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Product semantics and sensory analysis on wood – a pilot study

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Abstract
Designers need knowledge about peoples' perceptions, based on sensory examinations of wood. This study describes results of a combined tactile and visual perceptional assessment of five common wood species in Sweden. The species were graded with regard to ten words. Differences in ratings between tactile and visual inspections were compared and main differentiating words, in tactile and visual inspection respectively, were identified. For some species like pine the differences between visual and tactile inspections vary greatly whereas birch was more coherently perceived across examination model. Visual inspections created clearer differences between the studied wood species than tactile inspections. The results provide information about the most appropriate species designers should select when aiming to achieve specific goals concerning the message or 'expression' of the product. This study indicates applications of product semantics and sensory analysis in wood design. Topics for continued studies are discussed.

Keywords: Attitudes, marketing, perceptions, wood products.

1. Introduction

Wood is generally a well-liked material that has deep historical roots in most societies. It is also extensively applied in objects that are seen and touched by man. Wood surfaces are appreciated by people, for example, in interior design or artifacts. Wood is associated with warmth (Obata et al. 2005). Jonsson et al. (2008) found that wood was preferred to wood-plastic composites and that these material preferences were associated with properties like natural, pleasant, smooth, living and good value. More specifically, people seem to appreciate a combined impression of balance and activity from a varied wooden surface without too many deformations and irregularities (Broman 2000; Nyrud et al. 2008).

Wood is also a familiar material that over time has become integrated into local traditions for building and craftsmanship. This contributes to the status of wood – together with its appreciated qualities of naturalness, grain, texture, pattern and feel. The longstanding incorporation of the different applications of wood into the local culture, and hence the possible ways to describe the material, have been emphasized by Manzini (1989), Aalto (1956) and (Ashby and Johnson 2003, p 73). It seems like people regard wood in interior applications as "warm," "comfortable," "relaxing," "natural" and "inviting" (Rice et al. 2006). Rice et al. also suggest further studies on the effect of wood on people's emotional states (some early attempts on this issue are Sakuragawa et al. 2005; Tsenetsugu et al. 2007).

Sawn timber of soft- and hardwood is usually graded according to properties important for the function of the product, e.g., construction timber must fulfill certain strength requirements. Wood strength is influenced by the slope of grain, presence of compression wood and size and numbers of knots, and therefore the grades are expressed in terms of these characteristics. For wood used in visible applications, such as door frames, architectural interiors, furniture, cabinet doors and flooring, quality is decided by the appearance of the piece of wood. Different grades are based on type of knots, and if features like red-heart, sapwood, insect damage or checks are acceptable or not (Anon. 1994; Palm and Woxblom 2009).

People frequently touch wood, e.g., in furniture and interior decorations (Kobayashi 2002). It is therefore reasonable to investigate people's reactions to tactile sensations of different wood-based materials. One complication in this task is that visual impressions often dominate and generate more varied and nuanced reactions from people. For instance, in an analytical sensory analysis by Nyrud et al. (2008) the majority of the identified sensory attributes were visual. However, there have been attempts to expand the knowledge on tactile responses to wood. Hollins et al. (1993) investigated tactile reactions to various materials, including wood. Two main dimensions separating the materials were roughness-smoothness and hardness-softness. The study concluded that sensory approaches, with ratings based on stimulus, are suitable methods for the analysis of tactile perceptions. Analyses of specific physical properties' links to tactile perceptions were carried out on warmth (Obata et al. 2000, Obata et al. 2005), roughness (Fujii et al. 1997; Fujiwara et al. 2001; Fujiwara et al. 2004) and dryness (Kobayashi et al. 2002). Chen et al. (2009) established a relationship between materials, from physical measurements to sensory and affective judgments.

Although sensory analyses and consumer studies have considered both visual and tactile perceptions of wood (c.f. Jonsson 2008; Nyrud et al. 2008), few – if any – of the published reports compare visual and tactile perceptions of the wood material.

Van Kesteren (2007) underlined that material selection is a problem-solving activity, in which much information is needed. The author found that product designers normally need material information that is queried from databases, with the final product in focus. Moreover, the information should enable comparisons between alternatives. In addition, material samples are needed to take care of the non-technical aspects of material selection. Ljungberg and Edwards (2003) focus on the non-technical aspects of material selection, emphasizing the weight of fashion, market trends, cultural aspects, aesthetics, recycling and target groups. The authors claimed that the marketing of the new product/material is sometimes an underestimated success factor. An Integrated framework for Product Material Selection that incorporates these factors was presented, where perceptional aspects were covered.

In a study on non-tangible properties of materials, Karana et al (2009) discovered different meanings of different material samples. Sensorial properties were found to lie behind this apprehension of meaning. Karana et al. (2008) mentioned that these aspects had been insufficiently dealt with in new product development.

According to Ashby and Johnson (2003), user interaction with products involves several implications: technical, aesthetic and associative. These aspects can, to some degree, be represented in words. Hence, the actual material selection process involves the product, materials and processes, but also aesthetics and perceptions. All of them connect to the actual intention. The traditional material selection involves an analysis in which technical requirements focus the set of possible materials for a purpose. Material selection by synthesis also incorporates intentions, aesthetics and perceptions in the process. Other principles are also selection by inspiration or similarity. The authors infer that the best approach often is to combine different methods for materials selection.

Ashby et al. (2004) divide the material selection process into the following steps.

"(1) A method for translating design requirements into a specification for material and process. (2) A procedure for screening out those that cannot meet the specification, leaving a subset of the original menu. (3) A scheme for ranking the surviving materials and process, identifying those that have the greatest potential. (4) A way of searching for supporting information about the top-ranked candidates, giving as much background information about their strengths, weaknesses, history of use and future potential as possible."

Taking into our scope the totality of the material selection issue means considering 40,000 to 80,000 materials and at least 1,000 different ways of processing them. Although, in this study we focus on a sub-set of wooden materials with identical processing features this still underlines the relevance for developing appropriate methods for evaluating materials for exposed uses.

More knowledge about perceptions and associations caused by touching and looking at wood would provide a better tool for designing wood products for specific users and purposes. It can determine how surfaces that are mostly intended for visual examination should look, as it might indicate the most suitable wood species for tactile surfaces. This insight might also provide a basis for the marketing of wood products.

The objective of this paper is to:

- Determine how wood samples are characterized, based on visual and tactile impressions
- Determine the main dimensions of characterizations of visual and tactile impressions.
- Describe the expressions that are most important for separating groups of wood samples, based on visual and tactile sensations.
- Study how visual and tactile reactions for the same wood species differ.

2. Product semantics

Product semantics is the study of the perceived meaning and impression of man-made shapes (Krippendorff and Butter 1984). The theory claims that products can carry meaning and messages through their color, shape, form and texture, among other things. This meaning is affected by the prevailing context, mainly operational contexts, sociolinguistic contexts, contexts of genesis, and ecological contexts (Krippendorff 1989). By paying attention to the semantic significance of product design, as well as by providing the most appropriate material, producers can better communicate and create the aspired meaning for the receiver. According to Monö (1997), 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 also to develop a suitable language in which to talk about the symbolic qualities of products. Personal, situational and cultural factors may moderate these responses (Crilly et al. 2004). Demirbilek and Sener (2003) asserted that to a certain degree product semantics, e.g., the user's own descriptions, convey the user's emotional reaction towards the object.

Petiot and Yannou (2003) described a procedure to apply product semantics in new product development. It involves defining a semantic space (Osgood et al. 1957) and, through multivariate analysis of interview data, proceeding to the final suggestion of suitable design options. Linking product semantics and Kansei engineering allows the marketer to evaluate the potential market success of an offer to the customer (Nagamachi 1995; Nagamachi 2002; Llinares and Page 2007). The relationship between product semantics and Kansei engineering is explained by the fact that both methods focus on the consumer's ideas and feelings toward new products.

Referring to this theory, we assume that a wood product (surface) produces a meaning to the onlooker or user through its color and patterns. This meaning can, to some extent, be captured by different associations or descriptive terms. Hence investigating how subjects assess different alternatives – through visual and tactile impressions – allows the producer to identify the most appropriate materials (such as wood species) for specific applications.

3. Method

Materials

The wood species in the study were the principal wood types that are utilized for visual applications. We used wood samples of ash (Fraxinus excelsior), birch (Betula pendula), elm (Ulmus glabra), oak (Quercus robur) and pine (Pinus sylvestris). Pine is a softwood that is often used in interior applications. Oak is also well known in Sweden, frequently applied for flooring and furniture. Birch is another common hardwood used, for example, for furniture and interior design products. Elm and Ash are wood species that are becoming more trendy, e.g. for flooring. All wood species are used commercially in interior uses, although pine, birch and oak are by far more common.

The wood samples were selected to provide an undisturbed impression. They were all without knots and had been planed and sanded (however, no further applications were used). Knots were avoided, as it was expected that they would bias the results in a random manner. The pieces were therefore free from knots.

The descriptive words used for association to the samples were based on earlier elicitation studies on wood from Broman (2000), Bumgardner and Bowe (2002), Jonsson et al. (2008) and Nyrud et al. (2008). The final set of words was subsequently decided upon in a series of discussions among a group consisting of wood researchers, a psychologist, and wood industry representatives. The final set of words included the following terms: natural, exclusive, environmental, rough, inexpensive, reliable, warm, modern, snug, and solid.

Procedure
The interview data were collected in two rounds. First, tactile assessments were gathered from an initial panel of respondents. The second round of data collection involved visual examinations from a new panel of respondents. The reason for not consulting the same group for the tactile and visual examinations was that they would be exhausted, and probably also biased in their answers.

Hence 30 novice respondents, 18 women and 12 men, were recruited for the tactile study. The samples were presented in random order, one at a time. The samples were cut into pieces of size 16 cm x 6 cm x 2 cm. The size allows for easy examination in the hands of the subject. The wood species of the samples were not disclosed. The respondents were allowed to freely touch the samples, but their vision and hearing was blocked (Fig. 1). Soft pads were used on the wooden table to avoid sounds (by knocking) or vibrations from the wood. The words were read out one at a time in random order by the test leader, through a telephone connected to the hearing blocker. The respondent answered with 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 associated with the sample.

Fig.1. Test situation during the tactile study. Vision and hearing blocked. (Arranged photo)

The visual study was performed according to a similar protocol. The panel consisted of 15 men and 15 women. The group was somewhat older than those in the tactile study; 18 subjects were younger than 50, compared to 26 in the tactile study. Here, the samples were presented in pieces of size 40 cm x 13.5 cm x 2 cm. The words were read out one at a time in random order by the test leader. The size – larger than in the tactile study - was intended to present a larger exposed area for visual inspection. In this round, the subjects were not allowed to lift the object. The origin and processing of the wood surfaces were, however, identical to those in the tactile inspections. The wood samples were also presented here in random order, one at a time, in normal office illumination and with grey pads on the table (see Fig. 2).

Fig.2. Test situation during the visual study. (Arranged photo)

Analysis

The results were analyzed statistically. Ratings for the same wood species, based on visual vs. tactile examination, were compared and tested, in parametric and non-parametric tests. To provide a more comprehensible representation of subjects' overall assessments of the wood species, principal component factor analysis was performed on the visual and tactile ratings separately, and also on the pooled data. Factor scores for visual and tactile assessments on each wood species were computed and presented in a graph.

In order to identify the characterizations that were most central for separating wood species in visual and tactile examinations, respectively, a cluster analysis was done. Clusters of wood species with similar characterizations were identified. The clusters were subsequently compared through step-wise backward variable elimination.

4. Results

Comparison between tactile and visual studies

Visual and tactile ratings for each wood sample are presented in Fig. 3 to 7. Mean values and significant differences, based on parametric or non-parametric tests, are indicated in Tab. 1. The comparisons show that most differences are not significant. The most significant differences, or discrepancies, between tactile and visual examinations within the same wood species, are noticed for pine, elm and oak.

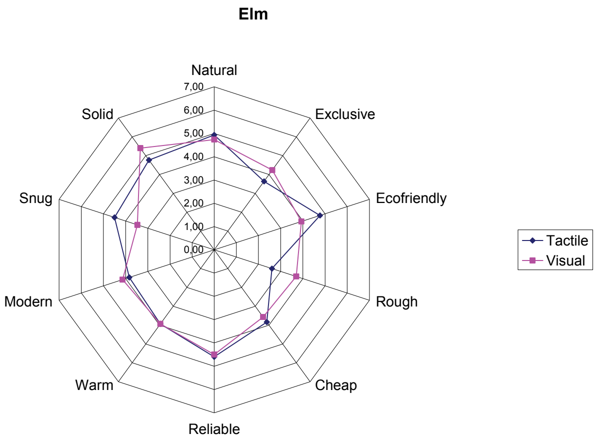


Fig.3. Elm, a comparison between tactile and visual results.

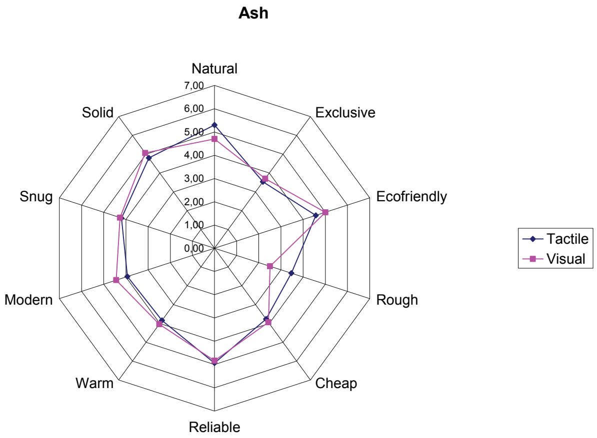


Fig.4. Ash, a comparison between tactile and visual results.

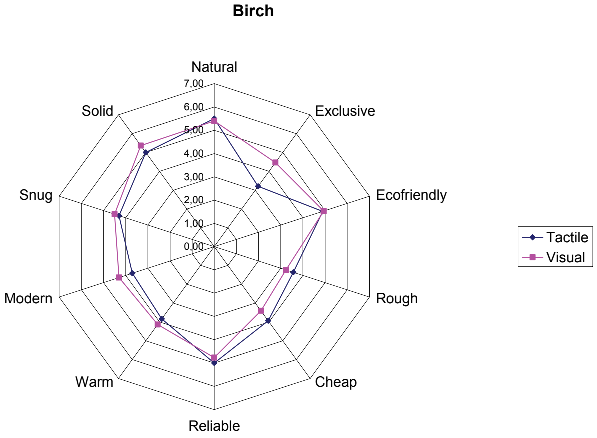


Fig.5. Birch, a comparison between tactile and visual results.

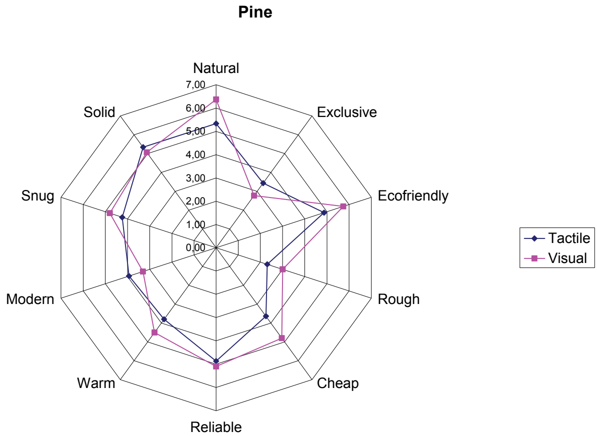


Fig.6. Pine, a comparison between tactile and visual results.

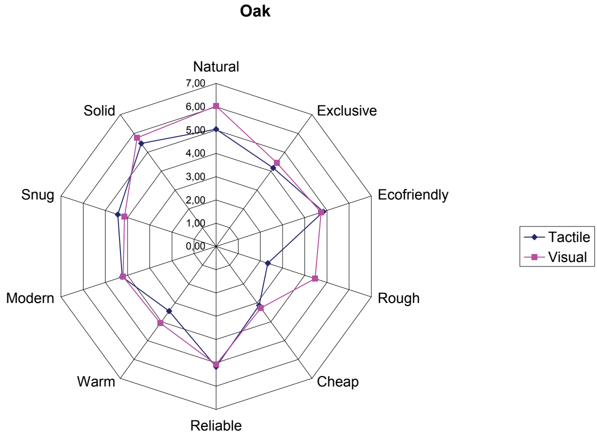


Fig.7. Oak, a comparison between tactile and visual results.

Table 1. Significant rating differences ($p<0.05$)

	Mean visual	Mean tactile
Elm		
Eco-friendly	3.9	4.8
Rough	3.7	2.6
Snug	3.5	4.5
Ash		
Exclusive	4.8	3.5
Inexpensive	2.8	3.8
Solid	5.5	4.8
Birch		
Exclusive	4.5	3.2
Pine		
Natural	6.4	5.3
Eco-friendly	5.7	4.9
Rough	3.0	2.3
Inexpensive	4.8	3.6
Oak		
Natural	6.0	5.0
Rough	4.5	2.3

Pine presented differences between tactile and visual ratings for several measurements, and birch seemed to be most coherent across the measurements. In most cases, visual inspections generated higher ratings. However, for elm, tactile assessments gave higher ratings for eco-friendly and snug.

Dimensions of visual and tactile comparisons

A principal component analysis was performed to detect how the subjects grouped visual and tactile data when perceiving the wood samples. The analysis was conducted on the visual and tactile investigations separately, and on the pooled sample (Tab. 2-4). Three-factor solutions were determined based on eigenvalue>1 criterion.

Table 2. Rotated Factor Pattern – Visual data

	Factor 1 *Exclusive*	**Factor 2** *Environmental*	**Factor 3** *Warmth*
Exclusive	**0.88086**	-0.00209	0.01167
Modern	**0.78913**	0.07193	0.27011
Solid	**0.58807**	0.35769	0.12205
Inexpensive	**-0.87139**	0.05824	0.12478
Eco-friendly	-0.01670	**0.85102**	0.01416
Natural	-0.01988	**0.83612**	0.00787
Reliable	0.41139	**0.60108**	0.26340
Warm	0.19683	0.25100	**0.77691**
Snug	0.42394	0.34914	**0.57054**
Rough	-0.17711	-0.22775	**0.50377**

Factor loadings higher than 0.4 in bold

Table 3. Rotated factor pattern – Tactile data

	Factor 1 *Environmental*	**Factor 2** *Exclusive*	**Factor 3** *Rough*
Natural	**0.85602**	-0.10427	0.15217
Eco-friendly	**0.82761**	-0.05093	0.07482
Warm	**0.72575**	0.01473	-0.24887
Reliable	**0.68826**	0.44129	0.19314
Solid	**0.63392**	0.34764	0.36827
Snug	**0.61058**	0.30140	-0.31232
Exclusive	0.19311	**0.80752**	-0.21682
Modern	0.05854	**0.71705**	-0.36134
Inexpensive	0.06430	**-0.80304**	-0.13590
Rough	0.05843	-0.15638	**0.80650**

Factor loadings higher than 0.4 in bold

Table 4. Rotated factor pattern - Pooled data

	Factor 1 *Environmental*	Factor 2 *Exclusive*	Factor 3 *Rough*
Eco-friendly	**0.79481**	-0.10632	-0.07651
Natural	**0.79082**	-0.15202	0.11830
Reliable	**0.68035**	0.32182	-0.01389
Warm	**0.59947**	0.18654	0.08725
Solid	**0.57701**	0.39188	-0.00718
Snug	**0.55874**	0.34275	-0.22170
Exclusive	0.17880	**0.84894**	0.02609
Modern	0.17291	**0.79202**	0.00086
Inexpensive	0.05127	**-0.79577**	0.12305
Rough	0.01943	-0.05319	**0.97747**

Factor loadings higher than 0.4 in bold

The factor scores generated by the pooled factor analysis are represented in Fig. 8 and 9. It confirms the inference that the visual study succeeded in generating more clear-cut differences between the wood species. The tactile factor scores are more centered in the graphs, indicating that tactile perceptions provide a weaker basis for separating the samples. The graphs also support the outcome from Tab. 1 that tree species with a high consistency between visual and tactile sensations are birch and, to some extent, oak (on factors 1 and 2), whereas pine generated differing sensations between touch and sight.

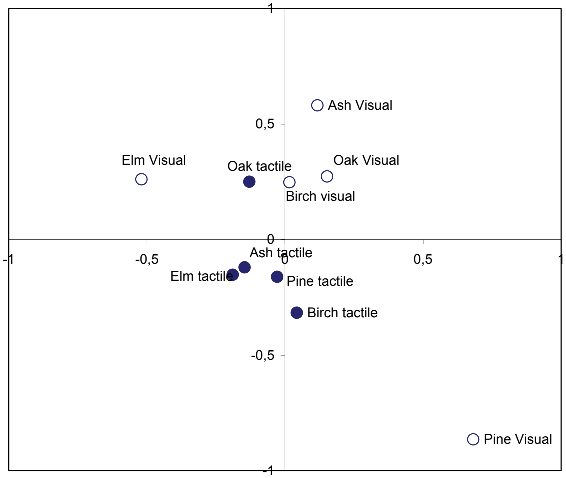


Fig.8. Factor scores on pooled factor analysis: Visual and tactile data (x=factor 1, y=factor 2).

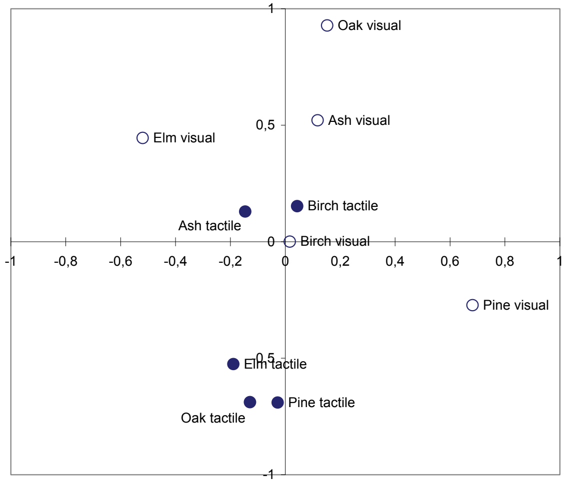
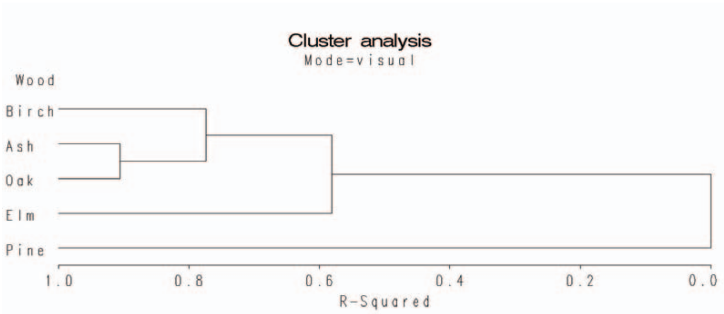


Fig.9. Factor scores on pooled factor analysis: Visual and tactile data (x=factor 1, y=factor 3).

Most central word separating wood samples

We proceeded to study the overall differentiation between the wood samples across visual and tactile examination. First, we used cluster analysis (Ward Method) to group the wood species into two groups. Separate analyses were run for tactile and visual assessments. The results are shown in the tree diagrams (Fig. 10). According to the cubic clustering criterion and R2-statistics, a two-cluster solution was appropriate in both the visual and tactile sub-studies. The visual data suggested a two-cluster solution, with only pine in one cluster and the broadleaves wood species - birch, ash, elm and oak - in a second cluster. The tactile study indicated that ash and birch should be in one cluster and pine, oak and elm in a second cluster.



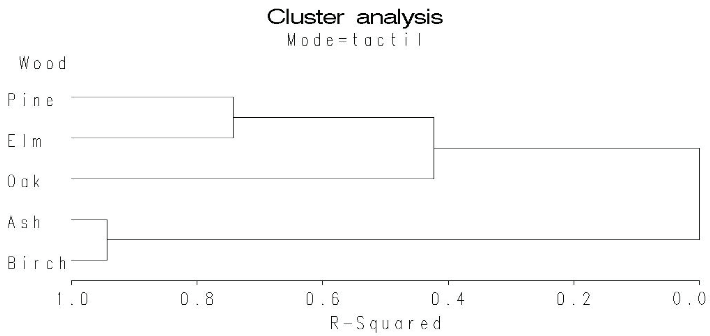


Fig.10. Clustering trees for visual and tactile studies, respectively

A logistic regression with a step-wise backward elimination of variables yielded the set of significant semantic attributes that separated (the means of) the two clusters. The results are displayed in Tab. 5 for visual perceptions and Tab. 6 for tactile perceptions. These variables can be viewed as the most consistent attributes that can be used to distinguish the main sub-sets of wood species – in visual and tactile examinations, respectively. The visual sub-study generated more important such variables: exclusive, eco-friendly, rough and snug. The tactile exercise only generated one variable: (rough).

Table 5. Attributes defining visual differences (pine vs. hardwood)

Parameter	DF	Estimate	Std. error	Wald Chi-Square	Pr>ChiSq
Intercept	1	1.6096	1.7031	0.8932	0.3446
Exclusive	1	1.8428	0.3920	22.0963	<.0001
Eco-friendly	1	-0.6778	0.2122	10.2019	0.0014
Rough	1	0.7575	0.2340	10.4786	0.0012
Snug	1	-1.2476	0.3486	12.8071	0.0003

Chi-Square 78.3241, Pr > ChiSq 0.0001

Table 6. Attributes deciding tactile differences (ash and birch vs. pine, elm and oak)

Parameter	DF	Estimate	Standard error	Wald Chi-Square	Pr>ChiSq
Intercept	1	-3.0551	0.6183	24.4145	<.0001
Rough	1	0.5437	0.1780	9.3338	0.0022

Chi-Square 9.9110, Pr > ChiSq 0.0016

5. Discussion

Our results showed that pine displayed differences between tactile and visual impressions for most aspects, whereas birch was more coherent from this perspective. Assessments based on tactile examinations gave, in most cases, more conservative characterizations than the counterpart characterizations based on visual examination. The most pronounced dimensions in perceptions were environmental, exclusive and rough (for tactile) and warm/snug (for visual).

When we attempted to determine the measures that were used for separating groups of tree species, we found that identifications were normally more comprehensive for visual examinations, in this case pine differed from broadleaves based on a range of attributes. The tactile examinations became more clustered and only the clearly tactile property 'roughness' was used to distinguish groups of wood samples from each other.

The chosen characteristics were apparently adapted more for visual examinations. Visual examinations presented more perceived differences between wood samples than did perceived tactile examinations. The most evident difference between visual and tactile assessments was noticed for pine. One possible reason is that pine is rooted in the Swedish culture and it therefore generates many associations when visually perceived.

Our results can be compared with those in Tsenetsugu et al. (2007), in that wood causes different physiological reactions among people. Hence, it is natural that people are not indifferent to wood surfaces. Although - as in Jonsson (2005) - we could not study the impression of wood versus other materials, or wood in different specific applications, our results clearly show that non-functional properties play an important role when wood materials are evaluated. The outcome that roughness is a feature sensed mainly by touch complements the studies by Fujiwara et al.(2001; 2004) and Hollins (1993) that found that sensory apprehension of roughness correlated with real surface distortion. Our results can only partially be compared to those in Bumgardner and Bowe (2002). However, the visual study conforms to the findings by Bumgardner and Bowe (2002), that pine is perceived as inexpensive. In our study, however, eco-friendly varied between the samples, especially when hardwood and softwood were compared.

The results can guide producers to select the best tree species, especially for providing visual messages. Broadleaves, especially ash, are most appropriate for conveying feelings of exclusivity, whereas pine is seen as more eco-friendly and natural.

There are several limitations with the analysis. The sample size is limited and we have not investigated if tastes depend on socio-economics or other background attributes among the subjects. It is also likely that the results only should be generalized within the Swedish context. And finally, the method to generate the most important descriptive words and associations for wood can of course be used and tested in other contexts and more specific applications.

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