# A PRODUCT SEMANTIC STUDY OF THE INFLUENCE OF VISION ON WOOD EVALUATION

*A. Roos**

Professor
Swedish University of Agricultural Sciences
Department of Forest Products
Uppsala, Sweden
E-mail: anders.roos@slu.se

*S. Lindberg*

Senior Researcher
E-mail: siv.lindberg@innventia.com

*A. Kihlstedt*

Researcher
Innventia AB
Stockholm, Sweden
E-mail: Annika.kihlstedt@innventia.com

(Received October 2012)

**Abstract.** Using product semantics, this study investigated how visual attributes of wood are perceived and interpreted semantically. The wood species alder, ash, aspen, beech, birch, elm, larch, lime, maple, oak, pine, and spruce were included. The subjects rated the samples based on the descriptive words natural, exclusive, ecofriendly, rough, inexpensive, modern, reliable, warm, cozy, solid, and light. The most significant differences in ratings were between softwoods and hardwoods. Principal component analysis yielded three dimensions based on visual perceptions: exclusive–modern, ecofriendly–natural, and light. Maple and ash and other hardwoods were seen as more exclusive and modern than spruce and pine. Pine, conversely, was perceived as the most ecofriendly–natural wood type. Beech and alder did not score high (or low) on any of the three dimensions, meaning that these gave a neutral impression. The potential use of these results in product design and interior design is discussed.

***Keywords:*** Wood design, perceptions, consumer studies.

## INTRODUCTION

Semantics are important in reflecting and shaping consumer perceptions (and subsequent purchases) of wood products. Insights in this area can benefit the wood industry in both product development and marketing. Wood is generally a well-liked material, and people appreciate wood surfaces, eg in interior design and furniture. Jonsson et al (2008) found wood to be preferable to wood–plastic composites and that these material preferences were associated with the perceived properties of natural, pleasant, smooth, living, and worth. Studies have also demonstrated that consumers prefer wooden surfaces to imitations (Jonsson et al 2008; Roos and Hugosson 2008).Wood is furthermore an established and well-known material that has become integrated into local traditions for building and craftsmanship. This contributes to the reputation of wood together with its qualities of naturalness, grain, texture, pattern, and feel. The long-standing integration of the different applications of wood into local culture and hence the possible ways of describing the material are also emphasized by Manzini (1989). The famous Finnish architect Alvar Aalto noted that wood is closely integrated with human history; its specific good and bad characteristics are well known by most architects (Aalto 1956).

* Corresponding author

Furthermore, wood is associated with time, and wooden objects are sometimes even perceived as improving with age (Ashby and Johnson 2003, p. 73). Some studies suggest an impact of wood on people's well-being and feelings of comfort, although this issue requires further study (Sakuragawa et al 2005; Tsunetsugu et al 2007). Rice et al (2006) showed that people regard wood in interior applications as warm, comfortable, relaxing, natural, and inviting.

The future competitiveness of wood products depends on the development of the material itself and on design and appearance. With general differentiation in many product markets, aesthetic and design considerations will become an increasingly important competitive factor for wood. Material selection is one important activity in the industrial design process (Ashby and Johnson 2003). Investments in product design and efforts related to design innovativeness have further been shown to enhance firm competitiveness (Gemser and Leenders 2001) and financial performance (Hertenstein et al 2005).

The material selection process is often influenced by the different associations that materials can have for users (Ashby and Johnson 2003). The typical characteristics that consumers assign to wood materials have been studied by a number of researchers (Broman 2000; Pakarinen and Asikainen 2001; Bowe and Bumgardner 2004; Scholz and Decker 2007). Bumgardner and Bowe (2002) and Bowe and Bumgardner (2004) found that wood species are rated differently on several semantically differential scales. The authors argued that these associations and differentials in the North American context could support the wood product industry in its market communication. The importance of appearance for the marketing of wood products has been demonstrated by Nicholls and Roos (2006) in a study of wood manufacturers. Marchal and Mothe (1994) presented several perceived attributes that influence consumer preferences and also identified differences among consumer segments. Attempts have been made to map how the properties of wood are related to preferences (Broman 2000) or willingness to pay (Brinberg et al 2007).

Visual aspects constitute what are probably the most distinguishing features of wood surfaces. Broman (2000) arrived at a rich repertoire of characteristics based on visual perceptions. In an analytic sensory study by Nyrud et al (2008), 15 of 18 elicited attributes were based on visual impressions.

A deeper understanding of people's perceptions of different wood species and how these perceptions are expressed would help producers of visible wood products, eg facades, joinery, and furniture, to adapt and even fine-tune their species selection for products with different applications. This insight would also support the innovation process. Few studies have attempted to investigate product semantics with regard to different wood species. However, on the basis of previous studies, we conclude that word-based interpretations of visual aspects of wood are important, especially because designers, in their selection of materials, normally have specific intentions about how the product should be used or perceived by the user. A good command of this process could generate increased value.

The purpose of this study was to explore how the visual attributes of wood are perceived and interpreted semantically. More precisely, we studied the semantic differentiation among the most common Swedish wood species.

## PRODUCT SEMANTICS

Product semantics is the study of the perceived meaning and impression of manmade shapes (Krippendorff and Butter 1984). It posits that products make a statement through color, shape, form, texture, gloss, etc. This meaning is transmitted in different contexts: operational, sociolinguistic, genesis, and ecological (Krippendorff 1989). Product semantics enable designers to communicate and create meaning in the selection of materials. Monö (1997) writes that a product can be seen as a triangle that consists of a technical unit, an ergonomic unit, and a communicative unit. According to these theories, levels of product semantic functions can be analyzed. One goal of product semantics is to develop a suitable language with which to talk about the symbolic qualities of products. Demirbilek and Sener (2003) claim that the users' own descriptions of objects to a great degree convey their emotional reactions to the object.

Petiot and Yannou (2004) described a procedure used to apply product semantics in new product development. It involves defining a semantic space (Osgood et al 1957) and using multivariate methods to determine design options. Linking product semantics and Kansei engineering allows the marketer to evaluate the potential success of an offer to the customer (Nagamachi 1995; Llinares and Page 2007).

In reference to this theory, we assume that a wood product uses color and patterns to produce a meaning for the onlooker or user. This meaning can to some extent be captured through different associations or descriptive terms. Hence, investigating how subjects assess different objects (through visual and tactile impressions) allows the producer to select the most appropriate materials (such as wood species) for specific applications.

## MATERIALS AND METHODS

### Materials

In this visual study, 12 wood samples were used: alder (*Alnus glutinosa*), ash (*Fraxinus excelsior*), aspen (*Populus tremula*), beech (*Fagus sylvatica*), birch (*Betula pendula*), elm (*Ulmus glabra*), larch (*Larix decidua*), lime (*Tilia cordata*), maple (*Acer platanoides*), oak (*Quercus robur*), pine (*Pinus sylvestris*), and spruce (*Picea abies*). These wood species naturally exist in Sweden. The samples were presented in 400- × 135- × 20-mm pieces. They were mostly free of knots, bark pockets, etc, and had been planed and sanded. Character features such as knots were not evaluated. Instead, the visual cues that most respondents evaluated were color and grain, although some wood types, eg ash, presented typical and characteristic color patterns.

### Descriptive Words

The words used in the study to describe and make associations with the samples were based on previous elicitation studies on wood by Broman (2000), Bumgardner and Bowe (2002), Jonsson et al (2008), and Nyrud et al (2008). To identify the most relevant words, group discussions were held with an expert panel: three wood researchers, one psychologist, and three wood industry representatives. The goal was to select words that were based on previous research and also terms that were relevant to the industrial production companies. The words related both to perceptions, what is perceived from the surface in terms of its roughness, for example, and to cognition, ie what associations are made; in terms of naturalness, exclusiveness, etc. The final set of words was natural, exclusive, ecofriendly, rough, inexpensive, reliable, warm, modern, cozy, solid, and light. The words and sources are shown in Table 1.

### Respondents

Thirty novice respondents, 15 women and 15 men, were recruited for the study. Sixteen of the respondents were employed at Innventia AB (Stockholm, Sweden) and the others were recruited from Academic Work (Stockholm), a recruitment company specializing in college and university students. The respondents are described in Table 2. Compared with the

Table 1. Descriptive words used in the study.

| | Source | | | |
|---|---|---|---|---|
| Property | Broman (2000) | Jonsson et al (2008) | Nyrud et al (2008) | Bumgardner and Bowe (2002) |
| Natural | | X | | |
| Exclusive | X | | | X |
| Ecofriendly | | | | X |
| Rough | | x | X | |
| Inexpensive | X | X | X | X |
| Light | | X | X | |
| Reliable | | | | X |
| Warm | X | X | | X |
| Modern | | | | X |
| Cozy | X | | | |
| Solid | X | X | | |

Table 2. Distribution of age and gender among the respondents.

| Age (y) | Women | Men | Total |
|---|---|---|---|
| 20-29 | 4 | 6 | 10 |
| 30-39 | 0 | 2 | 2 |
| 40-49 | 4 | 2 | 6 |
| 50-59 | 5 | 4 | 9 |
| 60-65 | 2 | 1 | 3 |
| Sum | 15 | 15 | 30 |

national average, the sample was biased toward younger and college-educated persons. However, because the purpose of this study was explorative and qualitative, strict unbiased representativeness was neither a feasible nor a key feature of the study.

## The Study

The wood samples were presented to each of the subjects in random order, one at a time, in normal office lighting with a gray pad on the table. The respondent was allowed only to look at the samples but not to touch them (Fig 1). The subjects were asked to rate the samples based on the descriptive words, which were read one at a time in random order by the test leader. Each subject answered by indicating an integer between 1 and 7, in which 7 meant that the word was strongly associated with the sample and 1 that the word was not at all associated with the sample.

Figure 1. Test situation (arranged photo).

## Analysis

Mean attribute ratings of descriptive words for each material and analysis of variance (ANOVA) statistics, including Tukey (means separation) tests, were calculated. These tests yielded the degree to which people thought a word described each sample and how wood species were perceived differently. Pearson correlation tables across all observations (subjects, samples) indicated the association between words that were elicited from the same stimuli. A principal component factor analysis (PCA) was carried out to identify further associations in how materials were characterized. The main purpose was to find words and concepts used to describe and associate with wood species.

Cluster analysis generated groups of wood species with similar perceived properties. The outcome is given in a multidimensional scaling (MDS) graph. Discriminant analysis and logistic regression finally assisted in identifying the most important differentiating concepts. The rationale for these analyses was to further distinguish groups of wood materials with similar appearances and to identify perceived key differences.

# RESULTS

## Correlations

Five correlations fell between |0.5| and |0.7| (ecofriendly–natural 0.54, modern–exclusive 0.66, modern–inexpensive 0.52, solid–reliable 0.56, cozy–warm 0.53), and one correlation coefficient reached |0.7| (inexpensive–exclusive 0.70) (Table 3).

## Ratings

The ANOVA table (Table 4) shows that the respondents' mean ratings for the characteristics of solid, cozy, and warm differed marginally. The properties that presented larger and significant differences between samples were exclusive, inexpensive, and light. Examples of pairs of tree species with few distinguishing features are alder–larch, alder–beech, and pine–spruce.

Table 3. Correlations between the descriptive ratings.[a]

| Property | Natural | Exclusive | Ecofriendly | Rough | Inexpensive | Reliable | Warm | Modern | Cozy | Solid |
|---|---|---|---|---|---|---|---|---|---|---|
| Exclusive | **0.10** | 1 | | | | | | | | |
| Ecofriendly | **0.54** | 0.06 | 1 | | | | | | | |
| Rough | 0.01 | −0.05 | −0.02 | 1 | | | | | | |
| Inexpensive | 0.04 | **−0.70** | 0.02 | **0.16** | 1 | | | | | |
| Reliable | **0.28** | **0.44** | **0.35** | −0.06 | **−0.37** | 1 | | | | |
| Warm | **0.21** | **0.25** | **0.27** | 0.06 | **−0.13** | **0.39** | 1 | | | |
| Modern | 0.06 | **0.66** | 0.19 | −0.07 | **−0.52** | **0.37** | **0.33** | 1 | | |
| Cozy | **0.22** | **0.35** | **0.25** | −0.04 | **−0.26** | **0.33** | **0.53** | **0.41** | 1 | |
| Solid | **0.19** | **0.43** | **0.19** | −0.07 | **−0.40** | **0.56** | **0.29** | **0.33** | **0.39** | 1 |
| Light | 0.04 | **−0.11** | **0.17** | **−0.27** | **0.19** | 0.01 | 0.02 | 0.06 | 0.08 | −0.06 |

[a] Bold = significant correlation at 5% level.

Table 4. Analysis of variance statistics.[a]

| | Natural | Exclusive | Ecofriendly | Rough | Inexpensive | Modern | Reliable | Warm | Cozy | Solid | Light |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Alder | 6.07 a | 3.52 bc | 4.83 ab | 3.59 abc | 4.55 bcd | 3.66 bcd | ↓4.21 b | 4.10 a | 4.17 ab | 5.10 a | 4.62 cd |
| Ash | 5.70 ab | ↑4.77 ab | ↓4.60 ab | 3.87 ab | ↓2.80 d | 4.60 abc | ↑5.40 ab | ↑4.50 a | 4.40 ab | 5.53 a | ↓3.03 e |
| Aspen | ↓4.70 b[b] | 3.70 bc | 5.00 ab | ↓2.50 c | 3.93 bcd | 4.43 abc | 4.83 ab | 4.03 a | 4.27 ab | 5.07 a | ↑6.67 a |
| Beech | 5.60 ab | 3.77 abc | 4.97 ab | 3.27 abc | 3.67 bcd | 4.07 abcd | 4.90 ab | ↓3.90 a | 3.90 ab | 5.40 a | 3.93 de |
| Birch | 5.40 ab | 4.47 ab | 4.93 ab | 3.23 abc | 3.40 bcd | 4.30 abcd | 4.77 ab | 4.13 a | ↑4.50 ab | 5.37 a | 5.27 bc |
| Elm | ↓4.73 b | 4.23 ab | ↓3.93 b | 3.70 abc | 3.57 bcd | 4.13 abcd | 4.50 ab | 3.93 a | ↓3.47 b | 5.40 a | ↓3.10 e |
| Larch | 5.79 ab | 3.45 bc | 5.00 ab | ↑3.96 ab | 4.52 abc | 3.59 bcd | 4.86 ab | 4.41 a | 4.21 ab | 5.17 a | 4.07 de |
| Lime | 5.70 ab | 4.27 ab | 5.07 ab | ↓2.83 bc | 3.87 bcd | ↑4.87 ab | 5.10 ab | 4.10 a | ↓3.80 ab | 5.13 a | 6.03 ab |
| Maple | 5.83 ab | ↑5.03 a | 5.03 ab | 2.90 bc | 3.57 bcd | ↑5.10 a | ↑5.63 a | 3.97 a | 4.37 ab | ↑5.97 a | 5.37 bc |
| Oak | 6.03 a | 4.43 ab | 4.73 ab | ↑4.47 a | ↓3.27 cd | 4.20 abcd | 5.07 ab | 4.07 a | 4.13 ab | ↑5.77 a | 3.10 e |
| Pine | ↑6.37 a | ↓2.77 c | ↑5.73 a | 3.00 bc | ↑4.80 ab | ↓3.30 cd | 5.10 ab | ↑4.50 a | ↑4.80 a | ↓5.07 a | ↑6.20 ab |
| Spruce | ↑6.17 a | ↓2.47 c | ↑5.37 a | 3.90 ab | ↑5.47 a | ↓3.10 d | ↓4.23 b | ↓3.93 a | 4.43 ab | ↓4.73 a | 6.00 ab |
| F-value | 4.12 | 7.46 | 2.43 | 4.41 | 6.24 | 4.73 | 2.52 | 0.70 | 1.61 | 1.37 | 33.19 |
| P > F | <0.001 | <0.001 | 0.006 | <0.001 | <0.001 | <0.001 | 0.004 | 0.742 | 0.095 | 0.183 | <0.001 |

[a] Mean ratings followed by the same letter within a column are not significantly different (Tukey's test, $p < 0.05$).
[b] ↑ = two highest values in column; ↓ = two lowest values in column.

Several differences were found between spruce and elm, and between pine and elm.

Pine was perceived to be more natural than most other samples, whereas elm and aspen were classified as somewhat less natural. The quality of exclusive mainly separated hardwood from softwoods, and maple scored the highest in this respect. Although the property called ecofriendly was not particularly useful in distinguishing between the wood species, pine and spruce had the highest ratings with regard to this property. Roughness was lowest for aspen and highest for oak. Ash and oak were the least inexpensive, and softwoods were seen as more inexpensive than hardwoods. Oak, elm, and ash were darker wood types, and pine, spruce, and lime were lighter. Only two significant differences were recorded in terms of the reliable characteristic. There were no differences at all in terms of the property warm. The trait called modern distinguished spruce from several hardwood species. Maple and lime were the most modern wood types; coziness only separated elm from pine.

## Principal Component Analysis

PCA was used to summarize the ratings for this large range of words. The overall Kaiser's measure of sampling adequacy (MSA) was 0.755, which renders the data set acceptable for PCA. All individual variable MSAs except for one (rough) exceeded 0.5. Rotated factor loadings and communalities are shown in Table 5. A three-factor solution was preferred based on the

Table 5. Principal component factor analysis, loadings[a].

| | Factor 1, Exclusive | Factor 2, Ecofriendly | Factor 3, Rough | Communality |
|---|---|---|---|---|
| Exclusive | **0.766** | **−0.405** | −0.012 | 0.751 |
| Reliable | **0.732** | 0.138 | 0.052 | 0.557 |
| Modern | **0.721** | −0.281 | −0.148 | 0.620 |
| Solid | **0.693** | −0.024 | 0.057 | 0.484 |
| Cozy | **0.666** | 0.193 | −0.029 | 0.481 |
| Warm | **0.590** | 0.273 | 0.166 | 0.450 |
| Inexpensive | **−0.651** | **0.546** | 0.055 | 0.725 |
| Ecofriendly | 0.383 | **0.712** | 0.043 | 0.656 |
| Natural | 0.329 | **0.656** | 0.164 | 0.579 |
| Rough | −0.106 | 0.031 | **0.807** | 0.664 |
| Light | −0.009 | 0.388 | **−0.734** | 0.689 |
| Eigenvalue | 3.62 | 1.76 | 1.28 | |
| Percent explained | 0.33 | 0.16 | 0.12 | |

[a] Bold = significant correlation at 5% level

criterion that the eigenvalue should exceed 1. Factor loadings exceeding 0.4 were considered significant and are highlighted with bold (Hair et al 1998). Two variables load significantly on both factors 1 and 2. The first factor is mainly characterized by the words exclusive, reliable, modern, solid, cozy, warm, and inexpensive (the latter negative). Factor 2 indicates ecofriendly associations together with naturalness and exclusivity (negatively). Factor 3, finally, presents significant loadings on rough and light (negatively).

Table 6 displays the corresponding factor scores, in which significant differences are indicated. Maple and ash scored high on factor 1, whereas alder and pine showed the lowest scores. Ash and maple were perceived as more exclusive and modern than spruce. Pine, conversely, was perceived as the most ecofriendly and natural, whereas elm scored low on the same factors. Oak and ash are rough and dark wood species, and aspen and lime are viewed as light and smooth wood species. Beech and alder showed moderate scores on all factors.

Table 6. Mean factor scores for the wood species.

| | Factor 1, Exclusive | Factor 2, Ecofriendly | Factor 3, Rough |
|---|---|---|---|
| Alder | ↓−0.298 ab[a] | 0.277 bc | 0.143 bcd |
| Ash | ↑0.416 a | ↓−0.580 de | ↑0.721 ab |
| Aspen | −0.072 ab | −0.020 cd | ↓−1.107 f |
| Beech | −0.019 ab | 0.191 cde | 0.187 bcd |
| Birch | 0.157 ab | −0.188 cde | −0.295 de |
| Elm | −0.206 ab | ↓−0.916 e | 0.522 abc |
| Larch | −0.164 ab | 0.206 bc | 0.533 abc |
| Lime | 0.119 ab | 0.032 cd | ↓−0.693 ef |
| Maple | ↑0.528 a | −0.186 cde | −0.429 def |
| Oak | 0.200 ab | −0.366 cde | ↑0.976 a |
| Pine | −0.110 ab | ↑1.032 a | −0.446 def |
| Spruce | ↓−0.560 b | ↑0.915 ab | −0.093 cde |

[a] ↑ = top two values, ↓ = two lowest values. Letters = Outcome of Tukey's multiple comparison test.

## Cluster Analysis and Discriminant Analysis

A clustering exercise was applied. Seven methods were tried from which the best solutions were based on Cubic Clustering Criterion, pseudo F, and pseudo $t^2$ criteria (SAS Institute Inc 1983). Five methods gave four-cluster solutions, two indicated five clusters, and one solution suggested a seven-cluster solution. Three methods—complete linkage, flexible beta, and the Ward method—provided identical four-cluster results. The clustering tree (the Ward method) is shown in Fig 2, and ANOVA tables are presented in Table 7.

The cluster analysis outcome is further illustrated in Fig 3, which is based on MDS in two dimensions. MDS is used to graphically present perceived differences and similarities between objects (Hair et al 1998). The input data consisted of the mean ratings of the wood samples (aggregate, decompositional approach). The convergence criterion was set at 0.01 and the gradient convergence at 0.01. Similarities were calculated

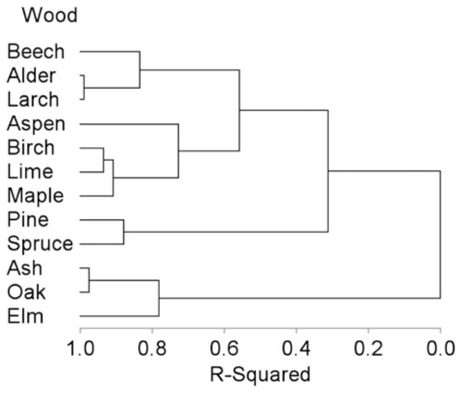


Figure 2. Cluster tree.

as Euclidean distances. Inspection of the scree plot of the badness of fit criterion ("stress measure") suggests that the number of dimensions is appropriate for the study's purposes. The stress measure for two dimensions was 0.006. Figure 3 shows the two-dimension configuration in which the circles illustrate the results of the hierarchical cluster analysis. Figure 3 shows one cluster containing pine and spruce, which is characterized as natural and inexpensive. Maple, lime, aspen, and birch were seen as exclusive and modern and distinguished from the cluster containing ash, elm, and oak, which was also exclusive but more expensive and dark. Finally, beech, alder, and larch have an intermediate position in the graph.

A stepwise discriminant analysis was conducted to characterize the clusters further and identify the variables that mainly separated the different groups of wood types. The iterations are described in Table 8. The final discrimination function is shown in Table 9, and the predictive properties are presented in Table 10 (error count: 37%).

Summing the total number of correct classifications yielded a precision percentage of 63%. The model performed best for the pine–spruce group B, in which 75% were correctly classified. The discriminant analysis confirms in part the main differentiating properties shown in the ANOVA table (Table 7).

Unfortunately, the variables did not meet the normal requirements for discriminant analysis: multivariate normality and equivalent covariance matrices. However, the application of discriminant analysis should be seen as a complement to the other statistical analysis methods used in the study.

To distinguish the clusters further and confirm the earlier outcomes, we subsequently conducted a multinomial logistic regression. The pine–spruce group was set as the comparison. Table 11 shows that pine–spruce was less exclusive and less modern than all the other clusters. Broadleaves were also seen as darker than the softwood species.

## DISCUSSION AND CONCLUSION

Broman (2000) discovered distinguishing features similar to those found in this study. However, because Broman mainly focused on pinewood surfaces and also included knotty materials, his results are not directly comparable with those of this study. In a study of wood, panels, and composite materials, Jonsson et al (2008) found that wood materials were seen both as more valuable and natural compared with panels and composites. This study, which used a narrower set of samples, suggests that the natural–ecofriendly look and the exclusive look

Table 7. Cluster means and analysis of variance table on cluster means.

| | Natural | Exclusive | Ecofriendly | Rough | Cheap | Reliable | Warm | Modern | Cozy | Solid | Light |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ash–oak–elm | 5.49 b[a] | 4.48 a | 4.42 b | 4.01 a | 3.21 c | 4.99 a | 4.17 a | 4.31 ab | 4.00 b | 5.57 a | 3.08 c |
| Asp–birch–lime–maple | 5.41 b | 4.37 a | 5.01 ab | 2.87 b | 3.66 bc | 5.08 a | 4.06 a | 4.68 a | 4.23 ab | 5.38 ab | 5.83 a |
| Beech–alder–larch | 5.82 ab | 3.58 b | 4.93 b | 3.60 a | 4.24 b | 4.67 a | 4.14 a | 3.77 bc | 4.09 ab | 5.23 ab | 4.20 b |
| Pine–spruce | 5.49 a | 2.62 c | 5.55 a | 3.45 ab | 5.13 a | 4.67 a | 4.22 a | 3.2 c | 4.62 a | 4.9 b | 6.1 a |
| P > F | 0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.013 | 0.902 | <0.0001 | 0.0928 | 0.0754 | <0.001 |

[a] Letters = outcome of Tukey's multiple comparison test.

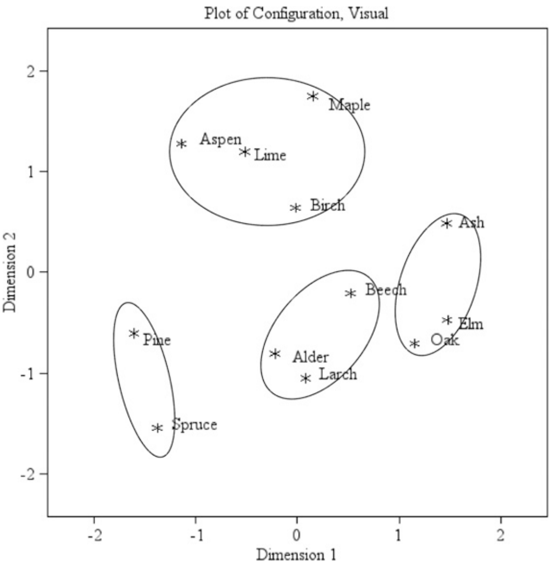


Figure 3. Clusters in multidimensional scaling plot.

are emphasized in softwood and certain hardwoods, respectively.

Nyrud et al (2008) discovered two main components that separate different wooden decking materials. The first was unevenness and knots vs even surfaces, and the second was degree of whiteness. However, this sample was fairly even and did not have knots. The light–dark dichotomy was important in both this study and Nyrud et al (2008).

Bowe and Bumgardner (2004) concluded that darker wood types were perceived as more expensive. This study's results partly confirm their results because darkness was negatively correlated with inexpensiveness and positively correlated with exclusivity. The coefficients were not high, however, and the separate factor for the degree of darkness and Fig 3 confirms the results of Nyrud et al (2008): exclusive and perceived valuable wood can be both light (maple) and dark (ash, elm, and oak).

Table 8. Discriminant analysis with backward elimination summary.

| Step | Removed | F value | Pr > F | Wilks' Lambda | Pr < Lambda |
|---|---|---|---|---|---|
| 0 | | | | 0.35829839 | <0.0001 |
| 1 | Reliable | 0.58 | 0.6313 | 0.36011337 | <0.0001 |
| 2 | Solid | 0.48 | 0.6993 | 0.36161661 | <0.0001 |
| 3 | Cheap | 0.81 | 0.4868 | 0.36419107 | <0.0001 |
| 4 | Warm | 0.86 | 0.4609 | 0.36692931 | <0.0001 |
| 5 | Ecofriendly | 1.97 | 0.1176 | 0.37322674 | <0.0001 |

Table 9. Linear discriminant function for clusters.[a]

| Variable | Ash–Oak–Elm | Asp–Birch–Lime–Map | Beech–Alder–Larch | Pine–Spruce |
|---|---|---|---|---|
| Constant | −17.993 | −23.861 | −19.927 | −27.217 |
| Natural | 2.205 | 2.151 | 2.428 | 2.669 |
| Exclusive | 0.894 | 0.800 | 0.502 | 0.063 |
| Rough | 2.103 | 1.808 | 1.994 | 2.051 |
| Modern | 0.578 | 0.601 | 0.396 | 0.071 |
| Cozy | 0.615 | 0.711 | 0.850 | 1.346 |
| Light | 2.110 | 3.702 | 2.783 | 3.939 |

[a] Wilks' Lambda F-value: 22.72, Pr > F < 0.001; Pillai's Trace F-value: 19.53, Pr > F < 0.001.

The results advise the use of particular wood species based on specific design intentions. For example, pine gives an air of naturalness and ecofriendliness, whereas maple is seen as exclusive. Both ash and maple appear to convey an impression of reliability. The PCA provides simplified guidelines for wood species selection. Again, pine and spruce are more natural, and maple is light and modern, whereas ash is dark and modern. This type of knowledge can be useful when interiors and furniture are intended for specific users. Using the different wording, the designers find the subset of wood materials that is most appropriate for the intended use. The wording can also help to ascertain the most suitable verbal marketing descriptions of wood materials, such as flooring. Potential beneficiaries of the approach include end consumers who can access help to design their new apartment, designers and architects when they search for wood with a statement, and producers when they select wood for furniture with a specific style.

The limited sample of subjects for the study limits the ability to generalize the results. Other considerations of course also influence wood species selection, eg the context and form. It is also possible that cultural factors may influence the study if it is conducted in different countries nor does the study reveal consumer semantics for wood when used in specific products.

Table 10. Percentage classified into correct cluster.

| Belonging to cluster | Classified into[a] Ash–Oak–Elm | Asp–Birch–Lime–Map | Beech–Alder–Larch | Pine–Spruce | Total |
|---|---|---|---|---|---|
| Ash–oak–elm | 65 | 8 | 15 | 2 | 90 |
| | 72.22 | 8.89 | 16.67 | 2.22 | 100 |
| Asp–birch–lime–map | 9 | 80 | 12 | 19 | 120 |
| | 7.50 | 66.67 | 10.00 | 15.83 | 100 |
| Beech–alder–larch | 21 | 19 | 36 | 11 | 87 |
| | 24.14 | 21.84 | 41.38 | 12.64 | 100 |
| Pine–spruce | 0 | 10 | 5 | 45 | 60 |
| | 0.00 | 16.67 | 8.33 | 75.00 | 100 |
| Total, column | 95 | 117 | 68 | 77 | 357 |
| | 26.61 | 32.77 | 19.05 | 21.57 | 100 |

[a] Upper value, number of observations; lower value, percentage of row classified.

Table 11. Multinomial logistic regression results.[a]

| | Ash–Oak–Elm | Asp–Birch–Lime–Maple | Beech–Alder–Larch |
|---|---|---|---|
| Natural | −0.27 | −0.52*** | −0.19 |
| Exclusive | 0.84***[b] | 0.87*** | 0.54**[b] |
| Ecofriendly | −0.38* | 0.004 | −0.14 |
| Rough | 0.19 | −0.09 | 0.05 |
| Inexpensive | −0.22 | −0.08 | −0.09 |
| Reliable | −0.05 | 0.06 | −0.12 |
| Warm | 0.08 | −0.22 | 0.07 |
| Modern | 0.43**[1] | 0.48*** | 0.29 |
| Cozy | −1.02*** | −0.81*** | −0.76*** |
| Solid | 0.17 | −0.003 | 0.10 |
| Light | −1.51*** | −0.22 | −0.10*** |
| Intercept | 10.18*** | 5.03** | 8.09*** |
| N | 90 | 119 | 86 |

[a] Likelihood ratio: 339.4, $p < 0.0001$; Wald statistic: 167.2, $p < 0.0001$.
[b] Significant at the 0.1 (*), 0.05 (**), or 0.01 (***) levels, two-tailed test.

Further research should develop a framework for species selection for different design purposes. A procedure for this can be found in the Kansei engineering method for translating a consumer's feeling and image for a product into design elements (Nagamachi 1995).

Wood species are mainly distinguished from one another based on visual perceptions, such as light–dark. However, the qualities called exclusive, modern, and inexpensive are also used to differentiate among the samples. The perceived differences mainly revolve around three factors: exclusive–modern vs inexpensive, ecofriendly–natural, and dark–rough. Hardwoods were more exclusive and softwoods less exclusive, whereas softwoods were perceived as more ecofriendly than hardwoods. The findings and methods in this study will help producers to select the right wood species, eg when the goal is to convey an exclusive or natural impression. It will also identify perceived features of a specific wood species, which can subsequently guide marketing efforts.

## REFERENCES

Aalto A (1956) Träet som byggnadsmaterial. *In* Schildt G. 1973. Alvar Aalto-skisser. Wahlström & Widstrand, Stockholm, Sweden, p. 90 (in Swedish).

Ashby M, Johnson K (2003) Materials and design—The art and science of material selection in product design. Butterworth–Heinemann, Burlington, MA. 336 pp.

Bowe SA, Bumgardner MS (2004) Species selection in secondary wood products: Perspectives from different consumers. Wood Fiber Sci 36(3):319-328.

Brinberg D, Bumgardner M, Danilosky K (2007) Understanding perception of wood household furniture: Application of a policy capturing approach. Forest Prod J 57(7/8):21-26.
Broman O (2000) Means to measure the aesthetic properties of wood. PhD thesis, Luleå University of Technology, Luleå, Sweden.
Bumgardner MS, Bowe SA (2002) Species selection in secondary wood products: Implications for product design and promotion. Wood Fiber Sci 34(3):408-418.
Demirbilek O, Sener B (2003) Product design, semantics and emotional response. Ergonomics 46(13/14):13461360.
Gemser G, Leenders MAAM (2001) How integrating industrial design in the product development process impacts on company performance. J Prod Innov Manage 18:28-38.
Hair JF Jr., Anderson RE, Tatham RL, Black WC (1998) Multivariate analysis (5th ed.). Prentice Hall International, Upper Saddle River, NJ. 730 pp.
Hertenstein JH, Platt MB, Vryzer RW (2005) The impact of industrial design effectiveness on corporate financial performance. J Prod Innov Manage 22:3-21.
Jonsson O, Lindberg S, Roos A, Hugosson M, Lindström M (2008) Consumer perceptions and preferences on solid wood, wood-based panels and composites—A repertory grid study. Wood Fiber Sci 40(4):663-678.
Krippendorff K (1989) On the essential contexts of artifacts or on the proposition that design is making sense (of things). Issues 5(2):9-39.
Krippendorff K, Butter B (1984) Product semantics: Exploring the symbolic qualities of form in innovation. Journal of the Industrial Designers Society of America 3(2):4-9.
Llinares A, Page A (2007) Application of product differential semantics to quantify purchaser perceptions in housing assessment. Build Environ 42:2488-2497.
Manzini E (1989) The material of invention: Materials and design. MIT Press, Cambridge, MA. 256 pp.
Marchal R, Mothe F (1994) Appreciation of oak wood for the French consumer and wood professionals. Ann Sci For 51:213-231.
Monö R (1997) Design for product understanding. Liber AB, Stockholm, Sweden.
Nagamachi M (1995) Kansei engineering—A new ergonomic consumer-oriented technology for product development. Int J Ind Ergon 15(1):3-11.
Nicholls DL, Roos J (2006) Lumber attributes, characteristics, and species preferences as indicated by secondary wood products firms in the continental United States. Holz Roh Werkst 64(4):253-259.
Nyrud AQ, Roos A, Rødbotten M (2008) Product attributes affecting consumer preference for residential deck materials. Can J Res 38:1385-1396.
Osgood CE, Suci GJ, Tannenbaum PH (1957) The measurement of meaning. Illinois Press, Urbana, IL.
Pakarinen T, Asikainen A (2001) Consumer segments for wooden household furniture. Holz Roh Werkst 59:217-227.
Petiot J-F, Yannou B (2004) Measuring consumer perceptions for a better comprehension, specification and assessment of product semantics. Int J Ind Ergon 33:507-525.
Rice J, Kozak RA, Meitner MJ, Cohen DH (2006) Appearance wood products and psychological well-being. Wood Fiber Sci 38(4):644-659.
Roos A, Hugosson M (2008) Consumer preferences for wooden and laminate flooring. Wood Material Science and Engineering 3(1 & 2):29-37.
Sakuragawa S, Miyazaki Y, Kaneko T, Makita T (2005) Influence of wall panels on physiological and psychological responses. J Wood Sci 51:136-140.
SAS Institute Inc (1983) Cubic clustering criterion, SAS Technical Report A-108. SAS Institute, Inc., Cary, NC. 56 pp.
Scholz SW, Decker R (2007) Measuring the impact of wood species on consumer preferences for wooden furniture by means of the analytic hierarchy process. Forest Prod J 57:23-28.
Tsunetsugu Y, Miyazaki Y, Sato H (2007) Physiological effects in humans induced by the visual stimulation of room interiors with different wood quantities. J Wood Sci 53:11-16.