Developing the Methodology to Investigate the Thermal Comfort of The Elderly for Sustainable Living in Hot-Humid Thailand

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Abstract
Gaining thermal comfort is one of the main requirements for housing and the ways in which thermal comfort can be obtained closely relate to sustainability. This paper describes how a survey instrument was designed to measure the physiological and psychological condition of the elderly in the hot-humid climate zone with a view to enhancing living conditions. Participants in the research were 60 years old or more and lived in retirement homes in Thailand. The fieldwork was conducted in three phases - an exploratory survey, instrument development, and pilot survey. The exploratory survey was conducted in Bangkok and Chiang Mai by interviewing 47 participants. The results show that both physical and mental health levels of the elderly affected their thermal perceptions as well as culture influencing adaptive behaviour. The exploratory survey was adjusted to account for apparent perception difficulties.

After developing the main instrument, a pilot survey was conducted in Bangkok to test several variables relating to personal matters, for example, health condition, thermal perception and adaptive behaviour. The research found that the education level of the elderly influenced their understanding of the questions and their capacity to answer them. However, a series of graphics were introduced to support the questions which helped responses to the survey considerably.

Keywords: methodology, thermal response, elderly, hot-humid climates

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1. Introduction

What does thermal comfort for sustainable living mean for the elderly in hot-humid climates? First, a sustainable design (Brawley, 2006) means several generations should be comfortable in the same house, including the elderly. For the elderly, thermal sensitivity changes gradually, so that they become less sensitive to heat (Huang, Wang and Lin, 2010; Ohnaka et al., 1993; Smolander, 2002) and much more sensitive to draughts (Sarkissian, 1986). Secondly, since the climate appears to be changing, improved design for thermal comfort should cover both hotter and cooler changes of environment. The IPCC (2007) confirmed the average temperature in South-East Asia is expected to increase 3-5°C in a century. It means that the vulnerable people such as the elderly would suffer greatly from heat stress in hotter summers. The elderly are also usually conservative which can lead to constraints on adaptive behaviour. However, there is limited research on the thermal comfort of the elderly in these climates. Thermal comfort studies in hot-humid Asia have been conducted in Thailand, Malaysia, Indonesia and Singapore, but none focuses on the elderly. Since there has been little consideration of housing design for the aged, elderly housing may become less comfortable over the next few decades. Therefore, research on the thermal comfort of the elderly and their physiological and psychological responses to excess heat, should necessarily concentrate on this area.

The surveys of thermal comfort and the responses of the elderly are presented in this paper. Drawing on the existing literature, the research responds to the question: 'which factors should be considered in conducting thermal comfort surveys of the elderly?

1.1 Context of the survey

Two retirement homes in Bangkok and four in Chiang Mai, Thailand were visited. These homes are in the government sector which provides social welfare to low income elderly who are without care-givers. There were 47 participants in the exploratory survey and six participants in the pilot survey.

With a difference in latitude and altitude, the temperature profile in both cities is slightly different. Bangkok is located in 13°45'N and 0 m. above sea level, whereas Chiang Mai city is at 18°47'N and 320 m. height. Given these differences, mean minimum to maximum temperatures in Bangkok ranged from 24.9-33.3°C, with the highest recorded temperature at 40.2° (Thai Meteorological Department, 2001). Although Chiang Mai is further from the equator and has a lower mean minimum-maximum temperature than Bangkok at 20.8-32.2°C, its 30-year highest recorded temperature is 42.4° (Thai Meteorological Department, 2001). Both cities have average humidity of over 70% for most of the year. This can lead to feelings of discomfort.

1.2 The literature on thermal comfort indices

Many indices have been developed to assess factors like thermal sensation, comfort, preference and acceptability. Moreover, scales can vary according to the sensitivity of the participant. Table 1 assembles all available thermal comfort indices for assessing thermal sensation, thermal preference and thermal acceptability, including their references. Although the ASHRAE seven-point scale for thermal sensation has been used widely, there are several different ways in which questions can be asked, depending on factors like age and education level of the participant and purpose of the survey. Regarding thermal comfort assessment, Bedford (1936) established a psychological instrument to assess comfort feeling with a seven-point scale. This scale was used for many years until ASHRAE enhanced it and it became the standard. ASHRAE has produced three later versions of the thermal comfort index, such as the thermal sensation vote (TSV, 7 to 9 point scale in 1992), the actual thermal sensation vote (ATSV, 7-point scale in 2010) and the thermal sensation index (TSENS, 7 to 11 point scale in 2011). Meanwhile, an overall thermal comfort assessment also has been used which was developed from the Bedford scale and been subsequently used in the International Standard Organization, ISO10551: 1995, *Ergonomics of the thermal environment – Assessment of the influence of the thermal environment using subjective judgement scales.*

Thermal preference assessment was launched by McIntyre (1978) and by ISO10551 (1995). Although the 7-point scale for thermal preference in ISO10551 gives more detail, McIntyre's instrument is far more popular because of its practicality. With a 3-point assessment, McIntyre's scale is applied by many researchers (De Dear and Brager, 2002; De Dear and Spagnolo, 2005; Hwang and Lin 2007; Lin, De Dear and Hwang, 2011; Haddad, et al., 2012; Yang, Wong, and Jusuf, 2013; Zhou, et al. 2013).

Thermal acceptability is more related to psychology than thermal sensitivity and preference and there are many indicators to define this. Direct thermal acceptability is the most practical scale. It can be analysed with thermal sensation and thermal preference to derive an overall thermal comfort perception. ASHRAE 55-2010 also provides a sensitivity scale for acceptability assessment by appraising seven degrees of satisfaction. On the other hand, ISO10551:1995 arranges the scale to identify the degree of tolerance. This scale classifies how well people tolerate a thermal environment, from perfectly tolerable to intolerable (see Table 1 Thermal acceptability). This scale was also applied to the concept of acceptability which specifies the number of degrees that represents a change from acceptable to somewhat unacceptable and so on.

There is no standard for perception of wind, solar radiation and humidity. Many researchers conduct surveys by applying five and seven point scales of the ASHRAE thermal sensation vote to identify wind and solar perceptions (Stathopoulos, Wu and Zacharias, 2004; De Dear and Spagnolo, 2005; Rangsiraksa, 2006; Hwang and Lin 2007; Lin, De Dear, and Hwang, 2011; Yang, Wong and Jusuf, 2013; Zhou, et al., 2013). Some researchers have also developed a humidity perception assessment (Toftum, Jørgensen and Fanger, 1998; Stathopoulos, Wu and Zacharias, 2004; Yamtraipat, Khedari and Hirunlabh, 2005; Yang, Wong and Jusuf, 2013). However, Stathopoulos, Wu and Zacharias (2004) present wind perception differently. By assessing five degrees of agreement, the perceptions of "Strong wind force sensation" and "Stronger wind desired" have been used for sensation and preference assessment. These were also applied for gauging solar perception. There are two approaches to answering this assessment: a degree of satisfaction with ambient conditions and a degree of agreement with the statement. The 3-point preference scale of "Want more", "No change" and "Want less" can be applied to both wind and solar preference. Also, it is easily understood by elderly people than other assessment questions.

Humidity perception is another subjective issue which needs to be discussed. It can be expressed from three different angles: relative humidity, sweating sensation and wetness of skin. Humidity sensation refers to a combination of environment and perception of humidity in general. People's reaction to humidity can be defined on a five-point sensitivity scale. Subsequently, Toftum, Jørgensen and Fanger (1998) suggested an improvement to the measurement of humidity perception by asking a question about skin wetness in the questionnaire. Additionally, the level of sweating sensation can be another way of identifying humidity response because in high temperatures, the body mechanism will promote sweating to relieve heat. However, in high humidity conditions, evaporative cooling will not reduce heat efficiently. Lastly, research suggests that discomfort in hot climates is usually influenced by wetness of the skin. It is assessed, for example, as 'Sweat runs off the skin', 'Body wet - clothing sticks to the skin', 'Body wet - chest and back', 'Chest and back slightly wet' to 'Normal dryness' (Berglund, Cunningham and Stolwijk, 1983; Nielsen and Endrusick, 1990).

Table 1 *Subjective perception: thermal environment*

Parameters	Standards/ Reference	Interview questions used	Scale	Scale details	Researchers
Thermal comfort					
Thermal comfort vote (combine Thermal sensation +comfort)	Bedford, 1936	"How do you feel at this moment?"	7-point	Much too warm (+3), Too warm (+2), Comfortably warm (+1), Comfortable (0), Comfortably cool (-1), Too cool (-2), Much too cool (-3)	Jitkhajornwanich, 2007
Thermal comfort (affective evaluation)	ISO 10551, 1995	"Do you find this environment…?"	4-point	Comfortable (0), Slightly uncomfortable (1), Uncomfortable (2), Very uncomfortable (3)	Zhou et al., 2013
			5-point	Above plus; Extremely uncomfortable (4)	
Thermal perception / Thermal sensation vote (TSV)	ASHRAE 55-1992, ISO 10551, 1995	"How are you feeling now (about the thermal conditions on this site)?" / "How do you rate your thermal sensation?"	7-point	Cold (-3), Cool (-2), Slightly cool (-1), Neutral (0), Slightly warm (+1), Warm (+2), Hot (+3)	Lin et al., 2013; Yang, Wong and Jusuf, 2013; Zhou, et al., 2013
			9-point	Above plus; Very cold (-4), Very hot (+4)	
Thermal sensation (TSENS) or Actual Thermal Sensation Vote (ATSV)	ASHRAE 55, 2004; ASHRAE 55, 2010; ASHRAE 55, 2011	"What is your general thermal sensation?"	7-point	Cold (-3), Cool (-2), Slightly cool (-1), Neutral (0), Slightly warm (+1), Warm (+2), Hot (+3)	Spagnolo and De Dear, 2003; Nakano and Tanabe, 2004; De Dear and Spagnolo, 2005; Hwang and Lin, 2007; Jitkhajornwanich, 2007; Haddad, et al., 2012; Yang, Wong and Jusuf, 2013; Zhou, et al. 2013;
			11-point	Extremely cold (-5), Very cold (-4), Cold (-3), Cool (-2), Slightly cool (-1), Neutral (0), Slightly warm (+1), Warm (+2), Hot (+3), Very hot (+4), Extremely hot (+5)	

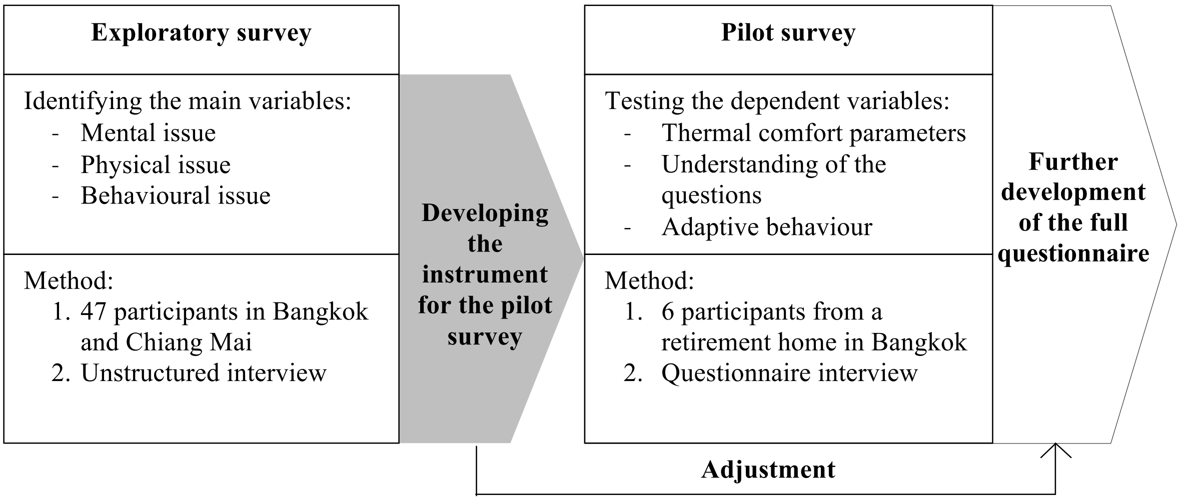
***Table 2** Subjective perception: thermal environment (cont.)*

Parameters	Standards/ Reference	Interview questions used	Scale	Scale details	Researchers
Thermal preference					
Thermal preference	ISO 10551, 1995	"Please state, how would you prefer it to be now?"	7-point	Much cooler (-3), cooler (-2), Slightly cooler (-1), Neither warmer nor cooler (0), a little warmer (+1), Warmer (+2), Much warmer (+3)	-
	McIntyre, 1995	"Would like it to be…?"	3-point	Cooler (-1), No change (0), Warmer (+1) or Colder (-1), Not wishing to change (0), Hotter (+1)	De Dear and Brager, 2002; De Dear and Spagnolo, 2005; Hwang and Lin 2007; Jitkhajornwanich, 2007; Haddad, et al., 2012; Lin, De Dear and Hwang, 2011; Yang, Wong and Jusuf, 2013; Zhou, et al., 2013
Thermal acceptability					
Personal acceptability	ISO 10551, 1995	"On a personal level, this environment is for me…?"	2-point	Acceptable rather than unacceptable (0), and Unacceptable rather than acceptable (1)	
	ASHRAE 55, 2010	"How satisfied are you with the temperature in your space?"	2-point	Acceptable, Unacceptable	Hwang and Lin, 2007; Lin et al, 2011; Haddad, 2012; Lin et al, 2013; Yang, et al, 2013
			7-point	Very satisfied (+3), Satisfied (+2), Slightly satisfied (+1), Neutral (0), Slightly dissatisfied (-1), Dissatisfied (-2), Very dissatisfied (-3)	
Weather acceptable	-	"Overall, the weather conditions are acceptable for your activity?"	5-point	Disagree (-2), Slightly disagree (-1), Uncertain (0), Slightly agree (+1), Agree (+2)	Stathopoulos, et al, 2004
Personal tolerance	ISO 10551, 1995	"Is it…?"	5-scale	Perfectly tolerable (0), slightly difficult to tolerate (1), Fairly difficult to tolerate (2), Very difficult to tolerate (3), and Intolerate (4)	

2. Methods

This research draws on qualitative methods to investigate the factors which can impact on thermal comfort. There were three phases to the research as shown in Figure 1: the exploratory survey, the questionnaire development, and the pilot survey, all leading to the development of the full questionnaire. The aim of the exploratory survey was to explore the main factors influencing thermal comfort. The aim of pilot survey was to develop and test variables in the survey instrument for finalizing the questionnaire. The individual phases are examined below.

Figure 1 : The relationship between the three survey phases



2.1 Exploratory survey

The exploratory survey was conducted in February 2014, by using unstructured interviews with 28 questions covering three main issues. Each interview took approximately an hour and included both facility managers and the elderly. The key variables of mental and physical condition and behavioural issues were identified in the exploratory survey to test their influence on thermal comfort assessment. Mental issues refer to the capability of the elderly to conduct a self-assessment. As a result of the combination of physiological and psychological factors, thermal comfort assessment relies heavily on self-assessment (ASHRAE, 2009). It also depends on the personal perceptions of the participant of their environment (Brager and De Dear, 1998). Therefore, the mental status of the participant should be assessed before conducting the interview to establish participants' capacity for self-assessment (Pfeiffer, 1975).

The second category of influences is physical. They refer to the vulnerability of elderly people. Many elderly have chronic diseases which influence their thermal sensitivity and thermal sensations (Novieto, 2013). For example, diabetes, hypertension, heart disease and stroke are commonly known to impact thermal perception. The third category of assessment, behavioural, refers to the activity and response of the participants to thermal stress. Behaviour includes routine and leisure activities. Shared spaces that the activities take place in, are also considered.

In the outdoor environment, solar radiation and wind are greater influencing factors on respondents than either temperature or humidity. Hong Kong researchers (Cheng and Ng, 2006; Ng and Cheng, 2012) strongly recommended that a shaded outdoor environment should be provided to prevent heat stroke. People can tolerate high temperatures in hot-humid climates with wind speeds of 3 m/s, which can bring a temperature above 34°C to acceptable comfort level quickly (Khedari, et al. 2000). On the one hand humidity itself does not directly impact the elderly in hot-humid countries like Singapore, Indonesia and Thailand because they are accustomed to high relative humidity. On the other hand, wetness of skin is a key factor of discomfort, although this is dependent on factors like air speed and individual health condition (Givoni, et al., 2006).

The adaptive behaviour questions were built from available adaptive tactics such as using hand-held fans noted in the exploratory survey. The pavilion and veranda were used for interviewing, since they are shared areas for the elderly. The interviews took place in separate sessions of morning, afternoon and evening to capture a variety of physical environmental conditions.

The outcomes from the exploratory survey led to three sections in the questionnaire for the pilot survey: thermal comfort, adaptive behaviour and the interview procedure.

2.2 Pilot survey

The pilot survey was conducted by using the questionnaire developed from the exploratory survey. Each question was used for testing a different individual variable. For example, the ASHRAE 7-scale thermal sensation vote was applied to determine thermal sensation variable. A 7-point scale was also applied to assess humidity, wind and sun. The 3-point McIntyre thermal preference scale was also applied to assess humidity, wind and sun preference. Lastly, thermal acceptability is a most complicated assessment since it depends on psychology rather than physiology. Consequently, a simplified version of thermal acceptability was adopted for humidity, wind and sun assessment in the pilot stage questionnaire.

The questionnaire contains three parts: A - Mental status, B1 – Thermal comfort and B2 – Adaptive behaviour. . Part A contains 15 questions and Part B has 21 questions; most are multiple choice. The interviews took approximately half an hour per participant. The pilot survey was conducted in November 2014. Participants who were residents of a retirement home in Bangkok were recruited for the pilot. The aim of this survey was to test the comprehension and practicality of the questions, so only six elders were questioned. Each participant was interviewed twice: during the daytime and in the evening.

After taking the pilot survey, all questions were reviewed to reflect the key factors more precisely. For example, questions relating to humidity and sweat perception were added to finalise the questionnaire after conducting the pilot survey.

3. Results and discussion

3.1 Exploratory survey

Outcomes from the exploratory survey can be discussed under the headings mental, physical and behavioural. Each element had a different level of influence on thermal perception in the elderly. Research suggests that culture can also play an important role in adaptive behaviour (Knez and Thorsson, 2006).

Mental factors – According to the retirement home managers, there are three levels of health status. Group A is the healthiest. They can take care of themselves on a daily basis and their intellectual functioning is intact. Group B is generally healthy but may need assisting in a minor activity such as washing clothes or shopping for food. Group B may have chronic physical diseases such as arthritis or heart disease which impacts on daily activity, yet people in this group still have an intact or only mildly reduced intellectual functioning when they were tested on the mini-mental self assessment. Group C is the lowest on the health status list. They may have a severe disease which requires a degree of nursing service, for example for the elderly with dementia. Since the participant needs to assess their thermal perception, their intellectual capacity should be intact or only mildly impaired. Since It is likely that Group C might have a mild intellectual impairment their response may be biased or their self-evaluation may be inaccurate. Therefore, only the A and B groups who are of sound-mind have been selected as participants.

Physical factors – Some chronic diseases affect thermal sensation and sensitivity. Body fitness also influences thermal perception. Physical issues can be identified in two groups, arthritis and heart disease and hypertension. The elderly who have arthritis or heart disease are usually inactive so they prefer staying at home which, ironically, makes them weaker. Their metabolic rate may drop which may also have a slight effect on their thermal perception. Regarding hypertension, elders with high blood pressure will be affected particularly in hot weather. Some of the participants reported a slight to serious headache due to hypertension during summer. Some become upset greatly about the weather which can cause them discomfort in summer more easily than elders without hypertension. Consequently, the questionnaire was adjusted to add a question about the factors that concerned elders when they felt most uncomfortable. The question was also asked "what factors bring a feeling of comfort for you when you feel uncomfortable?"

Behavioural factors – Cultural differences affect behaviour. Even though participants in both surveys are Thai, surprisingly, there are cultural differences among the regions of Thailand which influence adaptive behaviour. A traditional Thai space in both Bangkok and Chiang Mai is the veranda, although Thai attitudes to staying on the veranda are different. The elderly in Chiang Mai prefer staying in the veranda or the shaded outdoors when they feel hot. They expect that a breeze would provide more comfort as opposed to staying indoors. However, those in Bangkok will stay on the veranda when the outside is not too hot. Bangkok residents mentioned that sometimes the outdoors is subject to warm winds and it would be hotter than staying indoors. Moreover, the activity of an individual can lead to discomfort conditions. An active elderly person will manage to perform several activities even in hot weather. Thus, they will experience a higher metabolic rate and feel hotter than those who are inactive. Lastly, some elders tend to avoid drinking too much water to relieve heat. Since they are often afraid of an accident like a fall, they would prefer using fans for cooling rather than drinking water and walking to the toilet often. Consequently, they may feel uncomfortable more readily than those who prefer drinking water. The exploratory survey identified the following typical adaptive behaviours: drinking water, adjusting clothes, showering or washing faces, moving, walking, day napping or sleeping, using a hand-held fan or electric fans, or praying or bearing it until the uncomfortable conditions have gone.

3.2 Pilot survey

The pilot survey and the interview process introduced expected as well as some unexpected issues. The thermal comfort response is an expected outcome which required some adjustments before applying to the full survey. However, cultural differences between regions in Thailand were an unexpected factor and the wording and graphics were modified to support the elders' understanding of the questions.

Thermal comfort perception – Initially, thermal comfort parameters are the first focus. Then when outdoor environment is considered, other environmental parameters seem to have a stronger impact than just temperature. Wind and solar were reported to have a stronger effect on outdoor thermal comfort than temperature. Moreover, in hot-humid climate, humidity and sweating level also can create discomfort more than just high temperatures. The pilot survey found that humidity and skin wetness affected thermal discomfort. One-third of participants responded that their discomfort feeling derived from skin wetness.

The results suggest that the five-point thermal perception scale may not be sensitive enough to differentiate responses from older adults from those of adults in general. Research suggests that the ASHRAE 7-point scale can be applied to the elderly and in this case, the pictures can assist their understanding. However, regarding wind, solar, and humidity sensations, a five-point assessment is preferred for ease of discrimination between points by elderly respondents.

The pilot survey shows that McIntyre's thermal preference assessment is suitable for the elderly, but not for personal acceptability. Although asking for a direct answer to whether conditions are 'acceptable' or 'unacceptable' is the most practical evaluation, the pilot survey shows that the Thai elderly are more likely to accept every weather condition, including temperature, wind, solar and humidity. The pilot survey also shows that acceptability is influenced by a cultural perspective as well as a thermal perception. All respondents accepted the prevailing environmental conditions; One mentioned that since we cannot change nature, we have to accept it, even though we are uncomfortable.

Consequently, the questionnaire was adjusted i) to identify degree of overall acceptability, defined in five levels from 'Unacceptable' to 'Acceptable'. Also, ii) regarding the ambiguity of the term 'acceptability', the elderly should also be briefed on terminology. For example, in the questionnaire, "Unacceptable" means what happens when they feel uncomfortable with the weather and need some adjustments to be more comfortable such as using fans. "Acceptable", on the other hand, refers to the feeling of comfort without any adjustments.

Adaptive behaviour – Some adaptive behaviour alternatives are more frequently applied than others. For instance, 'opening the window' is a regular answer from all elderly who live in naturally ventilated rooms. Windows are closed only when it rains heavily. The frequency of individual adaptive techniques is calculated as a percentage of the total possible options. The response 'using mechanical fans' is in the second choice, at 60%. Moving to a cooler place and taking a shower are other common choices, at 50%. Drinking water is less common, at 40%. Apart from these, the frequency of adaptive responses using a hand-held fan – 25%; walking – 20%; day napping – 11%; and adjusting clothes – 5%. Unexpectedly, on one selected praying or bearing until it has gone as their heat relief technique.

Clothing which is another factor to determine thermal comfort, is greatly influenced by local culture. The elderly in Thailand are conservative, particularly females. They usually believe that the proper clothes relate to a well-mannered personality. Even though the environment is extremely hot, it is important for them to wear proper clothing in public. Therefore, the average clothing insulation for the female elderly is higher than that of males, at 0.32 clo with bra, blouse, panties and pants, and at 0.24 clo with a t-shirt and pants, respectively.

Interview procedure – There are many factors related to interviewing the elderly. The level of communication such as education level and language skills can lead to misunderstanding. Most elderly who live in retirement homes are not well educated. Half graduated from primary school Grade 4 which was the extent of compulsory education in their era. Therefore, interview procedures and wording need to not only be easily understandable but also acknowledge their context.

The use of language and wording has been modified and tested several times for the most effective response. For example, the word "acceptable" means you are happy with a condition without any difficulties, yet in Thai language, it means you can accept a condition with or without any trouble, until it becomes intolerable, then you will say unacceptable. Graphics can deliver answers quicker than long verbal explanations due to the precise expression in their context (see Figure 2). A similar approach has been used in a thermal comfort questionnaire for Iranian children (Haddad et al., 2012). The graphic was also applied for wind, solar radiation humidity and sweat sensations assessments. An example is the thermal sensation vote using a 7-point scale and illustrated in following graphic (Figure 2).

Figure 2 : An example of graphics to support the thermal sensation 7-scale question

Cold	Cool	Slightly cool	Just right	Slightly warm	Warm	Hot
-3	-2	-1	0	+1	+2	+3

3.3 Discussion

Three levels of humidity perception have been mentioned as relative humidity, sweating sensations and wetness of skin. The pilot survey shows that the sweating level can play an important role in discomfort in a hot-humid climate. Moreover, deterioration of sweat gland mechanisms in the elderly (Buono, McKenzie and Kasch, 1991; Kenney and Munce, 2003; Tortora and Derrickson, 2006), tend to limit heat loss by sweating, leading to increased feelings of heat. Therefore, sweating perception of the elderly should be assessed in the questionnaire.

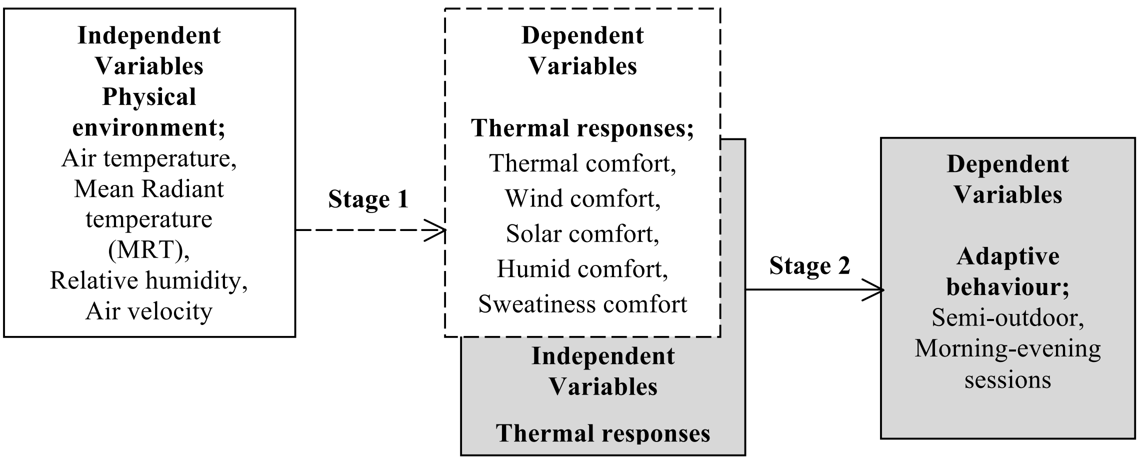
Furthermore, Picard (2014), has invented a physiological instrument that can measure the stress level of people. The sensor includes electrodermal activity (EDA) or skin conductance response (SCR) which spontaneously detects moisture from sweat glands on the skin. More skin moisture creates a higher conductance response. This instrument is able to sensitively detect changes across a range of stress levels.

Thermal comfort is a combination of physiology and psychology, and both need to be measured simultaneously. Conventionally, psychological responses can be assessed on site by using a Likert scale such as ASHRAE thermal sensation scale. Physiological responses can be evaluated by comparing the psychological data and the physical environmental profile later. Not much thermal comfort research has measured a direct physiological response. Since it is a direct measurement, the SCR could provide physiological evidence of discomfort feeling from heat. Therefore, if this device is combined with the subjective thermal comfort assessment, it can probably produce a more reliable result than the traditional method, by providing quantitative data and reducing interpretation bias in the interview process.

Therefore, the next stage of this study will apply both relative humidity and sweating sensation to interpret humidity perception. Although it has been suggested that humidity may not strongly impact on thermal comfort of people in hot-humid climates, the future survey will enable a better explanation of the relationship between skin wetness and discomfort among Thai elderly. To be clear, sweating level should be measured simultaneously with the subjective perception of sweatiness.

Regarding the analysis process in the next stage, Figure 3 shows the analytical model which distinguishes the relationship between the physical environment parameters and the subjective parameters of thermal responses, including how people react to both sets of parameters. First, physical parameters as independent variables will test the correlation with the thermal responses. As a dependent variable of Stage 1, thermal responses will become an independent variable for the second stage. Thermal responses will also be correlated with another dependent variable, adaptive behaviour.

Figure 3 : The overall analytical model of this research



Conclusion

The methodology to investigate thermal comfort for improving the sustainable living of the elderly included an exploratory survey, developing the instrument and conducting a pilot survey. The exploratory survey involved the main mental, physical and behavioural factors. The pilot survey suggested that thermal comfort perception, adaptive behaviour and interview procedures needed to be adjusted in the questionnaire. Physical and mental health factors, including education level also influence thermal responses. Consequently, the questionnaire was modified by adding explanatory graphics. Finally, the next step will use the analytical model to process the survey results. In addition, the model may well be useful for researchers in general who are exploring the relationships between the physical environment and the subjectivity of thermal responses.

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