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ORIGINAL ARTICLE

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Looking at computer-visualized interior wood: a qualitative assessment using focus groups

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Abstract The objective of this study was to explore and gather human reactions and perceptions on computer visualizations of interior wood. The subjective qualities of such products are important because they influence the most critical of consumer decisions: to buy or not. To learn more about a phenomenon than quantitative data can provide, qualitative methods are needed. Here, grounded theory was used with focus groups to form a map of 14 people's experiences of wood. Six computer-generated pictures with visible wood were varied into 18 pictures, such that two-by-two comparison resulted in 3500 words. These were combined into a map that was generated earlier, which had found 2000 words. The main dimensions found were light, color, unity, and authenticity. Light is more than brightness; shadows and lighting seemed more important for the wood feeling, and color and contrast gave life and warmth to the material on the screen. Respondents wanted wood that was more "woody" and "warmer" than wood actually is, that is, a hyper-realistic picture. Perhaps smart modification rather than photorealism should be the goal. Distribution of the earlier found activity and harmony was important for most respondents. In addition, many subjects discussed the composition and/or the context or purpose of the pictures. The impact of wood is not just related to the wood itself; it is also intertwined with its surroundings.

Key words Visualization · Qualitative method · Interior wood · Preferences

Introduction

Background

Wood is a material with esthetic qualities that are the subject of subjective preferences and values. These values tend to be seen as "soft" compared with the "hard" features that are easy to weigh, measure, and calculate, and subsequently are treated with less respect. In reality, these values are decisive for the most critical decision: to buy or not.[1]

It is when wood is used in products where the wood texture is visible that the highest price per cubic meter can be obtained.[2] However, in the wood products chain, it is common that knowledge of the preferences of the end customers is poor, especially concerning the esthetic features of wood,[3–5] although more recent studies have been oriented toward this subject.[6–8] The industry must become better at communicating wood and its features throughout the wood processing chain (from forestry and sawmills to housing and recycling). The efficacy and validity of using computers for visualization is well known and has been documented.[9] It has become more common to use computer-generated images to show how a room or a product will look when produced. Computer visualization is a useful tool in "wood communication," but vital knowledge about what factors are important when visualizing wooden interiors is still missing.

Previous work

Considerable work in the field of architecture regarding "experiencing beauty" has been conducted since Rasmussen[10] took on the whole field of experiencing architecture, and Hesselgren[11] used the psychological research approach. The theses of Fridell Anter[12] on the perceived color of painted facades and Svedmyr[13] on the materiality of painted façades are interesting, but are more directed toward color and paint.

Advances in computer capabilities and improvements in graphics software have made visualization easier and more accurate.[14] Results indicate that aspects of computer visualization, like resolution and color fidelity, may significantly affect observers' perceptions, understanding, and judgments. Some features of visualization are known to affect attention and interpretation and to arouse positive and/or negative emotions.[15–17] However, these studies deal with visualization

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in general or visualization of trees rather than wood and/or wooden interiors. Daniel and Meitner[14] discussed the validity of visualization as applied to forestry, but not to wooden interiors.

Tsunetsugu et al.[18] showed that a difference in wood ratio in the interior causes different measurable physiological responses: the 45% ratio room, with the highest scores in subjective "comfortable" feeling, led to a significant decrease in blood pressure and a significant increase in pulse rate, and the 90% room appeared to cause a rapid decrease in brain activity and an increase in pulse rate. The result is interesting, even if Tsunetsugu et al.[18] used physical rooms rather than computer visualization.

Nakamura and Kondo[19] used eye tracking to objectively quantify the visual inducement of knots, and to compare it with the arrangement of knots on each knotty wall panel image. They showed that many visual impressions of wood wall panels were influenced by a complementary effect between the subjective noticeability of knots and the visual inducement of knots.

Sakuragawa et al.[20] used semantic differentials and blood pressure measurements to measure psychological and physiological impressions of wood panels. They showed that visual stimulation from wood wall panels had an emotional and natural impression upon humans, and that the same visual stimulation induced different physiological responses depending on the values of the individuals.

Objective and scope

The objective of this study was to explore and gather human reactions and perceptions on computer visualizations of wood, and also to compare the results with earlier findings by Nordvik and Broman.[21] If it is possible to identify what people react to and how they describe it, it should be possible to know which factors should be given extra consideration in computer visualizations of wood.

This study concerns wood qualities involved when wooden interiors are computer visualized. This means wood as a part of the whole, and does not include nonvisual qualities (such as tactile or sound features). This study deals with the general questions of both wood and computer visualization as long as it is adequate for the experience of interior wood.

Theory

Linn[22] stated that it is impossible to view a product objectively, because it is customers, as subjective beings, that perceive the product. To learn more about a phenomenon than quantitative data can provide, qualitative methods are needed. The idea behind most qualitative research is not to generate generalizable statistics, but to investigate and understand a phenomenon and thereby generate theory from data.

1. Definition of phenomenon
   - Literature
   - Unit of analysis
2. Data collection
   – Material; collection and preparation (pictures)
   – Interviews (sampling); show material
3. Data analysis
   - Process data; transcribe interviews
   – Data reduction; sort and code data
      – *qualities* (words) into *categories* (iterations)
      – *categories* into *properties* (iterations)
   – Data display; assemble a map (iterations)
4. Conclusion drawing; generate theory (iterations)

Fig. 1. Basic structure of the qualitative grounded theory method[23,26]

Grounded theory

Glaser and Strauss[23] described how grounded theory was developed in sociology as a strategy for handling data in research, providing modes of conceptualization for describing and explaining. Figure 1 provides an overview of the method. Grounded theory is highly applicable to new areas under study when the aim is to generate theory and conceptualize, because evidence and testing never destroy a theory, but merely modify it. Generating a theory goes hand in hand with verifying it and it involves a process of research. A single case can indicate a general conceptual category or property; a few more cases can confirm the indication. The researcher's job is not to provide a perfect description of an area, but to develop a theory that accounts for much of the relevant behavior. Grounded theory can be presented either as a well-codified set of properties or in a theoretical discussion using conceptual categories and their properties. The researcher, as Broman[24] put it, "starts out in a confused state of noting almost everything he sees because it seems significant" when he begins to hypothesize with the sole purpose of generating a theory. The researcher is then no longer a passive receiver of impressions but is drawn naturally into actively generating and verifying his hypotheses through comparison of data. When using the type of purposive sampling called the maximum variation method,[25] the aim is to document unique variations that have emerged in adapting to different conditions. Maximum diversity in data requires dense development of properties and categories, integration of categories and properties, and delimiting scope of theory. An intensive interaction between investigator and object is essential to the formation of sound judgments.

Here, the grounded theory is used to make a map of an unexplored new landscape by dividing a phenomenon into categories, properties, and qualities. The principle[26] is to group data under different categories, that is, to sort the explained data into different groups, each consisting of a bundle of qualities of a certain property.

Earlier findings from LTU research

Broman[24,27] at Luleå University of Technology (LTU) has studied visual impressions of wood with a focus on methods of interrogation. Broman[27] indicated the possibility of drawing adequate conclusions about the experience of real wood from computer images of wood, and this was also confirmed by Bishop and Leahy.[28] Broman's most important findings center on the importance of the qualities of harmony and activity.

In an earlier study,[21] also investigating computer visualization of interior wood, the phenomenon was divided in four categories: appraisal, reality, entirety, and spirit (Table 1).

Materials and methods

The pictures

Six computer-generated pictures with visible wood interiors were collected from outside sources such as construction and architectural companies. Each original was varied using image-editing software (Adobe Photoshop 7.0) so as to obtain three versions of each picture with wide, but not extreme, variations in light, shadows, color, contrast, saturation (mostly a 10% plus/minus variation). Thus, the process ended up with 18 pictures that were scaled down so that one pair would fill the screen (roughly 510 × 450 pixels each). Figure 2 shows 3 original pictures (A, C, E) and 3 variations (B, D, F).

A system was prepared on a laptop computer for viewing the pictures two at a time for comparison in pairs. Each original picture was compared with the altered versions of it. The two-by-two comparison strategy was used to provoke opinions, where respondents first had to choose and then also justify their choice.[29] Instead of viewing the pictures on a laptop (with biases regarding light and angle conditions, etc.), the pictures were projected on a 2-m-wide screen in a controlled environment to ensure the same experience for all groups, sitting 3 m from the screen.

Interviews

Earlier studies[21] (Table 1) had resulted in valuable data (around 2000 words), but it was mostly in single-word form rather than as sentences or expressions. Inspired by the ideas behind focus groups[30,31] for gaining the data input, three groups were put together. The members of the groups were chosen to get three distinct groups: one younger group (20–30 years), one older group (40–60 years), and one expert group (architecture, construction, and wood expertise). All members of the groups were native Swedish speakers. Four or five persons of each sex made up each group and the members were already acquainted and comfortable with each other in accordance with the theory.[31] Together, the three groups constituted a broad selection of respondents (aged 20–60 years, both sexes, varied education, style, origin, and interests), which the grounded theory requires.[23,26] It is usually recommended that focus groups begin with heterogeneous groups and later move toward more homogenous groups.[32] However, because this was the second study on the same topic, the heterogeneity came from the difference between the three groups. Grounded theory points out that instead of representative sampling, a purposive or interactional sampling of cases is appropriate.[33,34]

The interviews or discussions took place in the same studio in Skellefteå (Sweden), under the same controlled conditions. They lasted just over 1 h each and were recorded on a minidisk recorder; supporting notes were also taken on paper. No video recording was used, because the goal was to find new words and expressions. The study was conducted in accordance with ethical principles.[35]

One researcher led the discussion and passed the word. In order to influence the respondents as little as possible, the wording of the questions was deliberately kept vague, although the purpose was precise. After a short introduction to the study, only one main question was used to evoke responses from the respondents. This question was: "Which picture do you think is better?" Initially, no further explanation was provided. To avoid directing the respondent too much, no mention of the wood itself was made in the main question. The comments about wood textures came naturally as part of the description of the pictures, because the pictures were dominated by wood objects. Supporting questions, used when needed, consisted of expressions like: (1) "And why do you think this picture is better?"; (2) "Is better the same as more appealing?"; (3) "Is the difference obvious?"

More than 3 h of interviews was recorded, which resulted in about 600 sentences (20 000 characters, 3500 words). According to the grounded theory, the collection of data ends when the answers stop presenting much new data.[23] By the end of the third focus group discussion, very few new words and descriptions were used and the amount of data was considered sufficiently stable to map the expressions such that thoughts of a fourth group were cancelled.

Table 1. Earlier map of qualities of computer-visualized interior wood

Appraisal	Reality	Entirety	Spirit
Opinion	Material	Detail error	Light
Taste	Realism	Harmony	Contrast
	Clarity		Color
			Life
			Warmth

From Nordvik and Broman[21]

Data processing

Miles and Huberman[26] claimed that the data analysis process in qualitative research contains the three subprocesses of data reduction, data display, and conclusion drawing. The data reduction process involves sorting information into categories so that the information begins to form a picture

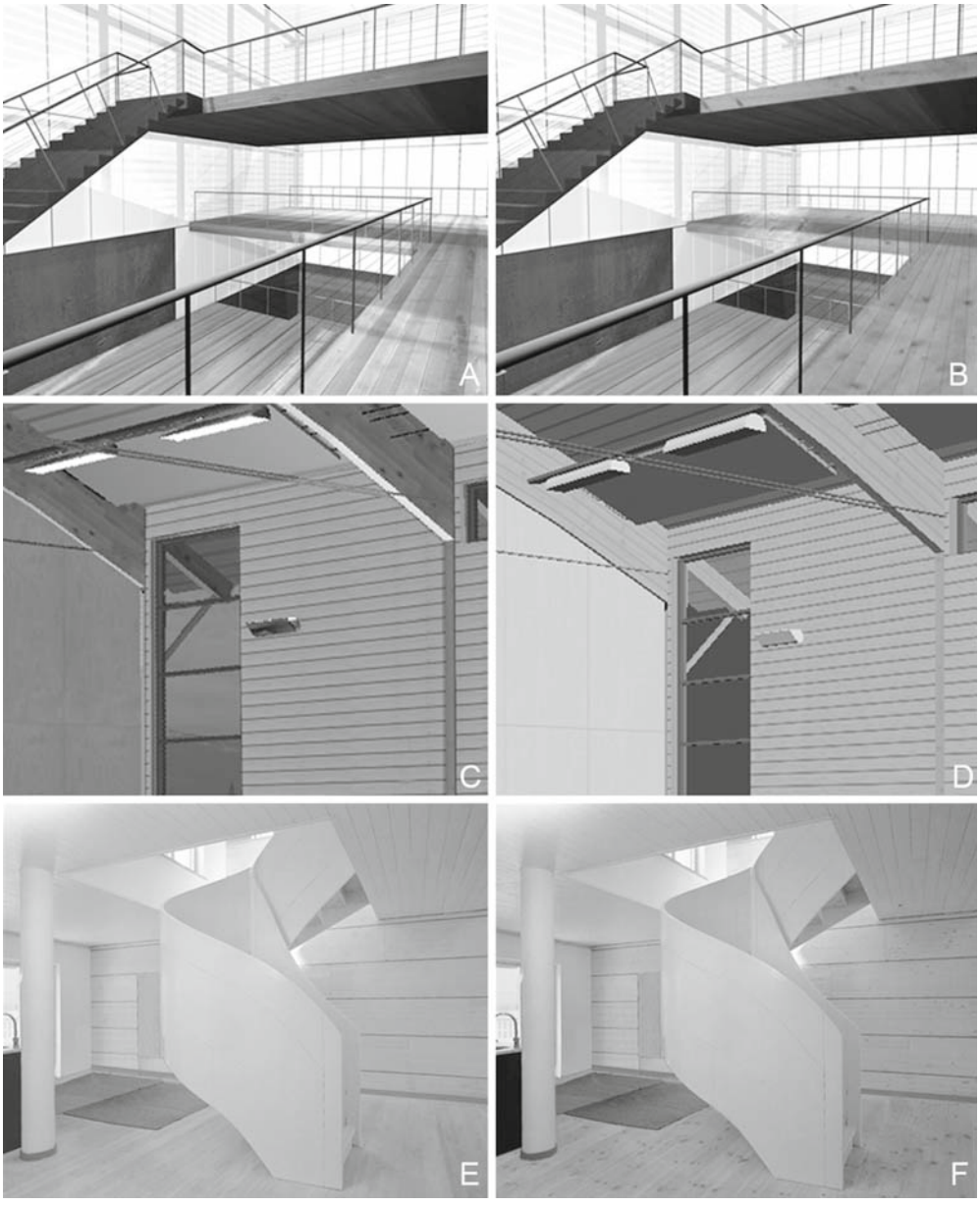

Fig. 2A–F. Example of pictures used in the interviews. *Left*, originals; *right*, variations

of the complex phenomenon under study. Data display presents an organized and compressed assembly of information, and helps to understand the phenomenon and draw conclusions. The conclusions become increasingly explicit as the data collection and analysis continues.

In order to take in all aspects of the data and to lift them to a generally applicable level, they have to be conceptualized.[23] Valuable words and phrases were transcribed exactly and then systematically grouped, regrouped, and conceptualized into different qualities, categories, and properties describing the phenomenon "computer-visualized interior wood," all according to the theory.[26] As seen in Fig. 1, after defining what phenomenon to examine, deciding how to collect data, and then collecting it, the data-analysis step consisted of transcription, reduction, and display. The data reduction was a subdivision and coding process where the qualities (actual words and sentences used) were sorted into categories (contrast, computer-made, etc.). They were then summarized into properties (light, color, etc.). Thereafter, a map of the qualities, categories, and properties describing the phenomenon was assembled. Joint collection, coding, and analysis of data are the underlying operations when generating theory. This generation requires that all three operations are done together as much as possible.[23] The goal is to find a small number of categories, and then a number of properties, which allows each data point to be transferred to one of them, that is, constitute an aspect of the property. Each word was "tagged" with information about what group, picture, and person it was connected to.

This work started after the first group, and was a continuous process through the last group. The work was conducted by one researcher, but with continuous support from fellow researchers and literature. Finally, the 2000 words from the earlier study[21] were taken into consideration. Thus, the cat-

egories and properties were determined a posteriori with as few a priori assumptions as possible.

Results

The data was divided into a map of how the comments were sorted. This was not necessarily a map of which factors were of importance when visualizing wood. What people saw and evaluated in a wood surface can be described in four properties: light, color, unity, and authenticity (Table 2). As stated earlier, data display presents an organized and compressed assembly of information, and helps to understand the phenomenon.[26]

Light was the most common category in all answers and groups. Many respondents described light as the single most important factor, and errors in light matters were of decisive importance. Shadows and lighting seemed to be important for feelings of authenticity, more so than brightness. Examples of this are statements like "very strange shadows" or "wood should give different reflections."

The experience of color seems to be very important for the overall "wood feeling," for instance, when distinguishing wood from painted nonwood materials. The combination of color and contrast was also often the first thing the respondents reacted at, at the same time as they decided whether the picture was realistic or not: "The shelves feel wishy-washy"; "Wood is not that color."

Remarks regarding unity were concentrated on harmony and the composition of the picture, but also the spatial feeling. The context (style, purpose) of the picture was also important. Activity, whether low or high in the wooden pattern (quiet or lively), or more connected to contrast or the distribution of elements (composition issues), seems to be essential for the feeling of life: "Wood doesn't fit into that furniture"; "These knots give life." A quality like contrast inflects light and color as well as activity.

Authenticity covers comments regarding the material characteristics as well as the quality of not feeling computer-made, wherefore qualities such as detailing, errors (repetition, scale), and authenticity are of importance. Comments on gleam and reflections were frequent: "There are no daylight reflections on the floor, it's not real," as well as material issues: "This is mixed heartwood," and detail errors: "The floor boards are the wrong direction."

Table 2. Experiencing computer-visualized wood: a map of descriptions

Light	Color	Unity	Authenticity
Brightness	Contrast	Composition	Computer made
Brightness	Contrast	Harmony	Scale
Lighting	Colorfulness	Activity	Authenticity
Light errors	Warmth	Life	Detailing
Gleam	Color	Context	Clarity
Shadows		Purpose	Material
Contrast		Style	Treatment
Pale		Taste	Construction
		Surroundings	Wood specific
		Spatial	
		Depth/space	
		Weight	
		Perspective	

Factors outside the nature of wood itself greatly affect our experience of wood. It is hard to draw a distinct line between the appearance of the wood interiors and attitudes relating to other phenomena that influence the pictures. The interviews indicated that light, shadows, and colors all interact to provide us with a complete picture; therefore, they also influence how we understand wood. However, wood normally exists in a context, which is why an isolated wood study probably would not have given a better map of descriptions. Many respondents asked for the context: the purpose of the picture, and what kind of room it was. Others did not like the room, and therefore found it difficult to describe the wood at all or wanted different wood in that surrounding. This suggests that it is impossible for wood to be free from the influence of the surroundings when visualized.

The earlier notation[21] of respondents demanding wood that was more "woody" and "warmer" than actual wood (a hyper-realistic picture with brighter colors and higher contrasts than real wood) was also found here: "It doesn't bring out the wood. The color contrast is too small between the wood and the rest." Maybe photo realism does not do all the work.

Although no decisive differences between the three groups were found, the wording varied according to each group's professions, with the expert group using more evasive words ("spatiality"), and members of the younger group looking more critically at the visualizations than the other groups.

Discussion

Linn[22] stated that when looking at the product from a producer's point of view, the central aspect of the concept is the physical product. When viewing the concept through the eyes of the consumer, it is somewhat different: the most central aspect is the consumer's basic need. Desires of sociological and psychological nature are also included in the peripherals of the concept.

One could argue that the total of 14 persons participating in the study was not adequate to make a good sample, but because the study was to complete the map from earlier investigations on this phenomenon,[21] and the interviews resulted in rather rich data, the number was considered sufficient. This is supported by the richer data from the current study.

If there are typical qualities, there ought to be qualitative differences that explain people's comments and valuations. This investigation points out two kinds of differences that seem to be of importance: on one side light and color and on the other unity and authenticity. The first kind is easily transferred into technical parameters that are possible to control, whereas the other is more connected to the overall feeling.

The current study speaks of brightness and color. While lightness runs from black to white and is perceived reflectance, brightness is a perceived, subjective, luminance.[36] Color is usually seen as a colorspace divided into lightness, chroma/saturation, and hue.[37] The pictures in this study were not varied using hue, because that would have made the differences too obvious.

The results were not unexpected, even if they sometimes pointed in new directions. In grounded theory it is important to compare the first maps with later ones. Compared with Nordvik and Broman[21] (Table 1), the map is different in the sense that the property "spirit" is divided into light and color, whereas the properties reality/authenticity and entirety/unity are very similar. Remarks on appraisal are sorted under all four properties. Quite a few of the qualities are also different. Context and composition are also seen as valuable for a subject's judgment.

It seemed difficult for viewers to separate what they understood and what they preferred; it could be easier to understand what kind of wood the picture is supposed to communicate, but because of other factors, such as the colors, light, and the picture composition, it might be easier to prefer another picture: "More realistic to the right, but more appealing surroundings to the left." This is of course something to consider when visualizing wood: "is this a selling or an informative picture?"

Some of these findings are general for all kinds of computer visualizations (like shadows and crucial detail errors), but some seem to be specific for wood visualization, like the demand for life, warmth, and perhaps even hyper-realistic pictures.

Affinity between current and earlier findings

The findings from other studies (Table 3) were added afterward and used for comparison of the results. None were directed toward computer visualization of interior wood, but related to the experience of architecture, wood, or visualization. Table 3 only shows the aspects that do have affinity; as seen in Table 4, there are many more aspects. Albeit these studies are not conducted as grounded theory studies, the aspects found are best described as being on the *category* level.

Semantic descriptions of environment (*Semantisk miljöbeskrivning*, SMB)[38] is mainly a tool for examining how people experience architecture, both interior and exterior. By presenting images, models or films of a chosen environment to volunteer participants, the emotional impression of the different environments can be measured. SMB can be used as planning support for new architectural objects.[38] SMB is based on the theories of Osgood et al.[39] concerning semantic differentials. In order to get representative words describing architecture, more than 1000 words were collected from a dictionary and evaluated on semantic scales and treated with factor analysis. In two steps, the number of words was reduced to 36 and these were considered as sufficient to describe the architectural environment. Compared with Osgood's factors (evaluation, activity, potency, novelty, and spatial quality), Küller[38] could identify eight factors (see Table 4.)

The words and factors from Küller[38] were used as valuable input for the current study. Even if the respondents in the current study also spoke of activity, context, and general appreciation, SMB naturally misses discussion of authenticity, because it is directed toward authentic environments.

In a study from the Swedish Pulp and Paper Research Institute (STFI), Jonsson[40] used the repertory grid technique[41] to find core values for wood. This method could be used to evaluate subjective experiences through individual ways to construct mental conceptions about a number of elements. It is also possible to analyze the data statistically. Jonsson[40] sorted the experiences into four categories (Table 5). When compared with Jonsson, a lot of the direct sensual effects are missing in computer visualization. Three of the qualities that seemed important in the current study, brightness, authenticity, and surroundings, are all directly

Table 3. Affinity between current and earlier studies on architecture, wood, and visualization

Current study	Küller[a]	Jonsson[b]	LTU[c]
Activity	Complexity	Surface character	Activity
Color	Social status	Surroundings	Color
Context	Affection	Feeling	Opinion
Unity	Unity	Authenticity	Harmony
Authenticity	Pleasantness	Pleasant	LoD, realism
Warmth		Brightness	Taste
Light			Lighting
Contrast			

LoD, Level of detailing
[a] From Küller[38]
[b] From Jonsson[40]
[c] From studies at Luleå University of Technology[42–44]

Table 4. Factors according to Küller

Pleasantness	Complexity	Unity	Enclosedness	Power/potency	Social status	Affection	Originality
Stimulating	Motley	Functional	Open	Masculine	Expensive	Modern	Curious
Secure	Lively	Pure style	Airy	Potent	Well kept	New	Surprising
Idyllic	Composite	Consistent	Closed		Lavish	Timeless	Special
Good	Subdued	Whole	Demarcated		Simple	Aged	Ordinary
Pleasantness							
Ugly							
Boring							
Brutal							

From Küller[38]

Table 5. Factors according to Jonsson

Sensory experience	Statements	Interpretation	Feelings
Brightness	Treatment	Naturalness	Feeling
Weight	Wood relation	Surface character	Pleasantness
Smoothness	Technical aspects	Material character	
Level of pattern		Authenticity	
Hardness		Relation to surroundings	

From Jonsson[40] with translation from Swedish by the author

supported by Jonsson. But where Jonsson has the advantage of using real wood pieces, every experience of visualization is what Jonsson calls an interpretation.

With reference to earlier studies at the Luleå University of Technology (LTU, see Table 3), the qualities of harmony and activity described by Broman[24,27] are confirmed here, as well as color and lighting described by Nordvik and Bromans.[21] Fellow LTU researchers reported three-dimensional (3D) computer visualization for communicating esthetics, but for long-span timber structures rather than interior wood.[42,43] They showed that the use of 3D computer visualization has great potential to influence the decision-making process. The study also showed that the level of detailing (LoD) and lighting are key activities for a successful 3D model. Janols[44] continued with case studies, surveys, and interviews on this topic.

The concept of Gestalt was first introduced in philosophy and psychology by von Ehrenfels[45] in his work *Über Gestaltqualitäten*. According to Gestalt psychology,[46] the whole is different from the sum of its parts. Based upon this belief, Gestalt psychologists developed a set of principles to explain perceptual organization, or how it is natural for humans to group the world and try to make sense of given stimuli. These principles are often referred to as the "laws of perceptual organization" or "Gestalt laws."

The basic law of Gestalt theory, the Law of Prägnanz, implies that if a perceptual field is disorganized when a human first experiences it, the brain imposes order on the field in a predictable way in the direction of a "good" Gestalt. This is a psychological task that does not necessarily involve a change in the physical environment but one which represents a change in how an organism "sees" its physical environment. A good Gestalt follows the laws of similarity (grouping of similar items), proximity (the nearness of the item's respective parts), closure (completed items, continuity, continuation of a pattern), etc.[47] One use of Gestalt laws in the current study could be to explain that the tolerance for disturbing detail errors (shadows/lighting, scale, pattern repetition) was generally low in the current study, because it inflected the experience of the unity.

To summarize, as seen in Table 3, the current findings are partly supported by the results from earlier studies.

Concluding remarks

The results of this study indicate that to receive a picture that most people would accept, the person visualizing wood will have to carefully use light and color in the right way. This does not necessarily mean that the photo must be realistic, but perhaps a smart modification providing the feeling of life, contrast, and activity. To achieve this, shadows and daylight (lighting) seem more decisive than brightness and even detailing.

The aspects discussed above seem to be important for the feeling of authenticity and unity, which also needs the right composition (harmony and activity) and context (surroundings and purpose), as well as the avoidance of single erroneous details (repetitive patterns and lighting or shadowing errors). In addition, more important than high resolution is the need for wood to be part of the whole picture and not to stand out or appear more worked than the surroundings.

Visualizing wood in a computer is challenging. A number of the factors (look, feel, smell) that synergize in giving us the impressions we get are missing ("I miss feeling the structure and warmth, wood doesn't work on a computer screen"). At the same time, a lot of the natural advantages of wood disappear on the screen, while a lot of the disadvantages of other materials also disappear. For example, the coldness of a stone material is not communicated. Yet how do we communicate the slightly softer echo from walking on a wooden floor? Computer visualization provides us with ways to illustrate things not yet built or items too ungainly for a seller to bring to the point of sale. Therefore, computer visualization is a tool for the future and we must learn to communicate what we can and cannot communicate through the computer. This result is a roadmap for further research, but it also gives an idea of what should be avoided when using computers for visualizing wood interiors.

Finally, we must not forget that it is impossible to visualize wood in computers. Visualization is something that takes place within each viewer's head and thus is a subjective phenomenon.

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