Wood Perception in Daylit Interior Spaces: An Experimental Study Using Scale Models and Questionnaires

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This paper explores the impact of daylit wooden environments on human perception and well-being. Several studies have shown that the use of wood in furniture, interior surfaces, and decoration helps create warm, bright, and pleasant ambiences, enhancing psychological well-being and comfort when compared to other materials. The main objective of this research was to assess the effects of different colors, finish, and ratio of wooden surfaces combinations on human perception. More specifically, participants compared simultaneously five different interior wooden scale models of room environments under the natural light of the northern hemisphere in terms of their appreciation, visual comfort, and well-being. The survey involved 80 participants with an exploratory questionnaire in order to compare and classify the different models. Conclusions showed a preference for clear, bright, and warm models for cognitive and small-scale tasks. Darker models in terms of reflectance and lighting ambiences were the least preferred, especially for women.

Keywords: Color; Wood; Visual perception; Scale model; Real sky; Daylighting; Ambience; Wood finish; Architecture; Environmental psychology

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INTRODUCTION

In architecture, the choice of materials for structure as well as for interior finishes constitutes a key phase in the design process, whether for the space functionality and building lifecycle, or for the creation of the desired interior ambience. Natural materials such as wood reduce the carbon footprint of constructions, either for their durability or their recycling and reuse potential. However, when selecting construction materials for interior surfaces, economy often takes precedence over environmental, energy-efficient, or perceptive advantages. Moreover, scarce research is available to determine the real impact of interior surfaces on human perception and comfort, and how people appreciate an interior space depending on its material, finish, color, and emplacement.

Natural materials such as wood could potentially enhance psychological well-being as well as comfort when used as interior surfaces. Kellert *et al.* (2008) addresses the notion of biophilia, which is the natural and inherent inclination of humans to associate with nature and untouched environments. This dependence on nature reveals mankind's evolution, which took place in natural environments: "We are much more adapted to natural than built settings. Being in nature is like going home, genetically (Gifford 2007)." Contact with natural light as well as a direct view of a natural scene, are part of the so-called "restorative" architecture that reduces stress and enhances well-being and comfort (Bell *et al.* 1996; Gifford 2007; Kellert *et al.* 2008; Steg *et al*. 2012; Burnard *et al*. 2015). Moreover, access to natural light has been demonstrated to produce an impact on occupants' mood and overall psychological state, while the photo-biological effect of natural light has an effect on circadian cycles, alertness, and arousal of the occupants (Van den Wymelenberg and Inanici 2009; Arsenault 2012; Borisuit *et al.* 2015). Kellert *et al.* (2008) defines some environmental features in restorative design that favours connections between natural and built environments, such as the use of natural colors, integrating natural elements such as fountains or rivers, windows allowing contact with air, natural light and exterior views, plants, and the choice of natural materials.

Several studies compared materiality to validate the predisposition of humans to prefer natural elements. Burnard *et al*. (2015) compared samples of building materials to classify them from natural to artificial, with participants from three different countries. Less processed materials (wood, brick, stone) were considered the most natural, and these results were similar from one country to another. Although this study classified wood as a natural material, the comparison was performed using samples; other studies examined the impact of wood for real spaces. Rice *et al*. (2006) compared several photographs representing various spaces decorated with diverse finishes and styles, from natural to synthetic or industrial materials. The results showed that the most popular spaces were naturally daylit and offered natural views. Moreover, the preferred spaces were predominantly composed of wood furnishing and surfacing. Participants considered those spaces as "natural", "inviting", "relaxing", "comfortable", "rustic", and "warm" compared with "cold" and "modern" in photographs characterized by the absence of wood (Rice *et al.* 2006). However, research on perception using photographic comparison was previously recognized as limited in terms of precision (Lau 1972). It is also complex to isolate the real impact of the material on perceived satisfaction since the photograph collection consisted of a large array of variables such as ceiling height, number of windows, presence of plants, color, and materiality of the walls and floors, *etc*.

Other studies assessed the specific impact of wood materiality on psychological well-being, comfort, and stress reduction by comparing physical spaces that were modified in various ways to ascertain behavioural and physiological differences in response to the environment or psychological tests (Tsunetsugu *et al.* 2007; Ohta *et al.* 2008; Fell 2010). Fell (2010) compared four identical office spaces apart for their furniture and the presence of plants. The results demonstrated that the presence of wood furnishing reduces occupants' stress levels, thus inducing more comfort. Wooden furniture offered stress reduction effects similar to those observed during human exposure to natural settings. Ohta *et al.* (2008) also compared wood to other materials in hospital rooms. The results show that cortisol levels (stress hormone) measured were significantly higher in the conventional room, while the questionnaire results show that the room redecorated with wooden panels was considered more thermally comfortable by occupants, even if ventilation, temperature, and moisture level of both rooms were identical throughout the study. Finally, Tsunetsugu *et al*. (2007) clarified the effect of wooden interior spaces on physiological health as well as visual comfort, when modifying the amount of wooden surface on walls and floor of three rooms (0%, 45%, and 90% of wooden materials). The measured physiological data showed a significant change of physical responses depending on the wood ratio in the room. Furthermore, the questionnaire results show that the most relaxing and comfortable room consisted of wooden material for 45% of its surfaces.

Wood is thus considered as a "natural" material and generally preferred over other materials. Its use in furniture as well as for walls and floor surfaces creates "restorative" interior ambiences that are warm, pleasant, reduce stress, and enhance psychological well-being and comfort. Nevertheless, wood is available in a remarkable diversity of shades and finishes that create ambiences varying from dark to light and from warmer to colder tones (Jafarian *et al.* 2016; Poirier *et al.* 2016). Colors of interior surfaces have an impact on emotional well-being and mood of inhabitants (Chain *et al.* 2001; Küller *et al.* 2009; Jalil *et al.* 2012; Kujisters *et al.* 2015; Huebner *et al*. 2016). Therefore, wood finish colors could potentially create ambiences that would modify inhabitants' perception of the space. Wood surface position (ceiling, floor, walls) as well as its surface to space ratio can additionally create various ambiences that could potentially affect human perception and satisfaction. Finally, in real settings, natural light creates various visual ambiences throughout the day depending on the varying sky conditions and sun path.

The systematic comparison of five wooden scale models different in terms of wooden surface finishes, ratio, and emplacement was conducted by Poirier *et al.* (2016) based on the results of a previous study (Jafarian 2016). In summary, models with south-east openings were analyzed and compared in terms of hue, brightness, and contrast under the exact same weather and daylighting conditions. Weather data were collected according to cloud cover, cloud thickness, and illuminance. The results showed that sky cloudiness and sun altitude have an impact on visual ambiences: as morning sun fully entering into the scale models created warmer atmospheres, afternoon clear sky without direct sun penetration created colder ambiences, similar to ambience under overcast skies. Furthermore, the interior finish color had a considerable impact on visual ambiences. Yellowish oaked models created warm atmospheres, changing throughout the day and in relation to weather conditions, while grayish models tended to be colder, creating dull and unchanging atmospheres. However, if those studies evaluated the impact of natural lighting diversity on various wooden spaces, inhabitants' visual perception and satisfaction of these spaces were not studied.

The main objective of this research was therefore to explore the effects of different colors, finishes, and ratio of wooden surface combinations on human perception. More specifically, the research involved simultaneous comparison of five different interior wooden scale models by participants under the natural light of northern latitude in terms of their appreciation, visual comfort, and well-being. Previous research by the authors (Poirier *et al.* 2016) suggested that the diversity of ambiences created by natural light throughout the day should affect color perception and helped formulate this research's hypotheses. The main hypothesis states that respondents should perceive and evaluate differently the different wooden scale models. Specific hypotheses state that questionnaire results for participants experiencing spaces under overcast skies and clear skies should show clear differences. Moreover, the remarkable diversity in terms of light and hue, which can be found in the five models, should allow diverse reactions and appreciation levels from participants. The use of an original and specially devised questionnaire allowing qualitative and quantitative assessments adapted to the research context should also allow more comprehensive conclusions.

EXPERIMENTAL

Experimental Settings and Scale Models Description

The light quality of Quebec city (46°49'N) is representative of a Nordic city, characterised with the presence of cold temperatures, ice formations, snow cover, and various types of skies throughout the year. Data collection took place in Laval University

School of Architecture parking lot for practical reasons. It offers a South-facing and generous open space, allowing skylight to enter the models' windows during morning and early afternoon. Figure 1 (right) illustrates the experimental settings featuring five scale models aligned in a south-east orientation for simultaneous visual comparison.

Physical models used in this exploratory research on ambiences were built at a 1:10 scale, determined as relevant since it was demonstrated to produce similar results to a 1:1 scale model in terms of luminous patterns and visual ambiences quality (Lau 1972; Lam 1977). The models were constructed by professional technicians of the Industrial Chair on Ecoresponsible Wood Construction (CIRCERB) under specifications and design established by Jafarian (2016). The selection of the scale model configurations is presented more specifically in previous research (Poirier *et al.* 2016). The scale models are made with different combinations of wooden panels, using three different colors namely cape cod gray (a gray, neutral, and cold finish), oak (a yellow, warm, and bright finish), and dark walnut (a brown, dark, and neutral finish). Each wooden panel is found in two types of finish: high gloss (90°) and low gloss (12°). White panels are made from white and mat painted melamine. The glass chosen for the models windows is a standard doubled glazing (3 mm clear, 12.7 mm air, 3 mm clear, 80.4% VT) with a neutral color since previous studies prove that this type of glass produces realistic ambience and has less influence on the interior atmosphere (Pineault 2009; Arsenault 2012). Figure 1 (left) shows an observer looking through the scale model's viewing aperture, in the exterior context.

Fig. 1. Observer looking inside the model (left). Experimental settings with the five scale models aligned in the parking lot, South-East-facing, with observers (right).

The selection of the spatial combinations of wooden panels focuses on the potentialities of finishes to enhance a wide array of architectural ambiences rather than the deterministic validation a unique variable. The selection allowed more flexibility in the use of a combination of variables, while color, gloss, and position are modified simultaneously. Five combinations were chosen according to results from Jafarian (2016) and a pilot study by Poirier *et al.* (2016). Conclusions of the pilot study determined the research constants:

- Each model should include a wooden floor since it corresponds to the surface where wood is most frequently located or expected;
- The centered front facing wall should be painted white to produce a relatively uniform reference point in terms of light reflection and hue; and
- The space should include a proportion of wooden surfaces situated between 35% and 85%. Figure 2 shows the selection and concepts of each physical model that were observed and compared by the participants.

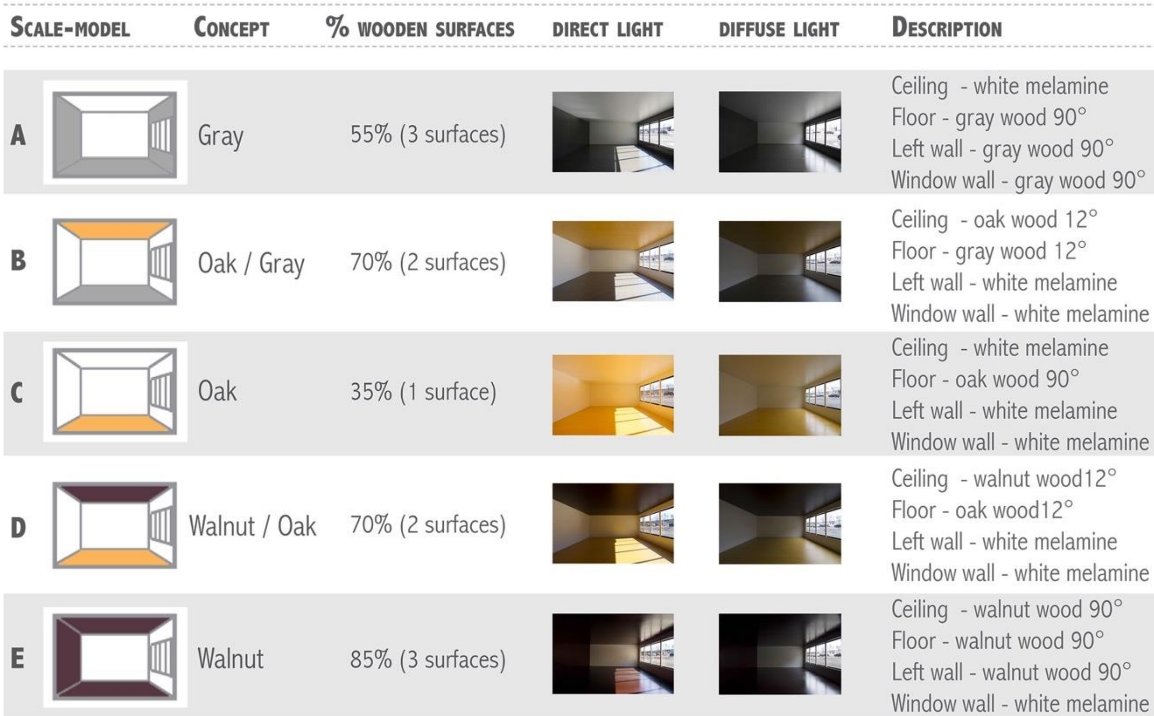


Fig. 2. Selection of wooden surfaces, location, and color combination of scale models

Questionnaire

A custom questionnaire was developed from a literature review of past experimental studies with similar methodologies. More exploratory questions were added to meet objectives related to wood appreciation. A preliminary version was reviewed by a dozen students and then statistically tested for reliability and validity (Poirier *et al.* 2016). The questionnaire was structured into four sections:

1. observers' perception and appreciation of each scale model assessed separately;
2. comparison and ranking of the models;
3. participants' demographic and personal status;
4. open questions about general perception of wooden spaces.

Participants were surveyed in relation to each scale model to determine the ranking in terms of preferences. The direct and almost simultaneous comparison of the different models allowed for the entire process to last less than 20 min. Although the questionnaire was self-administered, the main researcher remained available during the overall process.

Global appreciation

The first question aimed to validate the participants' first impression of the scale model and their global appreciation after initial observation (Burnard *et al.* 2015). It consisted of a closed question (section 1) to determine whether the space is considered comfortable during occupation hours. It consists of a binary choice ("yes" or "no") in addition to a third answer "uncertain" for greater accuracy.

Visual tasks

The second question addressed visual tasks associated with each scale model. It is also related to the definition of ambiences, which may assist designers in selecting appropriate interior materials for specific activities. Figure 3 presents a list of common activities and classified into categories extracted from IES Lighting Reference Handbook (2010) from visual tasks of orientation (large-scale, physical, and less-cognitive tasks), social activities (high-contrast task), common activities (relatively small-scale, more cognitive, or fast performance tasks), small scale cognitive tasks and extremely cognitive (unusual precise tasks) (IES Lighting 2010). Colors represent the different categories of visual tasks that were associated with each room type.

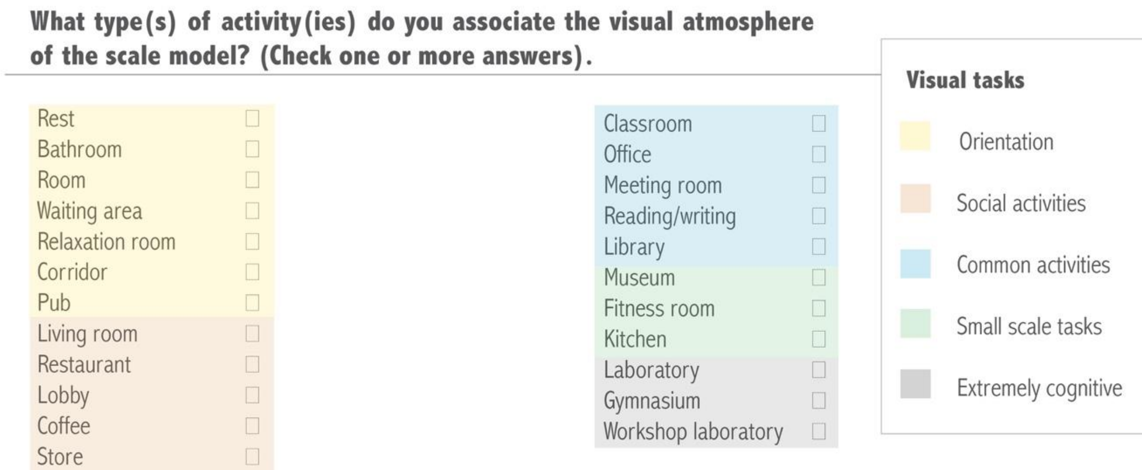


Fig. 3. Study questionnaire extract: visual tasks

Visual satisfaction

The last question of Section 1 aimed to discover visual perception and evaluation of a space and is commonly found in experimental studies (Sadalla and Sheets 1993; Büllow-Hübe 1995; Rice *et al*. 2006; Tsunetsugu *et al*. 2007; Dubois *et al*. 2007; Maruyama *et al.* 2008; Küller *et al.* 2009; Pineault 2009; Küller *et al*. 2009; Fell 2010; Wymelenberg *et al*. 2009; Arsenault 2012; Wastiels *et al*. 2013; Borisuit *et al*. 2015; Burnard *et al.* 2015; Kuijsters *et al*. 2015). A semantic differential scale (binary) in seven points is used to assess the produced effects of the ambience on the observers' perception. In the current study, those adjectives were grouped into six different categories that correspond to "*visual satisfaction*". This classification system, inspired by Russel and Snodgrass (1987) and Küller (1991) and developed by Büllow-Hübe (1995), Dubois *et al.* (2007), Pineault *et al.* (2007), and Arsenault (2012) was adapted to the study to discuss wooden ambiences in interior spaces. Figure 4 consists of an extract of the questionnaire showing six concepts to evaluate visual satisfaction: 1) visual comfort, 2) respondents' perception of how the environment may affect their well-being as well as perception of the atmosphere, 3) colors, 4) light, 5) naturalness, and 6) symbolism. Reliability analysis was performed for each category using Cronbach alpha to validate the internal consistency of the question. The "color" concept included the following pairs of adjectives relating to semantic scales: "warm/cold", "bright/dull", and "happy/sad". An excellent internal consistency was reached for those three pairs (α = 0.8993) validating that they were measuring the same concept, thus that analysis of the three adjectives together was possible. The concept "light" included the adjectives "uniform/variable", "light/dark", and "sufficient/insufficient". A good internal consistency was reached for all three scales (α =

0.8535). The concept “visual comfort” included the adjectives “comfortable/dazzling”, “convenient/inconvenient”, “stimulating/monotonous”, and “productive/unproductive”. An acceptable internal consistency was reached for those four semantic scales (α = 0.7338). Finally, the concept “perceived well-being” included the adjectives “restful/stressful” and “pleasant/ unpleasant”. Both adjectives were found as unacceptably correlated (α = 0.4768). These results show that the concept “well-being” could be redefined by using other adjectives to reach an internal consistency.

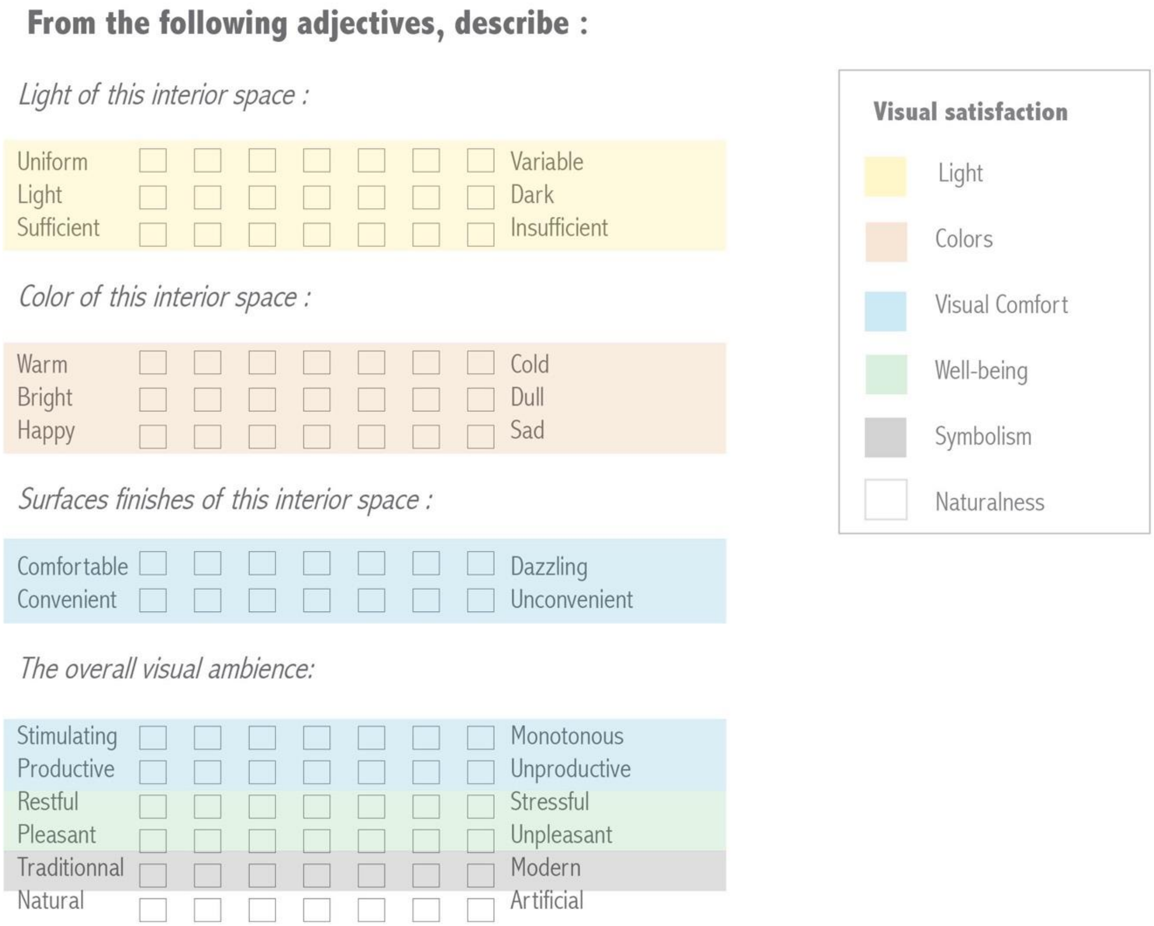


Fig. 4. Study questionnaire extract: criteria of visual satisfaction

Ranking

Section 2 consisted of a recapitulative assessment, which compared the five scale models. This section included both closed and opened questions. The first question, inspired by Burnard *et al*. (2015), addressed the classification of the scale models in order of preference. Answers could be related to personal taste as well as to those six visual satisfaction concepts that observers had to qualify previously (visual comfort, perceived well-being, light, color symbolism, naturalness). In the second open question, participants justified their choices in terms of favourite and least appreciated models. It allowed an understanding of determinant elements that influenced observers in ranking the models.

Open question

An exploratory open question concluded the survey (Section 4). Participants rated and expressed their appreciation level of wood in space. The question recorded their impressions in relation to the presence of wood to validate its positive or negative impact. Moreover, it identified new aspects, other than those discussed in the study, which can explain wood preference, and their relation to the six concepts of visual satisfaction.

Sample Characteristics

The questionnaire was self-administered to 80 members from Laval University, including 41 women (51%) and 39 men (49%). A five-dollar coupon was offered to participants for use at the department coffee shop. The sample was probabilistic and volunteered, which can however generate important bias. A good example of a bias is the ratio of the participants' provenance. Because the study was performed at the school of architecture, located about 30 minutes from the principal campus, participants were mainly students or professors from the architecture department (86%), and a smaller ratio of people were members of the university community from another domain (14%). Architecture students have a very particular way of perceiving spaces that can differ from the general population (Wastiels *et al*. 2013) thus limiting generalization of the results since experience and field of study have been proven to have an impact on visual perception (Gifford 2007). The age of participants was also inequitably distributed: 52 participants (65%) were aged between 20 and 24 years old. Since participants over 30 years old were in a minority, age groups were redistributed in two groups for statistical analysis, 24 years old and under (70%), and 25 years old and over (30%). However, even if the sample is not perfectly random, it is still possible to establish conclusions about architecture students' perception in relation to wooden environments.

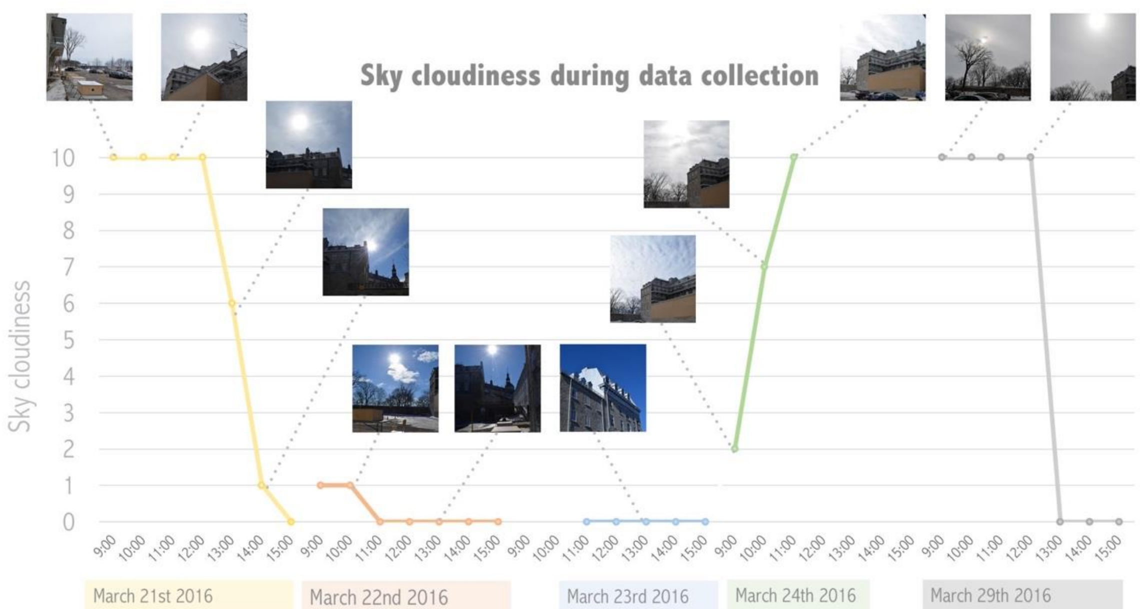


Fig. 5. Sky cloudiness conditions experimented during data collection

Upon arrival to the study setting, the research process was explained to participants and consent form signed. Participants were invited to observe each model for at least 1 minute before answering the questions. The overall process duration varied from 10 to 25 minutes, depending on the participant. During the answering process, for each participant, weather conditions (cloudiness and time of the day) related to the survey process was recorded by the searcher to describe the daylighting context. A complete record of sky conditions was established hourly in relation to each questionnaire data collection. Figure 5 shows a representation of the sky cloudiness that was experimented during the questionnaire data collection, which was taken during five consecutive days in the spring equinox.

Conditions varied from overcast to clear skies during the five days of data collection. The cloudiness scale from 0 (overcast sky) to 10 (covered sky), detailed in a previous study by Poirier *et al.* (2016), identified three luminous typologies that presented the most important differences in terms of hue and colors: sunny morning, sunny afternoon, and cloudy day. Participants were grouped according to those three categories of cloudiness for statistical analysis. Cloudiness conditions from 6/10 and over for cloud cover and thickness scales were determined as cloudy conditions, while less than 5/10 cloudiness conditions were determined as sunny. Morning was determined from 9:00 am to noon, and afternoon from 12:30 pm to 3:30 pm. A percentage of 31% of participants achieved the questionnaire under morning sunny conditions, 44% responded during afternoon sunny conditions, and 25% of the observers participated under cloudy conditions (morning or afternoon). Daylighting diversity had considerable impact on the interior ambience in terms of hue, contrast, and brightness (Jafarian 2016; Poirier *et al.* 2016). Thus, this classification aimed to verify whether cloudiness, as well as daylighting quality that enters the model has an impact on observer's perception of the space, and potentially on its visual satisfaction level.

Participants were divided in groups to facilitate the study process. Half of the participants experienced scale models in an order ranging from A to E, while the other half saw the models randomly. The sequence in which they evaluated the models can potentially create different results. Each of these variables (gender, field of study, age, weather conditions, and the order in which participants observed the models) were considered in the statistical analysis to rule on their effect on visual perception (Table 1).

Table 1. Descriptive Statistics and Variables

Explicative Variable	Frequency (on 80 participants)	Percentage (%)
Age of participant		
24 and under	56	70
25 and over	24	30
Gender		
Women	41	51
Men	39	49
Cloudiness		
Sunny AM	25	31
Sunny PM	35	44
Cloudy AM/PM	20	25
Field of study		
Architecture	69	86
Other	11	14
Order of models observation		
A-E	40	50
Randomly	40	50

Statistical Methods

The questionnaire met the specific goals of the study, which was exploratory and aimed to examine and investigate several variables of a wide spectrum rather than finding deterministic answers. The diversity and complexity of the questionnaire challenged conventional data analysis but triggered intriguing new research hypothesis. All statistical analyses were performed with SAS/STAT software (Version 9.4, SAS Institute Inc., Cary, NC, USA). Results were declared significant at the 0.05 ρ-value level. Protected Fisher's LSD (Least Significant Difference) method was used for multiple comparisons.

Global appreciation

Global appreciation was measured by the observers' first impressions as collected in the first closed question (Section 1) with the answer "uncertain" removed. By eliminating this category, the sample size was decreased from 398 to 335. A generalized linear model with binomial distribution and logit link was used to analyse this dichotomous variable that is to say, to model the probability of answering "yes". Because each respondent gave their appreciation on the five scale models, GEE method of estimation was used to take into account of the correlation between observations of the same respondent. The explicative variables (scale models, gender, age, and field of study as well as the cloudiness and the order or sequence of models observation) were included in the model. Moreover, the GENMOD procedure of the SAS program with "exchangeable" correlation structure was used for the analysis.

Visual tasks

This section defined the correspondence between types of ambiences and potential activities or visual task. For each visual task, the respondent determined if it was applicable or not to the five scale models. As the response was dichotomous (yes or no), a generalized linear model with binomial distribution and logit link was used to test the difference between the five scale models. The analysis was performed separately for each potential activity. Because each respondent determined the applicability of potential activity appreciation on the five scale models, the GEE method was used to estimate the correlation between observations of same respondent. The GENMOD procedure of the SAS program with "exchangeable" correlation structure was used for the analysis.

Visual satisfaction

Satisfaction scores for the five visual concepts (colors, light, visual comfort, perceived well-being, symbolism) were created by taking the means of the corresponding questions. Two types of analyses were performed on this data. First, the effect of scale model and visual concepts on the satisfaction score were studied. Each respondent generated a score for all 25 combinations (5 scale models x 5 visual concepts), and an analysis of variance model with repeated measures was adjusted to study the effect of scale model and visual concepts on satisfaction. Hence, scale model and visual concept are repeated factors.

Secondly, for each concept the effects of scale models, as well as the explicative variables gender, age, and field of study as well as the cloudiness and the order or sequence of models observation on satisfaction scores were studied. Again, an analysis of variance model with repeated measures was used. For all analyses, the MIXED procedure of the SAS program was used with a repeated statement to consider the correlation between observations on the same respondent. The covariance structure that minimizes the Akaike criterion was chosen, and the Kenward-Roger method was used to calculate the degree of freedom. Normality and homogeneity assumptions were met for all analyses.

Ranking of scale models

The Friedman test was used to compare the ranking given by the respondent to classify models from their favorite (1) to their least preferred (5).

Qualitative questions

Qualitative questions were analyzed by a manual text mining procedure. Words named by the respondents were classified manually into the visual satisfaction's concepts (color, light, visual comfort, perceived well-being, naturalness, symbolism) in which they seemed to be the more related.

RESULTS AND DISCUSSION

Global Appreciation

Global appreciation results show a significant effect for the interaction between gender and scale models (ρ-value: 0.0057) as well as for the observation sequence (p-value: 0.0031). None of the other variables (group of age, cloudiness, gender, field of study) had any significant effect on the global appreciation. Further investigation enabled the interpretation of those two significant interactions. Figure 6 presents the adjusted probabilities of appreciating the space of the 5 scale models for both genders and sequences separately. For each scale model, statistical comparisons were made between the two observations sequences and between the two genders.

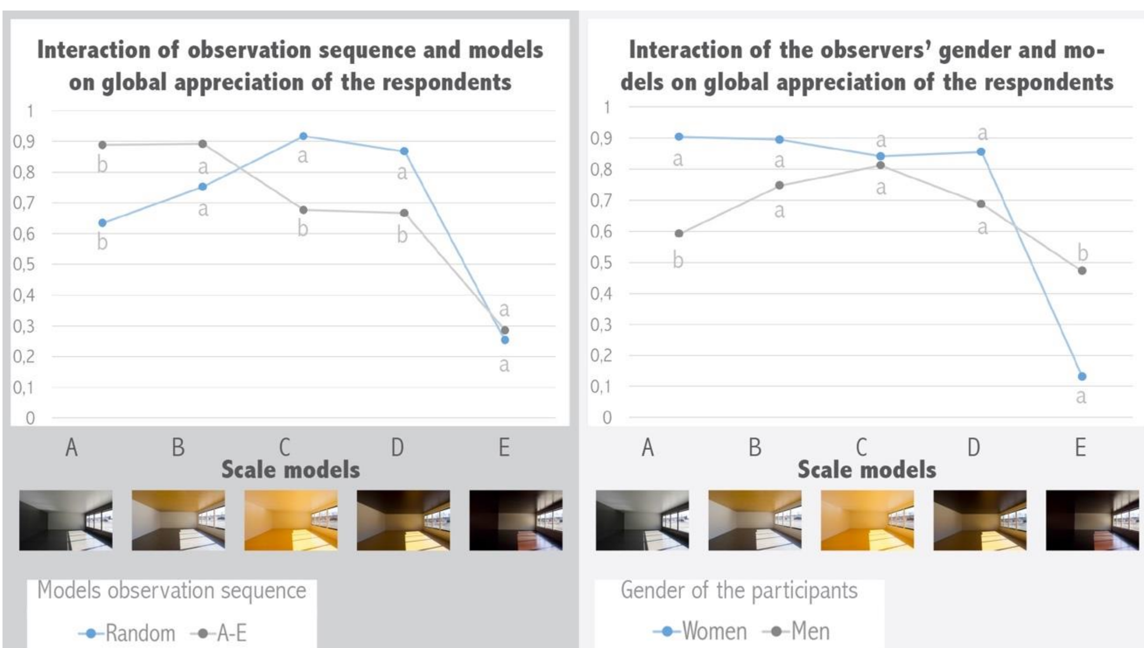


Fig. 6. Plots of adjusted probabilities: 1) interaction of observation sequence and models on global appreciation of the respondents 2) interaction of the observer's gender and models on global appreciation of the respondents.

When letters (a,b) shown on the plot are different for the same model, the difference is significant. For example, Model A was more appreciated when it was firstly observed (89%) than when the sequence was randomly experienced (63%). Model E was the least appreciated, with no significant difference between the random sequence (25%) and the A-E sequence (29%). Those differences show that the sequence in which observers experienced spaces can affect their appreciation of visual ambiences. Further studies using this approach should randomize the whole observers' sequences in which the models or spaces are seen to avoid those differences.

Appreciation results varied between women and men depending on model type. Two models, grayish Model A and dark Model E, presented a significant global appreciation difference. If women appreciated Model A (90%), they however remarkably disliked Model E (13%). Men tended to be more moderate in their opinions, with an average appreciation for Model A (60%) as well as for Model E (50%). Those differences show that men and women tend to have a different way of perceiving space, a finding that could be further investigated.

Visual Tasks

The chosen applicability of each potential activity was highly variable depending on the five scale models. The effect of the scale model score was not statistically significant for the following visual tasks: room, relaxation room, corridor, lobby, coffee, museum, laboratory, and workshop. Figure 7 shows the overall adjusted proportion answers by the observers for each potential activity or visual tasks and scale models. Table 2 shows the pairwise comparisons between scale models of the visual tasks that were significant. When letters (a, b, c, d) are different, results are significantly different between the score of each scale model. Blank spaces mean that there were no significant results between models.

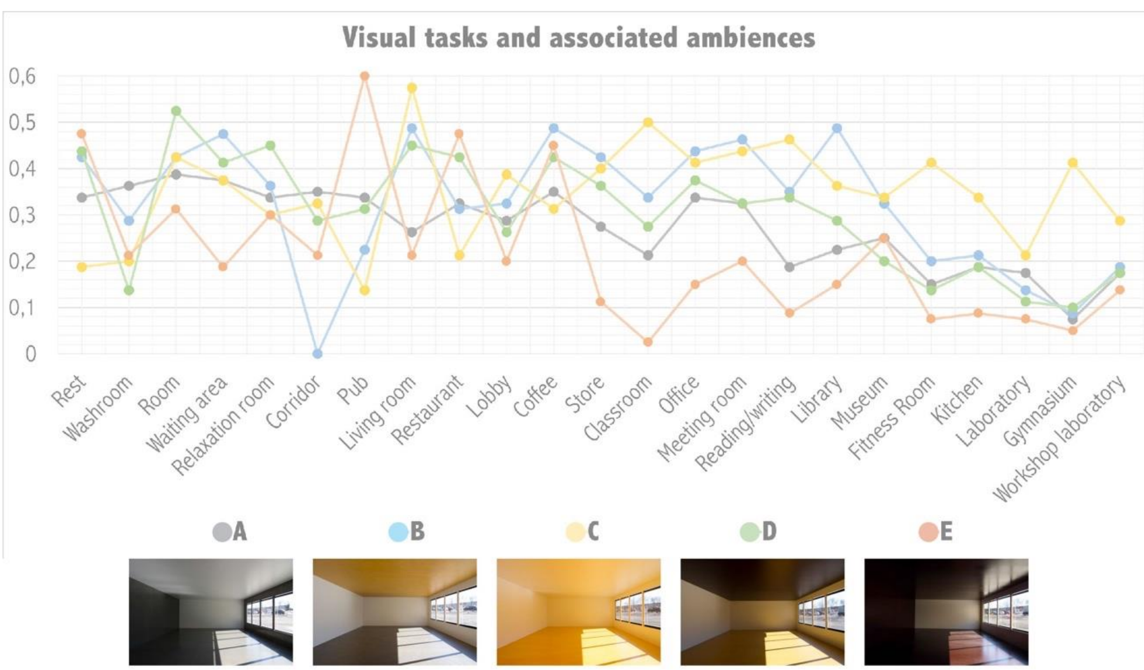


Fig. 7. Plot of adjusted means: interaction of the visual task and the associated ambiences score

Table 2. Visual Task Answer Comparisons between Models

Models \ Visual Tasks	Rest	W.C.	Room	Waiting area	Relaxation	Corridor	Pub	Living room	Restaurant	Lobby	Coffee	Store	Classroom	Office	Meeting	Readg/Writg	Library	Museum	Fitness	Kitchen	Laboratory	Gymnasium	Workshop
A	A	A		A			A	B	BC			B	B	A	AB	B	CD		BC	BC		B	
B	A	AB		A			A	BC	BC			A	B	A	A	A	A		B	AB		B	
C	B	BC		A			A	C	C			AB	A	A	A	A	AB		A	A		A	
D	A	C		A			A	B	AB			AB	B	A	AB	A	BC		BC	BC		B	
E	A	BC		B			B	A	A			C	C	B	B	B	D		C	C		B	
	Orientation tasks						Social activities					Common activities						Small scale			Extremely cognitive		

The results showed that a majority (60%) of people associated the dark and mysterious Model E with a pub, but a minority selected it to the bright and warm Model C (14%). The Model C was however associated as a living room (58%), closely followed by Model B (49%) and Model D (45%). Meanwhile, the darkest ambiences were not much selected for this potential activity (Model A: 26% and Model E: 21%).

The first activity scores remarkably differ depending on the model type. However, a tendency is observable for those following tasks: store, classroom, office, meeting room, reading/writing, and library. Those activities are related to more cognitive and small-scale visual tasks, which are related with work and concentration. The brightest Models C and B, were the most often selected, emphasizing that participants tend to prefer clear and bright spaces for common activity tasks. For example, Model B (49%) was the most often associated with a library environment, while Model E (15%) was the least selected. Finally, Model C was the most associated with the last visual tasks of the list that correspond to the most demanding in terms of brightness, such as a classroom (50%). A previous study (Poirier *et al.* 2016) showed that Model C corresponds with the brightest and the warmest model. Thus, people tend to prefer this type of ambience for cognitive and extremely precise tasks, whereas dark ambiences like Model E and Model A are not usually associated with these visually demanding tasks.

Visual Satisfaction

For the first type of analysis, ANOVA results indicate significant interaction ($F = 14.48$, $p < 0.0001$) between scale models and visual concepts. Figure 8 presents an illustration of this interaction. Value 1 on the Likert scale (Fig. 8) represents the best score, whereas value 7 represents the worst score. Letters correspond to results of multiple comparisons of scale models for each visual satisfaction concepts. When letters (a, b, c, d, e) are different, results between the different models are significantly different. As an example, the "visual comfort" concept for example, produces contrasting results, whereas the Model C score (2.9) was significantly higher than for Model A (3.7) and Model E (4,4) scores. However, Model C score was not significantly different from the Models B and D. Thus, the warm and bright scale model C as well as the Models B and D were considered as more visually comfortable than the dark models A and E.

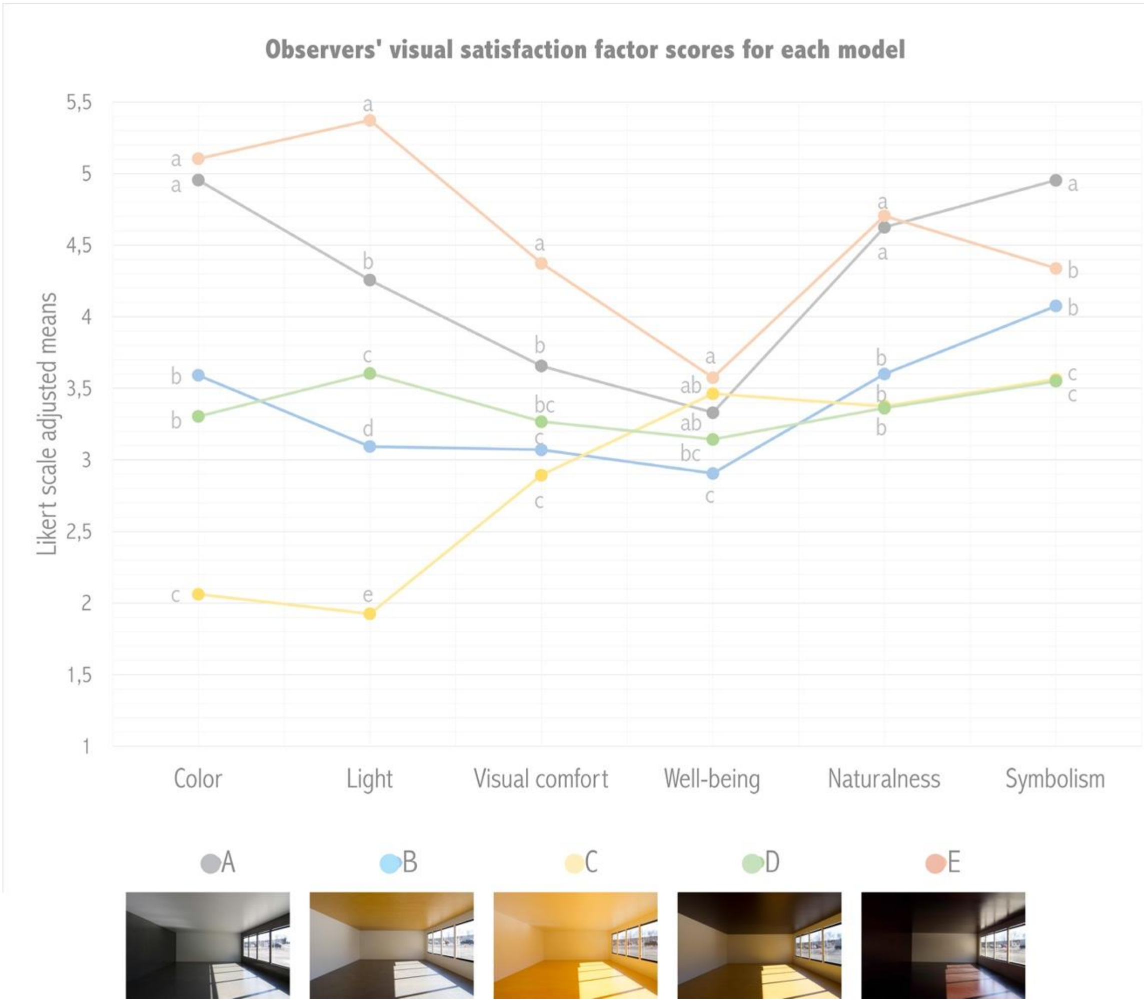


Fig. 8. Plot of adjusted means: observers' visual satisfaction scores for each model

For the second type of analysis, visual satisfaction in relation to variables of gender, age, and field of study as well as cloudiness and observation sequence were performed for each concept. Table 3 shows the p-value of the ANOVA table for each visual satisfaction concepts. Blue squares indicate a significant difference. As an example, the term of interaction Gender*Model for the "light" factor is significant (p-value: 0.0056), indicating that the observed difference for the "light" visual satisfaction factor was significantly different between men and women. However, the term of interaction Gender*Model for the "color" factor was not significant (p-value: 0.7999), meaning that the difference for the "color" visual satisfaction factor was not significantly different for women and men.

1- Color

The "color" concept included the following pairs of adjectives relating to semantic scales: "warm/cold", "bright/dull", and "happy/sad". The results showed that Model C received the best score and was thus considered the "warmest", "brightest", with "happy" colors (Fig. 8). Models E and A were not significantly different; they received the lowest scores and were considered "cold", with "dull" and "sad" colors. Table 3 reveals that the main effect of "cloudiness" and main effect of "model" were significant for the color concept.

Table 3. P-value of the ANOVA Table of the Six Visual Satisfaction Concepts

Source of variation	Color	Light	Visual comfort	Well-being	Naturalness	Symbolism
Group of age	0.6634	0.1575	0.4736	0.8278	0.8511	0.4430
Gender	0.6787	0.4458	0.2279	0.9149	0.6201	0.6470
Cloudiness	0.0269	0.9253	0.5228	0.6399	0.7825	0.2010
Field of study	0.9384	0.2778	0.4014	0.9665	0.6383	0.5219
Sequence of observation	0.1760	0.6337	0.2122	0.7272	0.2177	0.0133
Model	<.0001	<.0001	<.0001	0.0966	0.0036	<.0001
Group of age*Model	0.4595	0.7468	0.4827	0.9265	0.9099	0.8086
Gender*Model	0.7999	0.0056	0.0046	0.0270	0.5913	0.6130
Cloudiness*Model	0.2274	0.1852	0.4866	0.9834	0.6559	0.1248
Field of study*Model	0.5154	0.1723	0.2745	0.0795	0.6223	0.1724
Sequence of observation*Model	0.1464	0.3061	0.0917	0.0220	0.2447	0.3908

2- Light

The concept “light” included the adjectives “uniform/variable”, “light/dark”, and “sufficient/insufficient”. The five scale model scores were remarkably different (Fig. 8), whereas Model C received the highest score and thus relates to a “uniform” “light” considered “sufficient” in terms of daylighting environment. It was followed by Models D, C, and A. Model E had the lowest score and therefore, corresponded to an environment that would be perceived as “variable”, “dark”, and “insufficient” in terms of light. The main effect of the “model” as well as the interaction effect of “Gender*Model” were significant for this concept (Table 3).

3- Visual comfort

The concept “visual comfort” included the adjectives “comfortable/dazzling”, “convenient/inconvenient”, “stimulating/monotonous”, and “productive/unproductive”. Models C and B received the best scores and were considered “comfortable”, “convenient”, “stimulating”, and “productive” (Fig. 8). They were followed by Models D and A. Model E received the lowest score, and was considered the most “dazzling”, “inconvenient”, “monotonous”, and “unproductive”. The main effect “model” and the interaction effect of “Gender*Model” were significant for this concept (Table 3).

4- Perceived well-being

The concept “well-being” included the adjectives “restful/stressful” and “pleasant/unpleasant”. The questions did not seem to measure the same concept (α = 0.4768). Table 3 reveals that the interaction effect of “Gender*Model” and “Sequence of observation*Model” were significant for this concept. It is the only factor in main effect “Model” is not significant. However, it is difficult to interpret and these results show that the concept “well-being” could be redefined by using other adjectives to reach an internal consistency. The questionnaire focused on respondents’ perception of how the environment may affect their well-being instead of real indicators of psychological well-being that could have been measured in a real space.

5- Naturalness

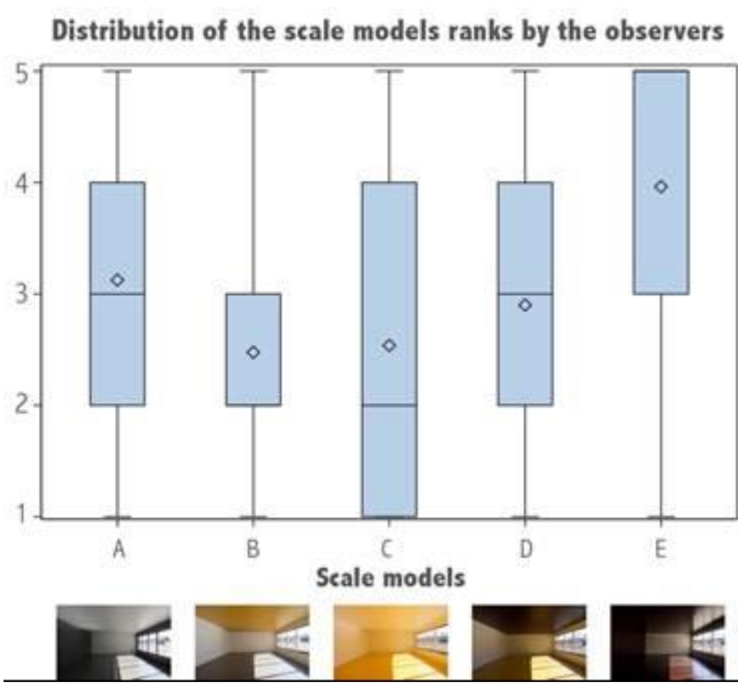
The concept “naturalness” was included in a single pair of adjectives “natural/artificial”, and its analysis factor was thus less powerful. Models C, B, and D were considered the most “natural” environments, even if their scores were moderated, while Models A and E were the most “artificial” environments (Fig. 8). Table 3 shows that the main effect “model” is significant for this concept.

6- Symbolism

The concept “symbolism” included the single pair of adjectives “traditional/ modern” and is also less powerful in terms of analysis. Models D and C were considered as the most “traditional” environments (Fig. 8). Model A was considered as the most “modern” environment. Figure 3 reveals that the main concepts “Model” and “Sequence of observation” are significant for this concept.

Ranking of Scale Models

Globally, means of ranks significantly differed between models (ρ-value: < 0.0001). Figure 9 compares models to each other and indicates the differences. LS-means with the same letter are not significantly different. The results showed that each model appears at least once as favourite and least preferred (Fig. 9). Model C received the highest ratio of “favourite” scores, but also the highest variability, indicating that opinion may be divided for this model. Model B had the highest average value with the least variability, indicating that a majority classified it between their 2nd and 3rd choice. Model E was the least preferred model, corresponding to the lowest average score. Models A and D were moderately liked. Therefore, with some reserve, it could be said that models B (mean: 2.54) and C (mean: 2.48) are the two preferred, while model E (mean: 3.96) is the least preferred.



T Comparison Lines for Least Squares Means of Scale models

		Rank LSMEAN	Model
	A	3.9625	E
	B	3.1250	A
C	B	2.9000	D
C		2.5375	C
C		2.4750	B

*LS-means with the same letter are not significantly different.

Fig. 9. Scale model ranking according to Friedman statistical analysis and distribution

Qualitative Questions

The ranking question was followed by a qualitative open question in which participants were invited to explain their preferred as well as the least preferred choice.

Table 4. Qualitative Data of Preferred and Least Preferred Models Classified into Visual Satisfaction Categories

						
Visual Satisfaction Factors	**Model B (Preferred)**	Score	**Model C (Preferred)**	Score	**Model E (Least preferred)**	Score
Color	Warm(9), color arrangement(8), balance between colors(2), contrast(2), complementarity(1), white(1), neutral(1)	24	Clear color(12), warm(8), wood color(5), presence of white(4), brightness, sunny yellow(3), color arrangement(1)	33	Too dark colors(7), dark wood(5), cold(3), dull(1), too impressive color(1)	17
Light	Luminous(8), uniform(4), clear(2), bright(1), control(1)	17	Luminous(23), bright(3), diffuse(3), abundance of light(1), uniform(1)	31	Dark(34), not luminous(13), too much contrast(4)	51
Visual comfort	Dull and pleasant finish(3), productive(2), work(1), stimulating (1), comfortable(1), less glare(1)	9	Comfortable(3), stimulating(2), uniform textures(2), productive(1), work(1), enthusiasm(1)	10	Dazzling(3), too impressive textures(2), not productive(2), not stimulating(1), soporific atmosphere(1)	9
Well-being	Pleasant(5), soothing(2), restful(2), relaxing(1), quiet(1), calm(1)	12	Pleasant,(2), calm(1), quietness(1), happiness(1), rest(1)	6	Unpleasant(3), sadness(2), oppressive ambience(2), numbness(1), Scary(1), austere atmosphere(1), confinement(1), suffocation(1), stressful(1)	13
Naturalness	Natural(2), not too much wood(1), pure(1)	4	Natural(5), pure(1)	6	Not natural, fake material(3), too much wood(2)	5
Symbolism	Modern(3), contemporary(1), professional(1), not too serious(1), height(1), simplicity(1), family(1)	9	Magnitude(3), clean(1), harmonious(1), sobriety(1)	6	night activities(5), crushing ceiling(3), cavernous(1), no applications(1), pub(1), narrow(1), small room(1), heaviness(1), mysterious(1)	15

The qualitative answers were analyzed for model B and C preferred answers as well as model E least preferred answers. A text mining procedure helped classify the different words into six categories of visual satisfaction (Table 4). The most repeated terms were often linked with “color” and “light” concepts, which confirms their determining importance when comparing spaces. Naturalness was the less repeated concept.

Model E with its dark walnut ceiling, walls, and floors was the least preferred because of its light, considered as being “dark”, “not luminous”, with “too dark colors”. This environment was perceived as “unpleasant”, “stressful”, even “scary”, with a “narrow”, “oppressive”, and “confined” atmosphere. It was associated with a lack of naturalness, including impressions such as “fake and artificial materiality”, with a presence of “too much wood” in the space. However, this environment was often preferable for “night activities”. Model C, with its oaked floor, white walls and ceiling, was mostly preferred because of its “luminous”, “bright” atmosphere, as well as its “warm”, “clear”, and “sunny” colors. The environment was considered “pleasant”, “comfortable”, and “stimulating” for working, as well as “natural” and “harmonious”. Model B was characterized as “luminous” and “bright” and was appreciated for its abundance of light. The combination of gray and oak colors was also particularly appreciated: people enjoyed the “balance” and “complementarity” of colors, as well as the “color arrangement”. This environment was felt as “pleasant”, “restful”, “modern”, and “pure”.

The questionnaire ended with an exploratory section with an open question: “Do you appreciate the presence of wood in a space? If so, why?”. All 80 participants (100%) responded positively to the question, affirming that the study sample greatly appreciated wood in interior spaces. Qualitative explanations were classified under the six categories with a text mining procedure similar as the ranking question, resulting in 252 different reasons stated by participants (Table 5).

Color related words corresponded to 29% of the explanations developed by observers. The main reason for the appreciation of wood in space stated 46 times was that it is “warm” and creates “warm ambiences”. Moreover, wood is appreciated due to the “hue of the wood species” and “clear colors”, especially when in “contrast with white walls”. Light (2%) as well as comfort (5%) were the less stated correlated words. The presence of wood was recognised as having an impact on perceived psychological well-being that could be experienced in a real environment (10%), while creating “restful”, “joyful”, “soothing”, and “relaxing” environments. Naturalness also appears as an important factor (16%): people consider wood as “natural”, “respectful”, creating certain “links/connections with nature”.

People also tend to prefer “untouched wood”. Wood symbolism was one of the most important preference factors for participants (22%) for its “beauty and estheticism”. Wood is considered as an “inviting”, “rich”, “polyvalent”, and “noble material”. Some people also associated this material with “childhood”, “protection”, and “home” memories. Surprisingly, a substantial number of words that were not related with the six visual satisfaction concepts were also mentioned (17%). Those words referred to other concepts such as “texture”, “defects of the grains”, “warm to the touch”, “contact with the feet”, “odour”, and “softness”. This allows the hypothesis that the visual satisfaction concepts did not include other senses such as olfactory and touching, and refers to the complex and more complete concept of environmental perception that could be investigated in future studies.

Table 5. Qualitative Aspects Related to the Appreciation of Wood in Relation to Visual Satisfaction Categories

Visual Satisfaction Factors	Reasons to Appreciate Wood in Space	#	%
Color	Warm(46), contrast with white walls(6), warm ambience(4), hue of the essence(3), clear color(3), color(3), natural color(2), change of color during the day(2), color of grain(1), soft color(1), dark hue(1)	72	28.6
Symbolism	Beauty and aestheticism(5), inviting(5), noble material(4), family(3), rich material(3), appreciated material(3), Quebec identity(2), craft(2), vernacular material(2), polyvalence(2), traditional(2), protection and security(2), home(2), modern(2), cachet(2), cultural(1), inspiring(1), elegance(1), childhood(1), sophisticated(1), history(1), character(1), fireplace(1), great moments(1), unique(1), magnitude(1), quality(1), originality(1), personality(1), simple(1)	56	22.2
Other (odor, defects, texture, touch)	Texture(15), defects and texture of grains(5), warm to the touch(4), not too much wood(4), contact with feet(3), odor(3), softness(3), constant temperature(2), engineering(2), sound(1)	42	16.7
Naturalness	Natural(15), link/connection with nature(5), untouched wood(4), natural aspect(3), lifecycle(2), respect of nature(2), concrete and other materials(2), natural color(2), forest(1), lake(1), contrast with city(1), pure(1)	39	15.5
Well-being	Restful(8), happiness(4), calm(4), soothing(4), relaxing(2), pleasant(1), cocoon(1), peaceful(1), not stressful(1)	26	10.3
Comfort	Comfortable(4), productivity(2), visually comfortable(1), dynamism(1), not dazzling(1), not boring(1), refreshing(1), inviting to work(1)	12	4.8
Light	Light reflection(2), uniformity of light(1), soft and delicate light(1), light slips(1)	5	1.9
TOTAL		252	100

Figure 10 shows a graphic representation of the main factors that participants qualified as reasons they appreciated wood.

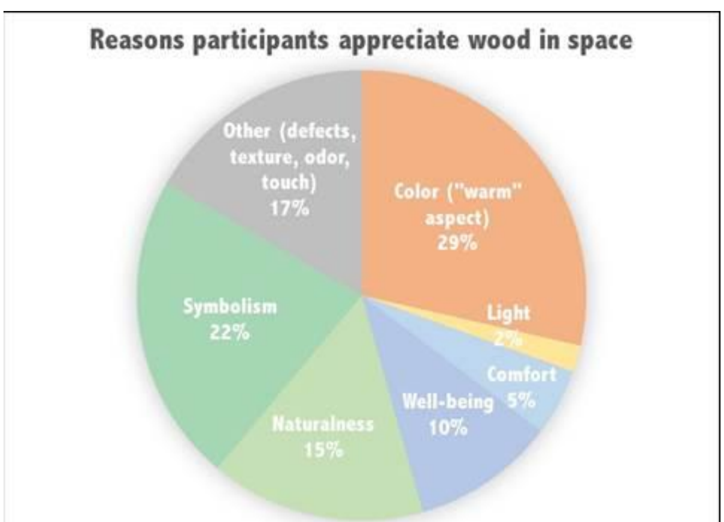


Fig. 10. Main factors that participants qualified as reasons they appreciated wood

Scale Model Appreciation

Model A

"Artificial" and "modern" Model A, featuring gray walls, grey floor, and white ceiling, was moderately appreciated. Previous lighting analysis (Poirier *et al.* 2016) described this environment as dark, dull, and cold. Moreover, it was the only model that did not undergo a significant change in visual ambiences throughout the day: morning sun, afternoon, and overcast sky created similar atmospheres for their hue, contrast, brightness, and saturation. Ranking and global appreciation results classified this model as one of the least preferred, followed by Model E. Interestingly, the sequence in which the models were seen and the gender of observers had an impact on the perception of this particular model. It was more appreciated when seen first, and women tended to appreciate it more than men. Visual tasks results showed that this model is moderately associated with most tasks, indicating that this kind of space is versatile and not only associated with one type of task, but also showing that it may not be the most appreciated in everyday life. Model A also received one of the lowest score for visual satisfaction, and was considered as the most "artificial", relating to a "modern" environment.

Fig. 11. Model A: qualitative adjectives most often cited by participants

Model B

"Luminous" and "pleasant" Model B, featuring a color combination of white walls, gray floor, and oak ceiling, was one of the most appreciated along with Model C. This environment was one of the brightest and least contrasted. Its color combination helped creating a moderately warm environment (Poirier *et al.* 2016). The model was equally appreciated by both genders and for all sequences of observation, showing that the environment was generally appreciated. The visual tasks answers highly associate this model with common and cognitive activities, such as “meeting room”, “library”, and “office”.

This finding confirms that bright environments are preferred for tasks related to concentration and attention. The overall visual satisfaction factor was positive for this model, and it received the best score for perceived well-being. Qualitative answers by participants helped explain why this environment was one of the most appreciated. It was described as “luminous”, “bright”, “pleasant”, and “modern”. Its colors combination was also appreciated for their “balance” and “complementarity”.

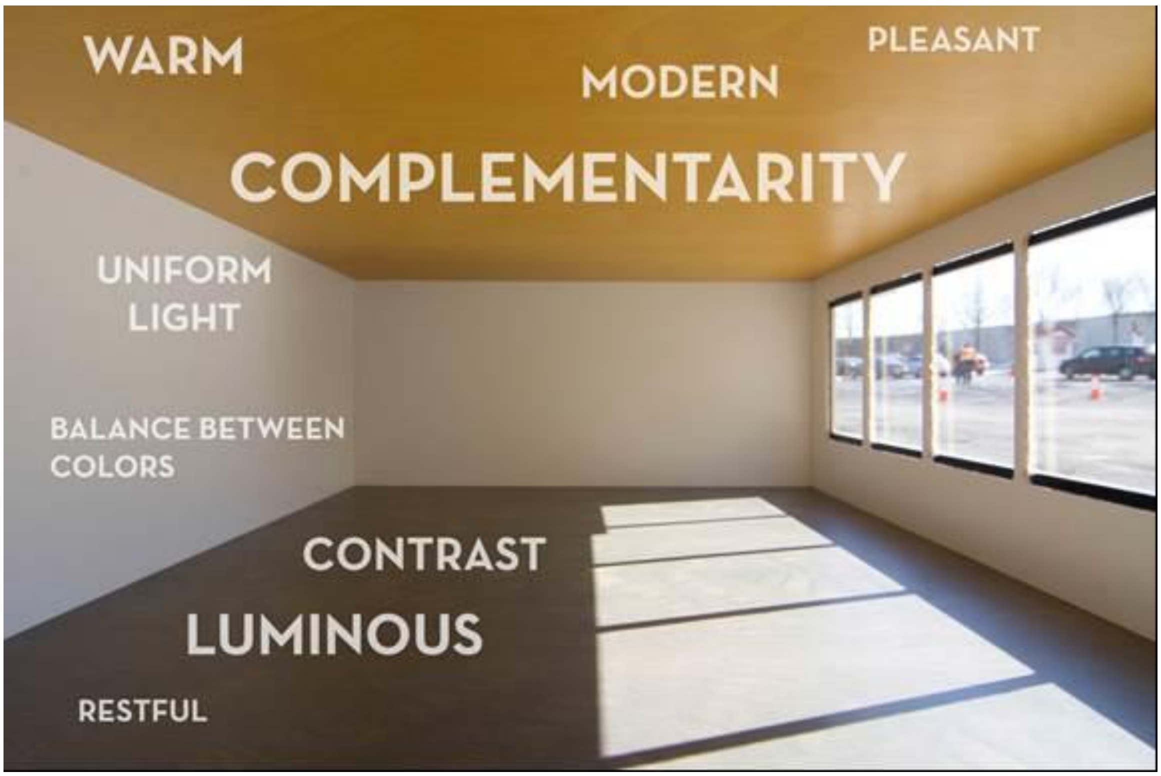


Fig. 12. Model B: qualitative adjectives most often cited by participants

Model C

“Warm” and “stimulating” Model C, featuring wooden oaked floor, with white walls and ceiling, was one of the preferred along with Model B. Lighting analysis (Poirier *et al.* 2016) described this environment as the warmest, brightest, and the least contrasted. Moreover, visual ambiences of Model C were significantly different throughout the day, depending on the sky cloudiness and sun position. This model was the most appreciated by participants for most questions.

Even if the observation sequence seemed to produce an impact on its global appreciation, men and women equally appreciated it. This model received the best mean score for ranking questions and was also the most associated for common activities, small scale and cognitive tasks, as “classroom”, “reading/writing”, and “fitness room”. This suggests that these types of activities are associated with bright and warm ambiences. Model C received remarkably positive scores for visual satisfaction associated with “color” and “light factor”, and was considered one of the most “traditional” space. Open questions provided additional reasons for the participants to rank this model as their favorite/preferred: it was described as “luminous”, “bright”, “warm”, “sunny”, “comfortable”, “stimulating”, “natural”, and “harmonious”.

Fig. 13. Model C: qualitative adjectives most often cited by participants

Model D

“Dark” and “Warm” Model D, featuring a color-combined environment, very similar to Model C but with an oaked floor and dark walnut ceiling, was moderately appreciated. Lighting analysis (Poirier *et al.* 2016) qualified it as one of the darkest and most contrasted.

The yellowish floor coating warmed the overall ambience, while the dark ceiling created a heavier and darker atmosphere. The moderated results in terms of appreciation often classified the space as moderately appreciated, closely followed by Model A. Visual tasks answers also showed moderated results, emphasizing that this type of environment could be used for many types of activities, but would not be appreciated by a majority of people.

Visual satisfaction concepts indicated rather positive results that were similar to Model B in terms of colors, visual comfort, perceived well-being, and naturalness. However, ever if this model was similar to Model C, the dark ceiling had a greater impact on global appreciation of participants. This model was considered one of the most “traditional”.

Fig. 14. Model D: qualitative adjectives most often cited by participants

Fig. 15. Model E: qualitative adjectives most often cited by participants

Model E

"Dark" and "scary" Model E, featuring dark walnut walls, floor, and ceiling was perceived as the darkest and consequently least preferred. It was also one of the most contrasted, as ambiences differed remarkably under overcast and clear skies (Poirier *et al.* 2016). Analysis classified this model as the least preferred, with its global appreciation level remarkably different for women who greatly disliked this environment and men, who moderately disliked it. Globally, most visual tasks were not associated with this environment, especially those with high illuminance needs. However, this dark atmosphere obtained high scores for visual tasks such as "rest", "pub", "restaurant", and "coffee", showing that even if this environment is the least preferred, it could still be relevant for some activities. Model E also received the lowest scores for visual satisfaction concepts such as "color", "light", and "visual comfort". It was considered one of the most "artificial" and "modern". Qualitative answers by participants emphasized that this environment was the least preferred because it was "dark", "not luminous", "unpleasant", "stressful", "scary", "oppressive", and produced a "confined" atmosphere.

Questionnaire Discussion

The questionnaire was developed and tested to reach research objectives. The use of a mixed questionnaire containing both qualitative and quantitative assessments offered rich and exploratory conclusions, but its analysis was complex and challenging. Reducing the number of variables and simplifying some questions should be considered in further studies.

Considering a wide selection of variables (model type, group of age, gender, cloudiness, field of study, sequence of observation) allowed the observation of potential interactions with the overall answers. Interestingly, the variable that usually had an important impact on the overall scores was the interaction between gender and models. Men and women tended to answer the global appreciation question differently, as well as for light, visual comfort, and perceived well-being visual satisfaction concepts. Men's responses were more neutral, while women's preferences were more clearly asserted. Men and women therefore have different ways of perceiving space, which is expressed more decidedly in relation to darker environments, a research finding which could be further investigated.

The second important variable was the observation sequence. Participants tended to rate an ambience differently depending on the order in which they experienced the models, an observation that also needs further study. For example, while Model A was more appreciated when it was firstly observed than when the sequence was randomly experienced, Model E was the least appreciated, with no significant difference between the random sequence and the A-E sequence, showing that the sequence in which observers experienced spaces can affect their appreciation of visual ambiences. Further studies using this approach should randomize the whole observers' sequences in which the models or spaces are seen to avoid those differences.

The observed effects of viewing order suggest the hypothesis that a real space could be more or less appreciated if the last observed space is in opposition or in harmony with this space, in line with the well-known architecture's concept of spatial sequences. Further studies should however use a complete randomized method to avoid those differences.

Finally, the other variables (group of age, field of study, cloudiness) did not have a significant impact on the results. However, the sample was not diversified, consisting of a majority of young students in architecture. A previous study (Poirier *et al.* 2016) showed remarkable changes in interior ambience hues depending on the hour of the day and cloudiness. The research hypothesis therefore stated that appreciation results should be different depending on the cloudiness experienced by the participants. For most questions, the cloudiness variable had no effects on the participants' answers. Nevertheless, for the "color" visual satisfaction factor, a significant change was observed for the variable, regardless of the model. Hence, the hypothesis was met because cloudiness had some impact on color perception.

Limitations of the Research

The research offers rich and wide arrays of possible interpretations related to the use of wood material and finishes in architectural spaces. However, the research could be refined in many ways. Probably the most important limitation relates to the sample (80 respondents), mostly composed of young architecture students who have a particular way of perceiving the environment. Further studies should use respondents from a more diverse corps of participants in terms of age, occupation and possibly other factors such as geographical origins (rural or urban area) and socio-professional categorization. The explorative questionnaire developed by the searchers needed sophisticated statistical analyses, and it could be simplified by removing certain questions. Moreover, a test measuring the current respondent's well-being, mood, or state of mind before taking the test could have been added, but it was not felt necessary because of the nature of the sample. The use of both qualitative and quantitative questions was challenging in terms of interpretations, but surely added a level of comprehension in the respondents' answers.

Scale models were built with professional wood finishes at a relatively large scale (1:10) to offer realistic viewing of indoor environments, but some limitations arise in terms of space variations. The study evaluated five different wooden environments in a south-east orientation during the spring equinox. Further studies could vary the interior ambiences in terms of finishes and materiality as well as building orientation and light diversity to cover more diverse environmental conditions. Furthermore, the study could suggest a potential activity instead of keeping the spaces empty: models could, for instance, contain furniture and aim to compare types of visual tasks. However, results would not be as generalizable in terms of building inhabitation and architectural applications.

The use of scale models helped observers to experience a space with real light and ambience. However, if many visual perception concepts could be evaluated, it has been difficult to measure the actual respondent's well-being because they remained observers. Therefore, responses gathered in the study were actually measuring expectations in terms of potential inhabitation of the spaces. Further studies could also evaluate the respondents' perception in real environments that could also evaluate other senses, such as touch and odor analyses.

CONCLUSIONS

1. This research contributes to the knowledge related to the impact of selecting different wood finishes on human perception and evaluation of the built environment. This research clearly shows that space evaluation is greatly affected by the general ambience as well as the interior surfaces.

2. Participants showed remarkably different levels of appreciation for each scale model. Warm, bright, and clear spaces can enhance inhabitants' concentration and cognitive tasks, whereas dark and contrasted spaces can considerably reduce the inhabitants' comfort and psychological well-being.
3. Men and women tend to differently perceive and appreciate spaces, while the order in which spaces are experienced tend to affect the overall participants' visual satisfaction.
4. Human perception and appreciation of a space may depend on many factors, such as users' experience, personality, and personal tastes. Hence, colors and finishes of wood surfaces should be chosen carefully by architects and designers. They should furthermore be adapted to visual task or activities that will be experienced in a given space.

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