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Developing behavioral models of citizens for adapting to and mitigating climate change: a study on four prefectures in Japan

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Individual behaviors of citizens are important for implementing the necessary measures for adapting to climate change. However, studies on the adaptive behaviors of ordinary citizens are limited. Therefore, in this study, we developed behavioral models to understand individual behaviors for adaption to and mitigation of climate change. We compared four behavior groups, namely, G1, individual mitigation; G2, individual adaptive; G3, long-term adaptive; and G4, solar-energy system installation behaviors. Following a questionnaire survey for the four behavioral groups, behavioral models were developed using structural equation modeling, which considered psychological factors along with selected attitudes, perceived effectiveness, norms, benefits, practicality, and intention. Furthermore, we considered the recognition and attribution of local climate change as key factors for adaptation behaviors toward local climate change. The behaviors of citizens in four prefectures in Japan, namely, Nagano, Tokyo, Saitama, and Kanagawa were considered. Among them, Nagano Prefecture, wherein the implementation of adaptation measures was at a low level while that of mitigation measures was at a high level, showed a differing trend. In the behavioral models, the recognition of local climate change directly affected the behavior of citizens in the individual adaptive behavior group. In both the individual adaptive and long-term adaptive behavior groups, the impact of benefits was substantial, with significant differences across local areas. Thus, effective adaptation strategies might involve tangible and familiar examples demonstrating the consequences of behavior, thus enhancing citizens' behavior evaluation perception and fostering its acceptance as a desirable behavior. Tailoring adaptation strategies to specific local contexts might also be necessity. To encourage citizens to adapt to climate change and its impacts, we propose two-way efforts, instead of providing one-way information, by supporting citizens to think about self-help and mutual help effectively. Our study can serve as a reference for future studies focusing on citizen behavior about climate change mitigation and enhance their adaptation for locally implemented strategies.

KEYWORDS

behavioral model, pro-environmental behavior, adaptation, mitigation, climate change, disaster risk behavior, psychological factors, Japan

1 Introduction

To address climate change, focusing on measures that deal with the impacts and risks in different regions is as important as developing and adopting mitigation measures for greenhouse gas emission reduction. Hence, implementing both measures at relevant scales is important (Adger et al., 2005; Kirshen et al., 2008; Hijioka et al., 2016; IPCC, 2022).

IPCC (2022) defined adaptation in human systems as "the process of adjustment to actual or expected climate and its effects in order to moderate harm or exploit beneficial opportunities" and stated that "adaptation planning in human systems generally entails a process of iterative risk management." As climate-related hazards increase in frequency and severity, disaster risk reduction is required at a greater level than ever before. The global priority of climate change adaptation and risk reduction for sustainable development has been recognized at several international conventions, including the Sendai Framework for Disaster Risk Reduction.

To adapt to climate change systematically and comprehensively, the Cabinet of Japan formulated and enacted the first National Plan for Adaptation to the Impacts of Climate Change, as part of the adaptation measures implemented in Japan in November 2015. The plan consisted of five basic strategies: (1) mainstreaming the idea of "adaptation" into government policies, (2) enhancing scientific works and findings, (3) promoting understanding and cooperation among citizens by sharing and providing information about risks related to climate change, (4) supporting adaptation measures in local regions, and (5) developing and enhancing international cooperation and contribution (Cabinet of Japan, 2015). The policy framework provided by the plan was subsequently revised in 2018, 2021, and 2023, per the Climate Change Adaptation Act (Act No. 50 of 2018, Government of Japan, 2018). The Climate Change Adaptation Act enforced adaptation measures in any given region. Following this act, local governments must make efforts to formulate adaptation plans and develop novel systems for collecting and providing data related to climate change.

The measures implemented for adapting to climate change were categorized into three levels: protection (preventive measures to avoid the spread of the negative effects of climate change), adaptation (measures to reduce the negative effects of climate change by adjusting measures based on what has occurred), and transformation (drastic changes to deal with the negative effects to alter their impact before they occur). Currently, Japan is focusing on the protection measures that can be applied to improve the existing facilities and possible response measures responses to different missions (Shirai et al., 2014; Baba et al., 2017). In general, national and local governments focus on enhancing tangible elements related to public assistance; however, self and mutual help have not been thoroughly explored as measures related to climate change.

Climate change adaptation behaviors at the individual level, including climate-related hazard risk reduction behaviors, have been typified by reducing the negative impacts associated with climate change. Therefore, natural disaster risk reduction measures at the individual and household levels can contribute to climate change adaptation. Integrated risk management has also been proposed to reduce the risk of community residents under climate change (Wouter Botzen et al., 2019). Several examples of specific disaster risk behaviors are reported (Grothmann and Reusswig, 2006); however, measures related to climate change adaptive behavior, often address only specific issues, such as agricultural measures for farmers (Arbuckle et al., 2015; Dang et al., 2018). Although research on adaptation in policies and governance systems is underway, only a few studies have comprehensively addressed the adaptive behavior of individuals from the perspective of ordinary citizens (van Valkengoed and Steg, 2019). Most of the current mitigation measures, including government public campaigns, focus on individual behavior. A significant portion of the public is highly interested in such efforts because they recognize that environment-friendly behavior can be beneficial (Stern, 2000; Kollmuss and Agyeman, 2002). Several examples of risk reduction behaviors have been noted when preparing for disasters, and the relationship between risk perception and individual perceptions and behaviors has also been reported (Bubeck et al., 2012; Kellens et al., 2013; Wachinger et al., 2013). The importance of developing self-help behaviors implemented at the individual level for self-protection and community support over the medium to long term as part of disaster preparedness has been highlighted. These studies suggested that individual behavioral choices are important for the effective implementation of adaptation measures (van Valkengoed and Steg, 2019).

This poses the following question: Can people's psychological perceptions explain individual behaviors in adaptation and mitigation measures and their pro-environmental behavior? The relationship between psychological factors and behavior has been reported for pro-environmental behavior practiced by citizens in their daily lives, and psychological models of various behaviors have also been reported. A well-known behavioral model that has been widely applied in its original or derived forms is the theory of planned behavior (TPB). It was originally designed to explain human behavior and not just their pro-environmental behavior. The theory of reasoned action (TRA) was originally proposed by Ajzen and Fishbein (1975, 1980) and contains three general constructs: behavioral intention, attitude toward the behavior, and subjective norms. The TRA is a simple model in which a person would act if he or she had the intention of doing so; it does not evaluate the surrounding circumstances. To address the limitations of the TRA, Ajzen (1991) introduced a modified model, TPB, in which perceived behavioral control (PBC) was added as a new component. The PBC considered other external factors, such as the actor's perceived ability to do what he or she could do, their knowledge of the issue, and time availability. The PBC has been expanded to incorporate more specific evaluation factors, such as cost-benefit and feasibility evaluations or practicality of the behavior. Nevertheless, TPB has been applied to explain several human behaviors, including pro-environmental behavior

Abbreviations: TPB, Theory of planned behavior; TRA, Theory of reasoned action; PBC, Perceived behavioral control; SEM, Structural equation modeling; HSD, Honestly significant difference; GFI, Goodness-of-fit index; ANOVA, Analysis of variance; AGFI, Adjusted goodness-of-fit index; CFI, Comparative fit index; RMSEA, Root mean square error of approximation.

(Davies et al., 2002), and some examples of TPB application to explain adaptive behaviors have been put forth effectively (Zhang et al., 2020; Zaremohzzabieh et al., 2021). Furthermore, as pro-environmental behavior is a type of altruism, different models of altruistic behavior have also been applied. Schwartz (1977) proposed an altruistic behavior model that included four constructs: personal and social norms, awareness of consequences, and denial of responsibility. The types of social norms, e.g., focusing on the influence of subjective norms (the expectations of others around them), injunctive norms (the perceptions of social morals or social pressure), and descriptive norms (the perceptions of the behavior of others around them), have also been subjected to investigation, owing to the importance of the influence of social norms (Cialdini et al., 1990; Thøgersen, 2006).

The public's awareness on the impacts of climate change and the related adaptation measures is lesser than that on other environmental issues (Hulme, 2009). In general, citizens in developed countries find it difficult to develop mitigation and adaptation strategies as responses because the threats of climate change generally occur away from their locations (Lorenzoni and Pidgeon, 2006; O'Neill and Nicholson-Cole, 2009). The more the people can feel and experience the impacts caused by (or believe that the impacts are caused by) climate change in their local region, the more they can perceive climate change issues as being relevant to them and thus take responsive actions (Blennow et al., 2012). This portrays a strong bias that is dependent on an individual's current situation (Brügger et al., 2015). Adger et al. (2013) suggested that culture and values should be considered when analyzing adaptation behaviors, thus indicating the need for further studies that consider different cultures.

Although a relationship has been established between the perception of climate change and the mitigation and adaptation behaviors of the citizens of Japan (Baba et al., 2011; Shirai et al., 2015), detailed investigations, especially in terms of influential psychological factors, are important for analyzing adaptive behavior as an individual's behavioral choice and exploring the differences between adaptive and mitigation behaviors. The enhancement of intangible elements that support self and mutual help can play a major role in the implementation of local adaptation measures. Therefore, studies and analyses that can promote these measures are of great significance.

In this study, we developed models capable of examining the behavior of individuals for adaption to and mitigation of climate change. We conducted questionnaire surveys to ascertain psychological perceptions and to analyze individual behaviors. This approach facilitated an exploration of the factors that can work as both the barriers and accelerators of the behaviors. The objective was to derive insights based on comparative research results across local areas to aid in the development of policy measures, foster individual adaptive and mitigation behavior, and encourage collaborative efforts within local communities. Furthermore, we conducted comparative analyses of adaptation and mitigation behavior models to offer recommendations on specific areas requiring distinct or integrated implementation approaches, drawing upon previous findings that facilitate mitigation behavior.

2 Materials and methods

2.1 Hypothetical model and factors

The hypothetical structure of the psychological model was based on the TPB, with three major processes as the basic structure: attitudes toward the behavior, norms, and personal evaluation of the behavior (including the concept of PBC). Additionally, the recognition of local climate change and perceptions regarding attribution of local climate change were assumed to determine specific attitudes such as general attitudinal concern. This is depicted in Figure 1; for example, evaluations of "benefits" and "practicality," lead to intentions, which then, lead to the practice of the behavior. To contribute to specific future measures for the promotion of such behavior by local governments and other entities, identifying the influence of specific psychological factors that promote or prevent behavior is important. Therefore, we adopted detailed psychological factors that comprise the three basic processes by subdividing them further into more specific factors as in a previous study of construction of psychological models of pro-environmental behavior (Aoki et al., 2013).

Attitude toward the behavior was divided into "attitude" and "perceived effectiveness." We focused on the "perceived effectiveness" as an important factor for socially desirable behaviors, such as pro-environmental behavior (Hirose, 1994, 2015). The perceived effectiveness also provided an aspect of knowledge about pro-environmental behavior (Kaiser and Fuhrer, 2003). Therefore, we decided to include it as a behavior toward the socially desirable goal of climate change mitigation and adaptation, as a distinct entity as opposed to using only the attitude toward behavior.

Norms included both social and personal norms. Social norms were further divided into "injunctive and descriptive norms," and indices of "personal norms" were also included. The Ajzen (1991) TPB used subjective norms as determinants of how a person perceives social norms. However, within social norms, injunctive and descriptive norms are factors that have different effects based on distinct components (Cialdini et al., 1990; Kallgren et al., 2000; Rivis and Sheeran, 2003). Furthermore, the process of Schwartz (1977)'s norm-activation model, in which social norms are internalized as personal norms that lead to behavior, has been supported. Hence, injunctive norm was set as an antecedent to personal norm.

PBC embodied "benefits" and "practicality" as personal evaluation of the behavior to determine how the evaluation of the consequences of a behavior, such as costs and benefits evaluation, could be the accelerator of the behavior (Lee et al., 2013) and how the practicality of the behavior may be the barrier to practicing it (Hirose, 1994, 2015; Blake, 1999). Among the evaluations of benefits that could have a strong influence on adaptation measures (Smit and Pilifosova, 2003), "safety" was classified as an independent indicator.

2.2 Study area

Four prefectures in Japan (Nagano, Tokyo, Saitama, and Kanagawa), each known for its unique local characteristics, were

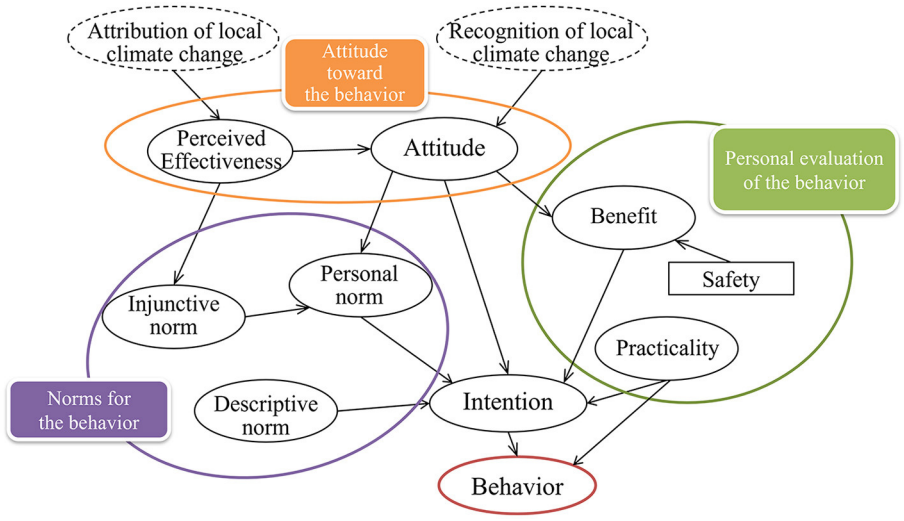

FIGURE 1
Behavior model for the hypothesis proposed in this study.

chosen as the target areas. Intense adaptation measures have been applied in these subnational regions; with highly aggressive adaptation measures in Nagano and Saitama prefectures. Nagano Prefecture is a cool region; therefore, the impact of rising temperatures on the agricultural sector in the region is of great concern. In addition, Nagano Prefecture is more advanced than the other prefectures, in terms of the positive behavior of its citizens toward the installation of solar energy systems and their pro-environmental perceptions (Aoki et al., 2010). Saitama Prefecture experiences several extremely hot days, and in the Tokyo Metropolitan Area, heatstroke and crop damage occur frequently because of high temperatures. In Tokyo and Kanagawa prefectures (in the metropolitan area), discussions on adaptation measures have been progressing rapidly. These areas were selected to ensure applicability to other local regions that experience comparable effects owing to climate change. Figure 2 is the map showing the targeted four prefectures. Figure 3 shows the current population composition by gender and age group in the four prefectures based on the 2020 Population Census.

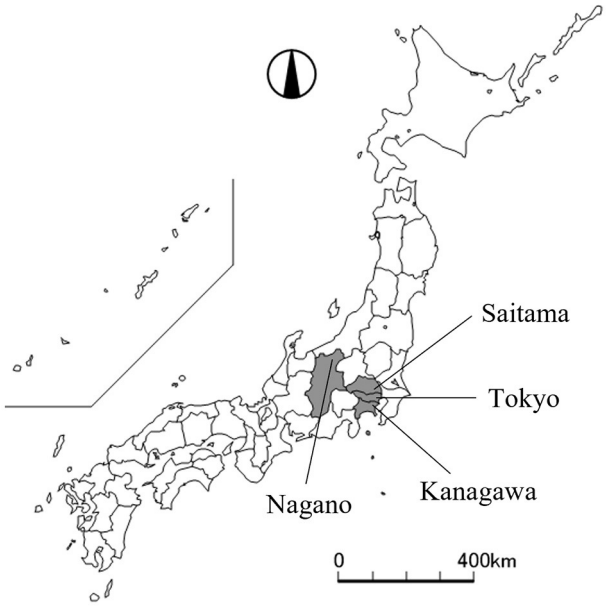

FIGURE 2
Map of the four target local areas (prefectures) in Japan.

2.3 Questionnaire survey: details and design

We performed an online questionnaire survey; online surveys have become a popular method for collecting data in Japan because it helps to reach out to more respondents (Kurisu and Bortoleto, 2011). We designed the questionnaire survey and commissioned a research company to implement the survey. The questionnaire survey is completed online and does not involve any intervention or invasion of the respondents. Therefore, we obtained the respondents' consent online only, following the prescribed criteria set forth by our research institution. The survey was conducted from May 29, 2014 to June 2, 2014. Men and women between the ages of 20 and 60 living in the target areas were equally assigned to 10 groups, comprising of five age groups and two gender groups. To ensure equal consideration of the perceptions of different age-sex groups, we utilized an allocation method of equal distribution by age-sex rather than relying on complete randomness or an allocation method that mirrors the actual age-sex composition of the area.

The questionnaire consisted of five parts: (1) the psychological perceptions of the target behavior groups (Table 1), (2) the practice rates of the target behaviors (Table 2), (3) the recognition of local climate change at the local scale, (4) perceptions regarding the

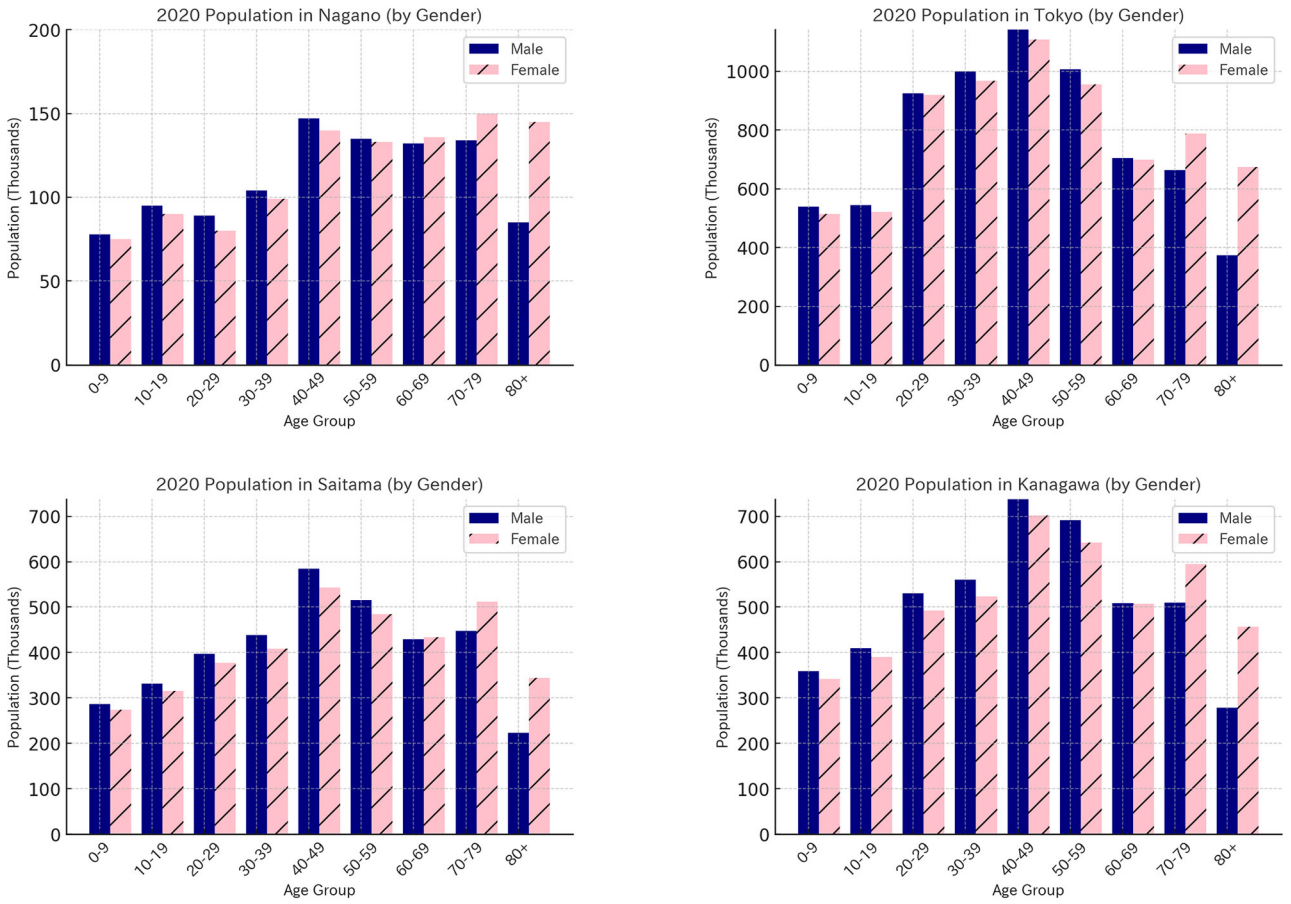

FIGURE 3
Population composition by gender and age group in the four prefectures.

cause of local climate-change effects, and (5) personal attributes. The next four paragraphs describe (1) through (4) in detail and the questionnaire was submitted as Supplementary material.

Table 1 portrays the indicators of the psychological perceptions of the target behavior group. With respect to psychological indicators, we considered "attitude," "perceived effectiveness," "social norms (injunctive and descriptive norms)," "personal norms," "benefits," and "practicality" as the main factors. The factors were chosen based on previous studies wherein psychological models that expanded the TPB of pro-environmental behaviors and influenced the practice of these behaviors were constructed (Aoki et al., 2013; Kurisu, 2015). We used different descriptions for the indicators of the perceived effectiveness factor, along with the indicators of mitigation and adaptation behaviors. Each indicator was rated on a 6-point scale, ranging from "strongly agree" to "strongly disagree," and the respondents were asked about their perceptions of each of the four behavior groups: G1, individual mitigation behavior group; G2, individual adaptive behavior group; G3, long-term adaptive behavior group, and G4, group that portrayed readiness to install solar energy systems.

Table 2 shows the classification of the 12 behaviors that individuals could choose into four behavior groups. Respondents were asked to rate the degree of behavioral practice of each of the B1–B12 behaviors on a 6-point scale. The target adaptive behavior consisted of two types (with each portraying four distinct behaviors): one entailed being inclined to carry out information acquisition and daily preparations as self-help behaviors to protect themselves (portraying G2) and the second included four drastic countermeasure behaviors (while considering medium- to long-term preparations and mutual help for the community or G3). For mitigation behaviors, three daily pro-environmental behaviors, such as saving electricity and reducing the use of plastic bags, were considered. In addition, installation renewable energy equipment, such as solar energy systems or G4 were introduced as a mitigation measure and as an adaptive measure by storing for future use as an emergency energy supply.

Furthermore, we investigated their awareness of local climate change through their experience living in the target area. "Perception of what is going on in their surroundings" can have a particularly large impact on adaptation behaviors (Blennow et al., 2012). Local climate change was defined as the changes that respondents experience in their daily lives, and the local administrative regions, which are closely related to their daily lives, were taken as the spatial extent of the changes. The respondents were asked whether or not they felt the following five specific local changes as physical impacts, without considering whether or not the changes themselves were caused by climate change. The

TABLE 1 List of indicators of psychological perceptions considered in the behavioral models developed in this study.

No.	Questionnaire items in the survey (indicators of psychological perceptions)	Psychological factors (hypothesis factors)
1.	It is good to do (behavior XX)	Attitude
2.	It is effective in preventing adverse effects (damage) of global warming and climate change (adaptation behavior and system installation)	Perceived effectiveness
	It is effective in reducing emissions of greenhouse gases, such as carbon dioxide (mitigation behavior and system installation)	
3.	It is effective for preparing for global warming and climate change (adaptation behavior and system installation)	
	It is effective in solving the problem of global warming (mitigation behavior and system installation)	
4.	I feel I should behave	Personal norm
5.	I personally feel it is necessary	
6.	Many people in the area are doing (behavior XX)	Descriptive norm
7.	Many of my acquaintances are doing (behavior XX)	
8.	It is determined and required by society	Injunctive norm
9.	It is socially recommended	
10.	It makes life more convenient	Benefit
11.	It is beneficial	
12.	It makes life more fun for me and my family	
13.	I can do it immediately/it does not require much time to do	Practicality
14.	I can do it easily/it does not require much effort to do	
15.	It is expensive (reversal item)	
16.	It ensures safety and security in the event of a disaster (adaptation behavior only)	Safety
17.	I want to do (XX behavior)	Intention

respondents were asked about each of the following five items: "Comparing your experience of the past few years with that 10 years ago, do you recognize any changes in the climate in your area?" The options in the questionnaire were as follows: (1) higher temperatures in summer and an increase in the summer, mid-summer, and extremely hot days and hot nights; (2) higher winter temperatures and fewer winter and mid-winter days; (3) increase in localized heavy rains, torrential rains, typhoons, etc.; (4) changes in snowfall (increase or decrease in snow cover or changes in snow quality); and (5) changes in the sense of seasons (shortening of the spring and autumn periods and an ambiguity of the four seasons).

Subsequently, the respondents were asked, "Do you think these types of local climate-change effects are caused by global warming due to an increase in the emissions of carbon dioxide and other substances?" for the same five items, to examine their recognition of effects caused by global warming and climate change. This is because the belief or fear of the impact of climate change and regional climate may be viewed as two different things (Hulme, 2009). In the Japanese questionnaire, we used the terms "global warming" and "climate change" both, rather than using "climate change" alone, because the term "global warming" is more recognized by the general public and indicates the difference between global and local changes. Both questions were answered on a 6-point scale, ranging from "strongly agree" to "strongly disagree."

2.4 Statistical analysis

Based on the results of the questionnaire survey, we analyzed and constructed behavioral models by structural equation modeling (SEM), using the IBM SPSS Amos ver.24 software. An exploratory factor analysis was also performed, to set the psychological factors as the latent variables for each observation index to better fit the responses rather than confirming them with these hypothetical factors. As SEM could simultaneously realize factor and path analyses, it could visually and quantitatively portray plausible complex relationships, while including factors that were not directly observable in the background of observed indicators and those indicating the relationships among those factors. This statistical modeling technique provides a precise measurement and can thus be used to test hypotheses models (Byrne, 2001; Ullman and Bentler, 2012). In addition, to consider the regional differences between the four prefectures, we conducted a simultaneous analysis of multiple groups, using the four prefectures as variables. Although the relationships between the factors were the same (the model structure remained unchanged), the influences between the factors (magnitude of path coefficient values) were assumed to change depending on the group (prefectures, in this case).

We also applied the modified index and goodness-of-fit index (GFI) to develop and improve behavioral models. Based on the previous findings on behavior studies and the interpretability of

TABLE 2 Results of analysis of variance (ANOVA) for the degree of behavior practice for the four prefectures considered in this study (as a factor).

Behavior group	Specific target behaviors	*F*-value	*p*-value
G1. Individual mitigation	B1. Refuse plastic bags and excessive packaging	4.00	**0.007**
	B2. Save electricity, by turning off lights and power frequently	0.23	0.879
	B3. Separate recyclable garbage for recycling	0.80	0.491
G2. Individual adaptative	B4. Always try to get warnings and forecasts for heavy rain, heatstroke, etc.	4.50	**0.004**
	B5. Try to voluntarily obtain information on the impacts of climate change and the required countermeasures	4.47	**0.004**
	B6. Prepare to protect against current heatstroke and water disasters	3.90	**0.009**
	B7. Choose the time and route when going out, in preparation for heatstroke and water disasters	1.22	0.302
G3. Long-term adaptative	B8. Considering that the impact will become serious in the future, discuss with family and make preparations, such as improving housing and securing evacuation routes	3.74	**0.011**
	B9. Considering disruptions in food and energy supplies, work on energy stockpiles and self-sufficiency at home and in the community	1.12	0.340
	B10. Discuss ways to support the elderly and help each other in neighborhoods and community groups during events of extreme heat or water disasters	2.56	0.054
	B11. Choose places to live or work, while considering the expansion of damage from water disasters, good ventilation, and adjacency to cool spots	1.30	0.272
G4. Solar-energy system installation	B12. Have/plan to install renewable energy equipment, such as solar power generation and solar thermal systems (solar hot water supply, etc.), at home	7.48	**0.000**

Bold values indicates $p < 0.05$.

the responses, we modified the arrangement and direction of the paths and added and deleted the covariance repeatedly; finally, a model with the same factor structure but a more plausible fit was selected as the preferred model. This methodology followed those of Ohtomo and Hirose (2007) and Bortoleto et al. (2012). Table 3 presents the model fit indices and formulae. The GFI, adjusted GFI (AGFI), and comparative fit index (CFI) are GFIs; the closer was the value of the index to 1, the better was the fit. Values of GFI and CFI higher than 0.9 suggested a good fit, while values of AGFI higher than 0.8 also suggested a good fit. The root mean square error of approximation (RMSEA) is also a GFI; the smaller was the value of RMSEA, the better was the fit. The values of RMSEA lower than 0.05 indicate a good fit. The χ^2-value indicates the result of the χ^2-test and is a threshold value of significance; the model is not rejected when the value is smaller than the threshold (Steiger, 1990; Byrne, 2001). A GFI of 0.9 was considered a good fit value; as model complexity increases, the GFI decreases (Schermelleh-Engel et al., 2003). Therefore, a need to increase the number of observed variables does not lead to the rejection of a model only because its GFI value is <0.9 (Toyoda, 1998).

3 Results

3.1 Practice rates of behavior groups

After the questionnaire survey, we received a total of 2,790 valid responses: 930 responses from Nagano Prefecture and 620 responses from each of Tokyo, Saitama, and Kanagawa prefectures. For each target prefecture, we obtained almost the same number of responses from the 10 groups of men and women, each in their 20–60's. All results thereafter were tabulated and analyzed separately for the four prefectures.

Within the 6-point scale used for analyzing the practice rate of behaviors for each target area, the response rate combining up to three scales on the affirmative side ("strongly agree," "agree," and "somewhat agree") was considered as the practice rate. The practice rates for each behavior group were summarized as follows: the practice rate was 73–90% for three individual mitigation behaviors, 53–72% for four individual adaptive behaviors, 33–48% for four long-term adaptive behaviors, and 22% for the installation of the solar-energy system (planned). The respondents who answered that they strongly agreed with the item "Physically impossible to install due to various reasons, such as rental housing," were excluded from the analysis. This was done to explore the differences in the perceptions of installation among only those who could take relevant actions. In the subsequent analysis, $n = 2{,}230$ was used only for the behavior of installing solar-energy systems, and the practice rate of the installation (and plans for installation) was 28%. However, for planned installation, the respondents were asked for "concrete plans for installation," and we assumed that the installation process had already begun. This is because the installation process of different systems may differ, owing to the timeframe

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TABLE 3 Model fit indices for the structural equation modeling.

Model fit indices	The formula
χ^2	$\chi^2(df) = (N-1)\,F[S, \Sigma(\hat{\theta})]$ *df is the number of degrees of freedom,* *N is the sample size,* *S is the empirical covariance matrix,* $\Sigma(\hat{\theta})$ *is the model - implied covariance matrix.*
GFI	$GFI = 1 - \frac{\chi_t^2}{\chi_n^2}$ χ_n^2 *is the chi-square of the null model (baseline model),* χ_t^2 *is the chi-square of the target model.*
AGFI	$AGFI = 1 - \frac{df_n}{df_t}(1 - GFI)$ $df_n = s$ *is the number of degrees of freedom for the null model,* $df_t = s - t$ *is the number of degrees of freedom for the target model,* s is the number of non-redundant elements in S, t is the total number of parameters to be estimated.
CFI	$CFI = 1 - \frac{\max\left[\left(\chi_t^2 - df_t\right), 0\right]}{\max\left[\left(\chi_t^2 - df_t\right), \left(\chi_i^2 - df_i\right), 0\right]}$ χ_i^2 *is the chi-square of the independence model (baseline model),* χ_t^2 *is the chi-square of the target model,* *df is the number of degrees of freedom.*
RMSEA	$RMSEA = \sqrt{\max\left\{\left(\frac{F[S, \Sigma(\hat{\theta})]}{df} - \frac{1}{N-1}\right), 0\right\}}$ $F[S, \Sigma(\hat{\theta})]$ *is the minimum of the fit function,* *df is the number of degrees of freedom,* *N is the sample size.*

χ^2, chi-square test; GFI, goodness-of-fit index; AGFI, adjusted goodness-of-fit index; CFI, comparative fit index; RMSEA, root mean square error of approximation (Schermelleh-Engel et al., 2003).

required between the preparation and actual installation, in addition to the time required for unique selections and fittings on site.

In terms of the differences between the age- and gender-based groups, the older-age group [based on multiple comparisons of Tukey's honestly significant difference (HSD) test, 50/60's > 20/30's; $p < 0.01$] and the female group portrayed higher practice rates [t-test; $p < 0.01$] for G1 (individual mitigation behavior group), especially those related to waste management. The same tendency has been observed previously for waste management and pro-environmental behaviors (Barr, 2003; Lee et al., 2013). Although similar trends were observed for G2 (individual adaptive behavior group), no noticeable difference was observed in the G3 (long-term adaptive behavior) or G4 (solar-energy system installation). There were significant differences in the G1 or pro-environmental behaviors of the age- and gender-based groups but no significant differences in adaptive behaviors and energy system installation. In addition, psychological factors have been demonstrated to influence pro-environmental behavior more than socio-demographic factors (Hines et al., 1987; Aoki et al., 2012). Therefore, to better elucidate the outcomes for each specific area, we concentrated on illustrating the relationship between psychological attitudes and behaviors, without controlling for age and gender factors in subsequent analysis.

3.2 Regional and behavioral differences

We conducted an analysis of variance (ANOVA), while considering the prefectures as a factor, to determine whether there were regional differences in the practice rates of the behaviors of the citizens of the four prefectures. As shown in Table 2, the results indicate significant regional differences [$df = (3, 2{,}786)$; $p < 0.05$] in six behaviors: (G1) "B1. Refuse plastic bags and excessive packaging," (G2) three behaviors of the individual adaptive behavior group (excluding B7), (G3) "B8. Considering that the impact will become serious in the future, discuss with family and make preparations, such as improving housing and securing evacuation routes," and (G4) "B12. Have/plan to install renewable energy equipment, such as solar power generation and solar thermal systems (solar hot water supply, etc.), at home." Further analysis was conducted to consider what local conditions might be contributing to these differences. Table 4 portrays the prefectures that demonstrated significant differences, based on multiple comparisons carried out using Tukey's HSD test. Significant differences were observed in the same six behaviors as in the previous analysis. For reference, the practice rate is also shown in the table. Regarding B1, the practice rate in Nagano Prefecture was significantly higher than that in Kanagawa Prefecture ($p < 0.05$). The highest practice rate was observed in Saitama Prefecture and the lowest in Tokyo, but the results differed because the practice rate was a reference value based only on the two values of practicing the behavior or not. For B12, the practice rate in Nagano was significantly higher than that in Tokyo and Kanagawa Prefectures ($p < 0.01$). The results of Nagano Prefecture's higher behavior practice rate in B1, a mitigating individual behavior related to shopping, and in B12, the installation of energy systems, were consistent with previous findings. Aoki et al. (2010) discussed regional conditions, including socioeconomic conditions such as larger residential areas, higher rates of private cars and marriages than in urban centers, municipal subsidy programs, differences in weather conditions, and regional character or traits based on local cultural identity in Japan (e.g., the regional character of Nagano's residents is often described as hardworking and resilient, although there is no clear evidence to support this). They reported that the higher practice rate in Nagano than in other prefectures was due to factors that cannot be explained solely by socioeconomic statistics and the availability of local government subsidy measures. However, for the three individual adaptive behaviors (B4, B5, and B6) and B8 within the long-term adaptive behaviors, the practice rates in Nagano Prefecture were significantly lower than that in Saitama Prefecture ($p < 0.01$). Among adaptive behaviors, regional differences were observed in the practice rates of four behaviors related to disaster preparedness, with Saitama Prefecture having a higher rate and Nagano Prefecture having a lower rate. Considering the regional conditions in Japan related to these differences, behaviors to cope with extreme heat may have a significant impact. In Saitama Prefecture, which is one of the regions that often experiences the hottest days, the practice rate

of behavior may have been higher because of the frequency of exposure to news concerning extreme heat, which is reported as extraordinary weather. As for heat, the reason may be that in Nagano Prefecture, which is originally a cold region, although adverse effects on agriculture and some cultural events are seen due to this, daily discomfort and damage within proximity to oneself, such as heat stroke, that is visible to everyone in general, are rarely seen. Of the subjects addressed as adaptive behaviors, preparedness for water damage may not have had as great an influence on differences as the heatstroke, since it is not a behavior that is repeated in daily life. This finding that behaviors showing regional differences were most represented in G2 supports the hypothesis that regional differences must be taken more into account in adaptive measures rather than in mitigation measures.

3.3 Psychological models of behaviors

First, we conducted an exploratory factor analysis to examine the factor structure. As a result, we used "attitude" and "intention" as the same factor (referred to as "attitude and intention"), assuming that people who perceive a behavior as a good thing (attitude) would also intend to implement it (intention). We extended and modified TPB to search for a model that better fits the target behaviors. Hence, attitudes and intentions, which are theoretically similar concepts as internal psychological factors for individuals, were treated as a single factor. Since the early researches, environmental attitude has been recognized to have significant influence on pro-environment behaviors (Van Liere and Dunlap, 1980; Hines et al., 1987). Simultaneously, there is a gap between environmental attitudes and pro-environmental behavior and attitudes and concerns are mediated by intentions before shaping into behavior, as well as the influence of other external factors (Bamberg and Möser, 2007; Gifford and Nilsson, 2014). Thus, attitudes and intentions have played similar roles as individuals' internal psychological factors that antecedent behavior, including a condition-dependent gap between them and behavior (Lord et al., 1984). In this survey, both attitude and intention are asked as cognitions of the specific target behaviors, rather than as attitudes toward the environment or climate change in general. For this reason, it was assumed to not have attitude as antecedents and steps leading to behavior via behavioral intentions but both could be viewed as psychological factors that indicated supportive or negative aspects of the target in the individual's internal beliefs toward the specific behavior. Regarding the recognition of local climate change in the target local area, several respondents expressed that they felt changes in the same manner for all five items. The most common response was "1. High temperatures in summer" (89%), and the least common was "2. High temperatures in winter" (56%). Similarly, several respondents answered affirmatively to the question of whether these types of climate-change effects were caused by global warming; the responses were similar (<75% for all items). This suggests that the responses were not about individual perceptions and represented a collective perception of climate change in the target local area; this was true even for the perceptions regarding whether the change was caused by global warming. Therefore, we incorporated these perceptions into all psychological models collectively as the factors of "recognition of local climate change" and "attribution of local climate change." In addition, installing solar-energy systems in each household was considered an effective mitigation measure, as well as an adaptation measure, because the systems could also serve as power sources in emergencies. For this reason, we used an indicator to ask about the perceived effectiveness of mitigation and adaptation measures, but the patterns of the responses were almost the same. Therefore, in the model for G4, the indicators for the perceived effectiveness of both the mitigation and adaptation measures were incorporated as a single factor.

Second, we carried out the SEM, and a better-fitting model structure was constructed, with reference to the modification index and GFI. The main change from the hypothetical model was the establishment of a direct influence path from "recognition of local climate change" to "behavior." The recognition of local climate change was assumed to be an antecedent of attitude, as it may be a cognition that corresponds to general concern or knowledge of environmental issues in the model of pro-environmental behavior. However, as indicated by the strong correlation between adaptive behavior and recognition of local climate change (Blennow et al., 2012), it was more plausible to set up a direct path. In addition, a path was set from "safety" (instead of "benefit"), to influence "perceived effectiveness" and "attitude and intention." Being safe and secure was assumed to be a form of personal benefit as well as a type of cognition of the consequences of behavior, and thus as a cognition in the latter stage of the behavior model, as shown in Schwartz's (1977) and Stern's (2000) models involving norms. However, it was more appropriate to set it as a type of belief that is an antecedent of attitude, as in Ajzen and Fishbein (1975, 1980), who included it in their explanations even though it was not depicted as an explicit factor in TRA explanations. Furthermore, the path from "perceived effectiveness" to "attitude and intention" was not directly connected and portrayed a structure that led to "intention" and "behavior practice" through behavioral evaluations (e.g., "norms" and "benefits"). Perceived effectiveness was assumed to be an antecedent of more general attitudinal factors, based on the theoretical background that it is a type of attitude (Hirose, 1994) and a form of knowledge (Kaiser and Fuhrer, 2003). However, since more of the target behaviors in this study were not implemented than pro-environmental behavior, the factors in the behavior model were also more significant as inhibiting factors. For this reason, as Kollmuss and Agyeman (2002) constructed a model in which many barriers were made explicit, the model took the form of a model in which even with the initial perception of effectiveness, only those that transcended the many barriers to norms and benefits would behave. In other words, even if one perceives the effectiveness of a behavior, the many barriers of the behavior evaluation process inhibit the behavior and prevent it from being implemented. It goes through the psychological process of recognizing that the behavior is socially required to be practiced (injunctive norm), with the one should practicing it (personal norm), and many others also practicing it (descriptive norm), while bringing benefits to the individual (benefit evaluation) and being feasible and easy to practice (practicality evaluation).

Figures 4–7 portray the structure of each psychological model constructed in this study. The observed indicators and error

TABLE 4 Results of multiple comparisons between the prefectures, with significant differences in behavior practice rates.

Behavior group	No. of the behavior	Practice rate (%)				Multiple comparisons (Tukey HSD)	
		Nagano	Tokyo	Saitama	Kanagawa	Significant differences	*p*-value
G1. Individual mitigation	B1	79	73	81	76	Nagano > Kanagawa	0.018
G2. Individual adaptative	B4	71	74	77	74	Nagano < Saitama	0.002
	B5	65	69	73	68	Nagano < Saitama	0.002
	B6	62	66	71	66	Nagano < Saitama	0.004
G3. Long-term adaptative	B8	41	47	52	46	Nagano < Saitama	0.006
G4. Solar-energy system installation	B12	31	23	29	24	Nagano > Tokyo/Kanagawa	0.001/0.000

Tukey's HSD test, Tukey's honestly significant difference test.

and disturbance variables have been omitted from the figures. The psychological factors extracted from the indicators are shown by the ellipses. The coefficient values of paths are shown as standardized coefficients. This study emphasizes on the comparisons of the trends of the relationships between behaviors and psychological factors, rather than conducting direct comparisons between the coefficient values of models. Therefore, instead of unstandardized coefficients, we present standardized coefficients, with the relationships being connected by the paths in the models and are indicated by a number between 0 and 1. For simplicity, the coefficient values and R^2 of the behaviors for each prefecture are shown separately in Table 5, and the coefficient values for Tokyo Prefecture are shown in Figures 4–7. A symbol is placed in the upper right corner of the coefficient values to indicate the *p*-value level to provide an understanding of the significance of the paths. The symbols are as follows: $^{***}p < 0.001$, $^{**}\ p < 0.01$, $^{*}p < 0.05$. While not considered significant at the 5% level, ^{y} for $p < 0.10$ is also shown for reference as well. The GFIs for each model are shown in Table 5 and the upper part of the figures. The GFIs show the model of G1 [$\chi^2_{(1,444)} = 5{,}886.1$, $p < 0.01$, GFI = 0.866, AGFI = 0.839, CFI = 0.930, RMSEA = 0.033] is better than other models. Because of the same structural constraints for conducting a simultaneous analysis of multiple groups and model complexity, not all indicators necessarily showed good fit, but one indicator in every model showed at least an acceptable criterion. In all three prefectures except Saitama, R^2 of the behavior, is also highest in that of G1 (0.46–0.55). In Saitama Prefecture, R^2 of G4 (0.52) is slightly higher than that of G1 (0.50).

Table 6 summarizes the relative characteristics of the paths a–f, while comparing the relationships between the psychological factors and the trends in their influence on the behaviors of the different groups. The table shows, in simplified form, whether the target paths are significant at the 5% significance level and whether the target paths that are significant have characteristics such as strong or weak relationships within each model among prefectures. First, in Path a (Figures 4–7 and Table 5), "recognition of local climate change" in the target local area, which is a perception of the surrounding environment, directly affects "behavior," relatively large coefficient values were observed in G2 (coefficient values for the four prefectures are 0.26–0.30, as shown in Table 5), compared to those in the other two adaptive behavior or G3 and G4. Notably, small values were obtained for the G3 (0.07–0.13) and G4 (ranging from −0.06 to −0.18). As all prefectures portrayed negative values in the case of G4, even if respondents are aware of local climate change, most of them do not install energy systems. This is a representative example of behavior that shows the gap between attitude and behavior, where internal cognitive factors alone do not lead to behavior because of the large influence of external factors. Because of the small value, we could reasonably conclude that system installation is not related to local climate recognition. However, it might be hypothesized that the type of people with lifestyle that makes them aware of changes in their surroundings would prefer small, immediate behaviors that they themselves take the initiative in undertaking, rather than large, single-point investment behaviors such as the system installation. Nevertheless, this hypothesis requires further investigation. Next, the path from "attribution of local climate change" to "perceived effectiveness" (Path b) portrayed a large effect in G1 (0.53–0.58); in the G3, the effect was small in almost all the prefectures (0.11–0.16), excluding Saitama Prefecture. In Saitama, where the practice rate of behaviors was high, the coefficient value was larger than that in other prefectures (0.31). In the G3, the coefficient value of the path from "perceived effectiveness" to "benefits" (Path c) tended to be larger (0.63–0.73) than that in the other behavior groups. The path from "practicality" (Path d) led to "attitude and intention," and "behavior," and strength of relationships differed depending on the behavior, as shown in Table 6. In the G1, the coefficient values of the path that affected "attitude and intention" were not large but somehow significant. Even if the behavior evaluation is positive, if attitudes and intentions are not fostered, they won't behave. There are direct correlations among indicators of practicality and behaviors because many people think it is highly practicality. However, in the model, the path became not significant or weak when the effect of attitude-intention was factored in. In the G2, both paths were not significant, excluding the path to "attitude and intention" of Nagano prefecture showed weak relationship. Indicators of practicality in the G2 showed less variation in responses than for the other behaviors, with many responses such

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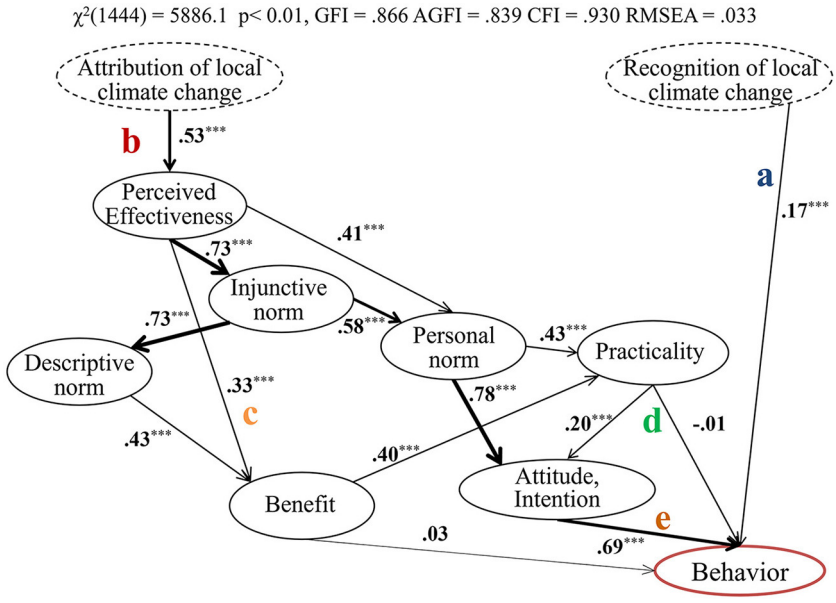

FIGURE 4
Model of the "G1, individual mitigation behavior" group. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, $^{\dagger}p < 0.10$. (a–f) Refer to the parts that are explained in the article. Numerical values are standardized coefficient values resulting from the analysis in Tokyo.

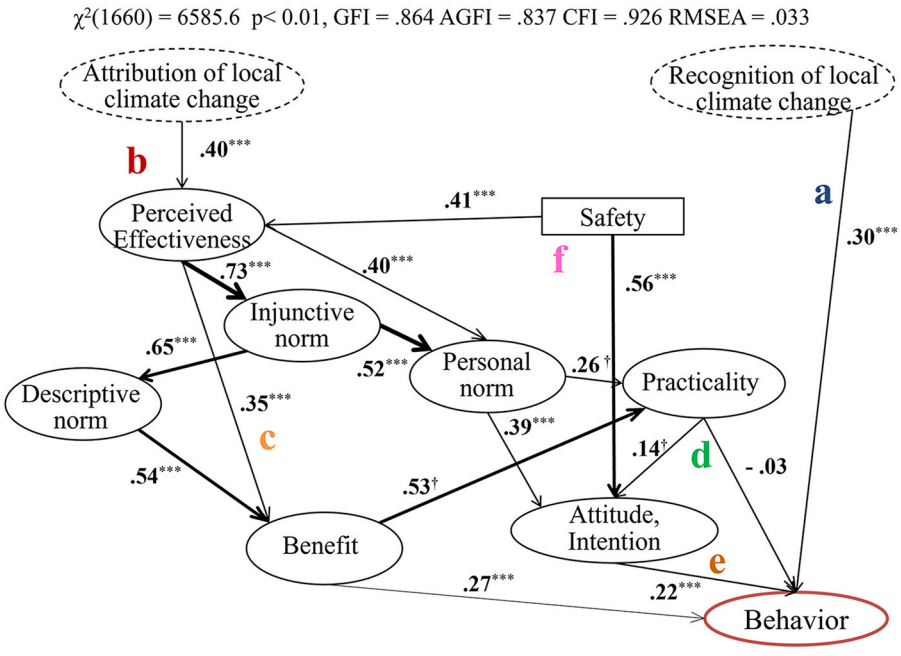

FIGURE 5
Model of the "G2, individual adaptive behavior" group. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, $^{\dagger}p < 0.10$. (a–f) Refer to the parts that are explained in the article. Numerical values are standardized coefficient values resulting from the analysis in Tokyo.

as somehow easy to do. Although the evaluation of practicality was on the positive side, it was not as clearly perceived as high as in G1. Practicality is considered high, but because there are so many options in terms of the means of behaviors (e.g., information can be obtained through a smartphone app or by looking in a local magazine), respondents do not have a clear perception of what they are doing, so the direct impact of practicality is not seen. In the G3, the coefficient value of the path to "behavior" were larger or significant. As a result, only G3 showed a direct relationship between practicality and behavior across all prefectures. This is because many respondents, especially those who indicated that they did not practice the behavior, clearly indicated that practicality

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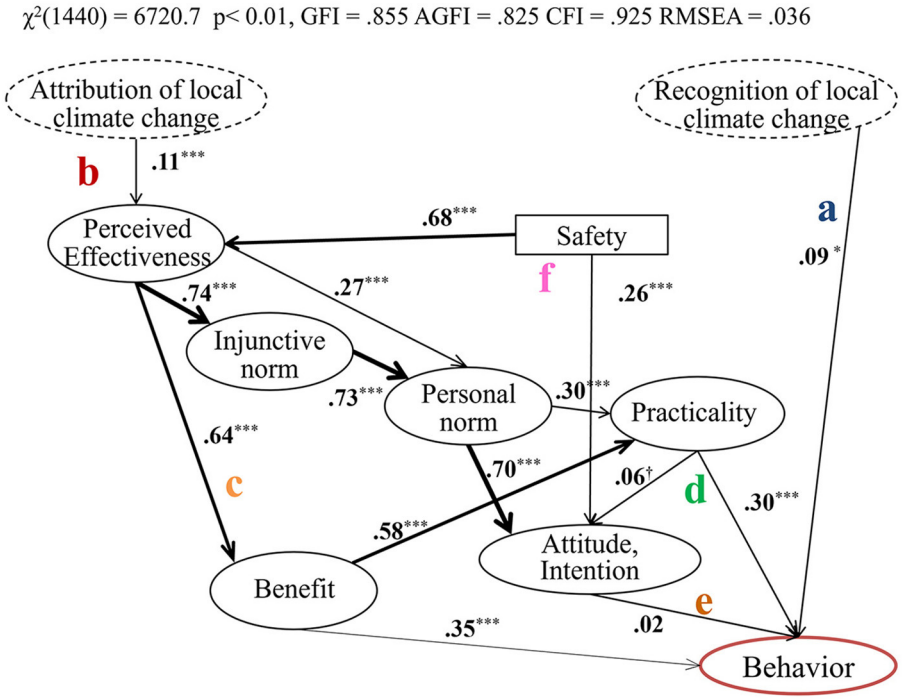

FIGURE 6
Model of the "G3, long-term adaptive behavior" group. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, †$p < 0.10$. (a–f) Refer to the parts that are explained in the article. Numerical values are standardized coefficient values resulting from the analysis in Tokyo.

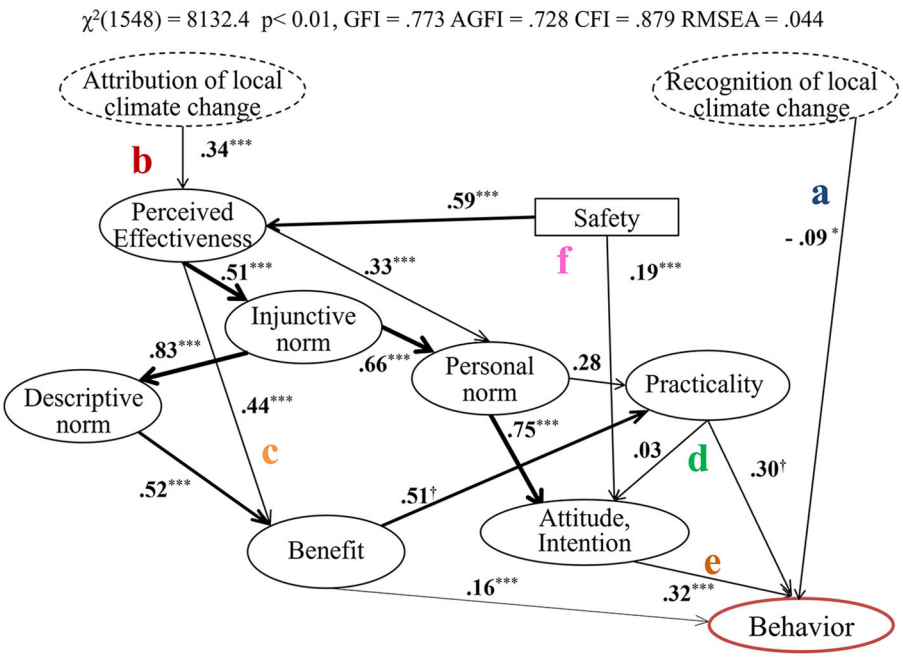

FIGURE 7
Model of the "G4, solar-energy system installation" group. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, †$p < 0.10$. (a–f) Refer to the parts that are explained in the article. Numerical values are standardized coefficient values resulting from the analysis in Tokyo.

was low. In the G4, the path from practicality to behavior is significant only in Nagano and Saitama, the two prefectures with higher levels of practicality. In all prefectures, the practicality of system installation is low. However, in the two prefectures with high practice rates, respondents answered somehow in the affirmative, although the practicality was not high, implying that

their perception of practicality increased as they planned their own implementation plans and observed the installation of the system by others. The respondents in Tokyo and Kanagawa, where there was no association with practicability, may have thought that the installation of the system was a one-time decision rather than a repeated investment, and therefore, some environmentally conscious people and those who thought it would be beneficial to their families may have installed the system, although they thought the practicality of the system was low. Different impacts were observed depending on the dissemination stage. The path from "attitude and intention" to "behavior" (Path e) had a large coefficient value (0.63–0.69) for the G1, but the paths were not significant for the G3. No direct correlation was found between "attitude and intention" and "behavior" in the G3. The destination of the path from "safety" (Path f) also differed, depending on the behavior. The perceptions of "safety" were linked to "perceived effectiveness," and "attitude and intention," with the indicators being related to adaptation behaviors. In the G2, a stronger relationship was observed between "safety" and "attitude and intention," (0.42–0.56), except for Kanagawa Prefecture. The G2 in Kanagawa Prefecture and the G3 and G4 demonstrated a stronger relationship between "safety" and "perceived effectiveness" (0.43–0.68). As we have seen, by constructing same-structured models in which the psychological factors were progressively related, we have shown differences in the relationships among the factors depending on the behavior and prefecture.

Furthermore, we focused on the differences in the paths of the behavioral model among the prefectures that portrayed significant differences in the practice rate of the behavior, as shown in Table 4. In the case of G1, with respect to Nagano and Kanagawa prefectures, the coefficient value of the path from "practicality" to "behavior" (Path d) was significant and negative in Kanagawa Prefecture. This indicated that in Kanagawa Prefecture, even though people recognized the practicality of the behavior, they did not implement relevant actions. Therefore, in Kanagawa Prefecture, social action measures that continue to raise awareness about attitude and intention may be effective in promoting pro-environmental behaviors, e.g., limited use of plastic bags. In the case of G2, with respect to Saitama and Nagano prefectures, in Saitama Prefecture, the coefficient values of Path f and Path e were large. In Nagano Prefecture, the path coefficient values from "injunctive norm" to "descriptive norm," "benefit" to "practicality" and "behavior," and "personal norm" to "attitude and intention" were large. This indicated that in Saitama Prefecture, there was a strong recognition that behavior assured safety. This may reflect the situation in Saitama Prefecture, which in recent years has experienced more extremely hot days than other regions in Japan, with the increase in heatstroke and other health problems often making the news. On the other hand, it is assumed that people in Nagano Prefecture do not feel any social requirements and benefits. Similarly, the practice rate of G3 was high in Saitama Prefecture. In Saitama Prefecture, the coefficient value of the Path b and Path c were relatively high. Therefore, "perceived effectiveness" and the "benefit" evaluation stimulated by it are considered to play a significant role in long-term adaptive behavior. In the case of G4, when comparing Nagano with other prefectures, the path coefficient value from "attitude and intention" to "behavior" (Path e) was larger, and the effect of "benefit" on "behavior" was not significant. For this reason, the progress of system installation in Nagano Prefecture was based not on the evaluation of benefits, but on the growing awareness that the installation of such systems was good behavior.

Table 7 portrays the influential factors that had the largest standardized overall effects on the behaviors (all direct and indirect paths combined), along with their effect values. The results showed that the factors do not differ by prefecture for G1 and G3, and that in all prefectures, "attitude and intention" portrayed a large impact on G1, and the evaluation of "benefit" had a large impact on G3 For G2, the factors differed by prefecture, with the largest influence from the evaluation of "benefits" in Nagano and Kanagawa prefectures, "recognition of local climate change" in Tokyo Prefecture, and "attitude and intention" in Saitama Prefecture, wherein the practice rate is the highest. For G4, the influence of "attitude and intention" was large in Nagano Prefecture, wherein the practice rate was high, from "perceived effectiveness" in Tokyo and Saitama prefectures, and from the evaluation of "benefits" in Kanagawa Prefecture.

4 Discussion

In the G1 (individual mitigation behaviors), individual psychological factors, such as "perception of the cause of local climate change," "perceived effectiveness," "attitude and intention," had a great influence on the practice rate of behaviors. Based on the differences in the practice rate in each prefecture and the most influential factors, the results indicate that internal perceptions, such as "attitude and intention," had a stronger influence on the citizens' behaviors. In the case of G4 (solar-energy system installation), in Nagano Prefecture, where the level of installation was high, there was a high influence of "attitude and intention" on behaviors. In other prefectures, the influence on behaviors was greater from the evaluations of "benefits," although the influence is less and that direct path was not significant in Nagano prefecture. Nevertheless, in other prefectures, both the perception of benefits and the practice rate of system installation are low. This may be because the psychological stage toward the installation of solar-energy systems was more advanced in Nagano Prefecture than the other prefectures, with "attitude and intention" portraying a direct and significant impact. Confirming the respondents' perceptions in this regard, the descriptive norms were highly recognized in Nagano Prefecture, with its citizens being aware of the diffusion of solar-energy systems. This suggests that it is effective to establish a measurement to raise the perceptions of benefits and effectiveness, as part of the evaluation of installing solar energy systems. Furthermore, the example of Nagano Prefecture also suggests that to raise descriptive norms that can affect the perceptions of benefits, it is effective to have people familiarize themselves with relevant behaviors on not only an individual basis, but also a local community basis, where they can see each other's behaviors. It has been reported that the influence of descriptive norms is particularly significant on behaviors that are visible to others (Cialdini et al., 1990). For G2 (individual adaptive behaviors), such as obtaining information and preparing for climate change, we observed a

TABLE 5 Coefficient values of different paths (a–f) of behavior models for the "G1. Individual mitigation behavior," "G2. Individual adaptive behavior," "G3. Long-term adaptive behavior," and "G4. Solar-energy system installation" groups.

Path			G1. Individual mitigation				G2. Individual adaptive				G3. Long-term adaptive				G4. Solar-energy system installation			
	From	To	NN	TK	ST	KG	NN	TK	ST	KG	NN	TK	ST	KG	NN	TK	ST	KG
a	Recognition of LC	Behavior	0.12***	0.17***	0.19***	0.14***	0.26***	0.30***	0.29***	0.30***	0.07*	0.09*	0.07†	0.13***	−0.06†	−0.09*	−0.18***	−0.12**
b	Attribution of LC	Perceived effectiveness	0.55***	0.53***	0.56***	0.58***	0.37***	0.40***	0.39***	0.30***	0.16***	0.11***	0.31***	0.16***	0.42***	0.34***	0.35***	0.36***
c	Perceived effectiveness	Benefit	0.34***	0.33***	0.34***	0.25***	0.21***	0.35***	0.31***	0.22***	0.63***	0.64***	0.73***	0.64***	0.49***	0.44***	0.44***	0.34***
		Injunctive norm	0.67***	0.73***	0.70***	0.72***	0.60***	0.73***	0.66***	0.68***	0.70***	0.74***	0.75***	0.72***	0.54***	0.51***	0.58***	0.47***
		Personal norm	0.46***	0.41***	0.47***	0.51***	0.52***	0.40***	0.48***	0.40***	0.34***	0.27***	0.41***	0.40***	0.33***	0.33***	0.28***	0.29***
	Injunctive norm	Descriptive norm	0.78***	0.73***	0.76***	0.75***	0.70***	0.65***	0.65***	0.68***	-	-	-	-	0.78***	0.83***	0.83***	0.81***
	Descriptive norm	Benefit	0.35***	0.43***	0.42***	0.46***	0.53***	0.54***	0.56***	0.51***	-	-	-	-	0.44***	0.52***	0.62***	0.62***
	Injunctive norm	Personal norm	0.50***	0.58***	0.51***	0.47***	0.44***	0.52***	0.41***	0.56***	0.64***	0.73***	0.56***	0.59***	0.68***	0.66***	0.70***	0.70***
	Personal norm	Attitude and Intention	0.72***	0.78***	0.76***	0.75***	0.56***	0.39***	0.46***	0.63***	0.58***	0.70***	0.55***	0.69***	0.67***	0.75***	0.70***	0.63***
		Practicality	0.38***	0.43***	0.41***	0.38***	0.21*	0.26†	0.31†	0.44†	0.22***	0.30***	0.17***	0.23***	0.20**	0.28	0.14†	0.04
	Benefit		0.37***	0.40***	0.38***	0.27***	0.51**	0.53†	0.37†	0.28†	0.64***	0.58***	0.68***	0.66***	0.50***	0.51†	0.62**	0.70†
d	Practicality	Attitude and Intention	0.30***	0.20***	0.22***	0.27***	0.10*	0.14†	0.06†	0.09†	0.20***	0.06†	0.16***	0.12**	0.05	0.03	0.05	0.04
		Behavior	−0.07	−0.01	−0.02	−0.15**	0.06	−0.03	−0.03	−0.02	0.35***	0.30***	0.30***	0.23**	0.27***	0.30†	0.27**	0.38†
	Benefit	Behavior	0.05	0.03	0.02	0.04	0.30***	0.27***	0.28***	0.35***	0.24***	0.35***	0.39***	0.40***	0.02	0.16*	0.30***	0.14†
e	Attitude and Intention	Behavior	0.65***	0.69***	0.63***	0.66***	0.16***	0.22***	0.31***	0.28***	0.02	0.02	−0.04	0.05	0.48***	0.32***	0.30***	0.23***
f	Safety	Perceived effectiveness	-	-	-	-	0.41***	0.41***	0.39***	0.51***	0.55***	0.68***	0.58***	0.62***	0.43***	0.59***	0.52***	0.47***
		Attitude and Intention	-	-	-	-	0.42***	0.56***	0.54***	0.32***	0.33***	0.26***	0.28***	0.25***	0.13***	0.19***	0.19***	0.34***
	R^2 of the behavior		0.46	0.60	0.50	0.55	0.31	0.33	0.41	0.44	0.34	0.42	0.42	0.44	0.42	0.43	0.52	0.39
	The GFIs for the model		$\chi^2_{(1,444)} = 5{,}886.1$ $p < 0.01$, GFI = 0.866 AGFI = 0.839 CFI = 0.930 RMSEA = 0.033				$\chi^2_{(1,660)} = 6{,}585.6$ $p < 0.01$, GFI = 0.864 AGFI = 0.837 CFI = 0.926 RMSEA = 0.033				$\chi^2_{(1,440)} = 6{,}720.7$ $p < 0.01$, GFI = 0.855 AGFI = 0.825 CFI = 0.925 RMSEA = 0.036				$\chi^2_{(1,548)} = 8{,}132.4$ $p < 0.01$, GFI = 0.773 AGFI = 0.728 CFI = 0.879 RMSEA = 0.044			

***p < 0.001, **p < 0.01, *p < 0.05. †p < 0.10 shown for reference only; not considered significant. Prefecture names; NN, Nagano; TK, Tokyo; ST, Saitama; KG, Kanagawa; LC, local climate change. n = 2,790; Nagano n = 930, Tokyo n = 620, Saitama n = 620, Kanagawa n = 620 for the "G1. Individual mitigation behavior," "G2. Individual adaptive behavior," and "G3. Long-term adaptive behavior" groups. n = 2,230; Nagano n = 790, Tokyo n = 451, Saitama n = 502, Kanagawa n = 487 for the "G4. Solar-energy system installation" group.

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TABLE 6 Characteristics of the target paths that portrayed different trends depending on the behavior model.

Path		G1. Individual mitigation	G2. Individual adaptive	G3. Long-term adaptive	G4. Solar-energy system installation
a	"Recognition of LC" to "Behavior"	Significant***	**Strong*** **	**Weak*,*** ,** (ST† is n.s.)**	**Weak*,*** ,** (NN† is n.s.)**
b	"Attribution of LC" to "Perceived effectiveness"	**Strong*** **	Significant***	**Weak*** **	Significant***
c	"Perceived effectiveness" to "Benefit"	Significant***	Significant***	**Strong*** **	Significant***
e	"Attitude and intention" to "Behavior"	**Strong*** **	Significant***	**n.s.**	Significant***
d	From "Practicality" to "Attitude and intention"	**Significant*** **	n.s.† (NN* is weak)	Weak**, ** (TK† is n.s.)	n.s.
	From "Practicality" to "Behavior"	n.s. (KG** is weak)	n.s.	**Significant***,** **	**NN*** and ST** are significant. TK† and KG† are n.s.**
f	From "Safety"	-	To "Attitude and intention" (excluding KG)	To "Perceived effectiveness"	To "Perceived effectiveness"

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$. not significant, n.s (including †$p < 0.10$ as a reference). A symbol is assigned in the upper right corner only if path coefficients for all prefectures exhibit the same p-value level. Otherwise, multiple corresponding symbols or a symbol next to abbreviated prefecture names are noted for the specific case. Prefecture names; NN, Nagano; TK, Tokyo; ST, Saitama; KG, Kanagawa; LC, local climate change.

TABLE 7 Factors that had the largest influence on behavior in each prefecture and model and their standardized overall effect values.

Behavior group	Nagano	Tokyo	Saitama	Kanagawa
G1. Individual mitigation	Attitude and intention	Attitude and intention	Attitude and intention	Attitude and intention
	0.65	0.69	0.63	0.76
G2. Individual adaptive	Benefit	Recognition of local climate change	Attitude and intention	Benefit
	0.34	0.30	0.31	0.35
G3. Long-term adaptive	Benefit	Benefit	Benefit	Benefit
	0.47	0.53	0.59	0.55
G4. Solar-energy system installation	Attitude and intention	Perceived effectiveness	Perceived effectiveness	Benefit
	0.48	0.43	0.52	0.42

significant direct influence of the recognition of local climate change on behaviors. Influences of personal evaluations, like "safety" and "benefit," were also significant. People tended to view these as practical behaviors, adopted based on perceived benefits, contrasting with normative practices. This shows a different trend from that of the pro-environmental behavior (G1), which has been often framed as altruistic behavior. Pro-environmental behavior, beneficial in a global and long-term context, may not offer immediate personal benefits and could entail costs. Such behavior is driven by strong internal attitudes and norms, even with lesser perceived benefits. Conversely, adaptive behaviors primarily aim at enhancing the life of oneself and one's family, providing individual benefits at that time, potentially offering societal benefits too by safeguarding communities and improving wellbeing as inherent aspects of these behaviors. For this reason, regardless of whether an individual is selfish or altruistic, the behavior itself is altruistic in the broadest sense. Pro-environmental behavior is not purely altruistic since it relates to one's own living conditions. However, given the less recognizable benefits to individuals, pro-environmental behavior aligns more closely with true altruism. In contrast, adaptive behaviors align more with reciprocal altruism, focusing on immediate benefits for individuals, their families, and their communities. Therefore, emphasizing the specific benefits of climate change adaptation behaviors, considering temporal and spatial scales, becomes critical. Similarly, although the practice rate of G3 (long-term adaptive behaviors) was overall low, the influential factors were the evaluations of "benefit" and "practicality." This suggests that specific appeals according to the situation and citizens' lifestyles may be effective in promoting relevant adaptation measures for both individual and long-term adaptive behaviors. For example, it would be effective to set up a place in the community to explore specific examples of behaviors and work together to design examples of behaviors for self-help and systems of mutual assistance as an approach to stimulate the evaluative perceptions related to the consequences of the behavior.

For adaptation measures, a notable variation was observed in both practice rates and influencing factors across the different local contexts within the prefectures. This result is in line with those

of previous studies that have focused on regional characteristics, where many studies on adaptive behavior have emphasized risk management at the local community level (Wouter Botzen et al., 2019) or have found that place attachment, including the local community, has influenced adaptive behavior (van Valkengoed and Steg, 2019). However, most direct regional comparisons on adaptation so far have been comparisons on local government regional adaptation plans (Baba et al., 2017). Further research is needed on the context in which specific factors that create regional differences in individual behavior of adaptation are revealed, including cultural differences (Adger et al., 2013; van Valkengoed and Steg, 2019). To change behavior based on regional differences of the results, it is necessary to first establish a system that enables people to recognize climate change in the local area and help perceive the benefits of the behavior. In long-term adaptation behaviors, "benefits" were an influencing factor. However, it was not a positive connection, wherein people behave because the benefits are high, but a negative connection, wherein people don't behave because they don't feel the benefits. Therefore, from a medium- to long-term perspective, it is considered effective to establish measures that enable citizens to envision and feel how their lives and community will benefit by undertaking drastic adaptation behaviors.

Among the different pro-environmental behavior subtypes of G1, only "B1. Refuse plastic bags and excessive packaging" showed regional differences. This is in line with the results of an eco-shopping study, which showed different behavior practice rates by region (Kurisu and Bortoleto, 2011), and with the regional differences owing to the plastic bag fee policy (Aoki et al., 2012; Heidbreder et al., 2019). The regional differences in G4 (installation solar energy systems) were also in line with studies showing the influence of urban policies such as subsidies (Mundaca and Samahita, 2020), as well as previous studies that explained regional differences based on external factors such as regional differences in renewable energy potential and the availability of large houses to install the systems in Japan (Aoki et al., 2012). Nevertheless, no differences were found in the behavior of waste separation for recycling, as most regions in Japan have high practice rates despite some minor policy differences among regions. There was no difference in energy-saving behavior either, which is in line with the findings of previous studies that have shown differences in individual psychological factors to be the major driving and inhibiting factors rather than socioeconomic factors such as regional factors (Hines et al., 1987; Aoki et al., 2010).

In pro-environmental behavior or individual mitigation behavior, recycling behavior is different from waste prevention behavior. Bortoleto et al. (2012) argued that the difference between the two relies on the fact that recycling is a public, procedural, and repetitive behavior, whereas waste prevention is a private and dynamic behavior that depends on the place of implementation. Reportedly, the factors that lead to behavior change differ between behaviors that are invisible to others and those that are seen by others (Cialdini et al., 1990). Similarly, for the adaptive behaviors, the factors influencing the behavior differed in terms of how the behavior was accepted and prevalent in the local community. Pro-environmental behavior is widely recognized as a socially desirable behavior that should be practiced, even though a gap may exist between the attitude and the behavior (Kaiser, 1998; Kollmuss and Agyeman, 2002; Bosone et al., 2022). There are many procedural, concrete, and repetitive behaviors, and the behavior discussed as G1 in this study falls into this category. G2 and G3 are more private and dynamic behaviors than waste prevention behaviors, as they are not visible to others unless a disaster occurs. Adaptive behavior is not the kind of behavior in which a government or other public organization calls on individuals to behave in a uniform manner and make it a social rule to do so. In terms of prevalence, social norms have a positive influence on typical pro-environmental behavior when most people do something about it, but adaptive behavior has a negative influence when there are only a few people who do it and social norms indicate that there is no problem even if they don't do it now. While mitigation behaviors are for the benefit of society, commonly referred to as earth-friendly behaviors or saving the earth, adaptive behaviors, focused on individual and their surroundings' preparedness for damage, were less influenced by social norms and not typically viewed as altruistic so far. Perhaps an abstract question of approval or disapproval of climate change adaptation behavior must yield different results, as it is considered a socially desirable behavior. When behavior is concretized and put down, the difference between adaptation and mitigation, necessarily due to the purpose of the behavior, is not represented as a difference in the factors that influence the behavior. This is implied by the fact that significant differences were observed among the four prefectures analyzed in this study, portraying different levels of diffusion. Although there may be models and characteristic factors that better fit individual specific behaviors, we were able to compare the same structure in other target groups in this study, thus adding to its significance. This will allow us to refer to the results of this study when we disseminate the results to society in the future as behaviors that should also be applied by individuals. Consequently, various methods of palliative interventions have been proposed at the penetration stage of behaviors (Schultz and Kaiser, 2012; Kurisu, 2015). Therefore, our findings on interventions to promote pro-environmental behaviors can be used for inducing behavior changes, to promote adaptive behavior, while focusing on local situations and implications.

Furthermore, adaptation measures can be implemented at various scales; notably, human behavior at a particular local scale (e.g., at an individual or local-community scale) is important (Adger, 2001). Wilson et al. (2020) suggested that to consider the behavior of an individual, one should not only consider the individual, but also the collective impact of the individual's surroundings. As suggested by the results of this study, individual adaptive behaviors are directly affected by "recognition of local climate change." Individual perceptions can be changed based on not only the numerical values of observational data but also the information that can be linked to the benefits of the citizens that they can experience themselves. Therefore, to promote the implementation of adaptation measures in local communities, we propose introducing prescribed actions as specific adaptation measures and supporting citizens to study and analyze appropriate local behaviors and weather information, so that they can develop their own specific action plans. In addition, identifying the local problems and developing relevant countermeasures within local communities can lead to positive changes in the local social norms

and foster an attitude that enables citizens to harmonize with their community members.

While TRA has shown that intentions are direct antecedents of behavior, Fishbein and Ajzen (1975) pointed to both causal relationships and discrepancies between intentions and behavior, highlighting a more complex relationship. Several different types of intentions exist, and in this study, we focused on goal-oriented intentions, similar to TRA and TPB. Other, less completely divisive and highly correlated, but certainly independent predictors are behavioral expectations, which predict one's own behavior in the future; implementation intention or behavioral planning, which is a more embodied plan of future behavior; and behavioral willingness is openness to or acceptance of the circumstances conductive to socially undesirable behavior (Gibbons et al., 1998; Ohtomo and Hirose, 2007). The difficulty in distinguishing between these issues is that even similar behavioral intentions require different understandings. The TPB, on which this study is based, indicates that goal-oriented intentions can be predicted using attitudes and subjective norms as antecedents, and that the correlation between intentions and behavior then depends on the extent to which people can control their behavior themselves (Ajzen, 2020). Ajzen (2020) explained three problems with the research methodology regarding the discrepancy between intention and behavior: restriction of range, lack of compatibility, and hypothetical bias; and three problems with the features of individuals' behavior regarding forgetting, change of mind, and low control over the behavior. Regarding the problem of discrepancy between intention and behavior as features of individuals' behavior, it is regarded as a gap between intention and behavior, and the influence of external factors and what kind of reinforcement is necessary for behavior change have been studied (Kollmuss and Agyeman, 2002; Webb and Sheeran, 2006; Hirose, 2015; Sheeran and Webb, 2016). This study does not aim to utilize behavioral intentions as future behaviors or to retrospectively uncover the reasons and causal factors that led to the initial execution of the target behavior. Instead, it seeks to illustrate the connection between whether or not the behavior was enacted at the time of the survey and the respondents' current perceptions regarding the behavior. By doing so, the study has identified whether any discrepancies between current behavior and intentions exist and, if so, what factors are responsible for these disparities. Although measuring behavioral intentions and behavior can be challenging, it is valuable to examine the relationship between the two as they are currently perceived by the respondents. These relationships may be highly or poorly correlated, and it is crucial to comprehend the context of these relationships in terms of the subject, target behavior, and social context.

The gap between intention to engage in pro-environmental behavior and actual behavior could be associated with a blend of moral values, habituation, rational decision making, emotions, ethics, and cognitive thinking (Ajzen, 2002; Ziegelmann et al., 2007; Bosone et al., 2022). Ajzen (2002) emphasizes how the interaction of rational behavior with past behavior and habituation can affect the consistency of behavior over time. Bosone et al. (2022) also investigate the impact of cognitive dissonance and dissonance on pro-environmental intentions, showing that cognitive dynamics and internal conflict play a role in the mismatch between intentions and actual behavior. Webb and Sheeran (2006), Sheeran and Webb (2016) studies reveal that the link between intention and behavior is complex. They found that significant changes in intention often lead to only modest changes in behavior, particularly when strong habits exist. Additionally, they suggest that intentions are more likely to translate into actions when the behaviors are easier to perform. Ziegelmann et al. (2007) also mention different types of intentions through a longitudinal study indicating that as behaviors become more routine over time, the role of implementation intentions becomes more significant in determining actual behavior, while the influence of goal intentions diminishes. In this study, G1, individual mitigation behavior, is a routine pro-environmental behavior; hence, it is expected to be influenced by habit and past behavior. However, the influence of attitudes and intentions on behavior was greater than in the other behavior groups, and the gap between intentions and behavior was not as large. This finding is consistent with those from previous research (Ajzen, 2002; Webb and Sheeran, 2006; Sheeran and Webb, 2016) that behaviors that are easier to perform, i.e., those with fewer external disincentives, are more likely to bridge the gap between intention and behavior. Conversely, the correlation between intention and behavior in the case of climate change adaptation behaviors was not as strong. This could be attributed to the fact that the behavior is not a routine, repetitive action and that external factors such as benefit as perceived consequences and perceived effectiveness as antecedents of attitudes and intentions, have not been sufficiently fostered, resulting in a low practice rate of the behavior within the target area of the study.

Regarding hypothetical bias, the influence of social desirability has been noted in prosocial behaviors such as pro-environmental behavior. Individuals tend to report better behavior than they actually engage in activities such as answering questionnaires, to appear more socially desirable (Scott and Willits, 1994; Ajzen, 2020). Furthermore, some research raises questions about the accuracy of measuring behavioral intentions, which may pose challenges in assessment (Geller, 1981; Norman and Smith, 1995). However, subjective self-reports are often considered valid, though not entirely accurate, indicators (Webb and Sheeran, 2006), and their use in an effort to minimize the influence of social desirability can be an economical and parsimonious method (Kaiser, 1998). To avoid response bias due to social desirability in this survey, we carefully designed the wording in the questionnaire to be neutral and did not present climate change action as a socially desirable behavior. Additionally, abstract situations tend to have a greater impact on social desirability (Brown et al., 2003), so we concretized the target behaviors in the questions. Finally, we clearly stated that the respondents' answers would be anonymous and confidential.

This study has several limitations. As this study captured the perceptions only at a single point in time, the changes in the actual behaviors of the respondents were not captured. In addition, while our analysis measured how individuals perceive social norms, it did not measure the interactions between citizens of a local community. Given the study's employment of an age-gender balanced sample, the uncovered regional disparities could be attributed to the varied perceptions among different age-gender groups within each local area rather than to demographic shifts in age-gender composition

owing to factors like rural depopulation. However, the sample did not follow the actual age-gender composition of the area and did not include minors or elderly people in their 70's or older. It should be noted that since this is not a large-scale survey representative of the broader area, there are limitations in generalizing the results of the analysis as differences specific to the localized target region. Furthermore, our study did not account for the relationship between subjective perceptions of climate change and the actual political measures implemented in the four prefectures.

5 Conclusion

In this research, we analyzed distinct behavior groups in response to climate change adaptation and mitigation: G1 (individual mitigation), G2 (individual adaptive), G3 (long-term adaptive), and G4 (solar-energy system installation). Cognitive psychological models of the same structure but reflecting unique influences of varied psychological factors were constructed for each group. Notably, while pro-environmental behaviors were predominantly driven by internal attitudes and normative beliefs, aligning with social desirability, adaptation behaviors were more significantly influenced by external factors, particularly evaluative perceptions related to the consequences of the behavior in implementation contexts.

Furthermore, our findings highlight the necessity of tailoring adaptation strategies to specific local contexts, given the substantial variation in psychological characteristics of adaptive behaviors across different local areas. Effective adaptation strategies might involve demonstrating the consequences of behavior, thus enhancing behavior evaluation perception and fostering its acceptance as a desirable behavior through concrete and relatable means. The findings propose that interactive efforts that enable citizens to think about both self and mutual help on their own are more effective than unidirectional information dissemination.

For advancing climate change adaptation and mitigation efforts, further research should concentrate on the individuals as behavioral actors and the local communities as distinct contextual entities. They are imperative to delineate the determinants of behavioral change, assessing the magnitude and nature of change across various levels.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical reviews and approvals were not required for this study in accordance with the local legislation and institutional requirements. In this questionnaire survey, the survey is completed online and does not involve any intervention or invasion of the respondents. Therefore, we obtained the respondents' consent online only, following the prescribed criteria set forth by the research institution in accordance with "Ethical Guidelines for Medical and Biological Research Involving Human Subjects" by the Ministry of Education, Culture, Sports, Science and Technology, the Ministry of Health, Labor and Welfare, and the Ministry of Economy, Trade and Industry of Japan.

Author contributions

EA: Conceptualization, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft. NS: Conceptualization, Investigation, Methodology, Writing – review & editing. KB: Supervision, Writing – review & editing. NM: Project administration, Writing – review & editing. MT: Funding acquisition, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2024.1283946/full#supplementary-material

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