

Visual effects of wood on thermal perception of interior environments

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ABSTRACT: There is a general consensus, supported by preliminary evidence, that exposed wood improves human perception of thermal comfort, though this idea has yet to be supported by meaningful effect sizes. This study sought to quantify human perception of thermal comfort of wood materials in a controlled laboratory setting. Participants experienced one of two wall treatments: exposed wooden wall panels and white-painted walls in a thermal environment set directly between “neutral” and “slightly warm” (81.5°F, 40%RH, PMV +0.5). We hypothesized that participants exposed to the wood walls would gauge their thermal preference to be closer to neutral than that of participants who experienced the same thermal environment but with the white wall treatment. Wood was found to have a significant and moderate effect on thermal comfort, with the mean response of the participants who received the wood wall treatment being thermally preferable over that of the white wall (wood wall: $M = 0.46$, $SD = 0.56$; white wall: $M = 0.68$, $SD = 0.51$; $p < 0.01$).

KEYWORDS: visual perception, wood, hue-heat hypothesis, biophilia, thermal comfort

INTRODUCTION

Thermal comfort is calculated as a product of six parameters: air temperature, mean radiant temperature, air speed, humidity, metabolic rate, and clothing level (ASHRAE 55). The adaptive model of thermal comfort has expanded on these parameters, including other non-thermal factors that contribute to thermal comfort: namely, the interaction effects among an individual's physiology, psychology, and behavioral processes (de Dear and Brager, 1997; ASHRAE RP-884). Most research focuses on physiology (primarily temperature acclimation) and behavioral processes (modifying one's thermal environment), but there is much to be learned about the relationship between psychological and physiological thermal perception, particularly related to visual perception interaction effects. This study is focused primarily on the psychological factor in the adaptive model and the interaction effects between psychology and physiology.

One example of visual perception significance is the notion that color can impact human temperature perception. This theory is referred to as the hue-heat hypothesis (HHH) and suggests that the subjective feeling of the temperature of an object can be altered by the object's color (Mogensen 1926). In architectural research, this typically takes the form of investigating colored light on temperature perception. A preliminary study on colored light (Fanger 1977) found that participants preferred a slightly lower ambient air temperature (0.4°C) when exposed to red-colored light. Chinazzo (2017) reported that colored light was found to have an effect on perception of thermal warmth; when exposed to orange light, subjects reported higher estimated temperatures than neutral (white) and blue light settings in a slightly warm environment.

Humans perceive wood in yellow and red hues (Masuda 1992), so wood materials are thought to be subject to the HHH as well. Rohles and Wells (1977) designed an early experiment of material impact on thermal comfort. Two groups of participants ($n=48$) were exposed to the same thermal environment: one group ($n=24$) in a climate chamber with white enamel walls and the other ($n=24$) in the same space but with the addition of embellishments, including wood paneling, red carpeting, furniture, and décor. The wood décor group reported feeling warmer than the embellished room group. This study is unique in its goal of investigating the

visual impacts of wood on thermal comfort. While many studies have investigated thermal perception of colored materials, few have explored wood materials specifically and fewer yet have utilized full-scale studies.

Wood might be perceived as warm because it is considered a *natural* material: that is, one that was once living as compared to its manufactured counterparts, such as concrete, glass, and steel, that, though technically also made from elements in nature, tend to be regarded as *cold* and *sterile*. Wastiels et al. (2012) found that wood was regarded as visually warmer than plaster, steel, or stone. Rice et al. (2004) investigated the visual impacts of wood finishes using a series of image cards with different images of interior finishes and furnishings, finding that wood was commonly determined as “warm” and “calming” as compared to other interior materials.

Biophilia is defined as the attraction of humans to nature and other forms of life (Wilson, 1984). Wood, therefore, boasts biophilic properties and is thought to both improve productivity and well-being as well as reduce stress and fatigue levels, among other psychological and physiological benefits. Results from Sakuragawa et al (2005) show that wood wall panels reduced depression scores and reduced systolic blood pressure in respondents as compared to white steel wall panels. Fell (2010) reports psychophysiological impacts of wooden materials, finding that furniture with wood finishes reduced stress levels in an interior environment by measure of skin conductance level. The effect of wood was even greater than the inclusion of plants in the same environment. Tsunetsugu (2007) found that certain ratios of wood to other materials could lead to comfortable and restful qualities in an interior space. Participants (n=15) exposed to a room clad in 90% wooden materials had lower diastolic and systolic blood pressure at the beginning of the test but an increase in pulse rate at the end. The same room with 45% wood coverage resulted in an increase in pulse rate, a significant decrease in diastolic blood pressure, and was subjectively determined to be the most favorable. This suggests that there might be a preferable ratio of wood with other finishes, and in this study, that ratio is certainly less than 100%.

Colored light and colored walls have been studied for thermal properties, and wood has been studied for psychological properties, but, to the authors' knowledge, wood has not yet been studied in isolation for visual perception of thermal comfort. The goals of this study are (1) to explore the impact of wood materials on perceived thermal comfort in the cooling season (2) to explore the perceived subjective qualities of wood materials and (3) to assess physiological associations of wood materials as indicators of stress response.

1.0. METHODS

1.1. Subjects

The University of Oregon Internal Review Board approved that this study was in compliance with all Human Subject guidelines (Protocol #12012017.001). Participants were recruited from University of Oregon in Portland and Portland State University. Fifty-six participants (20 female, 36 male) completed the experiment (Table 1). No participants reported significant vision impairment, suffered from any heart condition, or were ill at the time of the study.

Table 1. Participant demographic summary

	<i>n</i>	<i>Male</i>	<i>Female</i>	<i>Age</i>	<i>BMI</i>	<i>Time (in hours) since last meal</i>
Wood	28	20	8	29 +/-11.5	24.2 +/-4.8	3.5 +/-2.7
Gypsum	28	16	12	33 +/-10.8	22.5 +/-3.8	3.3 +/-2.9

Participants were instructed to arrive 15 minutes before the beginning of the session. Participants were permitted to use any mode of transportation so long as they did not arrive “sweaty or out of breath”. Of the 56 participants, 29% arrived by car, 32% by public

transportation, 25% by foot, and 11% by bicycle. Participants were instructed to arrive wearing or bring typical summer indoor clothing: a short-sleeved cotton T-shirt, long denim pants, and closed-toe shoes (0.5 clo). Participants were not informed of the purpose of the study, but they were briefed on the procedure via email before the start of their scheduled session.

1.2. Setting

The human subjects testing occurred weekdays in July-August 2018 at the Energy Studies in Buildings Laboratory climate chamber located at the University of Oregon's White Stag Building in Portland, Oregon. The climate chamber is an 8'x12'x9' enclosed room with capability to control radiant temperature, air temperature, humidity, and airflow. The floor is gray laminate tile, and the ceiling is white-painted aluminum panels. Participants were situated with their backs to the entrance to the chamber (a sliding glass door), centered in the climate chamber, to minimize impact from the outside environment and daylight variability. The wall treatments were floor-to-ceiling reversible panels with unfinished laminated wood on one side and painted off-white gypsum board (hereby referred to as "white") on the reverse (Figure 1.2, 1.3). This allowed for both wall treatments to be physically present in the chamber for all participants, but only one treatment was visible to each participant. A floor-to-ceiling black fabric curtain covered the wall treatments for the acclimation portion of the experiment (Figure 1.1). The wooden wall panels were intended to mimic that of cross-laminated timber assembly: laminated Douglas fir (Light reflectance value ~52). The white wall assembly was standard drywall coated with an off-white matte finish (Benjamin Moore #2022-70, Light reflectance value 89.27). Electric lighting was utilized in all conditions (Phillips, F32T8/TL835/ALTO, 3500 Kelvin).

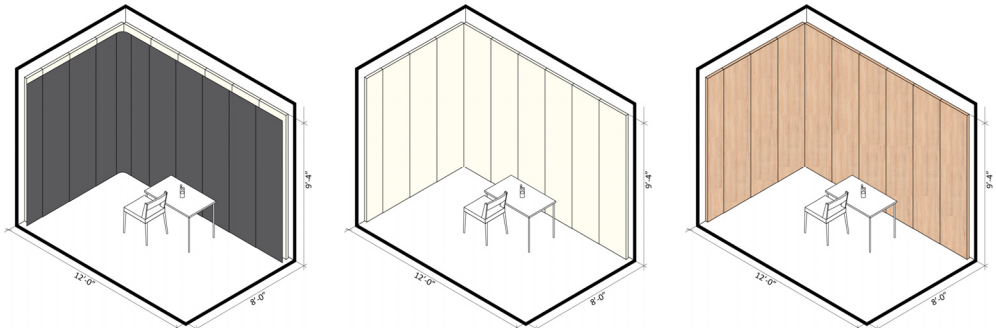


Figure 1. Wall conditions: 1.1 Black curtain (left), 1.2 White painted drywall (center), and 1.3 Wood (right)

1.3. Thermal environment and equipment

The thermal environment was maintained at +0.5 Predicted Mean Vote (PMV) value representative of halfway between "neutral" and "slightly warm" on the thermal sensation scale (ASHRAE 55). Air temperature and mean radiant temperature maintained ($81.5^{\circ}\text{F} \pm 1^{\circ}\text{F}$). Relative humidity was 40% RH ($\pm 5\%$), the seasonal average outdoor RH for the Portland TMY3 file. A data logger (Kestrel 5400 Heat Stress Tracker, accuracy $\pm 0.9^{\circ}\text{F}$ ambient temperature and $\pm 2\%$ RH) was positioned at desk height (0.75m) to the participant's right-hand side, with continuous monitoring of environmental conditions, logged every minute.

An ambulatory blood pressure monitor (ABPM) was used to record participant blood pressure readings at 5-minute intervals (Oscar 2, SunTechMedical, accuracy ± 5 mmHg). Internal body temperature was recorded at the start and end of each testing phase with an in-ear clinical thermometer (Braun ThermoScan Ear thermometer, accuracy $\pm 0.4^{\circ}\text{F}$) to check for high temperatures that might indicate illness.

1.5. Subjective thermal comfort survey

Surveys were conducted at 5-minute intervals with the exception of the first 20-minutes of the study during which participants acclimated to their environment. Surveys were completed on

a laboratory-provided iPad via a Qualtrics online survey. Thermal sensation (TS) was the standard ASHRAE seven-point scale ranging from cold to hot, with neutral as the middle value. A 5-point scale was used for thermal acceptability (TA), ranging from “clearly unacceptable” to “clearly acceptable”, with three unlabeled options between the two extremes. The three-point McIntyre scale (1978) was used for thermal preference (TP) to determine how subjects would prefer to feel without magnitude: warmer, cooler, or no change. The fourth and final question was temperature estimation (TE), which asked that participants give their best guess for the actual (dry bulb air) temperature of the room, with whichever scale (in °F or °C) participants had previously indicated they felt more familiar. The final question in the thermal comfort survey was open-ended and asked participants to “describe any other issues related to comfort in your space.” Table 2 lists the thermal comfort questions and their respective response options included in the thermal comfort survey.

Table 2. Repeated subjective thermal comfort survey items

<i>Thermal sensation (TS)</i>	At this precise moment, how are you feeling? (7-point scale)						
	Cold (-3)	Cool (-2)	Slightly cool (- 1)	Neutral (0)	Slightly warm (+1)	Warm (+2)	Hot (+3)
<i>Thermal acceptability (TA)</i>	How acceptable is your thermal environment? (5-point scale)						
	Clearly unacceptable (1)		(2)	(3)	(4)	Clearly acceptable (5)	
<i>Thermal preference (TP)</i>	How would you prefer to feel now? (3-point scale)						
	Cooler (-1)		No change (0)			Warmer (+1)	
<i>Temperature estimation (TE)</i>	Open-ended (°F or °C)						

1.6. Semantic differential survey

The perceived qualities of each of the wall treatments was assessed by use of a semantic-differential survey of sixteen word pairs judged on a 7-point bipolar scale. The word pairs were selected from existing literature investigating perception of wood materials (Rice 2007, Wastiels 2012). These pairs assess visual qualities (dark-bright, dirty-clean), tactile and thermal qualities (rough-smooth, cold-warm, soft-hard, light-heavy), and affective and preferential qualities (artificial-natural, cheap-expensive, old-new, unpleasant-pleasant, fragile-sturdy, common-unique, dislike-like, calming-exciting, complex-simple, uninteresting-interesting).

1.7. Procedure

In the first 15 minutes, participants' temperature, height, and weight were collected. A member of the research team would then apply the ABPM cuff. Participants were instructed to leave their arm down to their side and relaxed for each blood pressure reading. The first reading was taken before entering the climate chamber to minimize the effects of white coat syndrome. Participants then entered the climate chamber at minute zero, for the control condition. The first survey included demographic information, the first semantic word pair survey, and the first thermal comfort survey (Q1). After 20 minutes and at subsequent 5-minute intervals, participants were prompted to take the respond to the thermal comfort survey. The participants again completed the semantic word pair survey after the wall treatment was revealed (Q6). At the end of the session, a final survey assessing daily personal thermal comfort was issued (Q9).

1.8. Statistical analysis

The statistical analysis was carried out using RStudio software version 1.1.447. A Shapiro-Wilk normality test resulted in non-normal distribution of all thermal comfort survey data ($W=0.44-0.90$, $p<0.001$). For all non-normal data, a non-parametric Spearman correlation regression was used to compare thermal sensation and study variables. A non-paired, two-

tailed t-test was used to determine statistical significance when $p < 0.05$. Hotelling's *T*-squared statistic was utilized as a multivariate hypothesis test for determining significance of proportional data; which was appropriate for this application because we were testing the difference between the mean responses from distinct populations.



Figure 2. Standard experiment session timeline. The times at which surveys were completed are indicated by the letter Q. The acclimation period is the time during which a black curtain covered the wall treatment. At the 40-minute mark, the curtain was pulled away and participants then experienced either wood or white-painted walls for the treatment period.

2.0. RESULTS

The perceived thermal comfort survey responses were analyzed both independently and as a set. The first survey was regarded as training for the participants and was not included in the data analyses. Because the acclimation time was relatively short, all surveys other than Q5 completed in the control environment are subject to each participant's thermal adaptation and are therefore unreliable. Comparisons are made between the control and test environments to ensure consistent thermal conditions. The analysis focuses on the difference between the immediate thermal comfort response from control to treatment (Q5 to Q6) and the long-term thermal perception from control to the last survey of the treatment condition (Q5 to Q9) (Table 3).

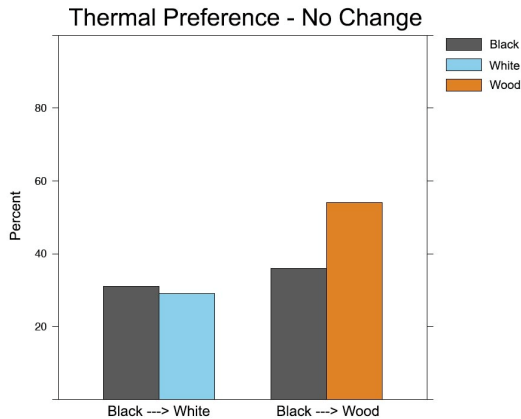


Figure 3. Percentage of TP responses indicating desire for 'no change' to the thermal environment. The blue (left) column indicates the last survey in the control condition (Q5) compared with the last response of the two wall treatment conditions (Q9).

Table 3. Mean perceived thermal comfort results for control (Q5) to first treatment exposure (Q6) and for control to last treatment exposure (Q9). Significance is indicated by "*" when $p < 0.05$

	Wood		White	
	Q5 Q6	Q5 Q9	Q5 Q6	Q5 Q9
TS	0.39*	0.39*	-0.03*	-0.36*
TA	0.21*	0.14*	-0.12*	-0.12*
TP	0.11*	0.18	-0.08*	0.10
TE (°F)	-0.36	0.79	-0.04	0.50

2.1. Thermal comfort results

Thermal comfort results are summarized in Table 3. Thermal sensation responses of participants who received the wood wall treatment was cooler and closer to thermally neutral

($M = +0.54$, $SD = 0.69$), than those exposed to the white wall treatment ($M = +0.68$, $SD = 0.72$), $t(56) = 1.67$, $p = 0.03$ (Figure 4). On the 5-point thermal acceptability scale, with 1 being “clearly acceptable” and 5 being “clearly unacceptable”, at the point at which the wall treatment was revealed (Q5|Q6), responses of participants who received the wood wall treatment were more accepting of the thermal environment ($M = 2.01$, $SD = 0.88$), than those of the white walls ($M = 2.41$, $SD = 1.09$), $p < 0.05$.

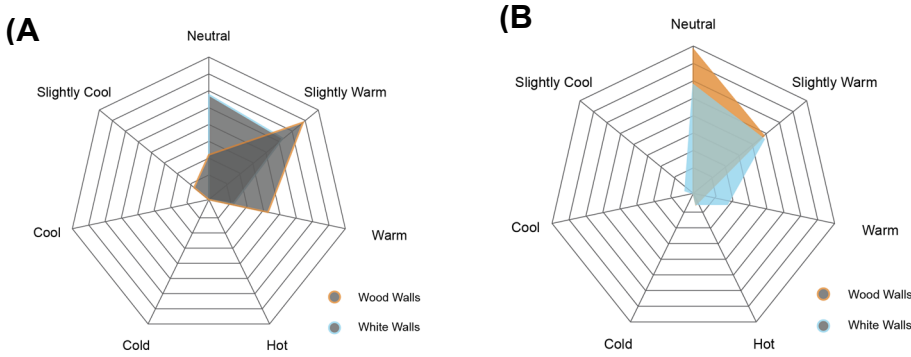


Figure 4. Radar chart of distribution of thermal sensation responses for (A) Q5: the last survey in the treatment condition (black curtain) for both wood and white groups (B) Q9: the last survey of the wall treatment in which groups were exposed to their respective treatment condition

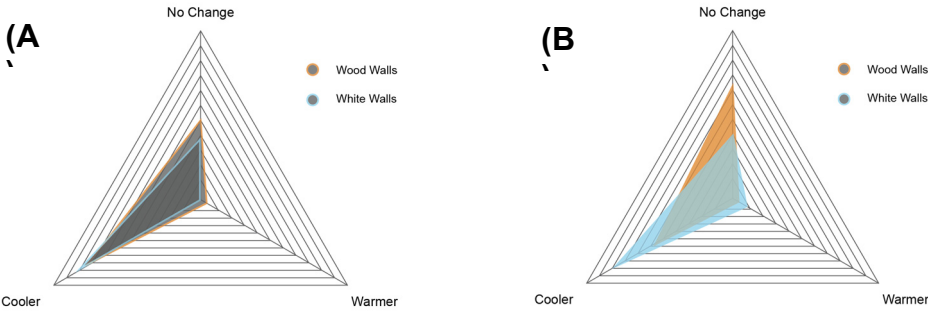


Figure 5. Radar chart of thermal preference responses for (A) Q5: the last survey in the treatment condition (black curtain) for both wood and white groups (B) Q9: the last survey of the wall treatment in which groups were exposed to their respective treatment condition

Wall treatment was also found to have a significant effect on perception of thermal preference. Mean participant response for white wall treatment revealed a desire for a cooler environment when compared to the control treatment prior ($\Delta_{\text{black|white}} = -0.08$, $SD = 0.39$), with the mean decreasing from the control to the wood wall treatment ($\Delta_{\text{black|wood}} = 0.11$, $SD = 0.57$, $p < 0.05$) (Figure 4).

At the point at which the wall treatment was revealed, perceived thermal preference of participants who received the wood wall treatment was cooler and closer to thermally neutral ($M = 0.46$, $SD = 0.56$), than those exposed to the white painted drywall wall treatment ($M = 0.68$, $SD = 0.51$, $p < 0.01$) (Figure 5). Because thermal preference is a directional scale without weight, the data are best represented in proportions. Proportioning the responses reveals that participants were more likely to respond with “no change” in the wood wall condition (54%) than the control condition prior (36%) and more than the white wall (29%) which decreased from the control condition prior (31%) (Figure 3).

2.2. Semantic results

The strongest correlation discovered was for the word pair natural-artificial to wall treatment, $r(56) = 0.77, p < 0.001$. Wood was considered more “natural” than white walls or the control. Wood was also significantly more “liked” than “disliked” as compared to the white walls, $r(56) = 0.58, p < 0.01$. Wood was also found to be significantly more “expensive”, “pleasant”, “sturdy”, “unique”, “interesting”, “new”, and “clean” than the white.

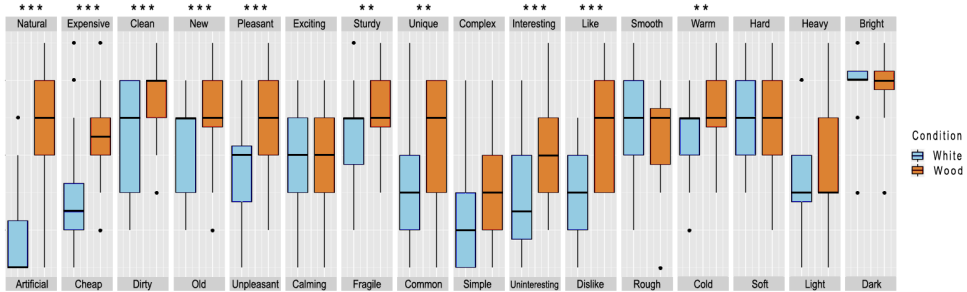


Figure 6. Semantic-differential word results by wall treatment. Significance is indicated at the top of each word pair; “*” $p < 0.05$, “***” $p < 0.01$, “****” $p < 0.001$

2.3. Physiological results

None of the physiological results varied by function of wall treatment with an meaningful effect size ($d > 0.2$), so the results will not be included in this paper. Possible reasons for this result are included in the discussion.

3 DISCUSSION

This study illustrates the success of PMV for predicting human thermal comfort. For the purpose of understanding perception, we are interested in a small range of responses on the PMV scale: from 0 “neutral” to 1 “slightly warm”; 82% of all thermal sensation responses in this study were one of these two choices.

The results for thermal sensation alone, though minimal, are not negative. The HHH would reason that there may be some concern that exposed wood surfaces may lead to a perceived overheating is the potential for wood materials to lead to an overheating effect in the cooling season because of the HHH. This study supports the alternative. While the cause cannot be identified, we hypothesize it is possibly due to a biophilic effect of wood materials. The perceived qualities of the wood walls might have led participants to feel more at ease, and therefore, more forgiving of the thermal environment.

We posit that we may be able to counteract slight increases in the temperature setpoint in the cooling season by leveraging the visual effects of wood materials on perception of thermal comfort. Based upon the perceived thermal comfort difference from white to wood (+0.2 PMV), with all other variables held constant (MRT, RH, air speed, met, clo), this translates to a potential air temperature difference of 1°F. This effect will likely not go above and beyond the acceptable temperature range of the adaptive model but should be explored in future research. Importantly, even if further studies do not show persistence of this effect, this study lends some confidence that the HHH does not create a new obstacle when trying to reduce heating and cooling demands in exposed wood buildings.

According to Humphreys and Hancock (2007), the use of any particular thermal comfort scale can result in a vote bias. It is for this reason that the thermal comfort responses were treated as a set. This double-inquiry method compares thermal sensation with thermal preference. The data revealed that participants who rated their thermal comfort as “neutral” often selected their thermal preference to be “cooler”. The desired thermal change does not always reflect the responses for thermal sensation. The perceived thermal comfort for individual preferences

is often different from what is desired. In this study, we were interested in determining not only how a person *feels*, but how they would *like* to feel. In perception research, this is critical. An individual might determine their environment to be thermally “neutral” but actually would *like* to feel either cooler or warmer, depending on the context. The thermal sensation and thermal preference scales led to inconsistent feedback from participants; for this reason, in this study, we define perceived thermal comfort as thermal contentedness. Participants were more likely to be thermally “content” in the wood environment than the white walls. The tendency to be more forgiving of the uncomfortable environment might be due to the biophilic properties of wood or its visual interest over that of white walls, but this study cannot articulate cause.

Of particular interest is the first survey after the treatment condition was revealed. The instantaneous effect of wood on thermal sensation appears to be very strong. Over the remaining time in the treatment condition, this effect lessened. This begs the question: Could the effect of wooden materials become negligible over time as the subjects acclimate to their new surroundings? Future research should extend the study time period to determine if there is a duration at which wood no longer affects perceived thermal comfort or if it persists. The inconclusive physiological results are inconsistent with previous research. This study utilized ABPM rather than skin conductance, which could account for some degree of variability. These results could be due to any of the following: (1) there are no parasympathetic effects with respect to exposure to wood, (2) white coat syndrome led to increased blood pressure in any number of the participants and increased variability in HR, (3) the time spent acclimating to the space was not sufficient enough to trigger a parasympathetic response.

The semantic differential word pair results reveal that people found the wood walls to have favorable qualities all-around than the white. These findings are consistent with the literature and support that wood is perceived as a “natural” material. The greater effect size of the semantic results over the thermal comfort subjective results or physiological data suggests that the relationship between humans and biophilic materials such as wood are primarily psychological and rooted in personal preference. Interestingly, in the word pairs, the wood walls were found to be “warmer” than the white, $r(56) = 0.31$, $p < 0.05$. Additionally, for all word pairs, there was no significant change between the control condition for the white and the control condition for the wood. This suggests that participants responded to the visual differences between the treatment walls as compared to other factors that might have affected their decisions, including uncontrollable factors such as smell, lighting, daily environmental differences, which seem to have had minimal effect on perceived qualities of the space.

Finally, perception of thermal comfort is important because it can contribute to the adaptive model of thermal comfort. In combining the subjective results with the physiological results, as expected, physiology is the strongest factor for predicting thermal comfort. This study suggests that perception of thermal comfort does not alter the body’s physiology greatly, but visual perception is influential in a person’s assessment of a space that is slightly uncomfortable, at least for over the duration of an hour. By contrast, in an extreme environment (i.e. +2 PMV, “hot”), we would expect most participants to report some degree of discomfort. In this scenario, it is unlikely that the participants would perceive improved thermal comfort regardless of the visual field.

3.1. Limitations

The authors recognize that the sample size was limited. With more time and funding, a repeated-measures study might have more effectively illustrated the individual preference between the two wall treatments and increased the power of the study. In hindsight, we would have liked to also study neural activity at the time the wall treatment was revealed, given the strength of the initial responses. Studying participants’ brain activity in conjunction with the data collected in this study may add a critical perspective useful in interpreting the results.

4.0. CONCLUSION

This study found that wood materials corresponded with thermal preference response indicating “no change” was desired, thus thermal preference was improved with exposure to

wood walls over that of white. Participants associated wood walls with positive qualities for nearly all word pairs. Effect of wood was most strongly correlated with objective (semantic) responses, followed by perception of thermal comfort, then minimally with physiological responses. We conclude that the effect of material perception is highly subjective and, in slightly uncomfortable thermal environments, visually “pleasant” or “warm” surroundings can improve perceived thermal comfort, even when the space may call for cooling.

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REFERENCES

- ASHRAE Standard 55 – 2010. Thermal Environmental Conditions for Human Occupancy. Atlanta, ASHRAE.
- Chinazzo, G., Wienold, J., & Andersen, M. (2018). Combined effects of daylight transmitted through coloured glazing and indoor temperature on thermal responses and overall comfort. *Building and Environment*, 144(May), 583–597.
- de Dear, R., Brager, G., & Cooper, D. (1997). Developing an Adaptive Model of Thermal Comfort and Preference. *ASHRAE Trans*, 104 (Part 1), 1–18.
- Fell, D. R. (2010). Wood in the Human Environment: Restorative Properties of Wood in the Built Indoor Environment (PhD Thesis). University of British Columbia. Retrieved from UBC Theses and Dissertations.
- Humphreys, M. A., & Hancock, M. (2007). Do People like to Feel ‘Neutral’?. Exploring the Variation of the Desired Thermal Sensation on the ASHRAE Scale.”*Energy and Buildings* 39 (7): 867–74.
- McIntyre, D.A. (1978). Three approaches to thermal comfort. *ASHRAE Transactions*. Vol. 84, No.1, pp.101-109.
- Masuda, M. (1992) Visual characteristics of wood and the psychological images (in Japanese). *Mokuzai Gakkaishi* 38:1075–1081
- Mogensen, M., & English, H. (1926). The Apparent Warmth of Colors. *The American Journal of Psychology*, 37(3), 427-428.
- P.O. Fanger, N.O. Breum, E. Jerking. (1977) Can colour and noise influence Man's thermal comfort? *Ergonomics* 20 (1), 11–18
- Rohles, F. H.; Wells, W. V. (1977). The role of environmental antecedents on subsequent thermal comfort. *ASHRAE Transactions*, 83, 21–29.
- Rice, J., Kozak, R. a, Meitner, M. J., & Cohen, D. H. (2006). Appearance Wood Products and Psychological Well-Being. *Wood and Fiber Science*, 38(4), 644–659.
- Sakuragawa, S., Miyazaki, Y., Kaneko, T., & Makita, T. (2005). Influence of wood wall panels on physiological and psychological responses. *Journal of Wood Science*, 51(2), 136–140.
- Tsunetsugu, Y., Miyazaki, Y., & Sato, H. (2007). Physiological effects in humans induced by the visual stimulation of room interiors with different wood quantities. *Journal of Wood Science*, 53(1), 11–16.
- Wastiels, L., Schifferstein, H. N. J., Heylighen, A., & Wouters, I. (2012). Relating material experience to technical parameters: A case study on visual and tactile warmth perception of indoor wall materials. *Building and Environment*, 49(1), 359–367.
- Wilson, Edward O. (1984). *Biophilia*. Cambridge: Harvard University Press.