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ORIGINAL ARTICLE

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Aesthetic properties in knotty wood surfaces and their connection with people's preferences

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Abstract For wood products that contain visible wood surfaces it is important to be able to describe, measure, and communicate the aesthetic properties desired. The aims of this investigation were to shed light on how people's preferences toward different wood appearances containing knots can be described and to create a better understanding of how to measure those preferences. A total of 215 persons from Sweden with different backgrounds were interviewed as to their preferences for 10 Scots pine wood surfaces containing knots. Their impressions and preferences were documented by a questionnaire with 54 questions and analyzed by a principal component analysis. A thorough description of what people see and value in a wood surface with knots is given in the body of the text. People's preferences are affected by a balance between two main properties: the degree of harmony and activity, and the importance of avoiding a state of disharmony when composing wood surfaces. When investigating people's preferences toward a knotty wood appearance, 13 of 54 questions proved to be important. Three questions detect the final assessment, and four describe the reasons for the final assessment. Finally, six questions describe the blend of wood properties in a more objective way and are to only a minor extent connected with the final assessments.

Key words Wood · Attitudes · Scots pine · Questionnaire · Interviewing technique

Introduction

When dealing with the area of aesthetics and wood, we often think of architecture, interior design, furniture design, and fine art, and less often about the impact of aesthetic features of the wood itself. Competent designers are very much aware of the innate qualities and textures of all materials, especially natural ones,[1] but in the case of wood aesthetics, from an industrial point of view, it is more difficult. The chain of producers processing, grading, and sorting wood from the raw material to the final product is long, and it is a huge task to concentrate and sell a certain amount of wood features to a specific customer. Hansen and Weinfurter[2] stated the largest perception gap between supplier and buyer of softwood concerned various aspects of lumber aesthetics.

Wood processing industries always have tried to maximize the yields in their processes, that is, to minimize the volume loss of wood. More rarely there have been efforts to optimize the yields measured in monetary terms. When optimizing the value yields instead of yields in utilized wood, the results often differ. A value yield depends merely on customer satisfaction. Customer satisfaction depends on the product's performance relative to a buyer's expectations; and high customer satisfaction creates high customer loyalty.[3]

In sawmills, grading rules originally installed to ensure a certain level of quality might actually limit quality. Some companies may try just to meet minimum specifications and do not realize the specific quality expectations of their customers.[2] The grades often do not refer to customers' specific needs.[4]

To have a good knowledge of our customers and their preferences for different wood properties should therefore be an important issue for the wood industry. Pakarinen[5] investigated the success factors of wood as furniture material, and he showed that the four most often mentioned attributes were reliable, environmentally friendly, good looking, and valued. Ozanne and Smith[6] investigated how the noneconomic buying criteria, such as the environment, affected customers and their purchase decisions. Both these investigations implied that by segmenting the market and applying more customer-oriented product development and manufacturing wood as an engineering material can exploit a number of competitive factors and achieve success in the marketplace. In a study of the appreciation of oak wood,

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Marchal and Mothe[7] claimed that wood with intermediate quality is not marketable because of the lack of genuine knowledge of people's taste. They concluded that all kinds of tastes coexist, but there are different groups of preference profiles. The overall criteria that affect people's choices are knottiness, cut orientation, tint, and annual ring width. In a preference study for Pacific Northwest hardwoods, Swearingen et al. concluded that the buyer–customer discrepancies may be due to the inability of the buyers to recognize some of the wood attributes their customers prefer.[8] Sadoh and Nakato[9] summarized that the surface properties of wood are still among the least known properties, although they are important, particularly in relation to psychological sensations of users of wood and wood products.

It can be concluded that although we know that wood has inherent aesthetic properties, we must be able to describe, measure, and communicate them. The aims of this investigation were to shed light on how people's preferences toward different wood appearances containing knots can be described and to create a better understanding of how to measure those preferences. This investigation is the fifth part in a major project called "characterization of the aesthetic features of wood."[10–13] The interview data used in this investigation have been earlier examined and described by the author.[11] This past study showed that there are differences in people's judgments for surfaces *with* knots and *without* knots. The data set was also suitable for the aims of this present investigation, but to simplify the analysis only surfaces with knots were used. This paper reviews some interesting results on how to describe and measure the aesthetic properties of wood and attitudes toward wood (ATW).

Materials and methods

Interviews were conducted in northern Sweden at Skellefteå Wood Festival during 2 weeks in 1995, and a specially developed questionnaire was tested.

Wood surfaces

A total of 16 different surfaces of a solid wood panel sized approximately 0.4 × 1.5 m (width/height) were used during the interviews. Only the results from wood surfaces with knots (10 panels) were used in this paper. Wood surfaces were made with as much variation in wood appearance as possible, and all wood surfaces were made of Scots pine (*Pinus sylvestris*). They were not meant to be representative of the look of Scots pine. The objective was to draw out feelings and to cover as many cases of the phenomenon as possible. The surfaces were sanded but were given no other surface treatment. At the festival the wood surfaces were placed in a half circle and the positions (order of the wood surfaces) were randomized. Six surfaces had clear wood, and ten surfaces contained knots. The interviewed persons were allowed to have physical contact with the wood surfaces, and they could see all 16 wood surfaces at the same time. All interviewed persons were asked to judge 1 of 16 wood surfaces allotted by the author. It was the look of the wood surface that was to be evaluated; no product examples were given. All had written and oral information about the aim of the study and what they were supposed to do. The 10 surfaces used are shown in Fig. 1.

Questionnaire

The questionnaire is thoroughly described in an earlier study[11] and only a short review is given here. The questions asked emanated from a former qualitative study.[10] The questionnaire contained 54 questions, and each answer had a seven-degree scale with opposite words at the ends describing a quality of the ATW phenomenon. For instance, an answer could look like the one below and indicate that the person considered the wood surface rather restful and uninteresting.

Please express your visual impression of the wood surface:

restful (_:x:_:_:_:_)	restless
interesting (_:_:_:_:_:_:x)	uninteresting

Some questions (answers) had the positive side to the left and some to the right. People were asked to put a cross on the scale at a point approximating what they thought about the wood appearance. The questionnaire contained 54 questions divided into five groups; and because of the large number of questions each person was asked to judge only one surface. Only the interview data from the first three groups were used in the present study. The last two groups had 25 detailed questions about what they thought about knots, color, texture, contrasts, among others, but they are not included in this paper. A rough presentation of the three groups of questions may help explain the contents of the questionnaire.

Group 1. My impression is that the surface is:

1. restful (_:_:_:_:_:_)	restless
2. uneventful (_:_:_:_:_:_)	eventful
3. symmetrical (_:_:_:_:_:_)	asymmetrical
4. rigid (_:_:_:_:_:_)	lively
5. imaginative (_:_:_:_:_:_)	unimaginative
6. contrasting (_:_:_:_:_:_)	indifferent
7. hard (_:_:_:_:_:_)	soft
8. clean (_:_:_:_:_:_)	dirty
9. cold (_:_:_:_:_:_)	warm
10. of high quality (_:_:_:_:_:_)	of low quality
11. cheap (_:_:_:_:_:_)	expensive
12. interesting (_:_:_:_:_:_)	uninteresting
13. common (_:_:_:_:_:_)	uncommon
14. stimulating (_:_:_:_:_:_)	boring
15. exciting (_:_:_:_:_:_)	unexciting
16. balanced (_:_:_:_:_:_)	unbalanced

Group 2. Try to assess the look of the wood surface with the help of the following characteristics:

17. not fresh (_:_:_:_:_:_)	fresh
18. light (_:_:_:_:_:_)	heavy
19. strict (_:_:_:_:_:_)	gaudy

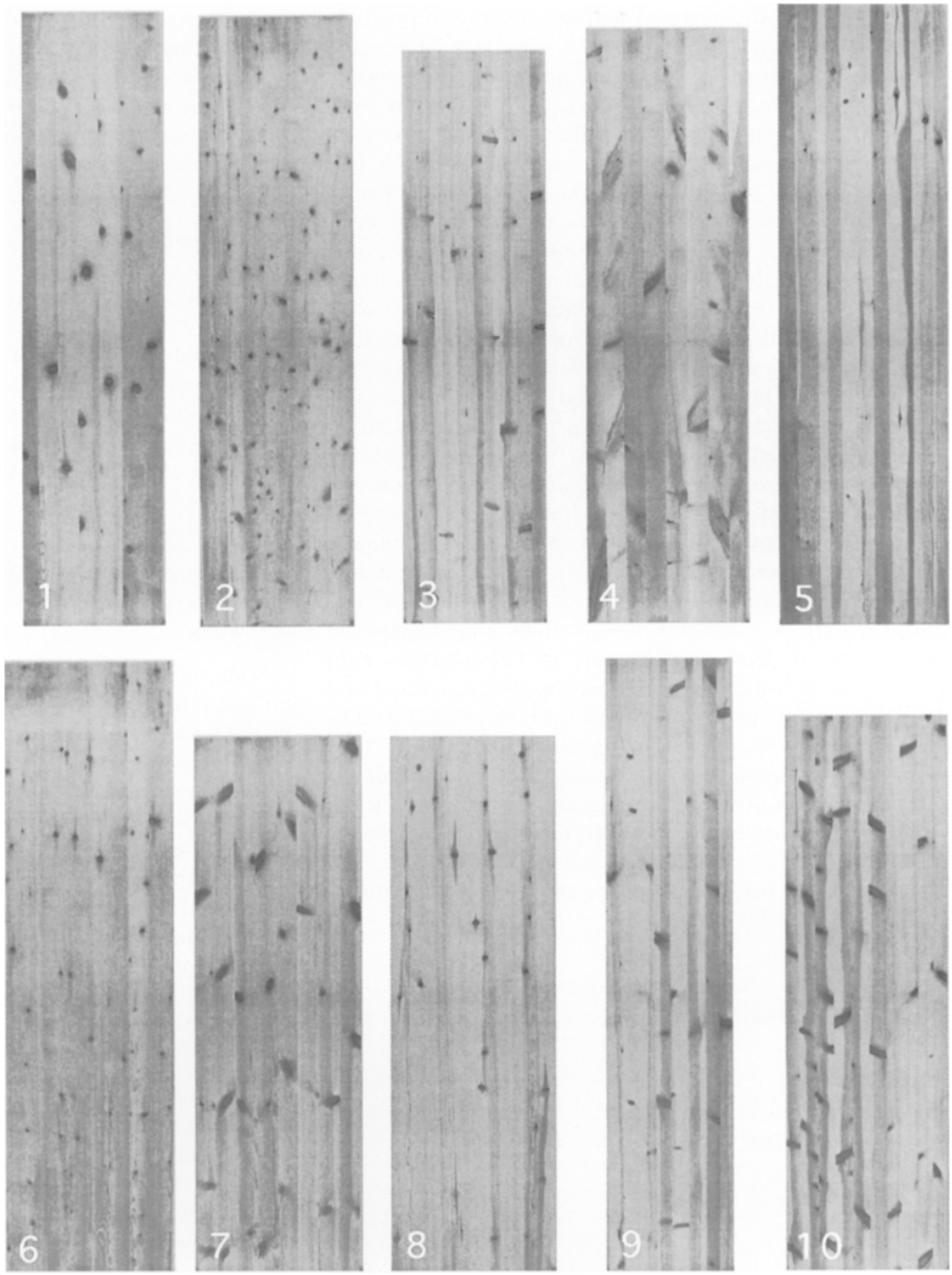

Fig. 1. Wood surfaces used in the study. Width 0.4–0.5 m, height 1.4–1.7 m

20. elegant (_:_:_:_:_:_:_) crude
21. genuine (_:_:_:_:_:_:_) artificial
22. solid (_:_:_:_:_:_:_) fragile
23. empty (_:_:_:_:_:_:_) rich
24. harmonious (_:_:_:_:_:_:_) disharmonious
25. beautiful (_:_:_:_:_:_:_) ugly

Group 3. I like the wood surface this much:

26. like it (_:_:_:_:_:_:_) dislike it

I find the wood surface:

27. objectionable (_:_:_:_:_:_:_) nice
28. exquisite (_:_:_:_:_:_:_) disgusting
29. easy to look at (_:_:_:_:_:_:_) hard to look at

Question number 26 was considered the final judgement of their impression of the wood surface. To make it possible to analyze the data quantitatively, every answer or degree on a scale was translated to an ordinal value. The values of the positions were linear, for example:

restful (3: 2: 1: 0 : −1: −2: −3) restless

The zero position indicates that the wood surface was neither restful nor restless. Before analyzing the results, all the scales were separated into two new variables. Following the example above, the new variables were "restful" (1, 2, 3) and "restless" (−3, −2, −1); that is, a positive answer (somewhere to the left) resulted in a positive value on the variable "restful" and a zero for variable "restless" and vice versa. The zero position was not used in the analysis reported in this paper. Thus the 29 questions became 58 variables (answers), and the data were recorded in a $58 \times N$ matrix, where N was the number of interviewed persons.

Analysis

Principal component analysis (PCA)[14] is commonly used for data reduction and easier interpretation. Hence, a principal component analysis was carried out to determine if a few linear combinations of the original variables might explain the variance–covariance structure in the preference data. It is a projection method suitable for summarizing and visualizing data and finding quantitative relations among the variables. In particular, projections handle data matrices with more variables than observations well, and the data can be noisy and highly collinear.[14] For studying the ATW phenomenon, score plots and loading plots are fruitful to examine; and to make it easier to interpret, all variables were standardized to unit variance. A multivariate computer program, SIMCA-P 7.01,[15] was used for the PCA.

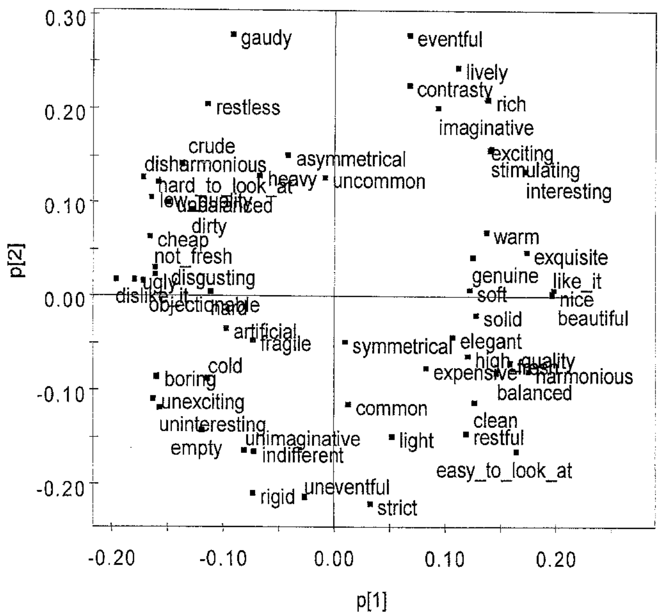

Fig. 2. Visualization of the "impression" questions and their impact on the model with all questions. Their loadings, that is, their importance, is represented by the distance from the origin. $P[1]$ and $P[2]$ are the loading on the first and the second principal components, respectively

Results and discussion

A total of 215 persons participated in the study judging the appearance of 10 wood surfaces containing knots made of Scots pine (*Pinus sylvestris*). Their ages ranged from 15 to 67 years, and the gender distribution was equal. Their professions were not known. Because of the large number of questions (the questionnaire took about 20 min to fill in) each person judged only one surface: about 22 interviewed persons per wood surface. Thus the data were collected in a 58×215 data matrix.

Principal component analysis – all questions

The sample variation was analyzed, and the first two components summarized 39% of the variation, as shown in Table 1 (All questions). Visualization by means of a loading plot of the "impression" questions/answers and their impact on the model is shown in Fig. 2. In Fig. 2 the first two principal components have been considered, but the interpretation is the same if one also interprets the impact of the third component, which accounted for only 5% of the variation. No strong outliers were found among the preference data. A loading plot is a summary of the relations among the variables (answers). Those questions situated furthest away from origo are the most important. They contain the largest part of the variation in the data set. If variables have the same location in the plot, one can assume that they describe similar properties of the phenomenon studied. A score plot is a summary of the relations among observations (persons). Loading and score plots are complementary and superimposible,[14] and a direction in one plot corresponds to the same direction in the other plot.

Interpreting the loading plot (Fig. 2) when all interview data are modeled demands high resolution of the plot, which is not practical in a scientific paper format. The variable names are used as markers just to give the readers a possibility to interpret the ATW phenomenon. We can see that the variables (answers) are circularly distributed in the hyperplane, and the first principal component (PC1) separates negative (left) from positive (right) assessments stated by the interviewed people. Interpreting the answers located close to the second principal component and far from the origin, they seem to distinguish between low and high activity in the wood surfaces. For instance, "gaudy" and "eventful" describe high degree of event and "strict" and "uneventful" describe low degree of eventfulness. Thus, PC2 seems to represent degree of eventfulness in a wood surface.

PCA – important questions

The motives for searching for the most important questions and thus reducing the number of questions used in an interview situation are twofold. First, if many different wood appearances are to be investigated, it is not rational to have too many questions; and second, the interpretation is easier if there are few but significant questions/answers collected. Thus, questions (answers) situated far from the origin and fairly well distributed around the circular swarm in Fig. 2 were chosen with great care. The criteria for selection were that both dimensions should be well described by the selected variables. No quantitative criteria was used in the selection process. Variables were chosen so an even distribution of answers around the circle was achieved. In such cases when variables were clustered, and hence describing

Table 1. Overview of the explained variation, R^2, and eigenvalue after each component for the two PCA models

Principal	All questions			Thirteen questions		
comp. No	R^2	R^2(cum)	Eigenvalue	R^2	R^2(cum)	Eigenvalue
1	0.30	0.30	17.35	0.37	0.37	9.50
2	0.09	0.39	5.47	0.15	0.51	3.84
3	0.05	0.45	3.09	0.07	0.58	1.76

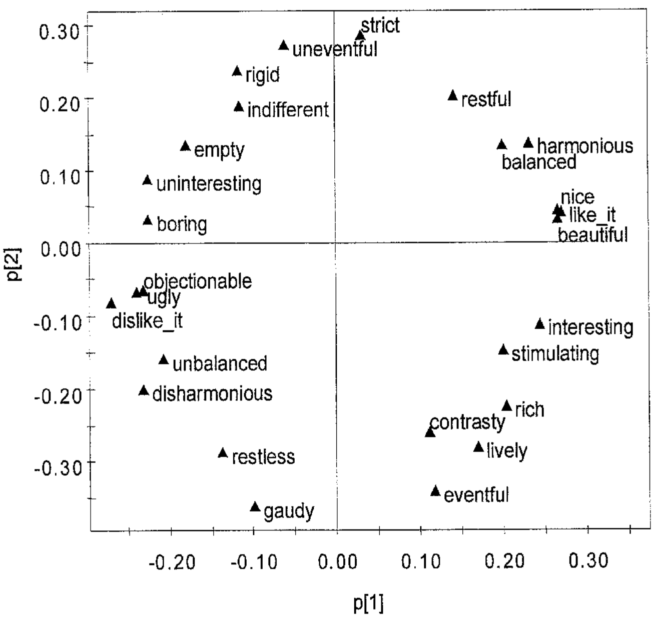

Fig. 3. Visualization of the "impression" questions and their impact on the model with only 13 questions. Their loadings (i.e., their importance), is represented by the distance from the origin

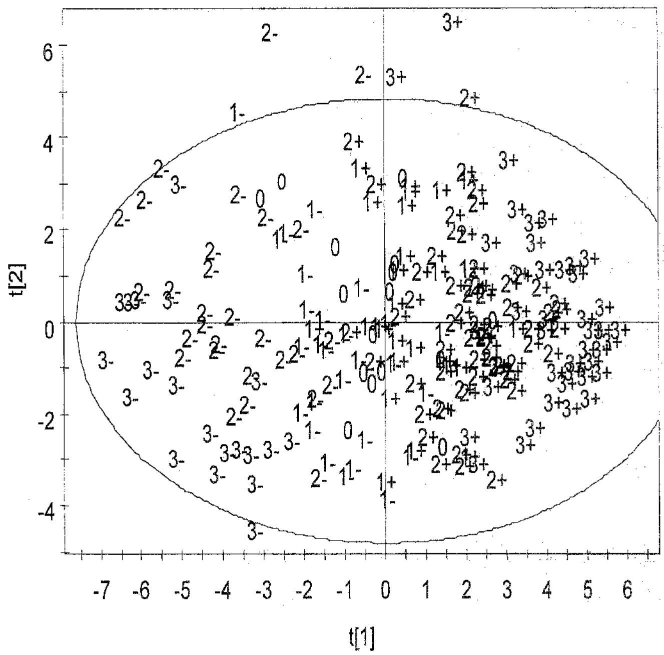

Fig. 4. Score plot for the model with 13 questions. The rank of question 26 (like_it/dislike_it) is used as a marker. The plot shows the variation among the 215 assessments. The position of each one of the 215 markers depends on the answers of all 13 questions. $t[1]$ and $t[2]$ are the scores on the first and the second principal components, respectively. Hotelling's T^2 test (95% tolerance) is shown by an *ellipse*

more or less the same thing, only one variable was selected from the cluster. A new model was computed with 13 questions where the first two components summarized 51% of the variation shown in Table 1 (13 questions). The loading and score plots are shown in Figs. 3 and 4, respectively. (Note that the location of the variables in Fig. 3 is reversed compared to that in Fig. 2.) Compared to the model with all answers, it is much easier to interpret how people have assessed the wood surfaces, but the same conclusions could also be drawn when interpreting Fig. 2 in detail.

Variables (i.e. answers) located far from the origin and near the horizontal axis are strongly correlated with people's liking. The answers are circularly distributed; and the nearer the vertical axis, the more the variable describes the blend of wood properties in the wood surface indifferent to their preferences. This is because the principal components are orthogonal to each other and thus linear independent. Interpreting the meaning of the answers (words) that are located close to the vertical axis, the second component seems to distinguish between low and high activity in the wood surfaces. In more detail, the questions like it/dislike it, beautiful/ugly and nice/objectionable detect the final assessment; and the questions balance/unbalance, harmony/disharmony, interesting/uninteresting, and stimulating/boring describe the reasons (why) for their final assessment. Questions such as strict/gaudy, restful/restless, rich/empty, contrasty/indifferent, lively/rigid, and eventful/uneventful describe the blend of wood properties in a more objective way and only to a minor extent are connected with the final assessments.

In Fig. 4 the positive assessments are situated to the right and the negative assessments to the left; and close to the origin are the observations where people were indifferent. To understand how people see and judge a wood surface, let us focus on the right side in Figs. 3 and 4. In the upper right quadrant are answers describing the degree of restfulness in the wood surface and in the lower quadrant to the right are answers describing the degree of eventfulness. High positive ratings are most frequent far to the right, but they are also spread as a bow up and down. That indicates that the interviewed people have had different sensitivity profiles or tastes regarding the amount of wood features in a surface (i.e., degree of eventfulness). One can also see that among all the positive answers there seems to be a balance between the degree of harmony and interest-creating features. For the negative responses (left) we have the same phenomenon, finding variables in the upper left quadrant describing the lack of event in a surface (uninteresting) and lower left the degree of disharmony. In Fig. 4 we see that almost all observations with strong negative scores are located in the lower left. Consequently, the most common reason for a strong negative attitude seems to be when a surface has a bad blend of wood features and hence is ranked as unbalanced, disharmonious, restless, and gaudy.

Harmony versus activity

If the surface numbers had been displayed in Fig. 4, they would have spread extensively in the score plot; that is, one particular surface can be assessed quite differently by different persons due to taste. Still, it would be convenient to be able to describe the wood surfaces in a simple way by means of interview data. In an attempt to simplify and to show the general pattern in the interview data for the 10 wood surfaces, the raw interview data were summarized together in three new variables: degree of acceptance, harmony, and activity. The criteria for classifying the answers in three groups was the position of the answers in Fig. 3 (right side). The names for the new variables were chosen so they described the included variables. The original scales were used, and all 215 observations and the new variables were put together as below.

D-acceptance = Like it/dislike it + beautiful/ugly + nice objectionable (1)

D-harmony = harmonious/disharmonious + balanced unbalanced + restful/restless + strict/gaudy (2)

D-activity = interesting/uninteresting + stimulating boring + rich/empty + lively/rigid + contrasty/indifferent + eventful/uneventful (3)

The mean values of the new variables for each wood surface are shown in Fig. 5. The surface order has been rearranged so the surface with the least degree of acceptance comes first and the most appreciated surface comes last. Surfaces with high degree of activity together with sustained degree of harmony received high preference scores (right). Surfaces (left) with a high degree of activity but a poor blend of features causing disharmony got low preference scores. The correlation between D-harmony and D-acceptance in Fig. 5 is 91%, but for D-activity the correlation is small. This indicates that most important when composing wood surfaces with knots is to focus on sustained harmony. The balance between harmony and activity is still important and is well visualized by surfaces 3 and 4 in Fig. 5. Surface 3 has a proper amount of harmony but a small number of wood features, resulting in a low score for D-activity and D-acceptance. On the other hand, surface 4 is classified as slightly disharmonious but has rather high D-acceptance. In this case it is possible that a high degree of positive activity-creating wood features affects people's preferences. A detailed analysis of each interviewed person (around 22 persons/surface) shows almost the same phenomenon regarding the balance between harmony and activity. Still, the spread in assessed quality is extensive for each surface owing to taste.

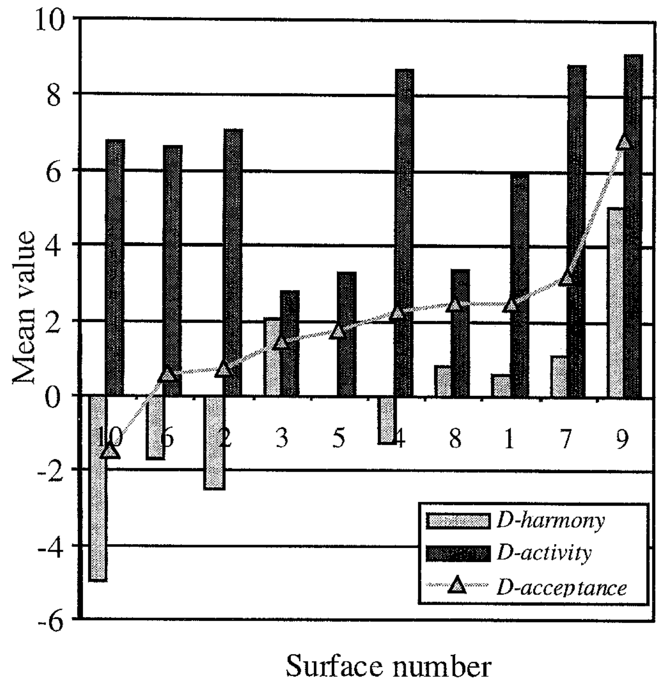

Fig. 5. Simple description of the 10 wood surfaces by means of three new variables. The surface order has been rearranged so the surface with least acceptance comes first and the most appreciated comes last

General aspects

The preference for a knotty wood surface is strongly connected with its physical blend of wood features, and when measuring aesthetic properties it is a case of general impression. This study shows that this general impression is affected by a balance between two main properties: the degree of harmony and activity. The most important factor when composing a wood surface containing knots seems to be to avoid a state of disharmony. The earlier studies[10–12] point out two main reasons for disharmony. One is a bad overall blend of wood features, and the second is if there are divergent features that mismatch on a surface. The first cause could be a wood surface with simply too much of something (see surface 2) or a bad mixture of knot shapes. The second cause could be, for instance, a mismatching lamella with divergent texture or color (surface 10) or a few large knots clustered together on a surface. If we succeed in maintaining a high degree of harmony when composing a wood surface, it can contain a rather large amount of activity-creating wood features and still obtain high preference scores. Of course there is a limit for that, and in Fig. 4 we see the spread in people's preference profiles.

The next issue is what questions to ask and how many. All 29 questions used in the study emanate from an earlier qualitative interview,[10] and therefore should cover the most common issues concerning people's preferences toward different wood appearances. From a multivariate statistical point of view, it is an advantage to have numerous significant questions that together help explain the phenomenon studied. To use many questions, though, is not practical in an interview situation. The conclusions drawn by the model with only 13 questions (Figs. 3, 4) are not altered when analyzing the model with all questions (Fig. 2). Therefore, it seems reasonable that the questions chosen describe people's preferences concerning a knotty wood surface in a proper way. Some of the questions are only to a minor extent correlated with the final assessment (situated near the PC2 in Figs. 2 and 3), and the motive for using them is that they describe a surface in a more objective way. Those questions also show a stronger correlation with the detailed questions about certain wood features than the questions located near the PC1 (reported in an earlier study[10]).

Limitations

Although the aim of the investigation was to see how people's preferences toward different wood appearances containing knots could be described, only one species of wood was tested, only 10 surfaces were examined, and the interviewed persons were only from Sweden. This lack of data may not be critical, as the objective was to evaluate the method and the questions used. There was also the problem of translating the words in the questionnaire from Swedish to English without losing valuable nuances in the languages. Another limitation was that no product example was evaluated. It may be difficult to assess a wood surface without knowing its function, and it is possible that the variations in the interview results for each wood surface would decrease if a product example was presented.

Generalizing the results of people's final assessment (Fig. 5) measured in this investigation is not valid. The more interesting issue is whether it is possible to use similar questions and interviewing techniques for other wood species, products, and people.

Conclusions

This study describes people's preferences concerning knotty wood surfaces and what questions to ask. This study shows that people's preferences toward a knotty wood surface are affected by a balance between two main properties: the degree of harmony and the activity. It is also shown that it is important to avoid creating disharmony when composing a wood surface. The results indicate that the following questions are suitable to use: The questions like it/dislike it, beautiful/ugly, and nice/objectionable detect the final assessment; and the questions balance/unbalance, harmony/disharmony, interesting/uninteresting, and stimulating/boring describe the reasons (why) for their final assessment. Finally, the questions strict/gaudy, restful/restless, rich/empty, contrasty/indifferent, lively/rigid, and eventful/uneventful describe the blend of wood properties in a more objective way and only to a minor extent are connected with the final assessments.

Trying to segment a market and thereby apply more customer-oriented products demands knowledge about differences in a market for a certain product category. Good knowledge regarding preferred blend of wood features for different products and countries is lacking. It would be of interest to use the proposed interview method applied to a number of products, species, and countries from two aspects. First, the interview method could be validated; and second, differences in customer preference profiles would be brought to light. The interview method and manner of formulating the questions can of course be improved. A combination of the presented questionnaire with about 13 questions and a paired comparison[16] design to determine the most preferred blend of wood features would probably give a more distinct answer about what wood qualities we should produce in the future. The connections between the interview data collected and the physical blend of wood features would be of interest for future studies.

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References

1. Encyclopaedia Britannica: interior design: http://www.eb.com
2. Hansen EN, Weinfurter S (1999) Softwood lumber quality requirements: examining the supplier/buyer perception gap. Wood Fiber Sci 31(1):83–94
3. Kotler P, Armstrong G, Saunders J, Wong V (1996) Principles of marketing. Prentice Hall, London, pp 441–448
4. Hansen EN, Bush RJ (1996) Consumer perceptions of softwood lumber quality. For Prod J 46(10):29–34
5. Pakarinen T (1999) Success factors of wood as a furniture material. For Prod J 49(9):79–85
6. Ozanne LK, Smith PM (1996) Consumer segments for environmentally marketed wooden household furniture. Wood Fiber Sci 28:461–477
7. Marchal R, Mothe F (1994) Appreciationof oak wood for the French consumer and wood professionals. Ann Sci For 51:213–231
8. Swearingen KA, Hansen EN, Reeb JE (1998) Customer preference for Pacific northwest hardwoods. For Prod J 48(2):29–33
9. Sadoh T, Nakato K (1987) Surface properties of wood in physical and sensory aspects. Wood Sci Technol 21:111–120
10. Broman NO (1995) Visual impressions of features in Scots pine wood surfaces: a qualitative study. For Prod J 45(3):61–66
11. Broman NO (1995) Attitudes toward Scots pine wood surfaces: a multivariate approach. Mokuzai Gakkaishi 41:994–1005
12. Broman NO (1996) Two methods for measuring people's preferences for Scots pine wood surfaces: a comparative multivariate approach. Mokuzai Gakkaishi 42:130–139
13. Broman NO, Grönlund A (1996) The end-users' requirements for the aesthetical features of Scots pine wood. In: Proceedings of the second IUFRO Workshop WP S5. 01-04, South Africa, pp 343–352
14. Eriksson L, Johansson E, Kettaneh-Wold N, Wold S (1999) Introduction to multi- and megavariate data analysis using projection methods (PCA & PLS). Umetrics, Umeå, Sweden
15. SIMCA 7.0 (1998) Reference manual version 7.0. Umetri, Umeå, Sweden
16. Courcoux PH, Séménou M (1997) Preference data analysis using a paired comparison model. Food Quality Preference 8(5/6):353–358