PERCEPTION AND EVALUATION OF (MODIFIED) WOOD BY OLDER ADULTS FROM SLOVENIA AND NORWAY[1]

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Abstract. Many building users prefer wood over other building materials, but it is unclear how modified wood is perceived compared with unmodified wood. Additionally, it is unclear which material properties play a role in the general preference for wood, how tactile and tactile–visual perceptions of materials affect user preference for wood, and whether human preference for wood is consistent across countries and cultures with different wood use practices. One hundred older adults from Slovenia and Norway rated and ranked wooden materials (ie handrails) made of either unmodified or modified wood and a stainless steel control sample. The materials were rated on a semantic differential scale (capturing sensory and affective attributes) by each participant twice: first, while only touching the materials and then while simultaneously touching and seeing the materials. Finally, each participant ranked the handrails in order of preference. Wooden handrails were generally more preferred than the steel sample. Preference ratings and rankings of modified wood were comparable to those of unmodified wood. Results were relatively consistent across both countries. Materials rated as liked were perceived as somewhat less cold, less damp, more usual, less artificial, more expensive, and less unpleasant. The ratings were fairly consistent between the tactile and tactile–visual tasks. In some indoor applications, certain types of modified wood could be used in place of unmodified wood while meeting human aesthetical preferences. Specific visual and tactile properties can predict material preference and could be considered in the material design phase. The tactile experience is important in overall material perception and should not be overlooked. These findings seem to be stable across countries with different wood use practices.

Keywords: Material preference, wood modification, elderly, handrails.

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INTRODUCTION

People spend most of their time indoors, and indoor environments can affect their health (Redlich et al 1997; Evans 2003). Focus in interior design has shifted beyond approaches minimizing harm, such as reducing outdoor noise, to creating restorative environments that can induce positive changes in well-being (Mcsweeney et al 2015; Markevych et al 2017). In recent years, research on restorative environments has begun to focus on older adults. An overview of the topic by Roe and Roe (2018) concludes that more attention should be paid, among other things, to restoration in residential (rather than natural) environments and to sensory stimuli. According to the authors, the residential environment, where older adults spend much of their time, "arguably offers the most important context for restoration," whereas "sensory stimulation in the living environment triggers curiosity and, in turn, our motivation to move around and explore" (490).

One of the main restorative design practices is to bring elements of nature into indoor spaces, as this can improve psychological and physiological indicators of human well-being (Mcsweeney et al 2015). Comparable outcomes have been observed when people were exposed to indoor wood (Sakuragawa et al 2005; Fell 2010; Nyrud and Bringslimark 2010; Burnard and Kutnar 2015; Zhang et al 2016; Zhang et al 2017; Demattè et al 2018; Nakamura et al 2019; Burnard and Kutnar 2020; Lipovac and Burnard 2020; Lipovac et al 2020; Shen et al 2020).

According to stress reduction theory, the observed positive response to nature is mediated by human aesthetic preferences that are predominantly innate (Ulrich 1983). The theory states that the initial response to a natural setting is affective (eg appreciation, interest), and that it precedes cognitive appraisal of the scene. This response is elicited quickly by different features of the natural environment, including water and vegetation, and many such (nonthreatening) features trigger a positive response. The initial affective response, along with one's experience and culture, influences cognitive appraisal of the scene, which can alter the initial affective state. The interplay between affect and cognition culminates in motivating (adaptive) behavior or functioning. The main predictions of the stress reduction theory are supported by findings showing that people from different cultures prefer natural environments over built environments (see Ulrich 1983, for a brief overview), and the environmental preference is positively associated with restoration (van den Berg et al 2003) and perceived restorativeness of the environment (Purcell et al 2001; Han 2010). Similarly, spaces furnished with wooden materials are perceived as more natural and preferred than environments without wood (Sakuragawa et al 2005; Nyrud et al 2014; Strobel et al 2017; Demattè et al 2018). Improved indicators of well-being and higher preference ratings have also been observed when wood was experienced only through touch (Bhatta et al 2017; Ikei et al 2017a, 2017b). These findings suggest that preference ratings of environments and materials could be used as an indicator of their potential restorativeness: investigating the perception of wood may help create materials that are not only useful in construction but may also contribute to restorative environments.

Modified Wood and Human Preference

Wood is generally perceived as more natural and liked than other common building materials (Rice et al 2006; Burnard et al 2017; Ikei et al 2017b). Recently, however, a lot of attention has been given to modified wood: wood that has undergone modification process that enhances its construction-related properties (Sandberg et al 2017). As a side effect, modification processes change material properties directly available to human senses, such as color, dryness, or roughness (Esteves and Pereira 2009; Bakar et al 2013). Due to its enhancements, modified wood can be expected to become more widely used in the future, but few studies have examined how people perceive it. Existing studies reported promising results: professionals and lay users liked certain thermally and chemically modified wood samples similarly to other types of wood in multiple settings (Gamache and Espinoza 2017;

Lipovac et al 2019). However, more evidence is needed to confirm these findings in other settings and determine whether modified wood is suitable for use in restorative environments.

Wood Properties and Human Preference

To determine whether materials can be used in restorative environments, we need to explore human preferences for materials and material properties that affect these preferences, including visual and tactile qualities of wooden materials, such as color, grain patterns, and surface treatments. People evaluate materials differently when these properties change (Waka et al 2015; Kidoma et al 2017). Studying these variations could help us develop materials that are more attractive to building users.

Human preference ratings (eg "like") can be viewed as the culmination of lower-level affective attributes (eg "interesting") and physical surface perceptions (eg "rough") (Okamoto et al 2016; Kidoma et al 2017). Existing studies have identified certain properties of wood that are associated with greater preference. When people sense wood by touch, they prefer untreated wood surfaces (compared with coated surfaces) (Bhatta et al 2017; Ikei et al 2017a), and their physiological indicators of well-being tend to improve (Ikei et al 2017a). People generally prefer wood surfaces they perceive as smoother (Jonsson et al 2008; Waka et al 2015; Bhatta et al 2017), and some evidence suggests this is also true for surfaces perceived as a denser, warmer, damper, softer, and more natural (Jonsson et al 2008; Waka et al 2015). In a study in which wood samples of outdoor tabletops were visually and tactilely inspected and ranked according to preference, greater preference was associated with perceived surface dampness and with material colors that were darker and closer to red on the green–red color component (Lipovac et al 2019). Other factors additionally influence visual preference for wood: people appear to prefer shinier and less knotty surfaces as well as surfaces with homogeneous color (Nyrud et al 2008; Sande and Nyrud 2008; Høibø and Nyrud 2010; Manuel et al 2015; Waka et al 2015). As relatively few materials have been studied in few contexts, how material properties influence preferences for wooden materials remains unclear.

The Relationship between Tactile and Visual Domain in Material Evaluation

Wood treatments are usually used to improve the performance of mechanical properties or to inhibit degradation of wood, but they often also change tactile properties, such as dampness. Moreover, coatings are frequently used to improve the longevity of the wood and reduce surface roughness. Such treatments might inadvertently negatively impact the tactile experience of materials: when touching materials, people rate unmodified as more liked than coated wood (Bhatta et al 2017), and their physiological state indicates greater relaxation (Ikei et al 2017a). The importance of focusing on surface texture to enhance the tactile experience of materials has been highlighted by Bhatta et al (2017). They argued that surfaces should have qualities that are perceived as natural. The significance of tactile material properties has been further explored in studies examining the consistency of perception between tactile and visual modalities. In a study in which participants rated naturalness of materials, ratings were consistent between tactile, visual, and tactile–visual experience of wood, suggesting that the tactile experience of materials is a rich source of information that is not substantially altered by the visual information (Overvliet and Soto-Faraco 2011). The authors of the study concluded that vision and touch are equally good at predicting naturalness. It seems that the tactile domain plays an important role in general material perception and should be further explored in different contexts of wood use.

Potential Cultural Effect on Wood Perception and Evaluation

Human affinity for natural elements may be widespread, but the role of culture should not be overlooked. When people observe wood, they can struggle in separating natural from artificial materials (Overvliet and Soto-Faraco 2011), and their knowledge about wood treatments can influence their perception of material naturalness (Rozin 2005, 2006). Perception of naturalness, in turn, can affect preference (Jonsson et al 2008). When participants from Slovenia, Norway, and Finland rated several materials on perceived naturalness, their ratings were generally consistent. However, the ratings between participants from Slovenia and the two Nordic countries diverged in certain instances where processed wood samples were rated: Nordic participants perceived these samples as less natural than Slovenian respondents (Burnard et al 2017). This divergence could stem from differences in the knowledge and familiarity with wood and wood processing between the country populations, which, in turn, could result from different practices of wood use in these countries. Wooden buildings have a rich tradition in the Nordic countries (Mayo 2015), whereas in Slovenia, relatively little wood is used for structural components of houses (Statistical Office of the Republic of Slovenia [SURS]). If perceived naturalness and general preference of materials may vary between countries, studying wood perception and evaluation in countries with different wood use practices may help us reach stronger conclusions about the (potentially) universal appeal of wooden materials.

Objectives

The objectives of this study were to investigate 1) general preference for modified wood compared with unmodified wooden materials (and a non-wood control sample), 2) the association between perceived wood properties and wood preference, and 3) the relationship between the tactile and tactile–visual domain of material perception. To extend the work of existing studies, wood samples used were brought closer to real-life context by using handrail samples instead of often used small rectangular blocks of wood. The study was conducted across two countries (Slovenia and Norway) with different practices of wood use, to explore possible cultural influences on perception and evaluation of wood. The sample of participants consisted of older adults, as they may physically interact with interior materials more often than other age groups (eg using assistive railings for walking), and, consequently, contact with pleasant materials may affect them more profoundly.

MATERIALS AND METHODS

Participants

One hundred older adults aged 60 yr or more (M = 68.46 yr, SD = 7.23; 41 women) from Slovenia and Norway participated in the study. Participants were eligible to participate if they had no health impairments that could interfere with the study protocol, such as severely impaired vision or significant cognitive impairment. Subjects were not compensated for participation. Before the testing, subjects signed an informed consent form explaining the study purpose and protocol, participants' rights, and data management practice.

Slovenia. Fifty participants (M = 71.14 yr, SD = 7.19; 27 women) were from Slovenia. Thirty-four of them were recruited and tested in an activity center for older adults (city of Koper), which is visited predominantly by retired people. The remaining 16 participants, who were tested at their homes, were recruited through the social network of the first author and through snowball sampling.

Norway. Fifty participants (M = 65.78 yr, SD = 6.27; 14 women) were from Norway. Eight of them were recruited and tested in various places (eg coffee shop, mall, library) in the city of

Figure 1. Handrail samples (from left to right: unmodified spruce, unmodified pine, acetylated radiata pine, thermally modified pine, thermally modified spruce, stainless steel).

Kristiansund. The other 42 participants, who were part of the still-active faculty staff, were recruited and tested at Norwegian University of Life Sciences (city of Ås).

Handrail Samples

Six cylindrical handrail samples were prepared (Fig 1); one was made of stainless steel and five of modified or unmodified wood. Specifically, we included handrails made of unmodified spruce, unmodified pine, acetylated radiata pine, thermally modified spruce, and thermally modified pine. The thermal modification was performed using the commercial ThermoD process at 212°C and superheated steam at the Heatwood company (Hudiksvall, Sweden). The handrail samples were 42 mm in diameter and 30 cm long. Each sample was mounted on a wooden base measuring approximately 30 cm × 15 cm × 5 cm, which was covered with white foil.

Semantic Differential Scale

Based on the previous work examining material perception in general (Guest et al 2011; Baumgartner et al 2013; Datta 2016; Okamoto et al 2016; Kidoma et al 2017) and wood perception in particular (Overvliet and Soto-Faraco 2011; Waka et al 2015; Kanaya et al 2016; Bhatta et al 2017), we selected sensory and affective descriptors that we considered relevant in the assessment of the materials used in this study. To each selected descriptor, we added a polar opposite descriptor. Altogether, we ended up with 11-word pairs, which captured tactile sensory properties (ie rough—smooth, warm—cold, dry—damp, soft—hard), affective attributes (ie unusual—usual, natural—artificial, cheap—expensive, pleasant—unpleasant, dislike—like), and visual sensory properties (ie dark—light, shiny—matte). The latter two-word pairs were used only in the part of the study in which participants could visually inspect the materials. Subjects responded to each word pair based on a five-point scale that consisted of the adverbs "considerably (eg rough)," "somewhat (eg rough)," "in the middle," "somewhat (eg smooth)," and "considerably (eg smooth)." The order *between* the presented word pairs was kept constant throughout the study; the word pairs followed each other in the same order as presented in this section. The order of descriptors *within each* word pair was also constant and followed the order presented in this paragraph. Note that to minimize possible effects of order within word pairs, the position of descriptors (ie left or right in the word pair) with positive and negative valence alternates among word pairs (eg the first word pair contains "rough" with negative valence on the left, the second word pair contains "cold" with negative valence on the right, etc.). The resulting scale was translated into Slovenian (Table S1) and Norwegian (Table S2). For simplicity, the remainder of this article presents only the item from the right-hand side of the scale (eg smooth) instead of the entire word pair (eg rough—smooth) when referring to the scale items.

Testing Procedure

The study consisted of three tasks. In the first task, participants could touch (but not see) the materials: they were instructed to keep their eyes closed during the test. Based on their tactile experience of materials, participants provided a response on a five-point semantic differential scale that was read to them. Responses were immediately entered into a computerized version of the scale. After completing the tactile task, participants proceeded to the second part of the study: tactile–visual task. This task was identical to the tactile task, except that the subjects could both touch and see the materials. Materials were presented to each participant in randomized order; however, for each participant, the order from the tactile task was repeated in the tactile–visual task, to allow for a better comparison of results on the two tasks. The third part of the study consisted of the ranking task. Participants were presented with all the materials at once to inspect them tactilely and visually. They were asked to rank the materials from most to least preferred by placing cards with numbers from one (most preferred) to six (least preferred). In total, the study session lasted approximately 30 min per participant. All sessions were conducted first in Slovenia and later in Norway.

Statistical Analysis

The data were processed and analyzed in R 4.0.2 (Team R Core 2021) using R Studio 1.3.959 (R Studio Team 2021) with the packages dplyr (Wickham et al 2020), ggplot2 (Wickham et al 2019), rstatix (Kassambara 2020), and rcompanion (Mangiafico 2019). Data from the entire sample of 100 participants were available and analyzed in all results presented below. There were no missing values, as the responses from subjects were entered directly into a computerized tool, which did not allow progressing without receiving a response.

We begin the analysis by examining the general preference of materials. We first calculate means and 95% confidence intervals (CI) for the scores on the item "like" for each material, separately for the tactile and tactile–visual tasks. We then test for differences between these scores with pairwise t-tests. The ranking task results present median ranks and bootstrapped percentile CI, and we test for differences between the ranks with pairwise Wilcoxon tests. For all tasks (tactile task, tactile–visual task, and ranking task), we first analyze results from the entire group of participants, continue with the analysis of results within each country, and conclude with the comparison of results between the countries. Note that in between-country comparisons, scores for each material are only compared with the scores of the same material, in contrast with overall and within-country comparisons, where scores for each material are compared with scores of all other materials.

The second section examines the association between the scores on the "like" item and the remaining items from the semantic differential scale. We calculate Kendall rank correlation coefficients between scores on the item "like" and scores on the other rating items, separately for the tactile and tactile–visual tasks.

The third and final section examines the relationship between the tactile and tactile–visual task scores: we first compare the scores between the tactile and tactile–visual tasks on all rating items (except "matte" and "light," which were not included in both tasks) across all materials and continue with computing Kendall rank correlation coefficients between the scores of both tasks.

In cases where multiple significance tests were used in the analysis (ie pairwise comparisons and significance tests of correlation coefficients), p values were adjusted with the Holm–Bonferroni method.

Data, data analysis R code, and supplementary tables are available in an open-access repository (Lipovac et al 2021).

RESULTS

In the following sections, we first present results on the preference of materials: scores on the item "like" from the semantic differential scale (for both tactile and tactile–visual tasks) and the ranks from the ranking task. We continue by presenting the association between scores on the item "like" and the remaining rating items. Finally, we present the relationship between the item scores on the tactile task and the tactile–visual task.

Preference of Materials

The scores on the item "like" from the tactile and tactile–visual tasks and the ranks from the ranking task are presented in Table 1. In both the tactile and tactile–visual tasks, all five wooden materials were on average rated similarly, as somewhat or considerably liked, whereas the stainless steel sample was on average rated as "in the middle" of the dislike–like item. Pairwise comparisons of scores between materials are presented in Tables S3 and S4. In both tasks, all wooden materials were rated statistically significantly higher than the stainless steel (median differences from 0.90 to 1.27, in all cases $p < 0.001$). In contrast, we did not detect statistically significant differences between ratings of wooden materials.

The results (Fig 2 and Tables S5 and S6) and pairwise comparisons (Tables S7 and S8) *within* each country show that the ungrouped scores mirror the overall results. In each country, wooden materials tend to be similarly liked and more liked than the steel sample in both the tactile and tactile–visual tasks. Some exceptions

Table 1. Mean scores on the item "like" from the tactile and tactile–visual tasks with 95% confidence intervals and median ranks from the ranking task with bootstrapped percentile 95% confidence intervals.

Material	Tactile task ("like" mean score)	Tactile–visual task ("like" mean score)	Ranking task (median rank)
Steel	3.01 [2.74, 3.28]	3.03 [2.75, 3.31]	6.0 [5.0, 6.0]
Spruce (thermally modified)	4.28 [4.10, 4.46]	4.02 [3.82, 4.21]	2.5 [2.0, 3.0]
Spruce (unmodified)	4.03 [3.81, 4.25]	3.93 [3.70, 4.17]	4.0 [4.0, 5.0]
Pine (thermally modified)	4.26 [4.08, 4.44]	3.97 [3.76, 4.18]	3.0 [3.0, 4.0]
Pine (acetylated)	4.20 [4.03, 4.37]	3.97 [3.76, 4.18]	3.0 [3.0, 3.5]
Pine (unmodified)	4.25 [4.06, 4.44]	4.12 [3.93, 4.31]	3.0 [3.0, 4.0]

were observed in the Slovenian sample. In the tactile task, Slovenian participants gave lower preference ratings to unmodified spruce compared with acetylated pine (mean difference = 0.52 [95% CI 0.19, 0.85], $p = 0.026$) and thermally modified pine (mean difference = 0.48 [95% CI 0.18, 0.79], $p = 0.027$). In the visual–tactile task, only unmodified pine (mean difference = 0.84 [95% CI 0.37, 1.31], $p = 0.012$) and acetylated pine (mean difference = 0.80 [95% CI 0.30, 1.30], $p = 0.035$) had statistically significantly higher preference scores than the steel sample.

Some differences were observed when the scores on the "like" item were compared *between* the countries (Fig 2 and Tables S9 and S10). In both tasks, Slovenian respondents gave acetylated pine (tactile task: mean difference = 0.48 [95% CI 0.14, 0.82], $p = 0.006$; tactile–visual task: mean difference = 0.78 [95% CI 0.39, 1.17], $p < 0.001$) and steel (tactile task: mean difference = 0.94 [95% CI 0.43, 1.46], $p < 0.001$; tactile–visual task: mean difference = 1.06 [95% CI 0.53, 1.59], $p < 0.001$) somewhat higher preference ratings than their Norwegian counterparts. Additionally, unmodified pine (mean difference = 0.56 [95% CI 0.19, 0.93], $p = 0.003$) and thermally treated spruce (mean difference = 0.40 [95% CI 0.02, 0.79], $p = 0.042$) received higher preference ratings in the tactile–visual task by Slovenian participants.

In the ranking task, thermally modified spruce was on average ranked the highest, followed by the three pine samples with the same median rank and the unmodified spruce with the lowest median rank among the wooden samples. Stainless steel was on average ranked the lowest among all materials. Pairwise comparisons (Table S11) show that all wooden materials except unmodified spruce were ranked statistically significantly higher than the steel sample (median differences

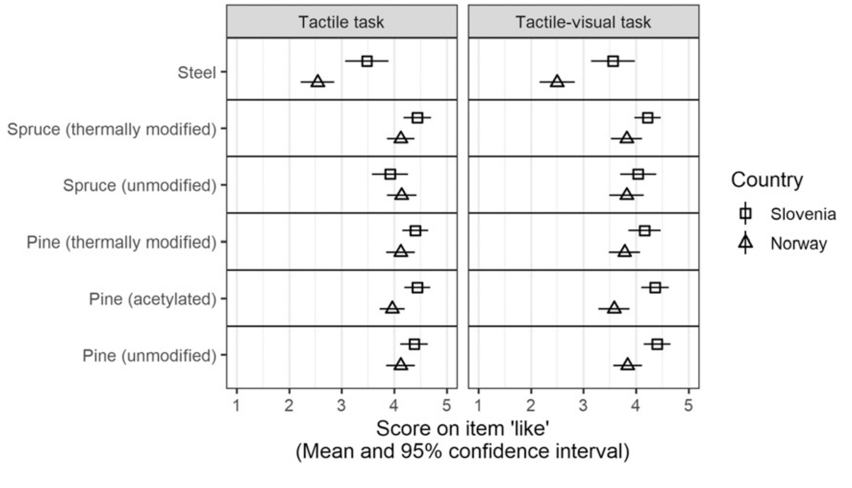

Figure 2. Scores on the item "like" split by countries.

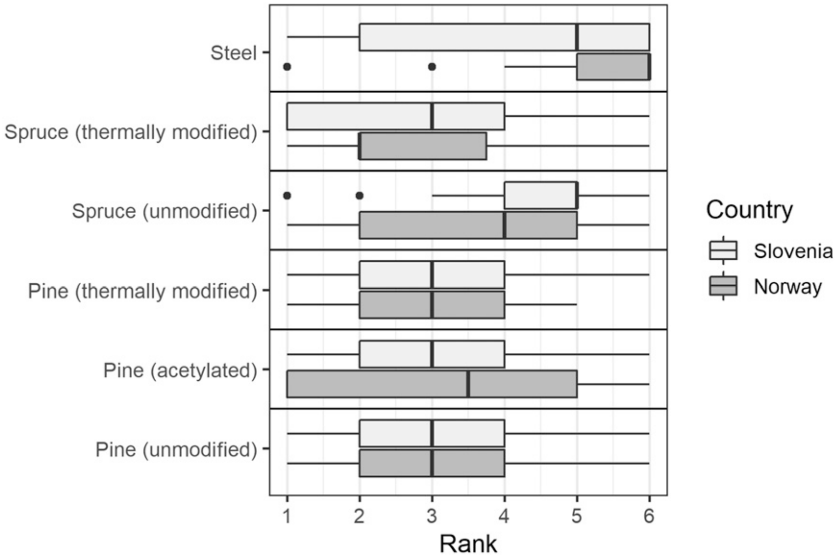

Figure 3. Ranks of materials split by countries.

from 1.5 to 2.0, in all cases $p < 0.001$). Specific differences were also detected between wooden samples: unmodified spruce was on average ranked lower than the other four wooden materials (median differences from 1.0 to 1.5, in all cases $p < 0.05$).

In general, similar results were observed in the ranks *within* each country (Fig 3, Table 2, Tables S12 and S13), with some exceptions: Slovenian participants gave unmodified spruce lower ranks compared with all wooden materials except thermally modified pine (median differences from 1.5 to 2.0, in all cases $p < 0.01$), and only thermally modified spruce received higher ranks than the steel sample (median difference = 1.5 [95% CI 0.5, 2.5], = p = 0.029). Comparisons *between* the countries (Fig 3) revealed differences in the ranking of two materials: compared with Norwegian respondents, Slovenian participants on average assigned higher ranks to steel (median difference = 0.0 [95% CI 0.0, 1.0]; $p = 0.014$) and lower ranks to spruce (median difference = 1 [95% CI 0.0, 2.0]; $p = 0.003$).

Rating Items Associated with the Preference of Materials

Table 3 presents Kendall rank correlation coefficients between the scores on the item "like" and the remaining items for the tactile and visual–tactile task. Correlation coefficients are similar across both

Table 2. Ranks of mean and median ranks of each material for both countries.

Material	Rank of mean rank—Slovenia	Rank of median rank—Slovenia	Rank of mean rank—Norway	Rank of median rank—Norway
Steel	5	5.5	6	6.0
Spruce (thermally modified)	1	2.5	1	1.0
Spruce (unmodified)	6	5.5	5	5.0
Pine (thermally modified)	4	2.5	2	2.5
Pine (acetylated)	2	2.5	4	4.0
Pine (unmodified)	3	2.5	3	2.5

The values in the table were obtained by first computing mean and median ranks for each material (separately for each country) and then assigning ranks to these mean and median ranks.

Table 3. The association between the scores on the item "like" and the remaining rating items for the tactile and tactile–visual tasks—Kendall rank correlation coefficients.

Item	Tactile task	Tactile–visual task
Smooth	−0.02	0.03
Cold	−0.37***	−0.36***
Damp	−0.24***	−0.25***
Hard	−0.04	0.00
Usual	0.33***	0.27***
Artificial	−0.43***	−0.36***
Expensive	0.07	0.11**
Unpleasant	−0.73***	−0.61***
Light	—	0.03
Matte	—	0.24***

** $p < 0.01$, *** $p < 0.001$. *p*-values are adjusted with the Holm–Bonferroni method.

tasks. In both tasks, materials rated as liked were perceived as somewhat less cold, less damp, more usual, less artificial, more expensive, and less unpleasant. The statistically significant positive correlation between scores on the items "like" and "hard" was found only in the tactile task. We did not detect statistically significant associations between the "like" item scores and the scores from the two items included only in the visual–tactile task (ie "light" and "matte"). The correlation coefficients are generally small to medium; the only exception is the negative correlation coefficient between the scores on the items "like" and "unpleasant," which is larger.

The Relationship between Tactile and Tactile–Visual Task Scores

The comparison of scores between the tactile and tactile–visual tasks on all items (except "matte" and "light" that were included only in one task) for all materials is presented in Fig 4 and Table S14. In general, the ratings are fairly consistent between the two tasks. Some discrepancies are noticeable for the items "usual" and "expensive."

Kendall rank correlation coefficients were calculated for scores on each item between the tactile and tactile–visual tasks (Table 4). Correlation coefficients are moderately high for the items "artificial," "unpleasant," "damp," and "like," and the three items capturing tactile sensory properties (ie "cold," "smooth," "hard"), and somewhat lower for the items "usual" and "expensive."

DISCUSSION

Preference of Materials

The results on the preference of materials show that wooden materials were generally similarly liked and more liked than the steel sample in both the tactile and tactile–visual tasks. This observation is mirrored in the results of the ranking task, in which wooden materials were on average ranked higher than the steel sample. These results are in line with existing studies, which have observed that wood is generally favored over other common building materials (Rice et al 2006; Ikei et al 2017b). The results of this study thus extend previous findings by showing that wood may be preferred over at least some other everyday materials, even when materials are presented in a form that more closely resembles the real-world context (ie presented as handrail samples instead of typically used small rectangular blocks of wood).

Preference ratings and rankings were fairly similar across the participants from Slovenia and Norway. The results *within* each country reflected the overall pattern: the wooden materials were generally rated and ranked similarly, while they were preferred over the steel sample. This pattern was clearly reflected in the results of the Norwegian participants, whereas some deviations occurred in the results of the Slovenian subjects. The Slovenians preferred unmodified spruce somewhat less than some other wooden materials. Although they still generally preferred the steel sample the least, their preference scores varied more than the Norwegian scores. This discrepancy between the countries could stem from cultural differences: clearer distinction in preference between the wooden materials and the steel sample observed among the Norwegians could have resulted from different general attitudes toward wood or steel. Nevertheless, even though the results from Slovenia and Norway varied, it should be highlighted that they are generally very similar.

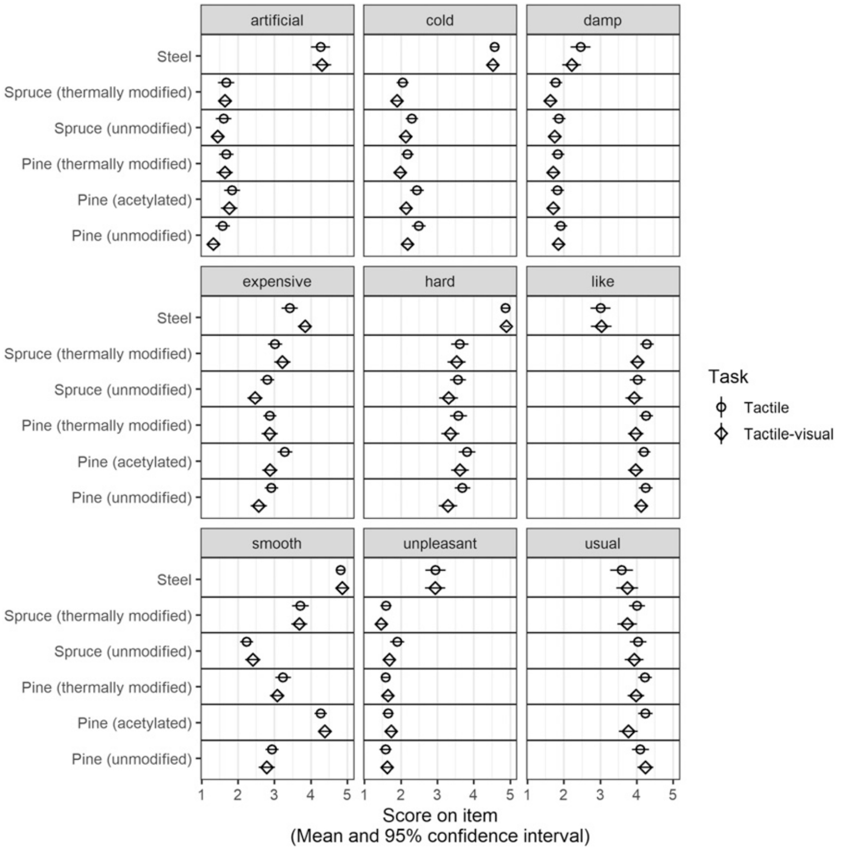

Figure 4. Scores on scale items split by tasks.

Comparison of the results *between* the countries showed that Slovenians, compared with Norwegians, gave higher absolute preference ratings (item "like") to the steel sample and certain wooden samples in both the tactile and tactile–visual tasks. This observation, however, is probably less informative than comparing the within-country results between countries. First, subtle language differences in the scales used in the two countries could have influenced absolute values of the preference scores. Second, lower absolute scores sometimes observed among the Norwegians could have resulted from the slight damage that the materials sustained in the second part of the study conducted in Norway. Comparing the countries on the ranking task, which is not influenced by the abovementioned issues, reveals the same pattern observed in the within-country analysis: Slovenians generally preferred steel more and unmodified spruce less than the Norwegians.

Analysis of the preference scores within wooden materials revealed that modified wood samples

Table 4. The association between the rating item scores on the tactile and tactile–visual tasks—Kendall rank correlation coefficients.

Item	Like	Smooth	Cold	Damp	Hard	Usual	Artificial	Expensive	Unpleasant
Kendall rank correlation coefficients	0.50***	0.60***	0.60***	0.52***	0.62***	0.33***	0.55***	0.37***	0.56***

*** $p < 0.001$. p-values are adjusted with the Holm–Bonferroni method.

were rated and ranked comparably to unmodified wood. The only wooden sample that was ranked somewhat lower than the others was unmodified (ie unmodified spruce). These observations contrast with the observations that treated materials are less preferred than the original, unmodified samples (Ikei et al 2017a). This suggests that modified wood exhibits tactile and visual properties that are, in terms of human preference, comparable to those of unmodified wood and different to those of wood that has been treated otherwise (eg with coating). Splitting these results by country showed similar results: wooden samples, regardless of their treatment, generally received similar preference scores within each country, suggesting that potential cultural influences might not influence the perception and evaluation of modified wood samples.

Association between Material Properties and Preference

Many perceived material properties were associated with a preference for wooden materials in both the tactile and tactile–visual tasks. Materials rated as liked were also rated as somewhat less cold, less damp, more usual, less artificial, less unpleasant, and, only in the tactile–visual task, more expensive and more matte. The observed associations between material properties and preference tend to be minor, which suggests that additional visual and tactile properties, beyond those examined in this study, are important in predicting material preference. Perceived material smoothness, hardness, and color lightness were not associated with preference scores.

The observed results are partially consistent with findings from existing studies. In line with the observations of Waka et al (2015), we observed that materials with higher preference ratings had been perceived as warmer. This suggests that perceived warmth might be associated with preference relatively independently of the context in which the wood samples are presented. In contrast to the findings of Waka et al (2015), who observed that preferred materials were perceived as a damper, we observed they were perceived as dryer. This discrepancy could have resulted from the way the materials had been presented: in handrails, dampness could be associated with (unwanted) slipperiness.

The perceived color lightness of materials was not associated with their preference scores. This observation contrasts with the study that found darker wooden materials had been preferred for an outdoor tabletop (Lipovac et al 2019), suggesting that the relationship between wood lightness and human preference may depend on the context of wood use. Similarly, our results contrast with the observations of Waka et al (2015), who found shinier samples were more preferred, whereas we observed that participants preferred matte materials. This discrepancy could be explained by differences in materials tested in the two studies. Waka et al (2015) examined only samples of wood, many of which likely varied in surface shininess. Our study, on the other hand, included wood samples with relatively uniform shininess levels, so the observed association—shinier materials being less preferred—might have been driven primarily by the presence of the (shiny) steel sample, which was generally the least preferred material. This could also explain why we have not detected the association between perceived smoothness and material preference, which is typically observed in other studies (Jonsson et al 2008; Waka et al 2015; Bhatta et al 2017): the ratings of the stainless steel sample, which was perceived as smooth but less liked, might have steered the association between perceived smoothness and preference toward the opposite direction than typically observed within wood samples. We found no relationship between perceived material hardness and material preference, possibly because the scores on the item "hard" did not vary sufficiently among the tested materials.

We observed that materials perceived as more natural tended to be preferred, similar to what has been observed in other studies (Rice et al 2006; Jonsson et al 2008; Ikei et al 2017b). Such studies, however, typically compared different types of materials instead of mostly different *wooden* materials. Our study thus extends these findings and shows that perception of naturalness may be an important predictor of preference even within the same material (ie wood). Two other items that predicted preference in our study and that we had not identified in other studies assessing the perception of wood, were "usual" and "expensive." Materials perceived as more expensive and more usual were generally rated as more liked. Possibly, perceived expensiveness can reflect the perception of overall material quality, which in turn may be inferred from the pleasantness of the tactile and visual material properties. However, the steel sample was generally perceived as the most expensive material, although it was generally less liked than the wooden samples. This suggests there is a more complex mechanism behind the association between perceived expensiveness and preference of materials.

We observed that people preferred materials with which they were more familiar (ie materials rated higher on the item "usual"). It is possible that preferred materials are more widespread in everyday life, increasing the chances that people will become familiar with them. The association between perceived usualness and preference is particularly interesting in this study, which includes several samples of modified wood that are currently rarely used in real life; so, the participants have probably had few opportunities to come into contact with them. This suggests that modified wood samples exhibit certain visual and tactile properties that are perceived similarly to properties of more common wooden materials.

Association between Tactile and Tactile–Visual Task Scores

Comparison of the results between the tactile and tactile–visual tasks showed that the scores of the two tasks correlate with each other. The highest correlation coefficients between the two tasks were observed in the rating items predominantly assessed by touch: "smooth," "cold," "damp," and "hard." This is unsurprising as the visual modality is not expected to substantially influence the perception of these properties. Somewhat weaker correlations were observed in the affective attributes "usual" and "expensive," suggesting that the perception of these properties changes to a greater extent when people can inspect materials visually. Interestingly, the correlations on the items "artificial," "unpleasant," and "like" were relatively high, comparable to the correlations observed in the items assessing tactile sensory properties, suggesting that the tactile experience importantly influences the perception of naturalness and preference of materials. This finding is consistent with the results of previous studies that reached similar conclusions: tactile domain is important in overall material perception (Overvliet and Soto-Faraco 2011; Waka et al 2015; Bhatta et al 2017). The results of this study extend previous findings by demonstrating the importance of the tactile domain even when assessed materials are brought closer to a real-world context.

LIMITATIONS AND RECOMMENDATIONS FOR FUTURE STUDIES

Due to transportation, the handrail samples were slightly damaged in the tests conducted in Norway, which might have led to some differences in scores that occurred between the countries. Other differences between the countries could have resulted from the demographic characteristics of the participants: most Slovenian subjects were retired individuals with different backgrounds. In contrast, most Norwegian subjects were still-active academic staff. The samples of the two countries additionally differed on gender: women represented 54% of the Slovenian sample but only 28% of the Norwegian participants. For these reasons, it should not be assumed that identified differences between the countries in material perception are due to differences in culture, until the findings are confirmed by future studies. Another limitation stems from the limited variety of selected wooden samples: we used only two types of modification processes despite using three modified wood samples. The findings of this study could be extended by testing additional materials treated with different modification processes and including additional rating items that could further identify and clarify the role of material properties influencing the perception of materials. Testing materials that are similar in all but one property (eg varying only on roughness) would better reveal the role of specific material properties in overall material preference. Future studies could also explore the perception of wooden materials in different furnishings, such as chairs and desks. More generally, the field of study would benefit from a theory explaining how and why specific material properties relate to preference of materials.

CONCLUSIONS

The results of this study confirm and extend previous findings showing that wooden materials tend to be more liked than other common materials—in our case, more than steel. The results also suggest that older adults prefer modified wood samples similarly to unmodified wooden materials. The findings are consistent across Slovenia and Norway, suggesting that different practices of wood use in these two countries do not significantly influence the perception of wooden materials. Preference of materials is associated with certain perceived material properties, and tactile experience has a significant role in the overall perception of materials. Altogether, the results suggest that wood, either unmodified or modified, may be a promising addition to restorative indoor environments for older adults.

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