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Thermal comfort and adaptive behaviour of the elderly: a systematic review

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ABSTRACT

Thermal comfort is linked to our health, well-being, and productivity. The thermal environment is one of the main factors that influence thermal comfort and, consequently, the productivity of occupants inside buildings. Meanwhile, behavioural adaptation is well known to be the most critical contributor to the adaptive thermal comfort model. This systematic review aims to provide evidence regarding indoor thermal comfort temperature and related behavioural adaptation. Studies published between 2010 and 2025 examining adaptive behaviour of the elderly people. According to the above literature review on the adaptive behaviour of the elderly, opening windows or closing windows, turning on or off air-conditioner and clothing insulation adjustment is the most common strategy for the elderly to adopt indoor thermal environment. In addition, older people tend to adopt indoor thermal environments by some behaviours without financial expenditure, such as opening or closing windows and clothing insulation adjustment. However, the elderly regard turning on the air conditioner as a priority strategy in the public space.

1. Introduction

The thermal comfort of the elderly is negatively impacted when exposed to temperatures that deviate from the ideal range, whether it is above or below. Lower temperatures have been shown to have a negative impact on physical dexterity and agility, whereas higher temperatures have been seen to impede older people fatigued and irascible [1]. The adaptive approach to the elderly is based on field observations of individuals in everyday life and is immediately applicable to everyday living conditions. It is a behavioural approach based on the observation that individuals in everyday life are not passive in their interactions with their surroundings but rather seek to improve their comfort whenever given the chance and time. They do this through modifying their clothing, activities, and posture, as well as their environmental temperature [2]. The principal pathways via which adaptive regulatory actions occur are shown in Figure 1.

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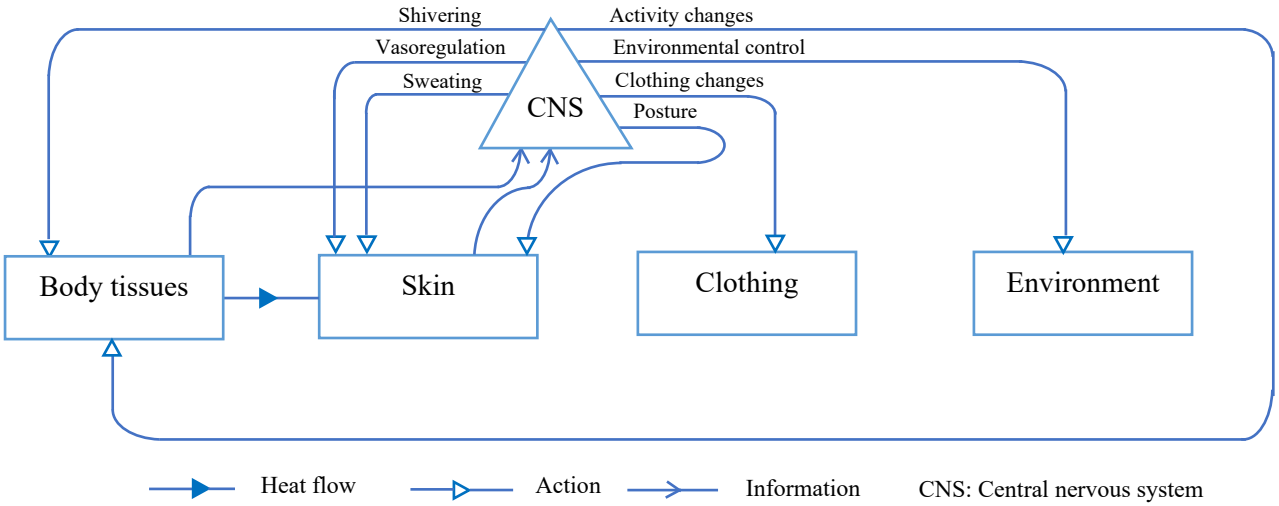

Fig. 1. Thermal comfort as a component of a complex adaptive self-regulating system

Brager and De Dear [3] categorised the manner in which individuals adapt to their surroundings into three categories: physiological adaptation, psychological adaptation, and behavioural adjustment. Physiological adaptation refers to all physiological changes that occur in the human body in response to heat (cold) stimulation, resulting in a progressive diminution of the stress response. There are two categories such as genetic adaptation and adaptation or habituation. The primary manifestations of the human body's physiological adaptation to its thermal environment are temperature regulation, cardiovascular and cerebrovascular alterations (such as a decrease in heart rate and an increase in blood volume and peripheral blood flow) and the function of perspiration. Psychological adaptation describes the extent to which people's routines and expectations influence their sensory information and responses. Adaptive models recognise the potential role of feedback cycles, in which a person's past and present thermal experiences in indoor and outdoor environments directly influence his thermal response and acceptance. All adjustments, whether intentional or unintentional, made by the behaviour regulator, including: (1) personal adjustments that change personal parameters to suit the surrounding environment, such as adjusting clothing, activity level and posture, drinking hot or cold beverages, moving to different places; (2) Technical or environmental adjustments when conditions permit, such as opening and closing windows or shading facilities, switching fans or heating equipment, controlling a thermostat; and (3) dietary adjustments when conditions permit, such as adjusting a person's diet or adding or subtracting certain foods [3].

To ascertain changes in occupant behaviour and the degree of thermal comfort inside a building, several research have been conducted [4-6]. The study population, climatic features, architectural type, and ventilation strategy all affect the outcomes.

To our knowledge, no extensive study has investigated an overview of indoor thermal comfort and corresponding adaptive behaviours of the elderly people. This systematic review aims to provide evidence on the temperature range in which the elderly experience thermal comfort across diverse indoor settings. The review's findings may provide a clearer insight into the adaptive behavioural preferences of the study population in achieving thermal comfort.

2. Methodology

In order to conduct this study, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) review approach was used [7]. This methodology is designed for systematic reviews and meta-analyses. Unlike traditional methods, systematic literature reviews are transparent and methodical in their pursuit of high-quality research on specified subjects. Notwithstanding the biases associated with the systematic literature technique, including the use of limiters (temporal, database, and journal limits), the employment of many databases facilitates the acquisition of a substantial number of articles aligned with the study objectives. Tranfield *et al.,* [8] delineate the procedures for formulating research questions, identifying relevant studies, selecting and appraising them, doing analyses and evaluations, and then reporting and using the results.

2.1 Searching Procedure

Science Direct and the Web of Science are two of the most esteemed and comprehensive sources from which the data was obtained. These databases include research articles from diverse peer-reviewed journals. We determined that Web of Science and Science Direct are the optimal choices, since they are predominantly used by bibliometric analysts [9]. The search technique used many engines, with Google Scholar as the main focus. Refer to Table 1 for a compilation of the databases that were examined and consult Figure 2 for a flowchart depicting the whole article selection procedure.

Table 1
Searching keywords

Search Clouds	Google scholar, Science Direct, Web of Science
Keywords	Adaptive behaviour, elderly people, building Adaptive strategy, the elderly, construction Senior citizen, residential buildings, adaptive behaviour Older adults, The seniors, occupant addressing strategies Occupant adaptation, nursing house, the elderly Older people, nursing institution, adaptive behaviour Adaptive strategies of older occupant, indoor built environment educational buildings

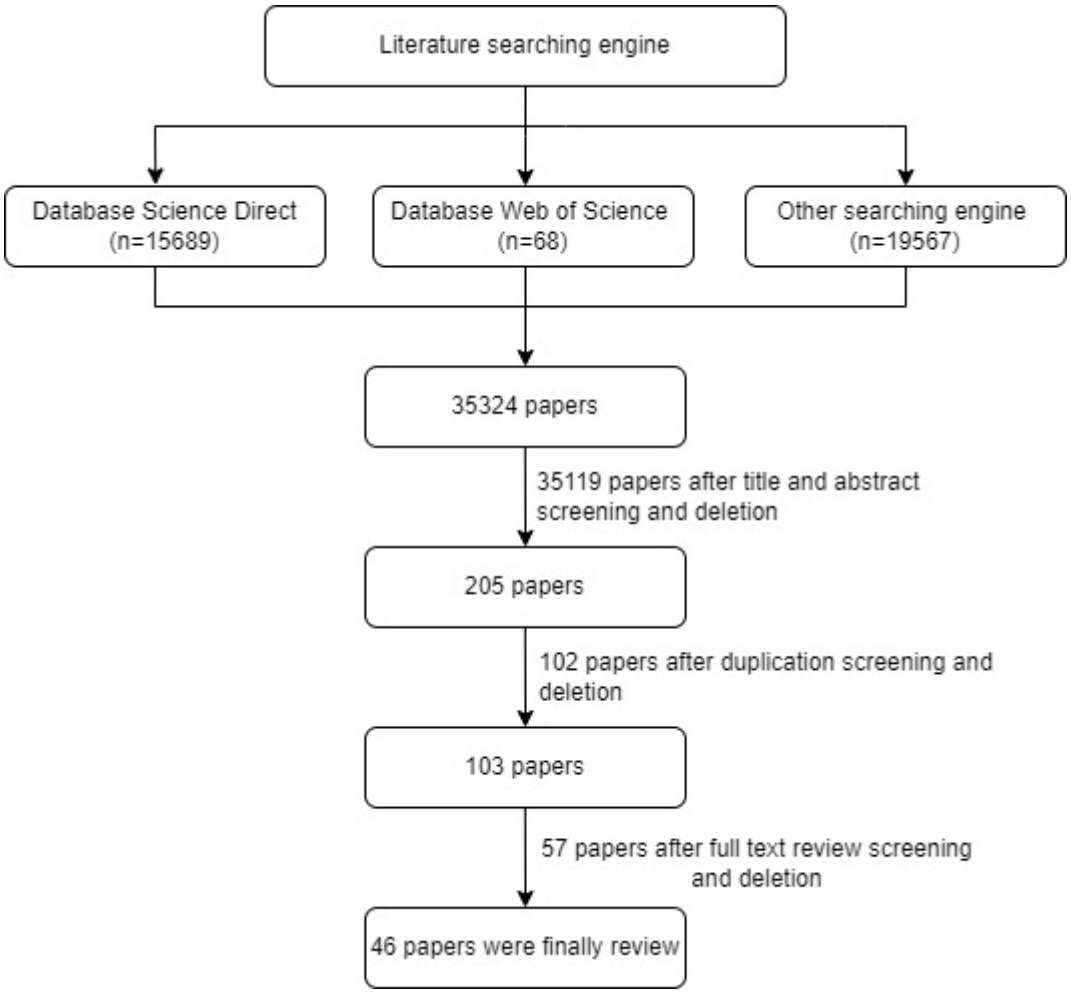

Fig. 2. Flowchart of the paper selection process

2.2 Paper Selection Process

We prioritised the most notable articles throughout our selection process. We used impact and citation measures with the Clarivate journal rating to locate these publications. The journals were categorised as A, B, or C for content categorisation purposes. These periodicals were considered trustworthy. The impact and citation metrics of journals facilitated the identification of esteemed publications for which Clarivate Analytics lacked appropriate classification. Subsequently, these publications were meticulously examined for articles and data.

Articles were identified and assessed based on the inclusion and exclusion criteria. We established a time range for papers inclusion from 2010 to 2025. The first exclusion was predicated on the database's discipline, a required measure due to the substantial volume of articles identified; this facilitated the retention of articles pertinent to adaptive behaviour, performance, or efficiency. Furthermore, at this juncture, non-peer-reviewed papers are eliminated, followed by the exclusion of those included in the literature review. The examination of subsequent papers facilitated an assessment of the study objectives. The incorporation of keywords in the title and abstract constituted a component of the screening procedure. Only papers that passed the final phase of review and screening were included in the research dataset.

The last phase of the analysis involves synthesising the papers and documents based on content, study type, and research domain. The research of the full-text article included many steps. The first selected categories include publication, theories, kinds of study, and analytical methodologies. This was executed in accordance with the protocols defined by Siva *et al.,* [10]. The examination included the conceptualisation and adaptation strategies used by diverse institutions. We end by explaining the study's findings and highlighting any deficiencies in the current literature.

3. Results

3.1 Adaptive Behaviour of Elderly People in Buildings

In buildings, adaptive behaviour is an important means by occupants to maintain comfort when feeling thermally discomfortable [11-13]. In this section, therefore, common adaptive behavioural actions that elderly people do in buildings have been reviewed, together with potential influential factors.

3.2 Window Opening Behaviour

In buildings, window opening behaviour has been confirmed as a major adaptive behaviour for elderly people [14-18]. In a study carried out by Hwang and Chen [14] including 87 older adults (average 71 years old) in residential buildings in Taiwan, it was observed that opening windows accounted for 90% of all adaptive actions in summer. This number is similar to that observed in another study carried out in Shanghai, China, by Jiao *et al.,* [16], which is 94.9%. In Detroit, US, White-Newsome *et al.,* [15] observed 15 different adaptive actions of 30 older adults, such as opening windows, changing clothes and turning on air-conditioner *et al.,* and from the study they suggested that opening windows was the most common adaptive behaviour, agreed by both Giamalaki *et al.,* [17], who conducted a questionnaire survey with 30 senior citizens in Crete, Greece, and Williams *et al.,* [18], who monitored 51 older adults in public space in Cambridge, Massachusetts. Giamalaki *et al.,* [17] have explained that a possible reason of preferring opening windows to adjust indoor environment by elderly people is a consideration of cost on energy consumption as this adaptive action is cost-free, comparing to other mechanical or air-conditioning solutions.

In existing studies, two factors have been suggested as having direct influence on elderly people's window operation in buildings, and they are indoor temperature and outdoor temperature. The influence from outdoor temperature has been confirmed in Hwang and Chen [14]. The common effect of outdoor and indoor temperature has been proved by Jiao *et al.,* [16], through field measurements and questionnaire survey with 672 elderly adults (over 70 years old); They found there were positive correlations between the proportion of opening windows and the prevailing mean outdoor air temperature as well as indoor temperature. For indoor temperature, its influence was confirmed in White-Newsome *et al.,* [15], through the research carried out in the United States including 30 senior citizens in residential houses. Specifically, the odd of opening windows increased when indoor temperature above 21.2 ℃, the odd decreased when above 29.4℃.

Many researchers have tried to explain the potential reasons of opening windows by elderly people, such as promoting indoor air velocity [16] or natural ventilation [19], reducing indoor temperature [16] or reducing indoor air pollutants [20]. A common reason proposed by researchers is to promote indoor air velocity. For example, Jiao *et al.,* [16] have realized

that opening windows would have a significant impact on the indoor air velocity during summer, i.e. 0.21m/s with open windows and 0.1m/s with close windows. This research conclusion was consistent with that of Shi *et al.,* [19] research investigated 10 residential buildings in Nanjing, China; they found that the common method for the aged people was to open windows to obtain a naturally ventilated indoor thermal environment. Another reason for opening windows is to reduce indoor air temperature seasonal. Jiao *et al.,* [16] recognized that opening window could exert an essential impact on indoor operative temperature during summer, i.e. 29.7℃ with windows close and 27.9℃ with windows open. However, opening windows was almost no impact on indoor air temperature during winter, i.e. 13.1℃ with close windows and 13.2℃ with open windows. Opening windows is also an effective strategy for the elderly to reduce indoor environmental pollutant. According to research conducted by Sharpe *et al.,* [20] in 100 older adult's homes in Glasgow, Scotland, they found the decreased numbers of Gram-negative organisms had close relationship with high frequency of opening windows in some elderly's homes, specifically, with the increase frequency of opening windows, the presence of Gram negatives decreases by 0.97 unit.

Table 2
Literature review on the influencing factors of window opening in the elderly

Behaviours	Factor	Researchers	Reference
Opening windows	Indoor temperature	Hwang and Chen	[14]
Opening windows	Outdoor temperature	Jiao *et al.,*	[16]
Opening windows	Outdoor temperature	White-Newsome *et al.,*	[15]

3.3 Air Conditioner Adjustment Behaviour

The impact of air-conditioners on the elderly's daily life has been evaluated in many existing studies in Table 2. From a questionnaire survey and interview conducted in Greece, Giamalaki *et al.,* [17] suggested that one of the most common adaptive behaviours of the elderly is turning on air-conditioner in the heating season and cooling season. Basu and Samet [21] also examined this adaptive behaviour in a study conducted in 42 households in Eastern America. They found air conditioner is the most common heat adaption measure used by the elderly, account for 88%. Similarly, Hansen *et al.,* [22] found that most Australian seniors prefer to turn on the air conditioner to adjust to the indoor thermal environment based on the research by telephone survey conducted in South Australia (SA) and Victoria, Australia, the report showed that the proportion of these older adults was 84.0% in SA and 73.1% in Victoria respectively.

Economic consideration and cognitive impairment of the elderly are two main factors to influence the air conditioner adjustment behaviour. If the elderly need to afford the energy cost of turning on the air conditioner, then economic consideration will affect the behaviour of older adults, otherwise it will not, which have been confirmed in many studies [18, 22, 23]. According to focus group and interview survey by Hansen *et al.,* [22] in Adelaide, Australia, older people reluctant to turn on air-conditioners in their residence because of the high energy costs. Based on the focus group study with 49 elderly people by Van Hoof *et al.,* [23] in Australia, even in extreme heat weather, many older adults mentioned they would rather go to public spaces such as shopping malls or libraries to cool down themselves than staying in their homes; others said they would go to relative's home to avoid the energy cost of

turning on air conditioners. In the study by Williams *et al.,* [18], they found 79.2% and 92.6% of the elderly in the central air-conditioners and the non-central air-conditioners groups reported that energy expenses were not a factor restricting the utilization of air-conditioners, because the energy cost could be covered by receiving full energy subsidies for aged people. Cognitive impairment is another factor of influencing elderly people to adjust air-conditioner, which confirmed by Daanen *et al.,* [24] and Hansen *et al.,* [25]. Due to the cognitive impairment of the elderly, it is difficult for them to operate the complex air conditioning system [24]. Hansen *et al.,* [25] found that unfamiliar with the operation instructions of some complicated air conditioners (modern reverse cycle air conditioners), it may be troublesome for some elderly people to turn on the air conditioners.

Table 2
Literature review on the influencing factors of turning on air-conditioner in the elderly

Behaviours	Factor	Researchers	Reference
Turning on air-conditioner	Economic consideration	Hansen *et al.,*	[25]
Turning on air-conditioner	Economic consideration	Sheridan	[26]
Turning on air-conditioner	Economic consideration	Van Hoof *et al.,*	[23]
Turning on air-conditioner	Cognitive impairment	Daanen *et al.,*	[24]
Turning on air-conditioner	Economic consideration	Soebarto *et al.,*	[27]

Improving thermal comfort efficiency is the potential reason for the older adults to turn on air-conditioner [28, 29]. According to physiological research by Spaargaren [28], it was easier to meet the thermal comfort range of established standards by turning on air-conditioner. And turning on an air-conditioner is a straightforward method to improve thermal efficiency in some households, especially for some low thermal efficiency homes [29]. Therefore, some associations advocate installing and turning on air-conditioners in the homes. For example, in order to avoid heat stress and achieve the thermal comfort of the elderly, the installation of air conditioners in their homes is recommended by the Australian Medical Association [30].

3.4 Clothing Insulation Adjustment Behaviour

Clothing insulation adjustment played a notable role in the thermal adaption of the elderly people in many studies [14, 16, 17] in Table 3. Hwang and Chen [14] found that adjustment in clothing is the most common adaptive behaviours; among all the behaviours of the older adults to alleviate themselves from thermal discomfort, the proportion of clothing insulation adjustment is 38% in the summer and 64% in the winter respectively. This is consistent with the study by Giamalaki *et al.,* [17], they also found the most common strategies of the elderly is clothing adjustment in the winter. Similarly, according to the research by Jiao *et al.,* [14], the percentage of the older adults chose to adjust their clothing insulation to adapt to the thermal environment is 95.6% in the winter and 94.9% in the summer respectively. Additionally, some studies explore clothing adjustment behaviour of the elderly in the summer [21, 25, 31]. Hansen *et al.,* [22] indicated a large number of older citizens wore cool

and light clothing in the summer. Nitschke *et al.,* [31] found that older people who changed their behaviour by wearing summer clothing account for 91.4%, based on the research conducted by 499 telephone survey in South Australia. Basu and Samet [21] conducted research in Maryland and found wearing less clothing is the most common strategy for the elderly to adapt to ambient heat exposures.

Table 3
Literature review on the influencing factors of changing clothing in the elderly

Behaviours	Factor	Researchers	Reference
Clothing insulation adjustment	Indoor temperature	Hwang and Chen	[14]
Clothing insulation adjustment	Subjective judgement consideration	Hwang and Chen	[14]
Clothing insulation adjustment	Indoor temperature	White-Newsome *et al.,*	[15]

Indoor temperature and judgement of the elderly are two factors to influence on older adult's clothing insulation adjustment behaviour. Huang and Chen [14] found the influence from indoor temperature as well as subjective judgement of the elderly. The influence from indoor temperature also confirmed by White-Newsome *et al.,* [15]. In the measurement and questionnaire survey carried out by Huang and Chen [14], when the indoor environment was thermally uncomfortable, they found adjustment in clothing is the adaptation strategy for the elders to adopt. Furthermore, in the same research, the elder's subjective judgment is another drive to improve thermal comfort by the mean of changing clothing insulation [14]. In addition, White-Newsome *et al.,* [15] found the odds of clothing insulation adjustment were lower as indoor temperature increased.

3.5 Other behaviours and factors

Other behaviours of the elderly and influencing factors have been evaluated by previous studies, including tuning on electrical fans [14, 15, 17], opening blinds and curtains [27, 31] and turning on heaters [17, 27]. The influencing factor of turning on electrical fans include economic consideration and indoor temperature. The influence from economic consideration have been proved by Giamalaki *et al.,* [17]; Hwang Indoor temperature was confirmed to have a direct influence on open blinds and curtains by Nitschke *et al.,* [31] and Soebarto *et al.,* [27]. Giamalaki *et al.,* [17] and Van Hoof *et al.,* [23] confirm the economic consideration of the elderly have an impact on turning on heaters. Giamalaki *et al.,* [17] found that turning on fans is the most common behaviours for the elderly in summer due to economic considerations. Hwang and Chen [14] found the common strategy for the elderly is the use of electrical fan, and the influencing factor in turning on fans is indoor temperature. The results are consistent with the research by White-Newsome *et al.,* [15]; specifically, they found the odds of turning on fans had increased when the indoor temperature above 23.8℃. In addition, some previous studies indicated that taking more fluid is one category of adaptive behaviour for the elderly in summer through questionnaire survey without mentioned any influencing factors [18, 21, 25, 26, 27, 31]. Apart from turning on electrical fans and drinking fluid in summer, Nitschke *et al.,* [31] found older adults adopt indoor thermal environment by opening or closing blinds and curtains. Soebarto *et al.,* [27] also found older people prefer to open curtains to admit

solar gain in winter and close curtains to reduce solar gain in summer. Moreover, some existing studies examined that turning on heaters is the behaviour to achieve thermal comfort by the elderly due to the economic consideration [17, 27].

Table 4
Literature review on the influencing factors of other behaviours in the elderly

Behaviours	Factor	Researchers	Reference
Turning on electrical fan	Economic consideration	Giamalaki *et al.,*	[17]
Turning on electrical fan	Indoor temperature	Hwang and Chen	[14]
Turning on electrical fan	Indoor temperature	White-Newsome *et al.,*	[15]
Opening or closing blinds and curtains	Indoor temperature	Nitschke *et al.,*	[31]
Opening or closing blinds and curtains	Indoor temperature	Van Hoof *et al.,*	[23]
Turning on heaters	Economic consideration	Giamalaki *et al.,*	[17]
Turning on heaters	Economic consideration	Van Hoof *et al.,*	[23]

4. Conclusion

The current research revealed that the adaptive behaviours that older people employed to stay warm in cold weather or cool in hot weather were complex and influenced by a large number of issues including the elderly's preferences and experiences, indoor temperature and outdoor temperature, as well as their economic considerations. According to the above literature review on the adaptive behaviour of the elderly, opening windows or closing windows, turning on or off air-conditioner and clothing insulation adjustment is the most common strategy for the elderly to adopt indoor thermal environment. In addition, tuning on electrical fan, opening or closing blinds and curtains, as well as turning on heaters of older citizens also investigated in some existing research. Regarding influencing factors, if the elderly need to meet their thermal comfort conditions through personal financial expenditure, they will be very cautious in adopting adaptation behaviours. Therefore, older people tend to adopt indoor thermal environment by some behaviours without financial expenditure, such as opening or closing windows and clothing insulation adjustment. However, the elderly regard turning on air-conditioner as a priority strategy in the public space.

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