THE INTERPLAY OF GENDER, AGE, EDUCATION LEVEL AND THERMAL SATISFACTION: EVIDENCE FROM BOSNIA AND HERZEGOVINA*

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Abstract

The aim of this paper is to analyze the relationship between gender, age, education, and thermal satisfaction of employees and users in public buildings, such as schools, public administration, and clinics. The study uses data collected from a randomized stratified sample from Bosnia and Herzegovina. The primary variable of interest is a dummy variable indicating whether individuals are satisfied with the heating of the rooms. Our results revealed that gender and education level might be significant factors. However, when controlling for the type of object, the observed differences were no longer present. Furthermore, our findings show that the results do not differ significantly when the dependent satisfaction variable is measured as binary (dummy) or on a five-point Likert scale. Logistic regression provides an intuitive interpretation in terms of odds. Our study also indicates that age may be a critical predictor in the evaluation of indoor temperature, with older participants reporting the rooms in institutions to be warmer than the younger ones. The outcomes of this research could be valuable in developing policies aimed at improving energy efficiency of buildings. Understanding optimal thermal satisfaction could have significant implications for thermal energy consumption, particularly in the context of how individual characteristics, such as gender, age, and education level, might contribute to the reduction of energy consumption. By addressing the demand side of the energy consumption equilibrium, we might contribute to the better use of existing energy sources. The findings of this paper could also offer useful guidelines when designing more complex studies, especially regarding the debate if the use of a Likert scale is appropriate.

Keywords: thermal satisfaction, age, gender, education level, Bosnia and Herzegovina

JEL: D1

1. Introduction

The purpose of this paper is to examine the relationship between gender, age, education, and thermal satisfaction of employees and users in public buildings such as schools, public administration, and clinics. Although the thermal comfort formula does not consider the role of gender and age, these factors might be important, as noted by Choi, Aziz, and Loftness (2010, p. 1529). However, their literature research section provided some evidence but no clear and consistent conclusions regarding differences between females and males or between young and old persons. Similarly, Wang, de Dear, Luo, Lin, He, Ghahramani, and Zhu (2018, p. 192) also found that there are no clear and consistent conclusions regarding differences between females and males or between young and old participants. As thermal comfort depends on the occupant's clothing, activity levels, and building characteristics, their modifications could achieve energy savings (Meier, 1994). However, as noted by Wang *et al*. (2018, p. 181), it is challenging to find a thermal environment suitable for all occupants because different groups of people might prefer different thermal environments. According to the "adaptive" hypothesis, "factors beyond the fundamental physics and physiology all interact with thermal perception" (De Dear, 1998, p. 1), including demographics, context, and cognition. De Dear (1998, p.2) argued that certain factors such as demographic and contextual variables are irrelevant to comfort responses in climate chamber settings. However, in the context of real buildings, adaptive modellers do not disregard these considerations. As such, the literature has been discussing the role of these variables for some time and they are an integral part of some existing theories, but their role remains contradictory. Our paper aims to present additional evidence by testing the differences in thermal satisfaction between different genders, age groups, and educational

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levels. We also tested how these variables behave when integrated into one model and when controlling for building characteristics. We present how logistic regression could be used to provide a more intuitive interpretation of the coefficients. Understanding optimal thermal satisfaction might have important consequences for thermal energy consumption. The COVID-19 crisis highlighted the vulnerability of energy sovereignty (Brosemer *et al*., 2020, pp. 1-5). The lack of energy can compromise essential health services, while energy production exposes more people to environmental pollution. Additionally, access to energy services may not be possible for all individuals if stable income is lost due to events like COVID-19. The Energy Outlook 2023 report envisions a rise in global energy consumption by 1.3%, but also an increase in coal consumption to compensate for gaps in gas supplies; the possibility of extreme weather conditions forcing companies to use fossil fuels and delay the energy transition; and pausing for the moment intentions to phase out the use of nuclear power (EIU, 2022, p.1). These circumstances highlight why it is beneficial to understand how individual characteristics such as gender, age, and education level might contribute to reducing energy consumption. Addressing the demand side of the energy consumption equilibrium, we might contribute to the better use of existing energy sources.

2. Literature review

According to Choi, Aziz, and Loftness's (2010, p. 1535) study on the effect of gender and age on thermal satisfaction in buildings, female respondents are generally less satisfied with the thermal environment. The study also found that individuals above the age of 40 are typically more satisfied with the thermal environment compared to younger people. However, the role of gender and age in thermal satisfaction is complex and not straightforward (Choi, Aziz, & Loftness, 2010, p.1535). Previous literature has shown that women are more likely to report thermal dissatisfaction than men (Cena & de Dear, 2001, p. 414; Karjalainen, 2007, p. 1594; Modera, 1993, p. 210; Parsons 2002, p. 595), but these gender differences are not always consistent. For instance, some studies have found no significant differences between genders in the controlled experimental setup (Fanger *et al*. 1974, p. 18; Grivel & Candas 1991, p. 365; de Dear *et al*., 1991, p. 874) or field study (Peng, 2010, p. 505), while others have shown that gender differences disappear when exposure times are increased (Hashiguchi, Feng, & Tochihara, 2010). In a systematic literature review by Wang *et al*. (2018, p. 185), 29% of studies reported significant gender differences, 32% reported weak or no significance, and 39% found insignificant results.

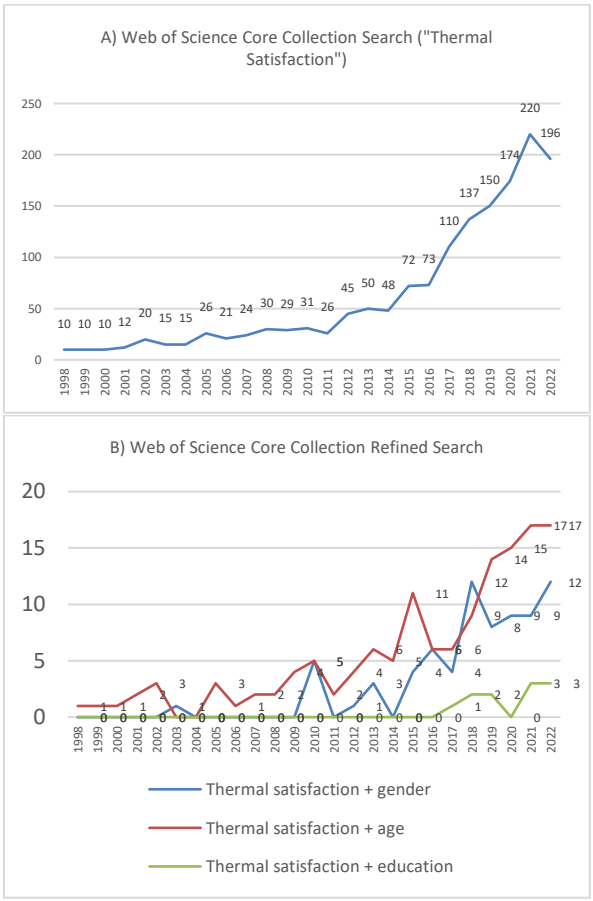

Figure 1. *Web of Science Core Collection search for the selected keywords*
Source: Authors' work

We conducted a search on the Web of Science Core Collection to investigate the level of research interest in the topic of thermal satisfaction. The search was performed using the keyword "thermal satisfaction" in the title, abstract, author keywords, and keywords plus fields. Our search resulted in a total of 1,554 articles published from 1998 to 2022 (refer to Figure 1, part A). However, we observed a significant increase in the number of papers published from 2012 onwards, with 220 papers published in the year 2020 alone. When we refined our search with additional

keywords such as gender, age, and education, we noticed a significantly lower number of papers (refer to Figure 1, part B). While the positive trend is evident, the low number of articles with these specific words might also indicate that this topic still needs more attention from the research community. Cena and De Dear (2001, p. 413) found that 12% of males expressed thermal unacceptability compared to 19% of females in the winter, while 8% of males and 14% of females expressed thermal dissatisfaction in the summer. The study attributed these differences to clothing variations. This implies that air conditioning systems must cater to the needs of two different sub-populations. However, Cena & De Dear (2021) concluded that "there is little difference (particularly in the summer) between the sexes in terms of thermal sensations" (p. 414). Though Karjalainen (2007, p. 1594) suggested that differences between male and female thermal sensations are typically small, their study indicated significant variations between males and females. Specifically, males were more content with room temperatures in both seasons. In the office environment, female participants were less satisfied with the thermal conditions in both seasons, felt colder more often, felt warmer more frequently during the summer, and felt they had less control over the temperature settings in the room during both seasons (Karjalainen, 2007, p. 1598).

Modera (1993, p. 210) found that women tend to be more sensitive to cooler environments, which leads to greater discomfort in such conditions. Similarly, Lan, Lian, Liu, and Liu (2008, p. 471) conducted two laboratory experiments on Chinese individuals and discovered that there are gender differences in thermal comfort. Their results support the finding that women are more sensitive to temperature but less sensitive to humidity than men. With respect to the preferred indoor environment, the study revealed that women prefer neutral or slightly warmer conditions, due to their lower skin temperature. However, Parsons (2002, p. 593) discovered only minor differences in thermal comfort responses between male and female participants when studying the effects of gender over three hours of exposure in simulated environments.The current literature does not provide a clear answer about how age affects thermal comfort, as pointed out by Choi, Aziz, and Loftness (2010, p.1529). Older people tend to prefer higher temperatures due to their lower level of activity during the day as they age (Meier, 1994). However, males may require different thermal comfort conditions with aging due to physiological changes, which is not the case with women (Young, 1991, p.205). According to Wang *et al*. (2018, p.188), in their systematic literature review, 23% of studies reported significant age-related differences in comfort temperatures, 23% reported weak or insignificant results, and 54% reported no significant results. Early climate chamber experiments found no statistically significant age-related differences when clothing was held constant. In a study by Taylor, Allsopp, and Parkes (1995, pp. 218-219), no differences were observed in preferred temperatures between elderly and young participants. However, elderly participants reported a lower level of comfort in cold-induced changes but higher comfort levels in heat-induced changes. In field studies, some studies found significant age-related differences, some found weak, and most reported no significant age-related differences (Wang *et al*., 2018, p. 188).

3. The sample and methods

As part of the "Social Monitoring and Evaluation for the Implementation of Energy Efficiency Improvements in Public Buildings" project, a survey was conducted from March to June 2021, collecting microdata from individuals who work or visit public buildings in four cities of Bosnia and Herzegovina (Zenica, Sarajevo, Mostar and Tuzla). The survey was conducted through CAPI administration and includes responses from users (such as patients, students aged 15+, and service users) and employees (such as doctors, professional staff, administrative staff, technical staff, and teachers) of seven different buildings, including schools, public administration, and clinics. The sample was collected using a random stratified method and is representative in terms of geographical location, building type, number of users, and investment amount.

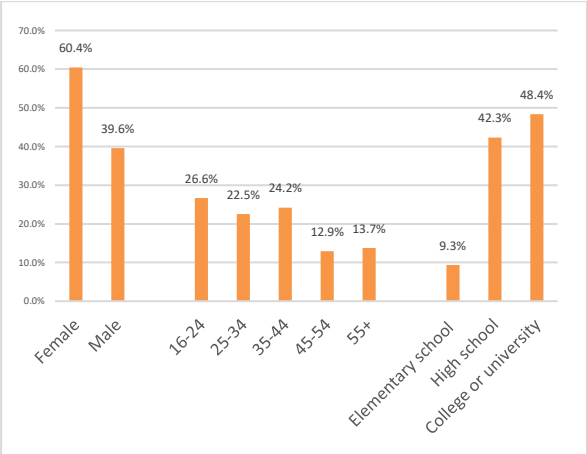

Figure 2. *Sample Characteristics*
Source: Authors' calculation

There were 364 participants in the survey. Females were more represented, making up 60.4% of the total sample. The participants from all age groups took part, but the majority were from the 16-24 age group (26.6%). The second largest age group was the 35-44 age group, representing 24.2%, followed by the 25-34 age group (22.5%). The respondents older than 45 and 55 were less represented, accounting for 12.9% and 13.7% respectively. Approximately 9.3% of the participants were not educated or only had elementary education, while 42.3% had a high school education, and 48.4% had a college or university degree. The study focused on measuring the level of satisfaction with the heating system in an institution. This was done by asking the participants to rate their satisfaction on a five-point scale, ranging from completely dissatisfied to completely satisfied, i.e., "To what extent are you personally satisfied with the heating of the rooms where you spend most time in this institution"? The study also looked at the perceived indoor temperature during the winter period by asking the participants to estimate the average temperature on the institution's premises: "In your estimation, what is the average temperature on the premises of the institution during the winter period"?" To analyze the data, multiple and logistic regression were performed using STATA 15.1. Additionally, a new dummy variable was created to only include the participants who were mostly satisfied or completely satisfied with the heating system.

4. Results and discussion

In this section, we present the results of our analysis. Firstly, we provide a brief description

Table 1. *Descriptive statistics*

		Frequency	Thermal satisfaction (%)	Average perceived indoor temperature
Total	Total sample size	364	34.89%	
Gender	Male	144	43.75%	19.40 (SD = 3.55)
	Female	220	29.09%	18.72 (SD = 3.85)
Age	16-24	97	32.90%	18.19 (SD = 3.53)
	25-34	82	32.93%	19.03 (SD = 4.08)
	35-44	88	32.95%	18.91 (SD = 3.96)
	45-54	47	40.43%	19.58 (SD = 3.25)
	55+	50	40.00%	20.49 (SD = 3.41)
Education	Elementary school	34	17.65%	16.62 (SD = 2.72)
	High school	154	40.91%	19.32 (SD = 3.49)
	College or university	176	32.95%	19.16 (SD = 3.98)
Institution	Clinic 1	44	25.00%	18.91 (SD = 3.78)
	Clinic 2	44	70.45%	21.91 (SD = 1.62)
	Clinic 3	39	10.26%	20.09 (SD = 2.94)
	Clinic 4	45	60.00%	20.81 (SD = 3,08)
	Faculty 1	50	40.00%	19.30 (SD = 2.73)
	Faculty 2	31	0.00%	15.61 (SD = 2.34)
	Police Academy	53	62.26%	20.42 (SD = 3.66)
	High school 1	58	1.72%	15.1 (SD = 3.01)

Source: Authors' calculation

Table 2. *Results of regression model with satisfaction being binary variable*

Independent Variable	Odds ratio (standard error)				
	Model 1 (Gender)	**Model 2 (Age)**	**Model 3 (Education)**	**Model 4 (Integrated)**	**Model 5 (Integrated with control variable)**
Constant	0.77 (0.13)	0.49 (0.11***)	0.21 (0.10***)	0.31 (0.15**)	0.16 (0.08***)
Female (FEM)	0.53 (0.12***)	-	-	0.56 (0.13**)	0.70 (0.18)
Age (AGE) Ref. group 16-24)					
25-34	-	0.997 (0.32)	-	1.00 (0.37)	0.55 (0.22)
35-44	-	0.998 (0.31)	-	1.05 (0.37)	0.67 (0.27)
45-54	-	1.38 (0.51)	-	1.49 (0.62)	0.91 (0.41)
55+	-	1.35 (0.49)	-	1.34 (0.51)	0.82 (0.35)
Education (EDU) - Ref. Elementary school or less					
High School	-	-	3.23 (1.55**)	2.77 (1.36**)	2.01 (1.02)
College/University	-	-	2.29 (1.09*)	2.04 (1.09)	1.67 (0.92)
Institution (INST) - Ref. group Education institution					
Health institutions	-	-	-	-	4.56 (1.42***)
Police academy	-	-	-	-	8.29 (3.32***)
Pseudo R^2	1.74%	0.35%	1.63%	3.32%	11.99%

Dependent variable: Thermal satisfaction (binary outcome)

***Significant at 0.01 level. **Significant at 0.05 level. *Significant at 0.10 level.

Source: Authors' calculation

of the percentage of the respondents who were satisfied with their heating system. After that, we present the results of simple regression to determine the relationship between gender, age, education level, and thermal satisfaction. Table 1 displays the main variables and the related descriptive statistics of the sample. Overall, 34.89% of the respondents were satisfied with the heating of the rooms where they spend most of their time in their institutions. As shown in Table 1, the percentage of the male respondents who were satisfied with the heating system (43.75%) was higher than that of the female respondents (29.09%). The male respondents also perceived the average indoor temperature to be 19.40°C, which is on average 0.68°C higher than that of the female respondents. Across various age groups, the proportion of the participants who were satisfied with the heating system ranged between 32.90% and 32.95% for the respondents younger than 44 years, and around 40% for the participants older than 44 years. Furthermore, the older respondents indicated a higher average indoor temperature than the younger participants: 20.49°C for the 55+ age group, 19.58°C for the 45-54 age group, 18.91°C for the 35-44 age group, 19.03°C for the 25-34 age group, and 18.19°C for the 16-24 age group. Except for the 25-34 age group, the descriptive statistics indicate that as the participants get older, they report a higher perceived indoor temperature. Lastly, the participants with high school degrees reported the highest thermal satisfaction (40.91%) as well as the highest perceived indoor temperature (19.32°C), compared to other levels of education. Our study aims to analyze differences in thermal satisfaction across groups. We considered satisfaction as a binary variable where 1 indicates mostly or completely satisfied respondents. To test this, we built several logistic models. The first model compared satisfaction levels between the male and female respondents. Our findings showed that the odds for females reporting satisfaction with the heating system are about 47% lower than the odds for males. Age did not seem to play a significant role in being satisfied with the heating system. However, education level did make a difference. The odds for the

Table 3. *Results of regression model with satisfaction being measured on Likert scale*

Independent Variable	Coefficients (standard error)				
	Model 1 (Gender)	**Model 2 (Age)**	**Model 3 (Education)**	**Model 4 (Integrated)**	**Model 5 (Integrated with control variable)**
Constant	3.07 (0.12***)	2.61 (0.14)	1.81 (0.15***)	2.34 (0.26***)	1.88 (0.24***)
Female (FEM)	-0.49 (0.15***)	-	-	-0.43 (0.15**)	-0.22 (0.14)
Age (AGE) Ref. group 16-24)					
25-34	-	0.22 (0.21)	-	0.25 (0.24)	-0.33 (0.22)
35-44	-	0.14 (0.21)	-	0.20 (0.24)	-0.25 (0.22)
45-54	-	0.23 (0.25)	-	0.30 (0.27)	-0.21 (0.24)
55+	-	0.36 (0.36)	-	0.35 (0.24)	-0.17 (0.23)
Education (EDU) - Ref. Elementary school or less					
High School	-	-	0.91 (0.26***)	0.72 (0.27**)	0.43 (0.24*)
College/University	-	-	0.65 (0.26**)	0.43 (0.30)	0.32 (0.26)
Institution (INST) - Ref. group Education institution					
Health institutions	-	-	-	-	1.34 (0.15***)
Police academy	-	-	-	-	1.77 (0.21***)
Adjusted R^2	2.62%	0.001%	2.80%	4.23%	26.87%

Dependent variable: Thermal satisfaction (measured on Likert scale)

***Significant at 0.01 level. **Significant at 0.05 level. *Significant at 0.10 level.

Source: Authors' calculation

participants with high school education were 223% higher than the reference group (elementary school or less), while odds for those with a college/university degree were 129% higher. However, when we examined these variables in an integrated model that controlled for the type of object (education, health, and police academy), we found that the differences were no longer observed. The odds of a respondent from health institutions reporting higher thermal satisfaction were 356% higher than those from education institutions, while for the policy academy, they were 729% higher. We concluded that while statistically significant differences can be observed when testing individual variables, the most variance in the model is explained by characteristics of the objects in which the respondents reside or work. Table 3 displays the outcomes of comparable models but with the distinction that instead of being calculated as a binary variable, thermal satisfaction is measured on a five-point Likert scale. The results indicate that gender alone can decrease thermal satisfaction by 0.49 points (Model 1) or 0.43 (Model 4). As with logistic regression, gender loses significance when the type of institution is introduced as a control variable (Model 5). The participants with higher educational attainment, such as high school, can expect 0.91 points higher satisfaction, while those with a college/university degree can expect 0.65. With control variables incorporated in the model, one of the education levels (high school) remained significant at 10%, which was not the case with the logistic regression model. Finaly, the aim of this paper is to investigate whether gender, age, and education have an impact on the reported indoor temperature. The dependent variable is the perceived indoor temperature in degrees Celsius. The results are presented in Table 4. Although the coefficient is negative, suggesting that the female respondents might tend to report lower indoor temperatures, this result is not statistically significant in all models. When not accounting for the institution, the participants in the 45-54 age group reported an

Table 4. *Results of regression model with perceived indoor temperature as dependent variable*

Independent Variable	Coefficients (standard error)				
	Model 1 (Gender)	**Model 2 (Age)**	**Model 3 (Education)**	**Model 4 (Integrated)**	**Model 5 (Integrated with control variable)**
Constant	19.40 (0.34***)	18.19 (0.39***)	16.61 (0.72***)	16.89 (0.79***)	16.42 (0.70***)
Female (FEM)	-0.68 (0.44)	-	-	-0,61 (0.44)	-0.38 (0.41)
Age (AGE) Ref. group 16-24)					
25-34	-	0.85 (0.62)	-	0.42 (0.73)	-1.16 (0.66*)
35-44	-	0.72 (0.59)	-	0.38 (0.72)	-0.97 (0.65)
45-54	-	1.38 (0.70**)	-	1.05 (0.79)	-0.41 (0.71)
55+	-	2.29 (0.72***)	-	1.97 (0.75***)	0.37 (0.68)
Education (EDU) - Ref. Elementary school or less					
High School	-	-	2.70 (0.79***)	2.20 (0.94***)	1.06 (0.74)
College/University	-	-	2.55 (0.79***)	1.99 (0.94**)	1.37 (0.831*)
Institution (INST) - Ref. group Education institution					
Health institutions	-	-	-	-	4.09 (0.45***)
Police academy	-	-	-	-	3.42 (0.57***)
Adjusted R^2	0.46%	2.43%	3.34%	4.84%	27.54%

Dependent variable: Perceived indoor temperature (°C)

***Significant at 0.01 level. **Significant at 0.05 level. *Significant at 0.10 level

Source: Authors' calculation

indoor temperature that was 1.38°C higher than those in the 16-24 age group (significant at 5%). Moreover, those aged over 55 reported an indoor temperature that was 2.29°C higher. The respondents with higher education levels tend to report higher indoor temperatures, with those having a high school degree reporting 1.97°C higher and those with a college/university degree reporting 1.99°C higher, compared to those with elementary or lower education levels. When all variables are included in the model, age (55+) and education are still significant. However, with control variables, only the college/university variable is significant at 10%. There are various factors that can impact how comfortable we feel in certain indoor temperatures. Female participants, in particular, may experience different levels of discomfort due to two main reasons (Wang *et al*., 2018, p. 185): behavioral and physiological. Behavioral reasons may include differences in clothing, which can result in females reporting a lower level of comfort. Physiological reasons are related to metabolic rate in cold exposure, stroke volumes, and blood circulation to the extremities in cold exposures (Wang *et al*., 2018, p. 186). When it comes to age-related differences, there are two possible explanations as to why no differences in preferred temperature are reported. These are heat production and heat dissipation (Wang *et al*., 2018, p. 187), which suggests that older people may have a lower metabolic rate or weakened vasodilatation and vasoconstriction.

5. Conclusion

The purpose of this study is to examine the relationship between gender, age, education level, and thermal satisfaction. Without considering the type of institution, our results show that gender and education level might be necessary to consider. However, when we examined these variables in an integrated model that controlled for the type of object, we found that the differences were no longer observed. The results show that there is no

significant difference when the satisfaction variable is measured binary (dummy) or on a five-point Liker scale. However, logistic regression is more intuitive as it offers interpretation in terms of odds. On the other hand, regression analysis offers interpretation by demonstrating changes in points. The study also found that age is an important predictor in the evaluation of indoor temperature, with older participants reporting higher temperatures in institutional rooms than the younger ones. The results of this study could be useful when designing policies to improve t energy efficiency of buildings, as the results may differ depending on age, gender, and education level. The study findings can also provide useful guidelines when designing more complex studies, especially regarding the debate whether or not the use of a Likert scale is appropriate.

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