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Clothing behaviour in Belgian homes

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Abstract. Clothing has a direct influence on the thermal comfort of an occupant and so, indirectly on the energy use of a building. Literary sources point out a lack of data about clothing behaviour in residential buildings. In order to assess the clothing behaviour two kinds of surveys are created: logbook surveys and online questionnaires. Both surveys are executed between March 11 and April 5, 2019. The mean clothing insulation worn during the investigation period is 0.58 clo. This clo-value differs from the clothing insulation values provided by Fanger, which are 1.0 clo for winter months and 0.5 clo for summer months. The influence of the indoor temperature, outdoor temperature, weather history memory, gender and age on the clothing behaviour is analysed. All variables have a small significant influence on the clo-value. It was found that occupants tend to wear the same clothes when they are at home. So, each participant clothes him/herself to be comfortable in their clothes and in the temperature of their own room. People who are used to live in lower indoor temperatures will, and are used to, wear more clothing insulation to be thermally comfortable than people living in warmer indoor temperatures. An adjustment in clothing behaviour can make a big impact on the energy use of residential buildings. A decrease in indoor temperature of 1°C can lead to heating energy savings of 10%. To remain thermally comfortable, the occupant must only wear an extra insulation value of 0.17 clo, which corresponds with a shirt. The question remains if occupants will effectively use the opportunity of changing clothes to lower their energy use.

1 Introduction

Clothing can be looked at from a variety of perspectives. It can be used as a safety layer in dangerous or unhealthy working spaces. But clothing is also a part of a culture, a society or a religion. Clothing can be used to express one's personality or to outwardly display a sign of togetherness as a group or organization. Above all, clothing is used as a thermal resistance and insulation layer, formed between a human's body and its immediate environment. People wear clothes to feel thermally comfortable. A change of clothes is an opportunity for people to play an active part in maintaining their own comfort. Especially in offices, where it is not always possible to change indoor temperatures or to operate a window, clothing adjustments are perhaps one of the most important opportunities to alter thermal comfort. But at work, there are limitations to changing clothes due to ethics, dress code, clothing availability, etc... At people's homes however, all the clothing segments are available, and people can wear what they want. Since clothing has an impact on thermal comfort, it therefore indirectly has an impact on the energy use in buildings. By putting on more clothes the heating setpoints could be lowered and energy could be saved. This is a way of energy saving that is often forgotten but can have an important impact. Therefore, getting insight in the clothing behaviour of occupants can lead to a better assessment of thermal comfort and a better design of HVAC-installations.

However, literary sources point out a lack of data about clothing behaviour in residential buildings [1–4]. Yan et al. [1] declared that several stochastic models have been developed to describe window operations, blinds and lighting, but that other behaviours such as operation of air-conditioning and clothing adjustment have been studied less. Especially, information regarding small clothing adjustments and clothing levels in homes is lacking [4]. Newsham [2] pointed out that seasonal changes in clothing have been frequently observed and seem effective in thermal comfort moderation, but that there are few data on short-term (within a day) clothing adjustments.

Furthermore, the ability of occupants to change clothes to directly adapt their thermal comfort is sometimes overlooked in the design of buildings. The responsibility of thermoregulation seems to lie exclusively with HVAC-systems and not with the individual occupant. The occupants can wear whatever he wants indoors, providing that they are prepared to pay the financial and environmental costs of the energy use [5]. This attitude is diametrically opposed to the goal of using less energy.

In this study the clothing behaviour of occupants of residential buildings is assessed, with a specific focus on

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short term clothing adjustments and clothing levels in the home.

2 Methods

Two kinds of surveys are used to collect data: logbook surveys and online questionnaires. Both surveys, executed between March 11 and April 5, 2019, query after the clothing behaviour of the participant, but each in a different way. The logbook survey (LB) is a survey on paper in which the participant notes his/her clothing behaviour every 15 minutes during one or two days. From this survey, information about clothing adjustments, sleepwear, activities, … throughout a whole day can be derived (Table 1). The surveys were conducted in a student home in Ghent, Belgium. The apartments are all equipped in the same way and have the same lay-out and orientation. All the 126 participants are from the same age group (age 18-28), making it relatively easy to compare results, e.g. for examining the influence of gender on occupant's clothing behaviour. Additionally, each participant received an indoor temperature sensor that they had to put in the room in which they were present. Outdoor temperatures were available from a climate station in Melle, near Ghent.

The online survey (OS) is a short questionnaire that inquiries about the participants clothing behaviour at the time of participation. Which clothes are being worn? How comfortable is the participant? In which room is the participant at that moment? etc... In total, 1243 answers were collected. It should be noted that people could participate more than one time. The respondents were aged between 7 and 85 years, with a majority of the occupants in the category 18 to 25 years (Figure 1). The respondents were as well mostly female (72%).

To be able to analyse the clothing behaviour of the occupants, the set of clothing garments a person is wearing are converted to a total clo-value. For this values from ASHRAE Standard 55 - 2010 [6] and ISO 7730 – 2005 [7] are used. The metabolic rate will influence the clothing behaviour of the occupants as well. Because of the variability in activity and metabolism of different occupants, accurate estimates of clothing insulation for an active person are not available unless measurements are made for the specific clothing under the conditions in question. However, because it is assumed that people will not be very active while filling in the online survey, no adjustments for clothing insulation values were needed. The metabolic rate of the participants of the logbook survey may increase during the day. However, too limited data is available so this will not be taken into consideration in this study.

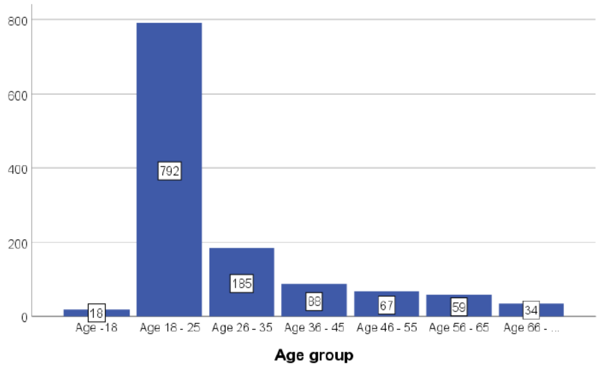

Figure 1: Histogram of the age groups

3 Results & Discussion

3.1 Clo-values

The mean clothing insulation is respectively 0.51 clo and 0.58 clo for the logbook study and online questionnaire. This corresponds with a clothing outfit consisting of shoes, socks, underwear, long trousers and a long-sleeve thin sweater. These values were obtained in early spring in Belgium. People can reach thermal comfort not only by adjusting clothes, but also by making a change in seating furniture. In this study the mean insulation value given by furniture (without accounting for bedding and blankets) is respectively 0.16 clo and 0.09 clo, for the logbook study and online questionnaire, which can be compared to the insulation provided by a standard office chair.

Table 1: Logbook paper with columns for time, activity, clothing, furniture, room and people that are present

Hour	Activity: Which activity are you performing? Indicate your <u>main activity</u> of the last 15 minutes. Only one activity can be filled in per line.	Clothes: Which <u>clothes</u> are you wearing? Indicate with a cross which clothes you wear for every 15 minutes. When you can't find your clothing item in the list, write it in the column 'other'.															Sit/lay on: If you are not standing: On which furniture are you sitting/laying?						Space: In which space are you?				Visitors: Are you alone or in company?		
		Underpants	Socks	Bra	Long trousers	Shorts	Skirt	Dress	T-shirt	T-shirt without sleeves	T-shirt with long sleeves	Thin sweater	Warm sweater	Slippers	Shoes	Other	Bed	Sofa	Extra blanket	Chair	Office chair	Other	Living area/ kitchen	Bedroom	Bathroom	Hallway	Alone	Partner	Other
05.30 – 05.45	sleep	x															x							x				x	
05.45 – 06.00	"	x															x							x				x	
06.00 – 06.15	"	x															x							x				x	
06.15 – 06.30	Wake up & get dressed	x		x	x				x															x				x	
06.30 – 06.45	washing	x		x	x				x																x		x		
06.45 – 07.00	eating	x		x	x				x											x			x				x		
07.00 – 07.15	Clean up	x		x	x				x														x				x		
07.15 – 07.30	washing	x		x	x				x																x		x		
07.30 – 07.45	Preparing to leave	x		x	x				x				x		x	scarf										x	x		
07.45 – 08.00	away																												
08.00 – 08.15																													
08.15 – 08.30																													
08.30 – 08.45																													

For the logbook study there is also data available on the clothes being worn during the night. The mean clothing insulation is 0.14 clo at night (underwear and t-shirt), with an added 4.07 clo due to bedding and blankets.

The mean clothing values in this study are close to the clothing value defined for summer months (0,5 clo) by Fanger [8]. However, this study is performed in early spring, with outdoor temperatures between 4 and 12°C, which are not representative for a Belgian summer. This indicates that the clo-values defined by Fanger and used in many thermal comfort and energy use calculations, overestimate the amount of clothes occupants wear in early spring.

3.2 Indoor temperature

Both indoor temperatures and clothing behaviour can make a direct impact on the thermal comfort. The average indoor temperatures of the room in which the participants stayed, were stagnant (Figure 2). It should be noted that the research period is rather short (less than a month), so it is logical that little variation is present. However, Schiavon and Lee [9], who performed a similar research over an entire year, reported that the indoor air temperature does not change significantly throughout the year in residential buildings. In the logbook study the average indoor temperature was 22,0°C (min = 20,2 °C, max = 27,2 °C). In the online survey participants were asked to report the temperature that was on their thermostat, however, only 46% of the participants provided this data. For these participants the average indoor temperature during the research period was 20,5°C (min = 13°C, max = 26°C). The difference between the indoor temperatures in the online survey and logbook study is 1,5°C, which is an important difference. The higher indoor temperatures with the young group of students is unexpected. This could be caused by the fact that the price of the student housing is a fixed price unrelated to the energy use, so the students can use as much energy as they want without having to worry about the price. While no data is available on the billing of the energy use for the participants in the online survey, it is assumed that the majority had to pay their own energy bills.

The indoor temperate of the room in which the participant stays at the time of participation (OS) is negatively correlated with the insulation value of the clothing he/she wears at that time (τ= -.103, p= .001) (Figure 3). This relation is as one may expect, the higher the indoor temperature, the lower the clothing insulation value. However, from these results we can not conclude that occupants adapt their clothing when the indoor temperature changes. Data is needed on a longer period to make such conclusions. For most occupants only data for one or two days is available which is not sufficient to be able to conclude something on changes of clothing related to the environment. One thing we can deduct is that each participant clothes him/herself to be comfortable in the temperature of their own environment, which varies between the different participants. Some occupants may be accustomed to a lower room temperature than others. This may be out of necessity (e.g. due to economic problems) or because the resident explicitly chooses to (e.g. to bear a smaller ecological footprint)[10]. This acclimatization can be shown by the relationship between the indoor temperature and the thermal comfort rating of the occupants (Figure 4). More extreme temperatures do not necessarily indicate less comfort. There is no significant difference in indoor temperatures for the different comfort categories (F(3,569) = 1.360, p=.254).

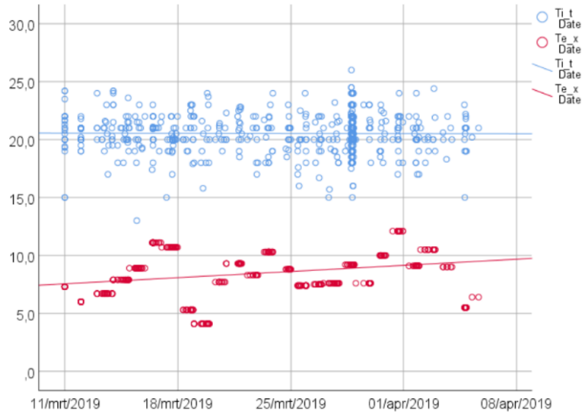

Figure 2: Indoor temperature (blue) and outdoor temperature (red) during the research period (OS)

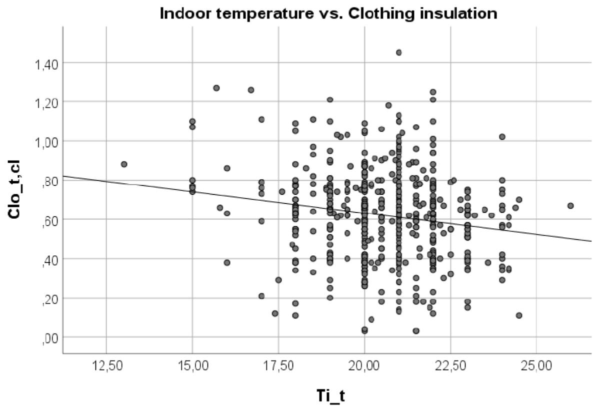

Figure 3: Relationship between indoor temperature and clothing insulation (OS)

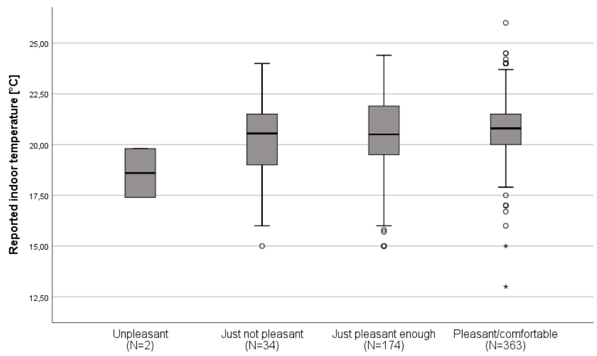

Figure 4: Indoor temperature for each comfort level

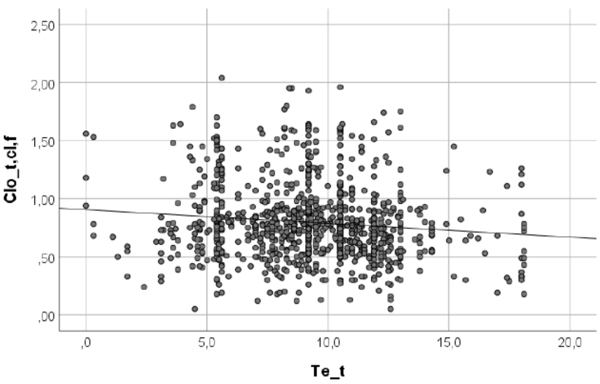

Figure 5: Relationship between outdoor temperature and clothing insulation (OS)

3.3 Outdoor temperature

The outdoor temperatures fluctuated between 4.1°C and 12.1°C, with a continuous rise in temperature over time (Figure 2). The relation between the outdoor temperature and clothing at the time of participation is analysed. No significant relationship could be found when analysing the temperature at the moment of participation and the clothing the occupant is wearing. However, a significant negative correlation between the outdoor temperature and the total clothing insulation (insulation value for clothing garments and furniture) at the time of participation is present (τ=-.072 , p=.001). This could mean that people make little adjustments in their direct environment to be comfortable, not by changing clothes, but more so by changes in seating furniture and blankets.

The negative relationship between the clothing worn by the occupants and the outdoor temperature is significant when instead of the outdoor temperature of that moment, the daily mean temperature is considered (τ=-.059 , p=.001) (Figure 5). This indicates that clothes are adapted not based on short time temperature changes but on longer periods of time. Occupants often choose a set of clothes in the morning and do not change this during the day. This is in accordance with literature. Morgan and de Dear [11] suggested that the timing of when clothing decisions are made is a key factor in explaining the relationship between clothing and outdoor temperature. Also, Schiavon and Lee [9] found a strong correlation between outdoor temperatures at the time when people get up and the clothes they wear during the day. Furthermore, an important factor in clothing choices according to literature is the weather history memory. People make clothing decisions partly by memory of the thermal outdoor environments of the day before, and possibly on what the weather is forecasted to be that day. [3,11,12]. In this study the influence of both the weighted outdoor temperature of the past 4 days [13], and the mean outdoor temperature of the last 30 days are researched. In the online survey, a slight negative significant relationship (τ=-.057, p=.001) exists between the weighted outdoor temperature of the past four days and the clothing insulation worn at the moment of participation. Similarly, a slight negative significant relation is found between the mean outdoor temperature of the last thirty days and the clothing insulation worn at the time of participation (τ=-.085, p=.001). The correlation is stronger for the past 30 days compared to the past 4 days, which could indicate that people take the temperatures from a wider period into account when making clothing decisions.

3.4 Gender

The participants in the online survey are mostly women (72%). In 5 cases the respondent could not identify him/herself as man or woman and indicated ‘other’. In the logbook surveys, the number of participants was more proportionally divided into 45% men and 55% women. In the online survey, the average difference in clothing insulation between genders is 0.04 clo (Figure 6). An insulation value of 0.04 clo (underwear) is relatively small and can be neglected. This is in correspondence with literature [4,8,9,13]. However, the logbook surveys, filled out by students, show a much larger difference in clothing insulation value between men and women (Δ clo = 0.12 clo) (Figure 7). This clothing difference corresponds with a t-shirt or blouse and cannot simply be ignored. It is found that this higher difference between genders is due to a lower clothing insulation worn by the male students. Women wear the same amount of clothing in both surveys. The fact that male bodies heat up more than female bodies [4], in combination with higher mean indoor temperature, can be a possible explanation as to why male students, compared to the female students and the participants of the online survey, wore less clothes during the period of the investigation.

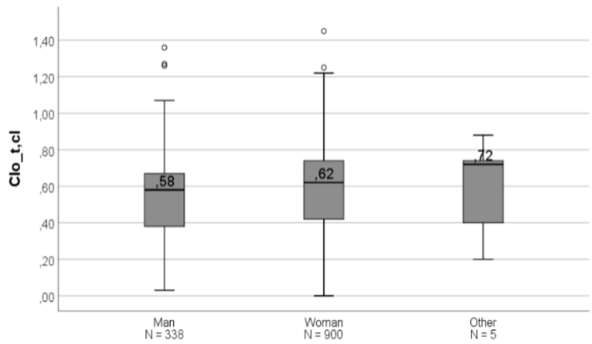

Figure 6: Clothing insulation according to gender (OS)

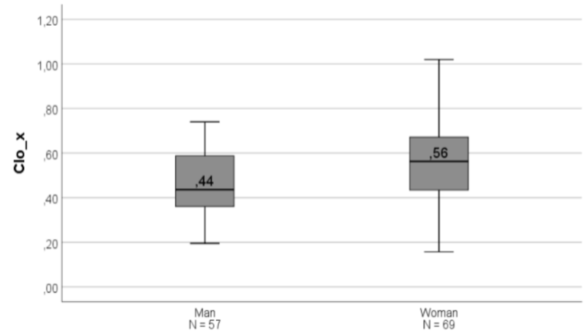

Figure 7: Clothing insulation according to gender (LB)

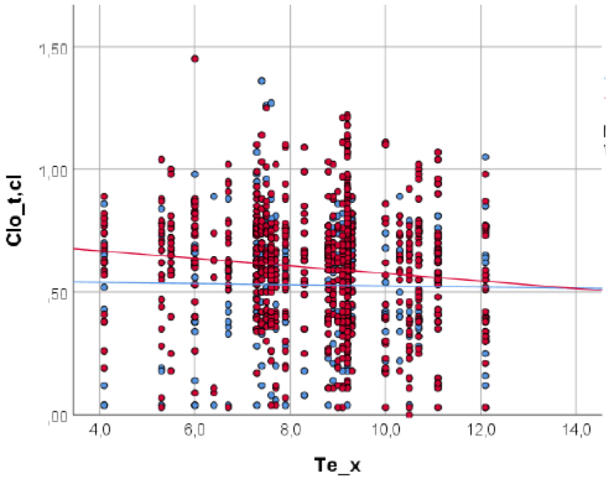

Figure 8: Relationship between outdoor temperature and clothing insulation according to gender (OS)

In the analysis of the clothing behaviour and the outdoor temperature, men seem to wear similar clothes every day, independent of the outdoor temperatures, while the clothing insulation of women varies over the different outdoor temperatures (Figure 8). This may be attributed to a higher weather sensitivity of women. Another possible explanation can be found in the high variance in options for women's clothing compared to the clothing options for men. With more options, the variation in clothing worn can be larger.

3.5 Age

The age of the 1243 participants in the online survey ranges from 7 to 85 years. The age-group 18 – 25 is the most represented with 64%. Figure 9 shows the significant positive relation between the clothing that the participants wear on the moment of the survey and the age of the participant (τ=.099, p=.001). The older the occupant, the more clothes he/she wears at home. A significant positive relationship also exists between age and indoor temperature (τ=.097, p=.001), the older the participant, the higher the indoor temperature. Older people maintain their comfort therefore both by adapting the environment and their clothing. It should be noted that the age-distribution of the data sample is not representative as only a smaller group of older people participated in the survey.

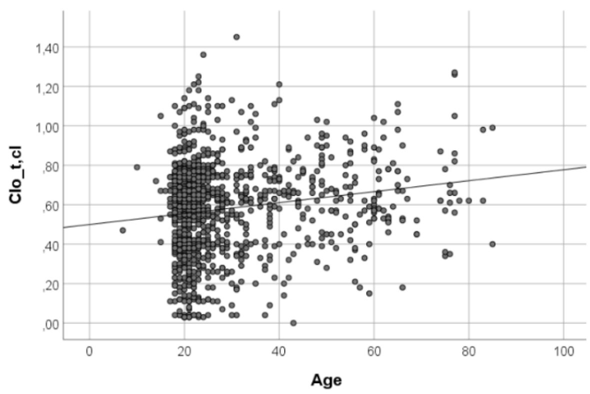

Figure 9: Relationship clothing insulation and age (OS)

3.6 Impact on energy use

Since clothing has an impact on thermal comfort, it therefore indirectly has an impact on the energy use in buildings. Newsham [2] concluded that in environments where clothing modifications are easy to make, like at home, HVAC set points could be made less stringent to save energy, with the expectation that clothing adjustments could maintain thermal comfort. Schiavon and Lee [9] came to a same conclusion; allowing and supporting a greater clothing adaptation and a wider range of indoor climatic conditions could save a relevant amount of energy without sacrificing thermal comfort. Of course, adjusting clothing to maintain thermal comfort is possible, but within limits. Clothing levels can be reduced only to levels of modesty and acceptability. A range of 18-27°C is according to Parsons appropriate to maintain thermal comfort with clothing adjustments [14]. A decrease in indoor temperature of 1°C can lead to heating energy savings of 10% [15,16]. For (near-) sedentary activities, where the metabolic rate is about 1.2 met, the effect of changing clothing insulation on the optimum operative temperature is approximately 6°C per clo, or 0.17 clo per °C. This means that a decrease of 1°C in indoor temperature can be lifted by an increase in clothing insulation of 0.17 clo, corresponding with a polo shirt, a short-sleeve dress, or a lightweight long-sleeved shirt. The question remains if occupants effectively use the opportunity of changing clothes to lower their energy use. Humans are creatures of habit. From the surveys we found that many participants, mainly young people, stay home in relatively few clothes in a constant room temperature. People do not only want to be thermally comfortable; they also want to wear clothes that they like and in which they feel comfortable in their homes.

4 Conclusion

In this study, the influence of five variables on occupant's clothing behaviour are researched: indoor temperatures, outdoor temperatures, weather history memory, gender and age.

The highest correlation with clothing behaviour comes from the indoor temperature. This is not the result of the adaptation of clothing to a changing indoor temperature, but more likely due to acclimatisation. People living in lower indoor temperature wear, on average, more clothes than people living in higher indoor temperatures. Outdoor temperatures and weather history memory also have an influence on the occupant's clothing behaviour. The temperature at the moment of querying did not have a direct influence on the clothing insulation, but the daily mean temperature, the weighted outdoor temperature of the past 4 days, and the mean outdoor temperature of the last 30 days did have an influence. Nevertheless, the temperature at the moment of participation was correlated with the total insulation value, including insulation due to furniture and blankets. This indicates that occupants cloth themselves based on their weather history memory, but that hourly variations in temperatures can be compensated with a change in seating furniture or blankets. In the logbook study it was found that women tend to adapt themselves more to the outdoor temperature than men. While in the online survey little difference could be observed between men and women. Older occupants tend to both adapt their environment and their clothing to feel thermally comfortable. It should be noted that the metabolic rate of the occupants was not taken into consideration in this study, which may seriously impact the clothing behaviour. This is something that needs to be included in the successive study.

It should be remarked that the correlation coefficients found in this study are relatively low. This could be the result of the rather short research period. A longer research period would allow more solid conclusions. Another possible explanation could be that people do not significantly change their clothing, even when outdoor or indoor temperatures slightly change. Occupant have specific habits in their homes. Many people commonly wear a basic comfortable outfit at home, independent of any (small) changes in indoor or outdoor temperatures. This basic outfit is only adjusted when confronted by extreme outdoor and/or indoor temperature change, like during a hot summer - or a cold winter day. If occupants were able to change their clothing habits by putting on an extra layer of clothing when they are at home, they would be able to lower their thermostat settings and save energy.

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