Simulating air-conditioning use in Office Buildings by Modeling the Relationship between Psychological Factors and Occupants' Behavior in Japan

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Abstract. This study explores the relationship between occupants' awareness, behavior, and environmental factors in office air conditioning systems. It aims to create an analytical tool for understanding air conditioning usage in Japanese offices. Using the Theory of Planned Behavior and the DNAs framework, the research establishes a model linking occupants' environmental awareness, age, and thermal preferences to their air conditioning behavior. Using agent-based modeling, key factors influencing air conditioning usage, including the impact of environmental awareness on air conditioning behavior were simulated. The results indicate that office occupancy rates and initial temperature settings significantly impact usage patterns. In conclusion, this study offers insights for improving energy efficiency in office air conditioning while maintaining occupant comfort. This study still has some limitations that real-world office buildings are more intricate than the model used, with factors like interpersonal influence and diverse job types impacting air conditioning usage differently. Future research aims to validate findings in actual office settings, collect additional data on usage factors, and expand simulations to explore energy-saving methods and occupant comfort enhancement beyond air conditioning behavior.

1 Introduction

The global building sector is critical to dcreasing energy use and emissions. Recent studies report that the commercial and public sector share of energy is 54 % in Japan and 44 % in the United States [1]. It has also been found that occupant behavior has a significant impact on energy use in private offices. Conservative working practices can save up to 50% of source energy compared to standard working practices, while wasteful working practices can increase energy use by 89% [2]. In order to mitigate these problems, it is important to consider how human behavior can be changed to become environmentally friendly.

The comprehensive assessment of occupants' energy-related behaviors from a psychosocial perspective has recently received attention [3,4]. These social psychological perspectives emphasize the impact of attitudes, personal norms, subjective norms, perceived behavioral control (PBC), and knowledge on energy consumption in residential and commercial buildings [5]. In terms of personal environmental behaviors (including green purchasing behaviors, water conservation behaviors, and waste management behaviors), the Theory of Planned Behavior (TPB) established by Ajzen [6] is considered to be a better approach to understanding personal energy conservation intentions and behaviors. Several studies have found that the TPB structure explains most of the variation in employees' behavioral intentions [7].

However, little research has been done so far on how consciousness influences behavior and how it affects building energy consumption. Therefore, the purpose of this study is to establish a simulation tool that can simulate the effect of consciousness on building energy consumption behavior by studying the relationship between consciousness and behavior. The significance of this study is that a simulation tool that incorporates consciousness can be widely used as a guide and reference.

2 Literature review and conceptual model

2.1 Behavioral models

TPB is a classic theoretical model for examining individual behavior, composed of attitude, subjective norm, and perceived behavioral control [6]. However, TPB has been criticized for its incompleteness. To enhance its validity, some research has advocated the integration of additional variables. The study by Botetzagias et al. demonstrates that personal moral norm is a necessary and conceptually different complement to the standard TPB framework [8]. Manning conducted a

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meta-analytic study and noted that the inclusion of descriptive specifications improved the explanatory power of TPB and successfully predicted behavioral intentions [9]. Wang et al. also confirmed through his research there was a significant positive relationship between energy knowledge and individuals' attitudes [10]. Therefore, in this study, three new factors (personal moral norm, descriptive norm, and environmental protection knowledge) will be incorporated into the TPB framework and serve as the theoretical basis for this study.

The DNAs framework was originally proposed by Turner and Hong [11]. According to their theory, the impact of occupant (or occupant group) behavior on building energy use can be described in terms of four main components: drivers, needs, actions and systems. These four components inhabit the "external world" (i.e., the built environment) and the "internal world" (i.e., human cognitive processes). Actions link the needs of the occupant's internal world to the external environment.

2.2 Behavioral simulation in buildings

When simulating behaviors, Agent-Based Modeling (ABM) is considered a suitable approach for simulating complex human behaviors. What sets ABM apart is that it involves autonomous decision-making entities, where agents can evaluate their own situations and make decisions based on their own behavioral rules [12]. A number of studies have been conducted to simulate human behavior in buildings. Yu employed agent-based simulation in the field of workplace design to model activity patterns and interactions of individuals [13]. The purpose was to test various office layouts for spatial planning and customize them using real data gathered through online surveys. Lee et al. developed a novel agent-based modeling approach for simulating a variety of occupant behaviors in commercial buildings, aiming to replicate real-world autonomous interactions of occupants with the environment and other agents while making decisions based on thermal comfort [14].

However, existing studies include those that investigate the relationship between awareness and energy behaviors, as well as those that establish energy behavior models. Yet, there is still limited research on how awareness influences behavior and impacts building energy usage.

2.3 Framework construction

Based on the above analysis, this study attempts to simulate the effects of consciousness and external influences on energy use behavior of people in buildings through ABM. Therefore, based on the previous theories and studies, a conceptual model of the energy-saving behaviors of office occupants was designed on the basis of agent simulation modeling theory, as shown in Fig.1.

3 Questionnaire design and results

In this paper, before the establishment of simulation system, first the questionnaire is created through a large number of network questionnaires to obtain psychological and air-conditioning behavioral data, according to the regression analysis of the data to establish a relationship model, to determine the influence coefficients of the various psychological elements on the air-conditioning behavior. Then the NetLogo platform, which is a programming language and integrated development environment (IDE) for ABM, is used to simulate and model the air-conditioning behavior and energy consumption of air-conditioning. After establishing the simulation system, the behavioral simulation is carried out according to the given parameters and the parameters are controlled. Therefore, the questionnaire is the first step of this study.

3.1 Questionnaire design and distribution

The questionnaire was meticulously designed based on a theoretical model developed from the TPB expanded a theoretical model and the theory of the DNAs framework as shown in Fig.1. The questionnaire was divided into two parts: environmental awareness and air conditioning usage behavior. The questionnaire items related to environmental awareness were designed with reference to the questionnaire designs of multiple researchers, including Xingjun Ru et al., and Lan Gao et al. [7,15]. There were a total of 14 questionnaire items. Among them, there were two options each related to environmental attitude (ATT), subjective norm (SN),

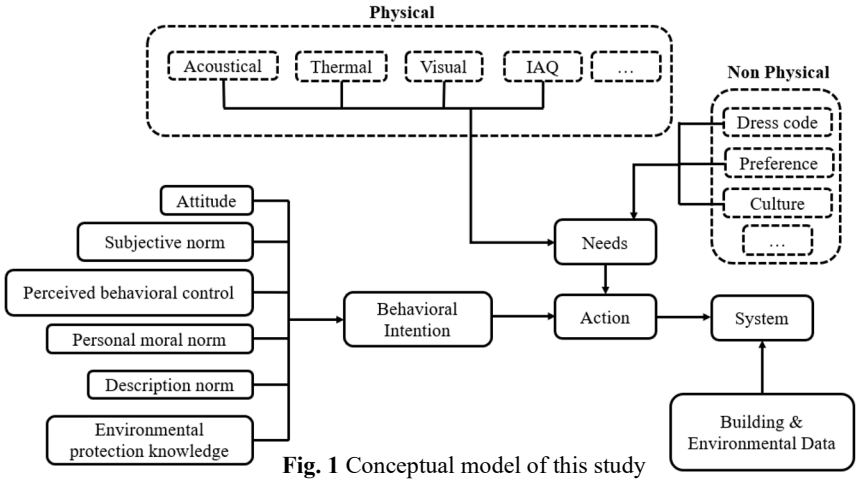


Fig. 1 Conceptual model of this study

perceived behavioral control (PBC), personal moral norm (PMN), descriptive norm (DN), environmental protection knowledge (EPK), and energy-saving behavioral intention (INT).

The questions related to air conditioning usage habits and behavior were a total of 21 questionnaire items. However, not all questions and options were used in the simulation system establishment study. Most items were measured using a Likert scale with a range from 1 to 5. In the section related to environmental psychology, a scale ranging from 1 (strongly disagree) to 5 (strongly agree) was employed for measurement. The specifics of the questionnaire are shown in Table 1.

The questionnaire was distributed through Surveroid, a specialized questionnaire distribution platform in Japan, ensuring easy access for participants, a user-friendly interface and less invalid data. The questionnaire survey began with a screening questionnaire designed to determine the respondents' primary work environment, specifically whether they worked in an office building. The screening question asked, "Which of the following options best describes your work environment?" Respondents who chose in this screening question that their work environment was primarily in an office building were selected to participate in the main survey.

3.2 Results of questionnaire

In November 2023, the questionnaire distribution was completed, yielding a total of 840 valid responses. Respondent profiles are shown in Table 2. The results of the reliability and validity analysis indicate that the Cronbach's alpha coefficients for all variables exceeded 0.6. Both the Kaiser-Meyer-Olkin (KMO) and Bartlett's tests supported the scales, as did the results of exploratory and confirmatory factor analyses. Consequently, the scale demonstrated high reliability and structural validity. Descriptive statistical analysis revealed a balanced distribution of the effective sample across sociodemographic characteristics such as gender, age, and occupation. Subsequently, statistical analysis software was employed to examine the internal and external influencing factors and mechanisms of energy-saving behaviors, providing empirical evidence and data for the development of simulation models. Simulation system construction and simulation results.

As shown in Table 3, behavioral intentions positively influence energy-saving behaviors ($P<0.01$), consistent with prior TPB-related research and our study framework. Energy-saving intentions are positively associated with summer temperature preferences ($P<0.01$) but not with winter temperature preferences($P>0.1$). Age correlates positively with summer temperature preferences ($P<0.01$), but this correlation is not observed for winter preferences ($P>0.1$), possibly due to the complexity of factors influencing winter preferences and questionnaire limitations. Room occupancy is unrelated to temperature preferences($P>0.1$) but negatively correlated with temperature change probabilities

Table 2. Profile of the respondents

		Frequency	Percent
gender	Male	557	66.3
	Female	283	33.7
age group	20~29	47	5.6
	30~39	171	20.4
	40~49	216	25.7
	50~59	236	28.1
	60~	170	20.2
total		840	100.0

Table 3. Correlations of AC use preference and other factors

	Temperature preference(16~30℃)		Probability (Change AC set temperature)	
	summer	winter	summer	winter
INT	0.21**	0.01	-0.15**	-0.13**
Age	0.18**	-0.02	0.18**	0.1**
Number of people in office	0.03	0.01	-0.11**	-0.11**

Note. **. Correlation is significant at the 0.01 level (2-tailed).
INT: energy-saving behavior intention

Table 1. Questionnaire questions & options

Categories	**Items**		**Options**
Psychological Factors	**ATT1:** The continuously increasing energy demand is a serious issue for society.		5.Strongly agree 4.Somewhat agree 3.Neither agree nor disagree 2.Somewhat disagree 1.Strongly disagree
	ATT2: I believe that energy conservation in daily life is useful for environmental preservation.		
	SN1: People who are significant in my life think that I should conserve energy wherever possible.		
	SN2: I value the opinion of people who are significant in my life when it comes to making decision on energy conservation.		
	PBC1: Convenience without compromising energy efficiency is also an important factor for me when promoting energy conservation.		
	PBC2: Whether or not saving energy is completely up to me.		
	PMN1: There is a moral responsibility to engage in energy-saving practices in everyday life.		
	PMN2: Save energy in my daily life is depending on my own moral obligation.		
	DN1: A number of employees in my company I know have participated in energy saving behavior.		
	DN2: My manager and the high-level management team have participated in energy saving behavior.		
	EPK1: The increase in greenhouse gases in the atmosphere over the past 150 years is primarily attributed to human activities.		
	EPK2: I know much about the energy-saving tips of daily life.		
	INT1: I intend to engage in energy-saving activities in the future.		
	INT2: I am going to behave pro-environmentally in the coming month to reduce my impact on the environment (e.g. by turning off the computer, printing less, using a mug etc.)		
Temperature preference	**T1(summer)**	What temperature setting do you find most comfortable in your office during summer and winter?	
	T2(winter)		
Probability of changing AC set temperature	**P1(summer)**	If you felt hot (cold) in your office 10 times during the summer, how many times out of 10 would you take the following actions? Please give the approximate number of times for changing air conditioning setting temperature. **Options(Times):** 1, 2, 3, 4, 5, 6, 7, 8, 9, 10	
	P2(winter)		
Other basic information	**Age:** Please select your age group. Options :20~29, 30~39, 40~49,50~59, 60 and over		
	Number of people in office room: In the office where you work, how many people are in the room you are in? **Options:** only for me, 2 people,3~4 people,5~9 people,10~19 people,20~49 people,50 and more than 50		
	Dress code: Tell us about the dress code in the office where you work **Options:** Formal (including uniforms), Semi-formal, Casual, Work clothes, Clothing varies widely from person to person, Other.		

(P<0.01). An independent t-test found no significant differences in temperature change probabilities and preferences based on office dress code in Japan (P > 0.1), so dress code will not impact the simulation. Gender differences were significant only for winter temperature preferences. To ensure simulation accuracy, only summer scenarios will be considered. Factors positively affecting air conditioning settings and change probabilities will be included as input values for the simulation environment.

4 Simulation system and results

The ABM described in this section was developed using the agent-based modeling integrated development environment NetLogo. The ABM is designed to simulate a full working day to depict the behavior of adjusting air conditioning set temperatures that occurs in an office setting. The model consists of two main components: agents and the environment. An agent represents an employee. The model's environment is designed to represent the workplace, including factors such as the number of people in the office and clothing requirements.

4.1 Decision-making frameworks for agent and behavior

According to the questionnaire results, it can be concluded that different levels of awareness and environmental factors have varying degrees of influence on people's inclination to change air conditioning temperatures. In the statistical analysis of the questionnaire data in this study, statistical software was used to analyze the effective positive impact of environmental awareness on behavioral intentions and the effective positive impact of behavioral intentions on energy-saving behaviors. To incorporate these influences into the Agent-Based Model (ABM), this section evaluated different models to establish the relationship between the age, awareness, room occupancy, and air conditioning temperature preference of office occupants and their probability of changing the air conditioning settings. After applying questionnaire data to various models such as linear regression, decision trees, random forests, and support vector machines (SVM), metrics like Mean Squared Error (MSE) and R-squared were used for evaluation. Ultimately, the linear regression model was chosen for its higher explanatory power and ease of interpretation and explanation. The relationship data were integrated into the ABM construction to serve as the basis for decision-making when individuals make behavioral changes. The linear regression model used to determine environmental awareness and behavior of changing AC set temperature is shown in Equations (1), (2).

$$Y_{INT} = \beta_1 + aX_{ATT} + bX_{SN} + cX_{PBC} + dX_{PMN} + eX_{DN} + fX_{EPK} \quad (1)$$

$$P = \beta_2 + gY_{INT} + hX_{Age} + iX_{People} \quad (2)$$

Where Y_{INT} is the intention to engage in energy-saving behaviors; X_{ATT}~X_{EPK} are environmental environmental awareness; P is the probability of the behavior of changing the AC setpoint; β_1, β_2 are constant terms. X_{ATT}~X_{EPK} will be used as inputs for simulation; X_{Age} is the age of people in office and X_{People} is the number of people in office. These two formulas use the questionnaire data to calculate the individual coefficients and are written into the code of the Netlogo platform for calculating the behavioral decision-making probabilities.

The simulation initiates at the start of the working hours, taking into accounts the time required for air conditioning temperature adjustments and the response time of individuals. It is configured to make a decision every half an hour regarding whether the air conditioning temperature setting should be altered. The primary criterion for this decision is whether the temperature setting aligns with the comfort level perceived by individuals. Additionally, based on the questionnaire analysis results, an assessment of the environmental conservation psychological influence is incorporated into this decision-making process. As individual comfort temperatures vary, and this study solely relies on questionnaire data, the preferences of individuals for temperature settings gathered from the survey are used as a measure of satisfaction in the simulation. A normal distribution of comfort levels was constructed based on the percentage of each setting's temperature preference in the questionnaire data (shown in Fig. 2) and included in the simulations. The probability density function (PDF) of a normal distribution formula is as follows:

$$f(T) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(X-\mu)^2}{2\sigma^2}} \quad (3)$$

Where $f(T)$ represents the satisfaction; T represents the air conditioner set temperature, and ranges from 16°C to 30°C. σ depends on the T's range, for T above 25°C, σ=3.5, for T below 25°C, σ=1.5.

The closer the temperature setting is to the comfort level, the lower the probability of adjusting the AC setpoint becomes. If the temperature changes, the new set temperature is calculated and output, continuing the simulation. If not, the current temperature is output. The assessment ends at the end of working hours, and all recorded data, including temperature changes, are then analyzed. The process of simulating people's air conditioning decisions is illustrated in Fig. 3.

4.2 Introduction of NetLogo system setting

Based on the statistical results, the summer office environment, which has a stronger correlation with each factor, was chosen as the simulation scenario for this study. The simulation system built using NetLogo is

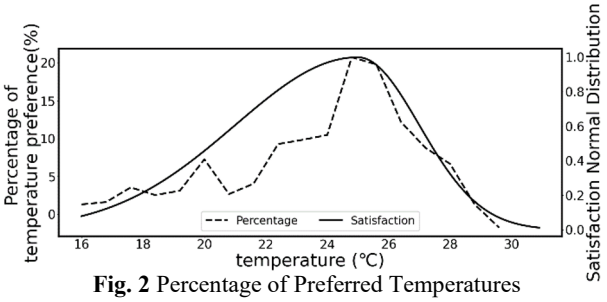


Fig. 2 Percentage of Preferred Temperatures and Normal Distribution of Satisfaction

depicted in Fig. 4. This system takes both physical and psychological factors into account, with the following components explained:

(1) The "view" section in the interface allows for observing the movement of individuals.

(2) The simulation settings and start button are responsible for updating settings when input parameters change. Clicking "setup" updates the configuration, while "go" initiates the simulation.

(3) Based on questionnaire analysis, this study found that the number of occupants affects the probability of turning lights on/off. Following a T-test analysis in statistical software, the number of occupants was categorized into three scenarios with the most significant probability differences: 1-2 occupants, 3-20 occupants, and over 20 occupants.

(4) In order to make the software widely applicable and suitable for simulating different office buildings, this study has added work time sliders and initial air conditioning temperature sliders to the user interface. The sliders for moving the start and end times of work can alter the simulated work duration, while moving the initial temperature slider adjusts the default initial temperature when work begins.

(5) The temperature graph in the interface provides a visual representation of changes in air conditioning temperature during the simulation.

(6) According to the research by Elie Azar and others, occupants in commercial and public buildings can be categorized into high energy consumers (HEC), medium energy consumers (MEC), and low energy consumers (LEC) to observe differences in energy consumption levels [16]. Therefore, in this study, the population is also divided into three groups based on their awareness levels. They are the high, medium and low environmental awareness group. Each group's awareness input includes the six environmental protection psychological factors from the extended TPB theory. Additionally, since the questionnaire analysis results indicate a significant correlation between age and the probability of air conditioning adjustments, each group is further subdivided into three age categories: young, middle-aged, and old-aged, with varying numbers of participants entered via sliders. In order to see a significant difference, all people were set to be the same age and level of consciousness in each simulation. Apart from these eight sections in the interface, including the regression models mentioned in Chapter 4.2, all other data and information are imported into the NetLogo code interface.

4.3 Results of simulation

The simulation of office air-conditioning usage in summer is divided into 2 cases, each case is divided into three scenarios (different number of people in the room), and each case has a different initial setup temperature, which is the default setup temperature when the air conditioner is turned on after the start of the work. case1

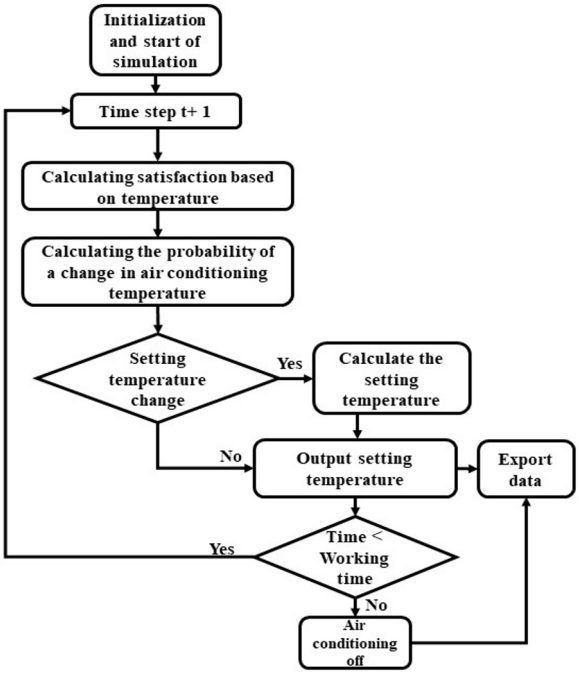
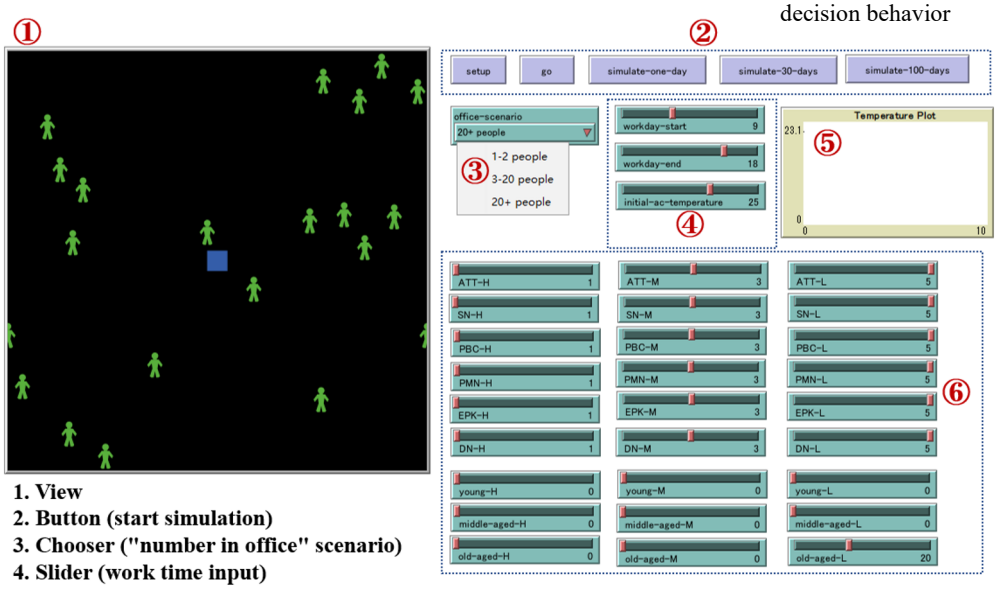


Fig. 3 Process of simulating people's air conditioning decision behavior



1. View
2. Button (start simulation)
3. Chooser ("number in office" scenario)
4. Slider (work time input)
5. Plots(change in temperature)
6.Slider (Consciousness Input and Age Input for "High, Medium and Low Consciousness Groups")

Fig. 4 The view of simulation system using NetLogo

has an initial setup temperature of 28°C, and case2 has an initial temperature of 25°C. 28°C is the recommended summer air conditioning setting temperature by the Japanese Ministry of the Environment [17], and 25°C was the optimal setup temperature for the questionnaire results. The input data for the simulation include the number of office occupants, initial set temperature, working hours, age and consciousness. The specific input data format and simulated case settings are shown in Table 4. All the calculations about inputs data are based on the mathematical model established by Equations 1, 2, and 3 mentioned in the previous 4.1chapter.

Considering the uncertainty of the simulation results, the output is the average value per day after each scenario has been simulated 200 times, which is equivalent to 200 days of simulation. This includes the average number of daily changes in the air conditioning temperature in the office, the average number of temperature changes per person per day, and the average temperature change in the air conditioning settings. The simulation results are shown in Fig.5.

Based on the findings presented in Figure 5, the following conclusions can be drawn:

a) As shown in Fig.5 (a) regarding the average daily number of temperature setpoint changes, when the initial temperature setting is 28°C, the number of changes increases with a higher number of occupants in the room. Except for the elderly group in the 20-person office, lower awareness leads to more frequent air conditioning changes. In each room, the middle-aged group has the highest average daily frequency of changing the air conditioning setting.

b) Fig.5 (b) shows the average number of times per person per day to change the temperature setting. When the initial temperature setting is 28°C, a higher number of occupants in the room leads to fewer changes per person, especially in the 2-person and 10-person scenarios, where the difference is most pronounced.

c) Fig.5 (c) shows the average change in air conditioning temperature. When the initial setting is 28°C, there is no clear correlation between awareness levels and the change in temperature settings. However, the elderly group tends to have a slightly higher average temperature change compared to the young and middle-aged groups.

d) Fig.5 (d) illustrates the average daily number of temperature setpoints changes. When the initial temperature setting is 25°C, there is a significant reduction in the number of temperature changes. The trends in the impact of age and awareness on the frequency of air conditioning changes are similar to those observed when the initial setting was 28°C.

e) Fig.5 (e) displays the average change in air conditioning temperature. When the initial setting is 25°C, there is no significant difference in the average temperature change compared to when the initial setting was 28°C,shown in Fig.5 (c).

5 Discussion

The main purpose of this study is to establish a tool for analyzing office air conditioning usage by exploring the relationship between awareness and behavior and conducting an analysis of air conditioning usage. First, through a questionnaire, this study obtained data on awareness and behavior, and through analysis, statistical relationships between awareness, external factors, and air conditioning usage behavior were determined. Based on the statistical results, this study selected summer office environments as the simulation scenario due to their stronger correlation with various factors.

According to the questionnaire results, there is a positive correlation between energy-saving intention and summer air conditioning temperature preferences. However, this correlation is not reflected in the simulation results as shown in Fig.5 (c) and (e). This discrepancy may be due to the simulation input data not being limited to environmental awareness alone but also including other influencing factors such as age, room occupancy, and temperature preferences. The combined effects of multiple influencing factors may affect the simulation environment's awareness and summer air conditioning temperature preferences.The questionnaire results also indicated a significant positive correlation between age and summer air conditioning temperature settings ($P<0.01$). In the simulation results shown in Fig. 5(c) and (e), for scenarios with the same number of occupants and awareness levels, the average temperature settings in the elderly group were slightly higher than in the other two groups, consistent with the questionnaire results. The ASHRAEA handbook also states that all men and women over the age of 40 should choose an effective temperature 1°C higher than thecomfort temperature required by those below that age [18]. Therefore, in offices with a higher average age, setting a higher air conditioning temperature can improve energy efficiency while providing greater questionnaire analysis regarding the influence of office comfort to a larger number of people. However, in the attire on temperature change probability and preferences, no significant differences were found among different types of clothing. This contrasts with the results of the study of Sloot et al. [19], which found

Table4. Input data types and setting conditions of simulated cases

Input data	Type and range of input data	Setting of case 1 **Fig 5.** (a)~(c)	Setting of case2 **Fig 5.** (d)(e)
Number of people in office	Optional scenarios: 1~2 people, 3~19 people, above 20 people	(1) 2 people; (2)10 people; (3)20people	(1) 2 people; (2)10 people; (3)20people
Initial temperature Setpoint	16~30℃	28℃	25℃
Work time	Start: 0:00~24:00; End: 0:00~24:00	Start: 9:00; end: 18:00	Start: 9:00; end: 18:00
Age	Young, middle-aged, old-aged	Young (average 30); middle-aged (average 40); old-aged (average 60)	Young (average 30); middle-aged (average 40); old-aged (average 60)
Awareness	ATT, SN, PBC, PMN, DN, EPK (range 1~5)	Low group: average 1 Middle group: average 3 High group: average 5	Low group: average 1 Middle group: average 3 High group: average 5

a significant correlation between clothing and summer temperature

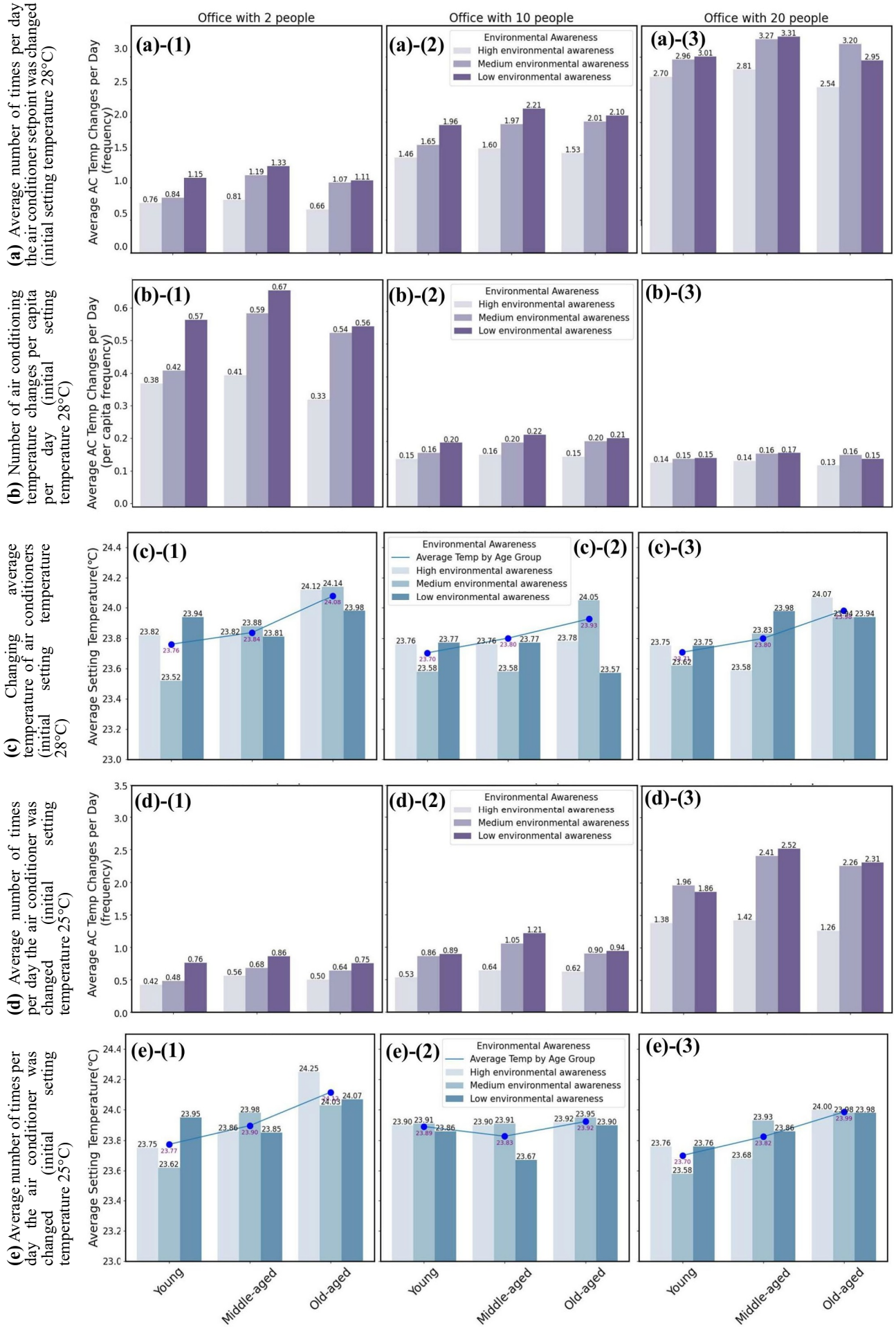


Fig. 5 Results of simulation

preferences in German office buildings. This study suggests that the cultural differences between Germany and Japan in office attire and behavior may have contributed to these differences.

In the simulation results, in different office environments with different age groups, the stronger the occupants' environmental awareness, the fewer times they adjusted the air conditioning temperature. This suggests that implementing measures to raise environmental awareness in office buildings, such as energy-saving lectures and environmental awareness campaigns, could be effective in improving energy efficiency in building air conditioning systems. The simulation results also show that in scenarios with more occupants, the per capita number of temperature adjustments is lower, indicating that the number of people in the office has a significant impact on air conditioning usage. Therefore, when designing office spaces, increasing multi-occupant open office spaces may be beneficial for reducing air conditioning energy consumption. In scenarios with different initial temperature settings, the number of times the air conditioning was changed was significantly higher at 28°C compared to 25°C, while the average set temperature was almost the same for both settings. Because frequent air conditioning on-off cycles can increase energy wastage, when setting the initial office temperature, factors beyond energy efficiency considerations, such as behavioral changes due to different comfort levels, should also be taken into account.

6 Conclusion

This study, based on environmental psychology, established a simulation system for air conditioning usage habits in Japanese office environments using data obtained through a questionnaire survey. Building upon the literature review, this paper conducted research based on the TPB theory and DNAs framework to determine the relationships between occupants' environmental psychology, age, heat preferences, and air conditioning usage habits. Through the Agent-Based Modeling (ABM) method, a simulation system was developed to simulate occupants' air conditioning usage patterns. The results indicate that in office buildings, environmental psychology, age, and the number of occupants in a room all have a significant impact on individuals' air conditioning usage behavior. This study's integration of awareness and behavior modeling holds novelty and originality and is of significant importance for energy management in various office buildings. Depending on occupants' awareness and characteristics in different office buildings, managers can strengthen energy management through various forms of environmental psychological interventions and environmental design.

However, this study still has some limitations. Real-world office buildings are more complex than the system established in this study. Factors like interpersonal influence and different job types in various office buildings affect air conditioning usage differently. In future research, this study plans to conduct validation experiments in actual office buildings, observe and gather more data on factors influencing air conditioning usage behavior, and validate the simulation results. Additionally, future simulations will not be limited to air conditioning behavior but will establish models for various behaviors to explore more effective methods for reducing building energy consumption and improving occupants' comfort in office buildings.

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