Research Results • 8

Research results from the Department of Forest Products at the University of Agricultural Sciences, Uppsala, Sweden

www.sprod.slu.se

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

Siv Lindberg, Anders Roos and Annika Kihlstedt

Abstract

Based on product semantics, this study investigated how visual attributes of wood are perceived and interpreted semantically. The wood species alder, ash, aspen, birch, beech, elm, lime, larch, maple, oak, pine and spruce were used. The subjects rated the samples based on the descriptive words natural, exclusive, environmental (i.e., ecofriendly), rough, inexpensive, dark, reliable, warm, modern, cosy, solid, and light. The most significant differences were between softwoods and hardwoods. Principal component analysis yielded three dimensions based on visual perceptions: exclusive/modern, environmental/natural and light vs. dark. Maple and ash, in addition to other hardwoods, were seen as more exclusive/modern than spruce and pine. Pine, on the other hand, was perceived as the most environmental/natural wood type. Beech and alder did not score high on any of the three dimensions. The potential use of these results in product design and interior design is discussed.

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

Introduction

Wood is generally a well-liked material. People appreciate wood surfaces – e.g., in interior design and furniture. Jonsson et al. (2008) have found wood to be preferable to wood-plastic composites and that these material preferences were associated with the properties of natural, pleasant, smooth, living and worth. Studies have demonstrated that consumers prefer wooden surfaces to imitations (Jonsson et al. 2008; Roos and Hugosson 2008).

Wood is also an established and well known material. It has over time 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 the local culture and hence the possible ways of describing the material are emphasized by Manzini (1989). People and specialists are generally conscious about wood potentials and limitations. The famous Finnish architect Alvar Aalto argued that wood is closely integrated with human history; its specific good and bad characteristics are well known by most architects (Aalto 1956). 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 an individual's well-being and feelings of comfort, although this issue requires further study (Sakuragawa et al. 2005 Tsenetsugu et al. 2007). Rice et al. (2006) show that people regard wood in interior applications as warm, comfortable, relaxing, natural and inviting. Rice et al. also suggest that further studies should be conducted on the effect of wood on people's emotional states.

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. Material selection is also one important activity in the industrial design process (Ashby and Johnson 2003). Investments in product design and efforts related to design innovativeness have 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 different users (Ashby and Johnsson 2003, p 73). The typical characteristics that consumers assign to wooden materials have been studied by a number of researchers (Broman 2000; Pakarinen and Asikainen 2001; Bowe and Bumgardner 2004; Scholz and Decker 2007). Bowe and Bumgardner (Bumgardner and Bowe 2002; Bowe and Bumgardner 2004) studied people's

 ISSN 1654-9759

word-based and appearance-based evaluations of different wood species. They found that different wood species are rated differently on several semantic differential scales. The authors argue that these associations and differentials in the North American context could assist the wood product industry in market communication. The importance of the appearance of wood for the marketing of wood products has been demonstrated by Nicholls and Roos (2006) in a study of wood manufacturers. Marchal and Mothe (1994) present several perceived attributes that influence consumer preferences and also identify differences between consumer segments. Attempts have also 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 is probably the most distinguishing feature 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 out of 18 elicited attributes were based on visual impressions.

A deeper understanding of people's perceptions of different wood species and how they are expressed would help producers of visible wood products – e.g., 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 – e.g., within the framework of Kansei engineering (Nagamachi 1995). Few studies have attempted to investigate product semantics with regard to different wood species. However, based on the previous studies, we conclude that word-based interpretations of visual aspects of wood are important, especially because designers, in their selection of materials (in this case wood species), 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 study the semantic differentiation between the most common Swedish wood species.

Product semantics

Product semantics is the study of the perceived meaning and impression of man-made shapes (Krippendorff and Butter 1984). It posits that products make a statement through color, shape, form, texture, gloss and so on. This meaning is transmitted in different contexts: operational contexts, sociolinguistic contexts, contexts of genesis, and ecological contexts (Krippendorff 1989). Product semantics enables designers to communicate and create meaning – e.g., in the selection of materials. An object can, according to Rune Monö (1997), 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) assert that the users' own descriptions of an object convey their emotional reactions to the object to a great degree.

Petiot and Yannou (2004) describe 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).

Referring 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 alternatives (through visual and tactile impressions) allows the producer to select the most appropriate materials (such as wood species) for specific applications.

Materials and method

Material

In this visual study, twelve wood samples were used: alder (*Alnus glutinosa*), ash (*Fraxinus excelsior*), aspen (*Populus tremula*), birch (*Betula pendula*), beech (*Fagus silvatica*), elm (*Ulmus glabra*), lime (*Tilia cordata*), larch (*Larix decidua*), maple (*Acer platanoides*), oak (*Quercus robur*), pine (*Pinus sylvestris*) and spruce (*Picea abies*). The wood species include most naturally existing wood species in Sweden. The samples were presented in pieces of 40 cm × 13.5 cm × 2 cm. They were mostly free of knots and had been planed and sanded.

The words used in the study to describe and associate 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). The design and final set of words were thereafter decided upon in a series of discussions in a panel of seven people consisting of wood marketing researchers, a psychologist, and wood industry representatives. The final sets of words were as follows: natural, exclusive, environmental (i.e., ecofriendly), rough, inexpensive, dark, reliable, warm, modern, cosy, solid, and light. It may seem superfluous to include both "dark" and "light". However, it is not always the case that these two concepts are direct opposites. The words and sources are shown in Table 1.

Table 1. Words for the study

Property	Source Broman (2000)	Jonsson et al. (2008)	Nyrud et al. (2008)	Bumgardner & Bowe (2002)
Natural		X		
Exclusive	X			X
Environmental				X
Rough			X	
Inexpensive	X	X	X	X
Dark		X	X	
Reliable				X
Warm	X	X		X
Modern				X
Cozy	X			
Solid	X	X		

Thirty novice respondents, 15 women and 15 men, were recruited for the study. Sixteen of the respondents were employed at Innventia AB (formerly STFI-PF). The others were recruited through a special agency. The age and gender distributions of the respondents are shown in Table 2.

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 grey pad on the table. The respondent was only allowed to look at the samples, not to touch them; see Figure 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, where 7 meant that the word was strongly associated with the sample and 1 that the word was not at all associated with the sample.

Table 2. Distribution of age and gender among the respondents in the visual study

Age	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**

Fig. 1. Test situation (arranged photo).

Analysis

The mean ratings of the species were compared and the correlations computed. Principal component analysis (PCA) was conducted to summarize the 12 variables using fewer dimensions.

Results

Correlations

The correlations between the properties are shown in Table 3. Five correlations were between |0.5| and |0.7| (Environmental-Natural 0.54, Modern-Exclusive 0.66, Modern-Inexpensive -0.52, Solid-Reliable 0.56, Cosy-Warm 0.53), two correlation coefficient reached |0.7| (Inexpensive-Exclusive: -0.70, Dark-Light -0.75).

Table 3. Correlations

Property	Natural	Exclusive	Environmental	Rough	Inexpensive	Dark	Reliable	Warm	Modern	Cozy	Solid	Light
Natural	1											
Exclusive	**0.10**	1										
Environmental	**0.54**	0.06	1									
Rough	0.01	-0.05	-0.02	1								
Inexpensive	0.04	**-0.70**	0.02	**0.16**	1							
Dark	-0.04	**0.21**	**-0.12**	**0.36**	**-0.17**	1						
Reliable	**0.28**	**0.44**	**0.35**	-0.06	**-0.37**	0.09	1					
Warm	**0.21**	**0.25**	**0.27**	0.06	**-0.13**	0.10	**0.39**	1				
Modern	0.06	**0.66**	0.19	-0.07	**-0.52**	0.02	**0.37**	**0.33**	1			
Cozy	**0.22**	**0.35**	**0.25**	-0.04	**-0.26**	0.02	**0.33**	**0.53**	**0.41**	1		
Solid	**0.19**	**0.43**	**0.19**	-0.07	**-0.40**	**0.11**	**0.56**	**0.29**	**0.33**	**0.39**	1	
Light	0.04	**-0.11**	**0.17**	**-0.27**	**0.19**	**-0.75**	0.01	0.02	0.06	0.08	-0.06	1

Bold: Significant correlation at $p < 0.05$

Ratings

The mean ratings according to the different descriptive words are shown in 'spider' diagrams (Figure 2 and Figure 3). The significant differences after Tukey-tests are noted in Table 5.

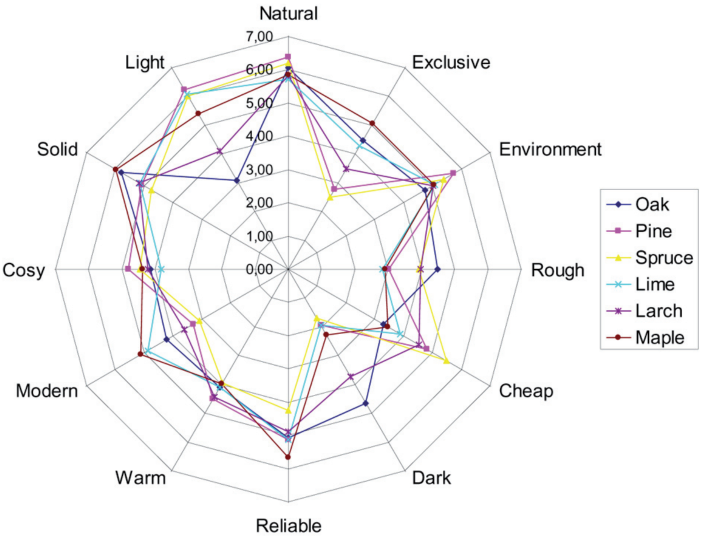

Figure 2. Ratings: alder, ash, aspen, birch, beech, elm.

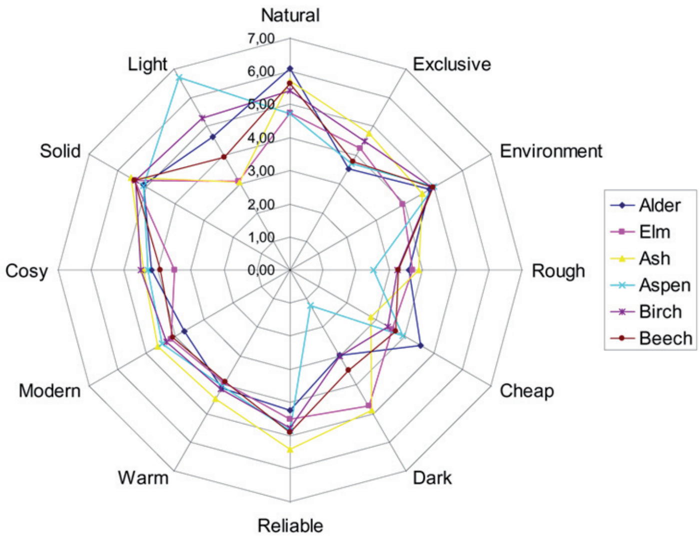

Figure 3. Ratings: lime, larch, maple, oak, pine and spruce.

The spider diagrams show that the respondents' mean ratings for several characteristics only differed in terms of the margin. This can be seen in solid, cosy and warm. This is also confirmed by the ANOVA table (Table 4). The properties that presented larger and significant differences were exclusive, dark, modern and light.

Table 4. ANOVA of mean ratings

Property	F-value	P-value
Natural	4.12	0.00
Exclusive	7.46	0.00
Environment	2.43	0.01
Rough	4.41	0.00
Inexpensive	6.24	0.00
Dark	30.86	0.00
Reliable	2.52	0.00
Warm	0.07	0.74
Modern	4.73	0.00
Cozy	1.61	0.09
Solid	1.37	0.18
Light	33.19	0.00

Table 5 complements Figures 2 and 3 by showing significant differences between the tree species. Examples of pairs of tree species with few distinguishing features are Alder-Birch, Alder-Beech, and Pine-Spruce. Several differences were found between Spruce and Elm, Pine and Elm, and Maple and Elm.

An inspection of Figures 2 and 3, and Table 5, present further details concerning the differences. Pine was perceived as more natural than many other samples, whereas elm was classified as somewhat less natural. The quality exclusive mainly separated hardwood from softwoods, and maple scored the highest in this respect. Although the properly environmental was not particularly useful in distinguishing between the wood species, pine and spruce had the highest ratings with regard to this property. Roughness was the lowest for aspen and the highest for oak. As the highly negative correlation coefficient between inexpensive and exclusive indicate, the two variables displayed inverse ratings. Ash and oak were the least inexpensive, and the softwoods were seen as more inexpensive than hardwoods. Oak, elm and ash were darker wood types, and pine, spruce and lime were lighter. Only three significant differences were recorded in terms of the reliable

Table 5. Significant differences between pairs of tree species according to Tukey-Kramer test

	Alder	Ash	Aspen	Birch	Beech	Elm	Lime	Larch	Maple	Oak	Pine
Alder											
Ash	D,Ch,L										
Aspen	N, R,D,L	R,D,L									
Birch		D,L	D,L								
Beech		D	D,L	L							
Elm	N,D,L		D,L	D,L	D						
Lime	L	D,L		D	D,L	E,D,L					
Larch		Ch,D	R,D,L	L			R,L,D				
Maple	M, Re	D,L	Ex,L		L,D	E,D,RE,L	D	Ex,D,M S			
Oak	D,L		N,R,D	D,L	D	N	R,D,L	M	R,D,L		
Pine	L	Ex,Ch,D,L	N	Ex,D	D,L	E,N,C,Ex,D,L	Ex,M,Ch,P	R,D,L	Ex,M	Ex,Ch,R,D,L	
Spruce	D,L	Ex, Ch,D,M,L	N,R, Ch,M	Ex,Ch,D	Ch,D,L	E, N,Ex,Ch,D,L	Ex,M	D,L	Ex,Ch,M,S, Re	Ex,Ch,D,L	

Significant differences ($p < 0.05$) for N=Natural, E=Environmental, R=Rough, Re=Reliable, W=Warm, C=Cozy/Snug, Ch=Inexpensive, S=Solid, Ex= Exclusive, D=Dark, M=Modern and L=Light characteristic. There were no differences at all in terms of the property warm. The trait modern distinguished the spruce from several other species. Maple and lime were the most modern. cosiness only separated elm from pine, and solid constituted a significant difference between maple and spruce and maple and larch.

Principal component analysis

To summarize the ratings for this large range of words, principal component analysis was performed. The overall Kaiser's measure of sampling adequacy (MSA) was 0.730, which renders the dataset acceptable for principal component factor analysis. All individual variable MSA:s exceeded 0.5. Rotated factor loadings and communalities after varimax rotation are shown in Table 6. A three-factor solution was preferred based on the criterion that the eigenvalue should exceed 1. Two variables present low communalities (below 0.5). However, they still load significantly on factors, and due to the exploratory character of the study, they were kept for further analysis. Factor loadings exceeding 0.3 are considered significant and are highlighted with bold font (Hair et al. 1998). Three variables load significantly on both factors 1 and 2. The first factor is mainly loaded by the ratings for the characteristics exclusive, modern and inexpensive (the latter negative). Factor 2 indicates naturalness and environmental associations together with reliability and warmth. Factor 3, finally, is loaded based on impressions regarding the degree of darkness and roughness.

Table 6. Rotated Factor Loadings and Communalities Varimax Rotation, n = 357

	Factor 1	Factor 2	Factor 3	Communality
Exclusive	0.86101	0.03914	0.07790	0.749
Modern	0.77968	0.08714	-0.11018	0.628
Solid	0.60279	0.33789	0.05920	0.481
Reliable	0.55992	0.49318	0.02485	0.557
Snug	0.48834	0.48536	-0.06709	0.479
Inexpensive	-0.83455	0.13948	-0.06299	0.720
Environmental	-0.02079	0.79879	-0.10922	0.650
Natural	-0.03769	0.76124	0.01329	0.581
Warm	0.36078	0.55953	0.08414	0.450
Dark	0.16658	-0.05200	0.89890	0.838
Rough	-0.20630	0.14762	0.61696	0.445
Light	-0.10409	0.15744	-0.86623	0.786
Percent explained	30.2	17.6	13.5	

Figure 4 shows the factor loadings and the recorded scores in relation to factors 1 and 2. Figure 5 presents the factor loading results for factors 1 and 3. Figures 6-7 display the corresponding factor scores. Significant differences in factor scores are indicated in Table 7. Maple and ash score high in terms of factor 1, where spruce and pine provide the lowest scores. Clearly, hardwoods are perceived as more exclusive and modern than softwoods. Pine, on the other hand, is perceived as the most environmental and natural, whereas elm scores low on the same factor. Oak, elm and ash are the darkest wood species, and lime, pine and aspen are viewed as lighter wood species. Beech and alder did not score high on any of the factors.

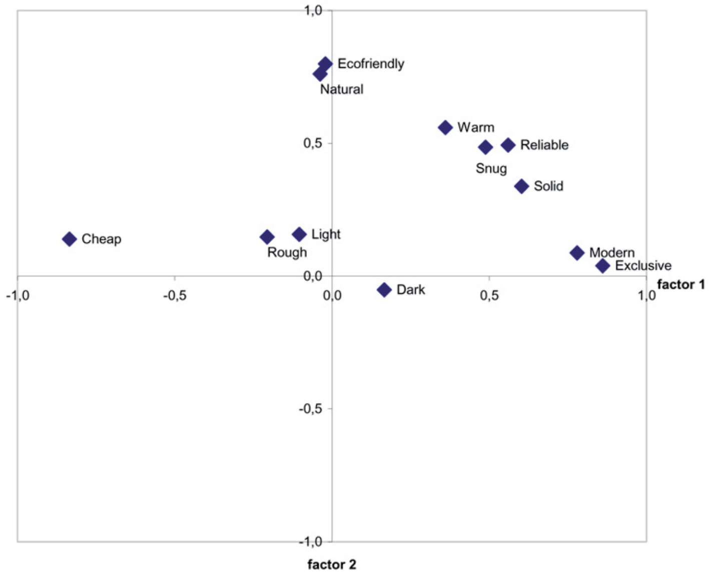

Figure 4. Factor loadings: factors 1 (horizontal) and 2 (vertical).

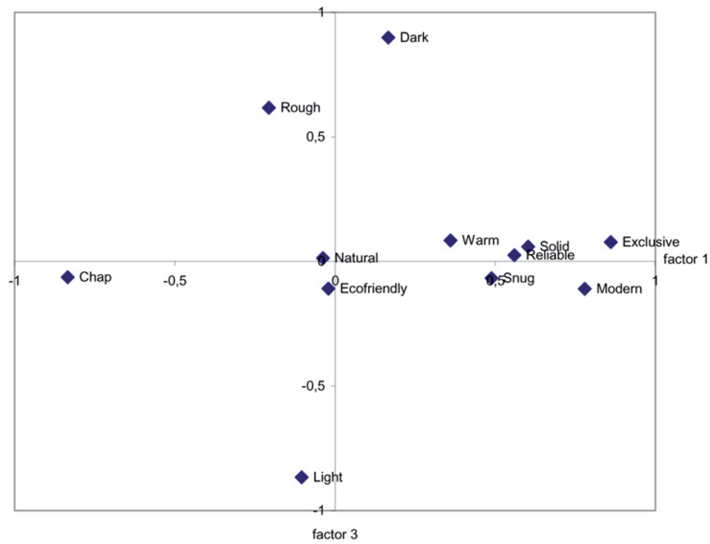

Figure 5. Factor loadings: factors 1 and 3.

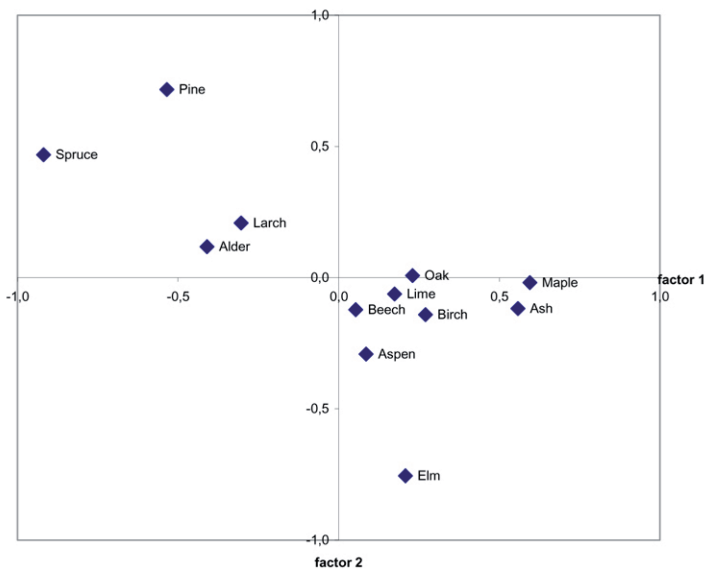

Figure 6. Factor scores: factors 1 and 2.

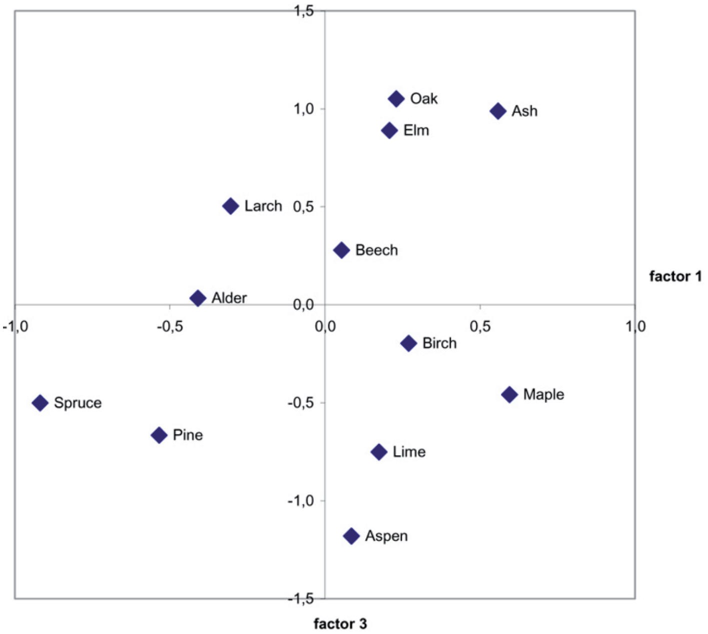

Figure 7. Factor scores: factors 1 (horizontal) and 3 (vertical).

Discussion

Wood species are mainly distinguished from one another based on visual perceptions, such as light-dark. However, the qualities exclusive, modern and inexpensive are also used to differentiate between the samples. The perceived differences mainly revolve around three factors: exclusive/modern vs. inexpensive, environmental/natural and light/dark/rough. Hardwoods were more exclusive and softwoods less exclusive, while softwoods were perceived as more environmental than hardwoods.

Broman (2000) reveals a similar feature wherein exclusive and elegant were distinguished as one dimension. However, because Broman mainly focuses 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) find that wood materials were seen both as more valuable and natural compared to panels and composites. Our study, which is conducted using a more narrow set of samples, suggests that the natural/environmental look and the exclusive look are emphasized in softwood and certain hardwoods, respectively.

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

Bowe and Bumgardner (2004) concluded that darker wood types were perceived as more expensive. Our results partly confirm their results because darkness is negatively correlated with inexpensiveness and positively correlated with exclusivity. The coefficients are not high, though, and the separate factor for the degree of darkness and Figure 7 confirms the results of Nyrud et al. (2008): Exclusive and perceived valuable wood can be both light (maple) and dark (ash, elm, and oak).

The results suggest the use of particular wood species based on specific design intentions. For example, pine gives an air of naturalness and environmental friendliness, whereas maple is seen as exclusive. Both ash and maple are considered 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 is intended for specific users. Using the different wording, the designers find the subset of wood materials that are most appropriate for the intended use. The wording can also help one to ascertain the most suitable verbal marketing descriptions of wood materials – e.g., flooring.

The limited sample of subjects for the study limits the

Table 7. Significant differences for factor scores according to Tukey-Kramer test

	Alder	Ash	Aspen	Birch	Beech	Elm	Lime	Larch	Maple	Oak	Pine	Spruce
Alder												
Ash	1,3											
Aspen	3	3										
Birch		3	3									
Beech		3	3									
Elm	2,3		3	3								
Lime	3	3	3		3	3						
Larch		1	3	3		2,3	3					
Maple	1	3	3		3	3		1,3				
Oak	3		3	3			3		3			
Pine	3	1,2,3	2	1,2	3	2,3		3	1	3		
Spruce		1,3	1,3	1	1,2,3	1,2,3	1	3	1	1,3		

Factor 1: exclusive, modern; Factor 2: environmental, natural; Factor 3: dark, rough

scope of generalization of the results. Other considerations do of course also influence wood species selection – e.g. the context and form. It is also possible that cultural factors may influence the study if it is conducted in different countries.

Further research should develop a framework for species selection for different design purposes. A procedure for this can be found in the Kansei engineering concept.

References

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

Ashby, M, and Johnson, K. 2003. Materials and Design – The art and science of material selection in product design. Butterworth – Heinemann, Byurlington, MA. 336 p.

Bowe, S. A., and Bumgardner, M. S. (2004) Species selection in secondary wood products: Perspectives from different consumers. Wood and Fiber Science 36(3): 319-328.

Brinberg, D., Bumgardner, M., and. Danilosky, K. 2007. Understanding perception of wood household furniture: application of a policy capturing approach. Forest Products Journal 57(7/8): 21-26.

Broman, O. 2000. Means to measure the aesthetic properties of wood. Doctoral thesis, Luleå University of Technology, Luleå, Sweden.

Bumgardner M. S., and Bowe S. A. 2002. Species selection in secondary wood products: Implications for product design and promotion. Wood and Fiber Science 34(3): 408-418.

Demirbilek, O. and Sener, B. 2003. Product design, semantics and emotional response. Ergonomics 46(13/14): 1346-1360.

Gemser, G., and Leenders M. A. A. M. 2001. How integrating industrial design in the product development process impacts on company performance. The Journal of Product Innovation Management 18: 28-38.

Hair, J. F. jr., and Anderson R.E., Tatham R.L., Black W.C. 1998. Multivariate Analysis (5th Ed.). Prentice Hall International, NJ. 730 p.

Hertenstein, J. H., Platt, M. B., and Vryzer, R. W. 2005. The impact of industrial design effectiveness on corporate financial performance. Journal of Product Innovation Management 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 and Fiber Science 40(4): 663-678.

Krippendorff, K. 1989. On the essential contexts of artifacts or on the proposition that ”Design Is Making Sense (Of Things)”. Design Issues 5(2): 9-39.

Krippendorff, K., and Butter, B. 1984. Product semantics: Exploring the symbolic qualities of form in Innovation, The Journal of the Industrial Designers Society of America, 3(2): 4– 9.

Llinares, A., and Page, A. 2007. Application of product differential semantics to quantify purchaser perceptions in housing assessment. Building and Environment 42: 2488–2497.

Manzini, E. 1989. The material of invention: Materials and design. MIT Press. 256 p.

Marchal, R., and Mothe, F. 1994. Appreciation of oak wood for the French consumer and wood professionals. Annales des Sciences Forestières 51: 213-231.

Monö, R. 1997. Design for Product Understanding. Liber AB, Stockholm.

Nagamachi, M. 1995. Kansei Engineering – A new ergonomic consumer-oriented technology for product development. International Journal of Industrial Ergonomics 15(1): 3-11.

Nicholls, D. L., and Roos, J. 2006. Lumber attributes, characteristics, and species preferences as indicated by secondary wood products firms in the continental United States. Holz als Roh-und Werkstoff 64(4): 253-259.

Nyrud, A. Q., Roos, A., and Rødbotten, M. 2008. Product attributes affecting consumer preference for residential deck materials. Can J For Res 38: 1385-1396.

Osgood, C. E., Suci, G. J., and Tannenbaum, P. H.1957. The Measurement of Meaning. Illinois press, Urbana.

Pakarinen, T., and Asikainen, A. 2001. Consumer segments for wooden household furniture. Holz als Roh- und Werkstoff 59: 217-227.

Petiot J-F., and Yannou B. 2004. Measuring consumer perceptions for a better comprehension, specification and assessment of product semantics. International Journal of Industrial Ergonomics 33: 507–525.

Rice, J., Kozak, R. A., Meitner, M. J., and Cohen D. H. 2006. Appearance wood products and psychological well-being. Wood and Fiber Science 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.

Sakarugawa, S., Miyazaki, Y., Kaneko, T., Makita, T. 2005. Influence of wall panels on physiological and psychological responses. Journal of Wood Science 51: 136-140.

Scholz, S. W., and 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.

Tsenutsugu, Y., Miyazaki, Y., and Sato, H. 2007. Physiological effects in humans induced by the visual stimulation of room interiors with different wood quantities. Journal of Wood Science 53: 11-16.

Siv Lindberg
INNVENTIA
Stockholm, Sweden

Anders Roos
Department of Forest Products
Swedish University of Agricultural Sciences, Uppsala, Sweden

Annika Kihlstedt
INNVENTIA
Stockholm, Sweden