	3.389	3.243	2.389	3.735	3.600	3.557
			(1.220)	(1.021)	(0.885)	(0.994)	(0.847)	(0.898)	(0.999)

Note. The mean values of each survey question are measured on 5-point Likert scales. Standard deviations are in parentheses.

4.2. Simple SEMs

The first SEM investigating the direct relationship between cognition and heat-protective action is presented in Table 3. All factor loadings of the cognitive factor were statistically significant at a 1% level. The latent construct of cognition showed a modest level of overall internal consistency with a composite reliability (CR) of 0.599 and an average variance extracted (AVE) of 0.332.

Table 3. Effects of cognition on preventive action.

Measured by	Std. Factor Loading	SE	*p*-Value
Cognition → Climate change	0.586	0.059	0.000 ***
Cognition → Adverse health effects	0.587	0.057	0.000 ***
Cognition → Local heat action plan	0.556	0.057	0.000 ***
	CR = 0.599, AVE = 0.332		
Regressed on	Std. coeff.	SE	*p*-value
Action ← Cognition	0.632	0.060	0.000 ***
	CFI: 0.993, TLI: 0.979, RMSEA: 0.054		

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The cognitive construct showed a significantly positive impact on the level of preventive health behaviors, which supported our first hypothesis. The positive standardized beta coefficient of 0.632 implies that as the level of cognition increases, the likelihood of engaging in preventive health actions also increases. It empirically verified that a higher level of cognition of heat waves promoted behavioral change during extreme heat events. The comparative fit index (CFI) of 0.993 and the Tucker–Lewis index (TLI) of 0.979 were greater than 0.9. The Root Mean Square Error of Approximation (RMSEA) of 0.054 was also lower than 0.06, indicating goodness of fit.

The second SEM model, investigating the direct relationship between emotion and heat-protective action, is presented in Table 4. Using the three survey questions regarding the level of concern about climate change, heat illnesses, and the need for a heat action plan, we created an emotive construct as a latent variable. Each of the factor loadings was standardized and statistically significant below the 1% significance level. CR was 0.794 and AVE was greater than 0.5, which showed high overall internal consistency.

Table 4. Effects of emotion on preventive action.

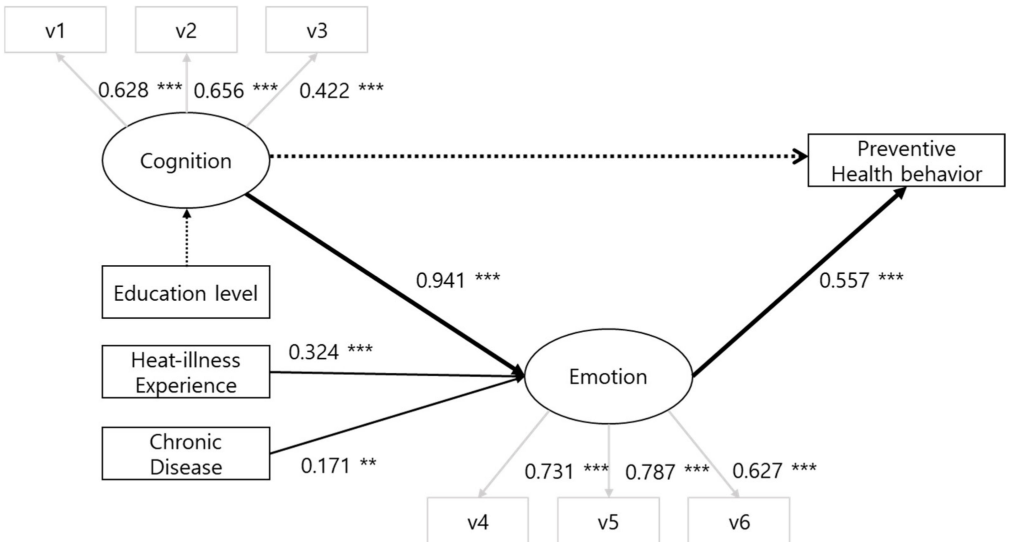
Measured by	Std. Factor Loading	SE	*p*-Value
Emotion → Concern about climate change	0.824	0.035	0.000 ***
Emotion→ Worry about heat illness	0.787	0.038	0.000 ***
Emotion → Feeling about the need for a heat action plan	0.630	0.040	0.000 ***
	CR = 0.794, AVE = 0.565		
Regressed on	Std. coeff.	SE	*p*-value
Action ← Emotion	0.650	0.042	0.000 ***
	CFI: 0.910, TLI: 0.729, RMSEA: 0.378		

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The emotive construct also displayed a significantly positive impact on preventive health behaviors, which supported our second hypothesis. The standardized coefficient of 0.650 means that the likelihood of engaging in preventive health behavior increases when the emotive factor increases with worries and need. CFI was 0.91, demonstrating goodness of fit. Yet the TLS and RMSEA showed a modest result. It is noted that although CFI and RMSEA are widely used to assess the fit of SEMs, the two indices can produce different evaluation results when the sample size is small [38].

4.3. Full SEM

In Figure 3 and Table 5, we present the direct and indirect effects of cognition on heat-protective action through an emotive construct. First, the validity of our structural model was based on the fit indices: CFI = 0.917, TLI = 0.881, RMSEA = 0.111. Although these indices are widely applied to assess the fit of SEMs, only CFI met the cutoff standard. The reasons for different cutoff values can be explained by the fact that our model employed many categorical variables and a relatively small sample number of 300. Meanwhile, we included the paths from the education level to the cognition level as a reference variable for middle school or lower, but it did not show any significant relationship with cognition. Thus we interpret a sequential relationship among cognition, emotion, and behavioral changes.



* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Figure 3. The full SEM (CFI: 0.917, TLI: 0.881, RMSEA: 0.111).

Table 5. Indirect effects of cognition and health condition on preventive action.

Mediated through Emotion	Std. Coeff.	SE	*p*-Value
Action ← Cognition	0.524	0.144	0.000 ***
Action ← Heat-illness experience	0.180	0.058	0.002 ***
Action ← Chronic disease	0.095	0.044	0.032 **
	CFI: 0.917, TLI: 0.881, RMSEA: 0.111		

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Cognition does not directly influence preventive health behavior (coeff. = 0.117, *p*-value = 0.451) However, cognition indirectly influences the preventive behavior through emotional responses. It affects emotion at a statistically significant level (coeff. = 0.941, *p*-value = 0.000), and then the emotion positively induces preventive health behavior (coeff. = 0.557, *p*-value = 0.000). This empirical result indicates that cognition level alone does not directly lead to preventive health behaviors, yet once they form emotional responses, people tend to comply with heat-related public guidelines. This relationship demonstrates that people who are aware of climate change, its negative effects, and the locally recommended heat-protective actions tend to have a deeper concern about the threat posed by heat waves and feel a stronger necessity for relevant public policies; they consequently take preventive measures in response to the public alarm system.

Table 5 shows the indirect effects of cognition and preexisting health condition on heat-protective action through emotional responses. In this formation, emotions play a mediating role in driving preventive behaviors. Since such emotions can be established from past experiences or from pre-existing health conditions [11], we compared the indirect effect of cognition on heat-protective action with that of pre-existing health conditions. The indirect effect of cognition was 0.524, which is much greater than the indirect effects of the two indicators: heat-illness experience (coeff. = 0.180) and chronic disease (coeff. = 0.095). This result implies that policy interventions to promote knowledge about climate change, the health risks of heat, and local policy measures can effectively increase the likelihood of individual preventive health behaviors.

5. Discussion and Conclusions

5.1. Understanding the Interrelationship between Cognition, Emotion, and Action

With an eye toward the lack of discussion around the individual adaptive capacity of older adults during extreme heat events, this paper explored the behavioral mechanism of the preventive response of the elderly to public warnings of a heat event. Elaborating the mediating role of emotion in human behaviors, we investigated the interrelationship between cognition, emotion, and heat-protective action, through face-to-face surveys and SEM analysis.

The major finding is that an increased degree of awareness of climate change, heat waves, and local policy measures significantly influences people's emotional responses and increases the preventive actions they take during extreme heat events. By applying an integrated structural equation model, the empirical results show that cognition level alone does not directly determine older adults' preventive health behaviors. However, when the cognitive input affects their emotions, they tend to comply with heat-related public guidelines. Although the direct effect of cognition is not statistically significant, higher levels of cognition reinforce the older adults' preventive behaviors in response to heat waves through emotional responses. This indicates that the effect of cognition on preventive health behavior is fully mediated by individual emotional responses to heat waves.

Moreover, it is generally expected that people who have weak health conditions or have past experiences of heat-related illnesses are more likely to take preventive action against heat waves. Our results showed that the mediating role of emotion between cognition and heat-protective action is much larger than that of emotion between pre-existing health conditions and heat-protective action. It implies that an increased degree of awareness of climate change plays a greater role in improving one's adaptive capacity than does one's pre-existing health condition.

Furthermore, our finding disagrees with several extant studies [13,28,39]. Those studies stressed that people may not make behavioral changes despite their awareness of heat warnings and heat-related risks. We, however, found that promoting knowledge about climate change and the adverse health effects of heat waves amplifies the emotional response and hence plays a role in driving preventive health behaviors. This implies that policy interventions to educate the general public can effectively increase the likelihood of individual compliance with the relevant preventive measures.

5.2. Policy Implications and Further Research

This study suggests that policies based on communication and education would help vulnerable groups of people to adapt to extreme heat events. Previous studies have argued that public health programs or media campaigns promote climate change literacy and public understanding of climate problems [27,28,40]. By investigating the factors determining the compliance with such public policies, this study addresses that public policies that inform people about the danger of heat waves through mass media and an official website can help the vulnerable population to engage in health preventive activities, with taking advantage of the integrative mechanisms of cognition, emotion, and behavioral changes.

The role of community engagement can play a crucial role, especially for the elderly, due to the emotional responses. In an era of abundant information, knowledge about heat waves has been mostly well understood, but the elderly may find such information difficult to access. To maximize their effectiveness, public interventions should be designed with consideration of community solidarity since other members of the community, such as friends, neighbors, or volunteers, can make daily visits to the elderly and inform them how to respond to extreme heat events.

This study is not free from limitations. First, the self-report survey we employed in this study is prone to a response bias. We measured the individual's perceived level of cognition, emotion, and behavioral changes. Those self-reported answers might be distorted by acquiescence or social desirability bias. Second, there is a time gap between the time of the survey and the event of interest. The survey was conducted in February 2019, while the subject of the survey questionnaire was the summer of 2018. The respondents had to recall their experiences from a few months earlier, which may have resulted in minor inaccuracies in their memory. Third, the process of stimulating emotional responses for protective behavioral changes might have some side effects. Excessive concern about climate issues might adversely affect mental health, or prevent even an appropriate level of outdoor activities [41]. In a future study with the addition of these questions, we could consider the issue.

Heat waves are expected to increase in the future. Governments need to identify vulnerable populations to provide better information about heat risks. Further studies with a focus on these vulnerable groups are needed to better understand the most effective interventions and approaches that will mitigate the adverse health outcomes they experience. This study suggests that locally based public interventions to promote appropriate responses to heat-related health risks offer an effective way to develop more targeted and effective communication strategies for these vulnerable groups.

Author Contributions: H.J.Y. conceived the idea, analyzed the data, and wrote the paper. H.Y. supervised the study and involved in manuscript writing. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Korea Environmental Industry and Technology Institute through the Urban Ecological Health Promotion Technology Development Project, funded by the Korea Ministry of Environment under grant number 2020002770003, and the Creative-Pioneering Researchers Program through Seoul National University. This work was also supported by Incheon National University Research Concentration Professor Grant in 2020.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Question design and constructs.

Category	Questions	Mean	SD
Action	Y: To what degree does the heat alarm system or the emergency text message affect your behavioral change?	2.873	1.220
Cognition	V1: How much are you aware of climate change?	3.400	1.025
	V2: How much do you know about the adverse health effects of heat waves due to climate change?	3.307	0.888
	V3: How much do you know about local heat action plans to reduce the health effects of heat waves (i.e., cooling shelters, emergency contacts, and health care services)?	2.450	0.958
Emotion	V4: How much do you worry about the impacts of climate change on your life in the future?	3.793	0.832
	V5: How much do you worry about the impacts of heat waves on your health in the future?	3.650	0.885
	V6: How much do you feel the necessity for a heat alarm system to reduce adverse health effects such as heat stroke or heat exhaustion?	3.583	0.966

Y: Scale ranges from 1 = *Not influential at all* to 5 = *Very influential*; V1: Scale ranges from 1 = *Not aware at all* to 5 = *Very well aware*; V2-V3: Scale ranges from 1 = *Do not know at all* to 5 =*Know very* well; V4-V5: Scale ranges from 1 = *Do not worry at all* to 5 = *Worry very* much; V6: Scale ranges from 1 = *Not necessary at all* to 5 = *Very much necessary*.

References

1. Lefevre, C.E.; Bruin, W.B.; Taylor, A.L.; Dessai, S.; Kovats, S.; Fischhoff, B. Heat protection behaviors and positive affect about heat during the 2013 heat wave in the United Kingdom. *Soc. Sci. Med.* **2015**, *128*, 282–289. [CrossRef]
2. Zografos, C.; Anguelovski, I.; Grigorova, M. When exposure to climate change is not enough: Exploring heatwave adaptive capacity of a multi-ethnic, low-income urban community in Australia. *Urban Clim.* **2016**, *17*, 248–265. [CrossRef]
3. Bai, L.; Ding, G.; Gu, S.; Bi, P.; Su, B.; Qin, D.; Xu, G.; Liu, Q. The effects of summer temperature and heat waves on heat-related illness in a coastal city of China, 2011–2013. *Environ. Res.* **2014**, *132*, 212–219. [CrossRef]
4. Ellis, F. Mortality from heat illness and heat-aggravated illness in the United States. *Environ. Res.* **1972**, *5*, 1–58. [CrossRef]
5. WHO. *Improving Public Health Responses to Extreme Weather*; WHO Regional Office for Europe: Copenhagen, Denmark, 2008.
6. Abrahamson, V.; Wolf, J.; Lorenzoni, I.; Fenn, B.; Kovats, S.; Wilkinson, P.; Adger, W.N.; Raine, R. Perceptions of heatwave risks to health: Interview-based study of older people in London and Norwich, UK. *J. Public Health* **2008**, *31*, 119–126. [CrossRef]
7. Bassil, K.; Cole, D.; Smoyer-Tomic, K.; Callaghan, M. *What Is the Evidence on Applicability and Effectiveness of Public Health Interventions in Reducing Morbidity and Mortality during Heat Episodes?* National Collaborating Centre for Environmental Health: Vancouver, BC, Canada, 2007.
8. Khare, S.; Hajat, S.; Kovats, S.; Lefevre, C.; Bruine, B.W.; Dessai, S.; Bone, A. Heat protection behaviour in the UK: Results of an online survey after the 2013 heatwave. *BMC Public Health* **2015**, *15*, 878. [CrossRef] [PubMed]
9. Smoyer, K.E. A comparative analysis of heat waves and associated mortality in St Louis, Missouri-1980 and 1995. *Int. J. Biometeorol.* **1998**, *42*, 44–50. [CrossRef] [PubMed]
10. White-Newsome, J.L.; Sanchez, B.N.; Parker, E.A.; Dvonch, J.T.; Zhang, Z.; O'Neill, M.S. Assessing heat-adaptive behaviors among older, urban-dwelling adults. *Maturitas* **2011**, *70*, 85–91. [CrossRef] [PubMed]
11. Kalkstein, A.J.; Sheridan, S.C. The social impacts of the heat-health watch/warning system in Phoenix, Arizona: Assessing the perceived risk and response of the public. *Int. J. Biometeorol.* **2007**, *52*, 43–55. [CrossRef] [PubMed]
12. Toloo, G.; FitzGerald, G.; Aitken, P.; Verrall, K.; Tong, S. Evaluating the effectiveness of heat warning systems: Systematic review of epidemiological evidence. *Int. J. Public Health* **2013**, *58*, 667–681. [CrossRef]
13. Bassil, K.; Cole, D. Effectiveness of public health interventions in reducing morbidity and mortality during heat episodes: A structured review. *Int. J. Environ. Res. Public Health* **2010**, *7*, 991–1001. [CrossRef]
14. Gasparrini, A.; Guo, Y.; Hashizume, M.; Kinney, P.L.; Petkova, E.P.; Lavigne, E.; Zanobetti, A.; Schwartz, J.D.; Tobias, A.; Leone, M.; et al. Temporal variation in heat–mortality associations: A multicountry study. *Environ. Health Perspect.* **2015**, *123*, 1200–1207. [CrossRef]
15. Sheridan, S.; Dixon, P.G.; Kalkstein, A.J.; Allen, M.J. Recent trends in heat-related mortality in the United States: An update through 2018. *Weather Clim. Soc.* **2021**, *13*, 95–106. [CrossRef]
16. Chau, P.; Chan, K.; Woo, J. Hot weather warning might help to reduce elderly mortality in Hong Kong. *Int. J. Biometeorol.* **2009**, *53*, 461. [CrossRef]

17. Weisskopf, M.G.; Anderson, H.A.; Foldy, S.; Hanrahan, L.P.; Blair, K.; Torok, T.J.; Rumm, P.D. Heat wave morbidity and mortality, Milwaukee, Wis, 1999 vs 1995: An improved response? *Am. J. Public Health* **2002**, *92*, 830–833. [CrossRef] [PubMed]
18. Coelho, F.; Pereira, M.C.; Cruz, L.; Simoes, P.; Barata, E. Affect and the adoption of pro-environmental behaviour: A structural model. *J. Environ. Psychol.* **2017**, *54*, 127–138. [CrossRef]
19. Akompab, D.; Bi, P.; Williams, S.; Grant, J.; Walker, I.; Augoustinos, M. Heat waves and climate change: Applying the health belief model to identify predictors of risk perception and adaptive behaviours in Adelaide, Australia. *Int. J. Environ. Res. Public Health* **2013**, *10*, 2164–2184. [CrossRef] [PubMed]
20. Madrigano, J.; Lane, K.; Petrovic, N.; Ahmed, M.; Blum, M.; Matte, T. Awareness, risk perception, and protective behaviors for extreme heat and climate change in New York City. *Int. J. Environ. Res. Public Health* **2018**, *15*, 1433. [CrossRef] [PubMed]
21. Champion, V.L.; Skinner, C.S. The health belief model. *Health Behav. Health Educ. Theoryres. Pract.* **2008**, *4*, 45–65.
22. Janz, N.K.; Becker, M.H. The health belief model: A decade later. *Health Educ. Q.* **1984**, *11*, 1–47. [CrossRef]
23. Richard, L.; Kosatsky, T.; Renouf, A. Correlates of hot day air-conditioning use among middle-aged and older adults with chronic heart and lung diseases: The role of health beliefs and cues to action. *Health Educ. Res.* **2010**, *26*, 77–88. [CrossRef]
24. Goransson, C.; Eriksson, I.; Ziegert, K.; Wengstrom, Y.; Langlus-Eklof, A.; Brovall, M.; Kihlgren, A.; Blomberg, K. Testing an app for reporting health concerns: Experiences from older people and home care nurses, Int. *J. Older People Nurs.* **2017**, *13*, 1–10. [CrossRef]
25. Rosenstock, I.M. Historical origins of the health belief model. *Health Educ. Monogr.* **1974**, *2*, 328–335. [CrossRef]
26. Rosenstock, I.M.; Strecher, V.J.; Becker, M.H. Social learning theory and the health belief model. *Health Educ. Q.* **1988**, *15*, 175–183. [CrossRef] [PubMed]
27. Ban, J.; Shi, W.; Cui, L.; Liu, X.; Jiang, C.; Han, L.; Wang, R.; Li, T. Health-risk perception and its mediating effect on protective behavioral adaptation to heat waves. *Environ. Res.* **2019**, *172*, 27–33. [CrossRef] [PubMed]
28. Lane, K.; Wheeler, K.; Charles-Guzman, K.; Ahmed, M.; Blum, M.; Gregory, K.; Graber, N.; Clark, N.; Matte, T. Extreme heat awareness and protective behaviors in New York City. *J. Urban Health* **2014**, *91*, 403–414. [CrossRef] [PubMed]
29. Arlt, D.; Hoppe, I.; Wolling, J. Climate change and media usage: Effects on problem awareness and behavioural intentions. *Int. Commun. Gaz.* **2011**, *73*, 45–63. [CrossRef]
30. Lee, T.M.; Markowitz, E.M.; Howe, P.D.; Ko, C.-Y.; Leiserowitz, A.A. Predictors of public climate change awareness and risk perception around the world. *Nat. Clim. Chang.* **2015**, *8*, 20. [CrossRef]
31. Chapman, G.B.; Coups, E.J. Emotions and preventive health behavior: Worry, regret, and influenza vaccination. *Health Psychol.* **2006**, *25*, 82. [CrossRef] [PubMed]
32. Mattern, J.; Garrigan, S.; Kennedy, S.B. A community-based assessment of heat-related morbidity in North Philadelphia. *Environ. Res.* **2000**, *83*, 338–342. [CrossRef]
33. Kim, H.; Ahn, J.; No, J. Applying the Health Belief Model to college students' health behavior. *Nutr. Res. Pract.* **2012**, *6*, 551–558. [CrossRef]
34. Wang, J.; Wang, X. *Structural Equation Modeling: Applications Using Mplus*; John Wiley & Sons: Hoboken, NJ, USA, 2012.
35. Hahm, Y.; Yoon, H.; Jung, D.; Kwon, H. Do built environments affect pedestrians' choices of walking routes in retail districts? A study with GPS experiments in Hongdae retail district in Seoul, South Korea. *Habitat Int.* **2017**, *70*, 50–60. [CrossRef]
36. You, Y.; Kim, S. Revealing the mechanism of urban morphology affecting residential energy efficiency in Seoul, Korea. *Sustain. Cities Soc.* **2018**, *43*, 176–190. [CrossRef]
37. Li, C.-H. Confirmatory factor analysis with ordinal data: Comparing robust maximum likelihood and diagonally weighted least squares. *Behav. Res. Methods* **2016**, *48*, 936–949. [CrossRef]
38. Lai, K.; Green, S.B. The problem with having two watches: Assessment of fit when RMSEA and CFI disagree. *Multivar. Behav. Res.* **2016**, *51*, 220–239. [CrossRef] [PubMed]
39. Sheridan, S.C. A survey of public perception and response to heat warnings across four North American cities: An evaluation of municipal effectiveness. *Int. J. Biometeorol.* **2007**, *52*, 3–15. [CrossRef] [PubMed]
40. Sampei, Y.; Aoyagi-Usui, M. Mass-media coverage, its influence on public awareness of climate-change issues, and implications for Japan's national campaign to reduce greenhouse gas emissions. *Glob. Environ. Chang.* **2009**, *19*, 203–212. [CrossRef]
41. Berry, H.L.; Bowen, K. Climate change and mental health: A causal pathways framework. *Int. J. Public Health* **2010**, *55*, 123–132. [CrossRef] [PubMed]