Identifying preferred surface, colour and lighting characteristics

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The challenge designers and architects face today is a rapidly increasing amount of lighting options and material choices. Hence to identify preferred characteristics of materials and lights is becoming a matter of an educated guess, than an intuitive decision. New tools can support this decision process. To consider light and surface characteristics in one integral approach is the essential feature of the method described in this paper. The use of two psychological dimensions to categorise visual appearance is efficient as it is suited to analysing existing spaces and for testing anticipated conditions. With the axes soft–hard and warm–cool it is possible to describe the impact of surfaces, colours and lighting on visual perception, but also on the appearance of whole scenes and interiors. The desired reduction of design options can thus be realised by combined consideration of design requirements, physical restrictions and the localisation of perceptions in a semantic space.

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Introduction

Light is a fundamental part of our daily lives. Although it is immaterial and we are often not conscious about aspects of its presence, light influences behaviour in several ways. By falling on objects and the surrounding environment, light interacts with surfaces and affects how a scene visually appears. The image derived from what the audience sees very much shapes the expectations the audience will have about a space and hence influence their actions. The world around us consists of objects that relate to each other in specific ways. Architects and designers create a masterplan of how the built environment unfolds in front of our eyes. They seek to control expectations through manipulation of, for example, building shape, spatial layout, room size, material choice and colour. Appearance science clearly points out that lighting is, among other things, another factor that affects our interpretation of a perceived object or scene. The frameworks of total appearance by CIE [1], image scales by Kobayashi [2] and suggested measures of design impact by Hutchings and Luo [3] are concepts that are utilised to link physical parameters to psychophysical descriptions and ultimately to the feelings or expectations that are derived from the observed object or scene.

In practice decisions about surfaces, colours and lighting depend strongly on the anticipated total appearance. As part of the design and planning work desired impact and psychological reactions are defined first. Once there is a clear view established, actions are taken to give spatial ideas shape. This process is much about breaking down the desired spatial experience in elements that have specific quality traits embodied. With the aim to facilitate a successful decision process about surfaces, colours and lighting the author described previously [4] a two dimensional system to characterise visual appearance along the axes soft–hard and warm–cool. Whereas this model has been applied to analyse appearance of interior scenes [5] and material surfaces [6], it offers a remarkable potential to narrow down the amount of choices for building elements that can fit a specific design idea. This paper presents a tool to reach well-argued and empirically grounded design decisions. Hence it provides interior designers, architects and other planning professionals the opportunity to identify and name preferred perceptions, associations and emotions in more precise ways.

Identifying preferred appearance

The perceived characteristics of materials and colours vary under different lighting conditions. Showcases featuring selections of materials under variable lighting conditions (Figure 1) have proven very successful to identify preferred combinations.

Figure 1: Material wall illuminated with fluorescent down-lights, halogen up-lights and a combination of fluorescent down-lights and halogen spots.

Typical for such an approach is a proximate visual evaluation that is used to filter what will best match the anticipated design. The tangible presentation in front of your eyes opens opportunities for discussion and invites judgements why one combination is a better fit than another. Empirical data about reasons why certain colours match better with cool or warm lighting are given later in this paper.

The observation that visual appearance varies with different lighting initiated a search for descriptors that can systematically characterise perceptions. A two dimensional diagram with the axes warm–cool and hard–soft that Hutchings and Luo [3] suggested for mapping elements of illumination had before been used for colour applications and for elements of the built environment like chairs [2]. Recent results about colour perceptions have confirmed the logic behind this arrangement by proving that the hard–soft category is independent of the chromatic dimension while the warm–cool category depends strongly on hue [7].

Whereas LED based lights today can provide warm light or cool light and have characteristics of collimated light or diffuse light, traditional light sources had more distinct characteristics. Typical for fluorescent tubes is that they emit diffuse light, which is in general described as soft light. In contrast halogen and high intensity discharge lamps often have small light emitting areas, which in turn enable optics to focus light. The visible effect is that such light generates strong shadows, which commonly leads to the interpretation of hard appearance. Furthermore, halogen or incandescent sources exemplify warm light better than any other light source. By dimming these sources, their warmish light gets even more reddish hence warmer. This effect is very iconic. Today there can be LED sources found that mimic this characteristic.

Lighting in a scene can either be described on the basis of physical characteristics (amount of light), human perceptual or psychological dimension (perceived brightness) or its impact on the audience (attract gaze). Representing visual appearance in semantic space is not only of analytic interest, but can also be used to link physical characteristics to perceptual dimensions. (Figure 2).

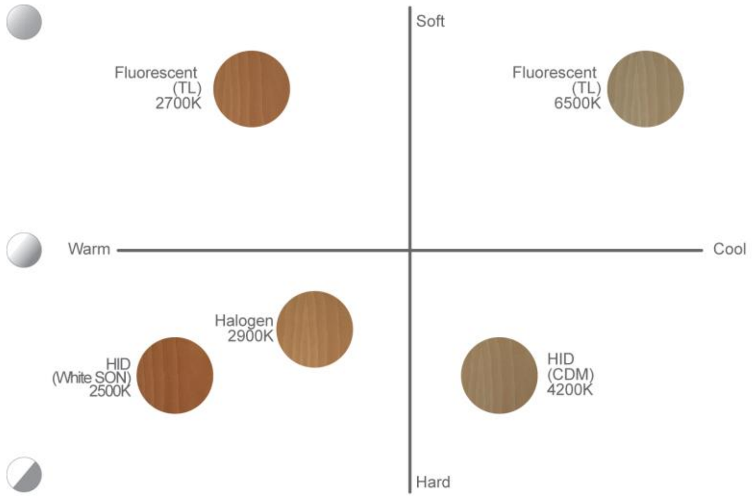

Figure 2: Characterisation of the appearance of differently illuminated wood samples in semantic space. Kobayashi's two dimensional diagram with the axes warm–cool (horizontal) and hard–soft (vertical) that Hutchings and Luo suggests using for mapping elements of illumination, and Frandsen's 'scale of shadows' (left) representing lit and shaded parts of a sphere.

What makes the two axes warm–cool and hard–soft a convenient choice is that both are universally applicable to characterise lighting, surfaces, objects or whole interiors. For lighting neither warm (cool) nor hard (soft) impressions translate straight to a sensory input of this kind. Both dimensions actually belong to the realm of contact stimuli [8]. Temperature is perceived via skin or via touching a surface. Hardness, roughness and softness are perceived via active touch. Due to the immaterial existence of light there can't be any physical parameter of lighting that directly correlates to the touch sensation. The physical parameter that aligns best with the warm–cool axis is the correlated colour temperature (CCT). Given in Kelvin the CCT is a measure of the reddish and bluish light components. Daylight has a higher CCT than light from a halogen bulb; we perceive it as being more bluish. The correlated colour temperature can only be determined for achromatic light. Concerning chromatic light there are a few greenish and purplish hues, which are perceived as neither warm nor cool. Other hues that contain red are in general perceived as warm, those that contain blue are in general perceived as cool. In terms of lighting the axis hard–soft correlates to shadow pattern. Situations featuring strong shading and clear-cut cast shadows are generally perceived as hard. Very diffuse lighting, which eliminates all shadows, is commonly characterised as soft. The 'scale of shadows' by Frandsen [9] is a quantitative measure for diffuseness of light. It uses the distinctness of the zone between the directly lit part and the shaded part of a sphere as a criterion. An alternative measure to indicate shadow characteristics is the vector to scalar ratio describing the flow of light [10]. An additional measure that could be projected on the axis soft–hard is the highlight contrast potential as indicator of the sharpness of lighting [11]. In summary more distinct shadow or highlight patterns provide strong contrasts, which in turn, evoke a hard impression of the scene.

Using comparative observations to characterise appearance of material samples

The following section describes in detail the appearance of some material samples under selected light conditions. All material samples are depicted from the material wall shown in Figure 1. Firstly appearance of three samples—a stainless steel plate, a wooden tile with inlays and a plush textile—under light from fluorescent tubes and halogen lamps are compared to each other. Measured luminance profiles are given to enable interactions between light and surface to be traced. Luminance measurements were done using a LMK Mobile Rollei d30flex (Techno Team Bildverarbeitung GmbH, Ilmenau). For the first two materials illumination with small halogen sources creates a harder impression, whilst in the case of the plush textile the situation is somewhat ambiguous. The halogen up-lights create a stronger contrast and therefore emphasise the irregular and intrinsically soft appearance. Under diffuse fluorescent light the material looks flatter and more uniform, which could be interpreted as being harder (Figure 3).

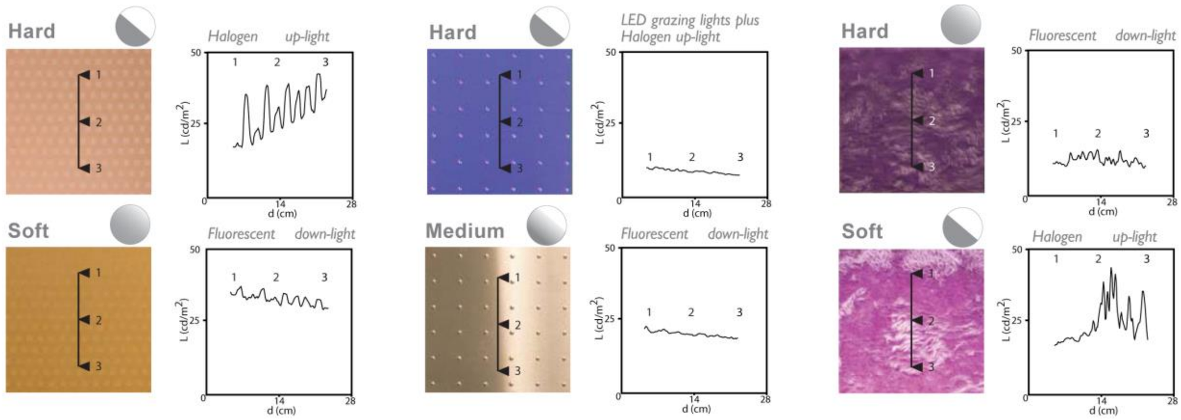

Figure 3: Photographs and measured luminance profiles for three samples lit by fluorescent and halogen sources. The numbers describe three positions along the measured profiles. The disk symbol indicates light diffuseness.

In order to illustrate more possible types of interaction between light and material, three additional case studies are presented. These examples demonstrate interpretations caused by the way light reflects off the material. The three topics studied include perceived depth of materials, manufactured versus natural material, and thread direction of material. Again, luminance graphs are used to illustrate the light interaction on the material surface.

The first case study features corrugated aluminium illuminated by fluorescent down-lights, halogen up-lights, and a combination of blue LEDs grazing right, red LEDs grazing left and halogen up-lights (Figure 4). The interaction of the fluorescent light on the material is soft. Light shadowing can be depicted on the underside of the waves. As shown in the graph, the variance in luminance is smooth and the material is therefore perceived as being rather shallow. The interaction of the halogen light from below on the corrugated aluminium is relatively harsh. Shadowing can be depicted on the upside of the waves. The graph shows that the variance in luminance is sharp, and the material is therefore perceived as having depth.

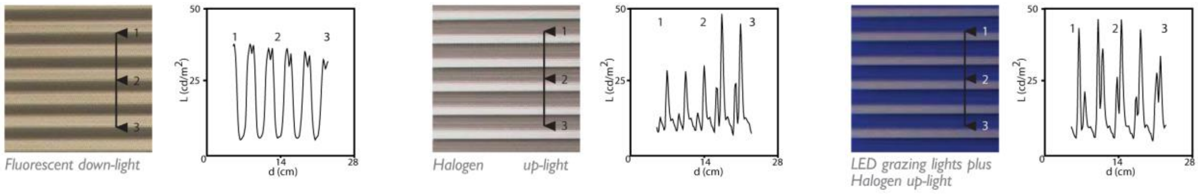

Figure 4: Photographs and measured luminance profiles for the corrugated aluminium sample under three different light conditions.

The second case study concerns the difference between manufactured and naturally grown materials. It is observed that the interaction of light upon material varies according to the materials natural or manufactured qualities. Under a fluorescent down-light the three material examples shown are aluminium, painted board and beech timber (Figure 5).

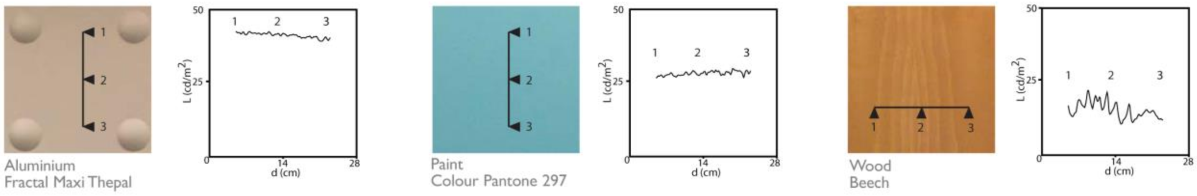

Figure 5: Photographs and measured luminance profiles for three samples lit by fluorescent lights.

This manufactured aluminium has a predominately smooth surface. Due to the manufactured nature of the aluminium, the luminance is practically unchanged across the centre of the panel because the surface is uniform. This painted sample has a smooth surface. Due to the painted nature of the panel the luminance is almost constant across the panel because the surface is uniform. This material could be said to have a semi-specular gloss, as very slight variances do occur in its luminance. This beech material has a smooth surface but there are natural highlights. Due to the organic nature of the beech, the luminance is variable across the centre. The graph depicts these organic features of the material that are accentuated by the light source. This material could be described as being diffuse and variances do occur in its luminance.

A strong visual effect was observed in the third case study. Depending on the light direction and the direction of material thread, the appearance of a material can become ambiguous. Under a light scenario of halogen up-lights and two types of grazing lights, alternate rotation of a Vescom Ontario material was analysed (Figure 6).

Figure 6: Photographs and measured luminance profiles for the differently oriented material samples.

As can be seen from this graph, the interaction of light on the identical surfaces varies considerably according to the direction of the material thread. The horizontal panel presents a more extreme luminance range due to the light being projected perpendicular to the thread, whereas the vertical panel's thread is parallel with this light and the interaction is therefore milder. As a result, for most observers the materials appeared to be different because the visual patterns perceived from a distance differed greatly.

Evidences from empirical research

Light emitting diodes are quickly replacing other light sources. The available range of LEDs in the market spans easily from very warm (2500K) to cool (6500K). In addition industry provides products with different spectral power distributions to fit, for example, bakery products or fashion shops. In comparison to fluorescent light sources LEDs have proven to evoke more natural and more preferred appearance of objects and coloured surfaces [12]. Empirical studies involving interior design students have demonstrated that preference for warmer or cooler light depends on the hue of the surface examined [6, 13]. These experiments demonstrated that LED lighting with a warm CCT of 3000K is generally preferred for reddish hues. Light with a CCT of 4000K fosters a cooler visual impression and is therefore a better choice for bluish hues. These findings correspond well to what experienced lighting designers advice. Of specific interest for the design and planning practice are the results why one light condition is preferred and the other not. To reveal underlying motivation explanations given by nineteen architecture students have been analysed. Five clusters of reasons why either warm or cool LED lighting is preferred were identified. Table 1 is translated from German [14] and lists all categories, with examples of expressions used and an indication how frequently they are named.

Category	**Example of an expression**	**Frequency distribution**
Colour impression	'Looks extra red'	28%
Material surface	'Relief more clear'	23%
Reference	'Looks more natural'	21%
Sensual association	'Very soft'	18%
Affect	'Appears more friendly'	10%

Table 1: Reasons to explain preference for cooler or warmer illuminated material samples.

The semantic space defined by the axes warm–cool and hard–soft can be utilised to analyse and characterise appearance, but it can also be utilised as tool to extract promising design options. The diagram then acts as a catalyst in finding a suitable solution. Figure 7 illustrates the usage of semantic space to reduce design options and guide towards a solution. The data presented in the Figure 7 is derived from evaluations of twenty materials used in interiors. All were illuminated by four different types of spotlights [6]. Two materials, blue flagstone and staghorn sumac wood, do appear twice in the diagram. For situations that ask for a hard visual appearance spotlights with high intensity discharge lamp (HID) are best suited. For a softer visual impression an LED spotlight is a better choice. The specific types of LED spotlights used in the experiment featured tuneable colour characteristics. By using such a fixture it is possible to change the correlated colour temperature of the emitted light and therewith shift appearance towards the right (cooler) or left (warmer).

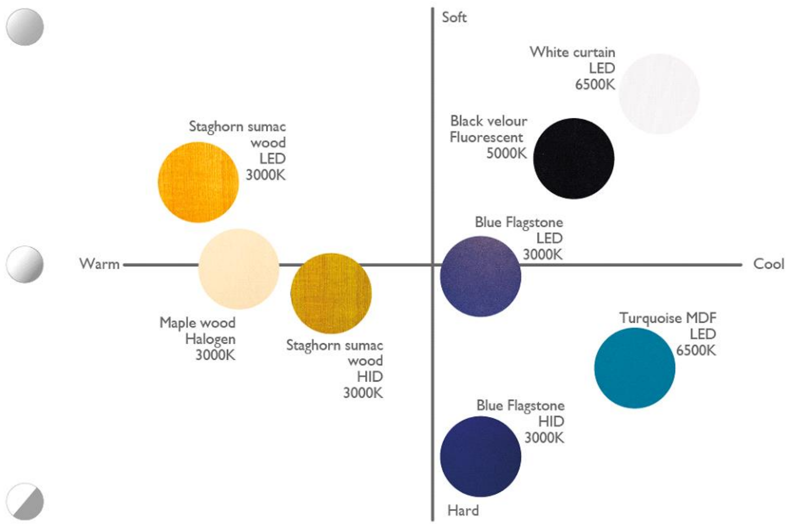

Figure 7: Results of the experimental evolution of selected material-light combinations mapped on the semantic space.

In comparison to LED and halogen lamps the spectrum of a HID lamp contains less reddish light. Therefore it cannot be recommended for use in combination with staghorn sumac wood. From its position at the lower region of the semantic space we can tell that a glossy turquoise material will appear considerable harder as for example a black velour material. For black velour and turquoise coloured medium-density fibreboard (MDF) preference ratings do not provide a specific advice. Hence, we may expect that cool and warm lighting is accepted. This is different for the white curtain, if a curtain is supposed to appear brightly and clean, than light with a higher correlated colour temperature is to prefer.

In general we might think that a material group like wood will be favoured in similar light conditions. But some explorative evaluations indicated that from eight tested wood types not all are preferred to be seen in warm light. Robinia wood for example was very well received when lit by neutral (4000K) lighting [13]. This example illustrates that for anisotropic materials measuring spectral reflection characteristics is by far not sufficient to predict what type of light would suit best.

Conclusions

Appearance research assesses the visually perceived properties of materials in different categories, such as surface texture, colours, gloss and translucency. Although all these categories help to distinguish materials, for design relevant decisions isolated considerations will not accomplish the goal. Best advice is to consider appearance in a holistic manner and bundle decisions for surfaces, colours and lighting. Quantification of total appearance in semantic space can increase accuracy of the predictions during the design process and enables all parties involved to communicate more clearly. Usage of the psychological axes warm–cool and hard–soft provides all benefits of a well understood and proven system.

Whereas traditional light sources had very typical intrinsic characteristics, LEDs today can be manufactured to fit a large range of requirements. Together with an ever increasing choice of materials there are needs evident to back-up intuitive design decisions for colours, lighting and surfaces by well-grounded argumentation.

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