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Assessing gloss under diffuse and specular lighting

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Abstract

The visual sensation of gloss is built on cues deduced from the interaction between light, surfaces sunder evaluation, and surrounding conditions. Gloss is a second-order attribute of the visual appearance, this means that its perception is not directly encoded on biological sensors but constructed from the global scene in the field of view of the observer. It is then a complex quantity to measure. When most studies based on simulated samples stress on the importance of realistic observation conditions, we measure the effect of environment complexity over perception of real samples. We test two different lighting conditions: either diffuse or a combination of diffuse and collimated lighting in order to approach natural complex illumination patterns. Under both lighting conditions, we test two environments: a standard black light booth, designed according to the ASTM D4449, and a realistic office cubicle. Samples consist in a seven-level gloss scale ranging from full matt to high gloss. These are presented to observers through pair comparison protocol, according to a maximum likelihood difference scaling algorithm. Our results confirm that gloss constancy is maintained even if the convergence of illumination varies. We however measure that the constancy is lost for matt samples perception.

KEYWORDS
diffuse lighting, environmental effect, MLDS, specular lighting, visual gloss

1 | INTRODUCTION

1.1 | General considerations on gloss

Gloss is a second-order attribute of the visual appearance. This means that its perception is not directly encoded on biological sensors but constructed from the global scene in the field of view of the observer. First definitions of gloss were derived from the early works synthesised by Hunter and Harold.[1] The main impact of these studies was the segmentation of a complex perceptual quantity into different classes. Each class led to the development of an associated measurement standard. The most famous of these would be the specular gloss index measured at 60°[2] provided by the glossmeter as a physical descriptor of visual gloss and widely used in the industry (automotive, luxury goods, pulp and paper, plastics and packaging). However, present gloss index measurements cannot describe the full extent of visual gloss. These are unidimensional and nonlinear with respect to the sensation.[3,4] Moreover, the concept of visual gloss has evolved since the 1940s: from a physical definition anchored to the quantity of light reflected in key configurations, it is now described as a perceptual *gestalt*, that is, to say a global appraisal of a whole scene.[5] A proper way to study this gestalt would be to consider the three elements in which gloss originates: the illumination, the sample, and the observer. Illumination and samples do have a physical interaction, following optical reflection laws while illumination and observer or sample and observer have a psychophysical interaction, based on a broader subjective context.

2 | EFFECTS OF THE ILLUMINATION

In 1993, Sève described the change in the glossy appearance of a material related with a change of solid angle of illumination. He noticed that parts that were seen as glossy under real-life illumination were perceived as matt under diffuse lighting.[6] From the remark that an object is seldom observed under laboratory conditions, with a point-shaped immobile lightsource, Fleming and his colleagues let to the description of realistic illumination maps for visual evaluation. They showed that gloss judgments made by observers were facilitated under such realistic maps.[7] They later inferred that we could be using a subjective knowledge of the statistical properties of illumination to suppress unlikely configurations.[8] Leloup et al tested the joint effect of both specular and diffuse illumination over the visual gloss sensation.[9] They showed that perceived gloss was depending on the luminance distribution of the observed scene. For real samples of similar specular gloss and distinctness-of-image gloss (DOI), the observed contrast between the reflected image and its surroundings changes the perception of the sample. In a recent study on real samples, Van Assen and his colleagues proposed two hypotheses emphasizing the importance of illumination realism.[10] The first one is that part of our cognitive appraisal of gloss is built on acquired competencies. The second one is that the visual system could rely on common objects whose deformations can be detected in the observation environment. They also reported a decrease in perceived gloss under realistic illumination. In a complementary experiment, Leloup and colleagues investigated the effect of the level of illumination over the gloss perception of glass and paper samples.[11] They confirmed that their observers used two choice criteria, namely, DOI vs contrast gloss in the evaluations. Obein and colleagues, basing their study on psychophysical measurements at 20° or 60° geometries, demonstrated that when samples are observed in the specular direction, gloss sensation is identical whatever the illumination direction. From this property, they proposed the "gloss constancy" stating that gloss could be described as an intrinsic property of a sample.[4] Ji and colleagues confirmed Obein's results and reported a linear relation between the gloss perception and the difference in luminance factors (specular included minus specular excluded- hence the diffuse part of reflection) from their samples.[3]

2.1 | Effects of the observation

In 2003, Ng and his colleagues demonstrated that in the domain between 10 gloss unit (or GU) and 60 GU of 60° specular gloss, the gloss perception was following Weber-Fechner law, stating a power relation between sensation and stimulation.[12] Gloss is a multidimensional quantity. The first authors to look for gloss dimensions were Billmeyer and O'Donnell.[13] In a similar way, Sève shows that two paper samples of same specular gloss but distinct specular peak shapes can be appreciated differently whether observers base their evaluation on the peak intensity or width.[6] In 2001, in a study based on simulated samples, Ferwerda and colleagues[14] proposed two dimensions for gloss, respectively, linked to contrast gloss and DOI. In a study based on real artefacts, Ged and colleagues found three dimensions to visual gloss. The first one was attributed to specular gloss, the second one to the opposition between DOI and haze and the last one to the nature of the type of roughness present on the artefacts.[15]

Gloss perception can also be described using imagery treatment techniques. Through simulated samples, Nishida and colleagues suggested that the retrieval of the gloss information by the visual system could be associated with the asymmetry of the pixel luminance distribution of their stimuli.[16] Arguing that luminance distributions do not bear structural information concerning the lightsource, Anderson and Kim suggest that the visual system could be treating distinct information such as the consistencies between the geometrical structure of the surface and its reflected luminance extrema.[17] Marlow and the same authors describe the visual system as able to distinguish plausible glossy reflections from improbable ones.[18] They later stress on the importance of specular lowlights as a possible cue for establishing the visual sensation.[19] Consequently, rather than describing raw reflected image statistics, the notion of specular contour, based on perceived luminance gradients is now emerging.[20]

2.2 | Effects of the sample

The gloss sensation is built on cues created by the interaction between light and object's surface. These clues could be, at least partially, embedded in the specular peak region. Consequently, altering the surface would impact the specular peak shape and the gloss of the sample. Considering curved samples, Koenderink and Van Doorn proposed a model of combined parabolic isophote curves.[21] They establish the concept of an invariant isophote, independent of both directions of illumination and reflection. Beck and Prazdny showed that when glossy reflects are applied on vase image, its curvature increases its perceived gloss.[22] More recently, Fleming Torralba and Adelson investigated the effect of specular reflects on the detection of the shape of objects. The compression and the dilatation of specular reflects both follow the curvature of the surface.[23] In 2008, Ho and colleagues[24] studied joint interactions of bumpiness and specular behavior of sample simulated with the Ward model.[25] They find that the interaction of these two properties can be described as a simple additive contamination of each by the other. Qi and colleagues later add to this study the notion of mesoscale roughness. They propose a model in which interactions between roughness and perceived specularity are nonlinear.[26] Regarding the effects of texture on gloss perception, we also have to refer to the works from Kim and colleagues.[27] They demonstrate a sensitivity of the visual system to constraints on the structure of orientation fields generated by diffuse shading and pigmentation. In Ged and colleagues study, the type of roughness was discriminated by observers that were solely asked to evaluate gloss[15] thus implying that the sample roughness geometry would impact the gloss perception.

2.3 | Objectives

Building on the previous mentioned works, our objective is to quantify the effect of both the nature of illumination and surrounding conditions on gloss sensation. We aim to test up to where the concept of gloss constancy is valid according to the gloss level in these different conditions. To achieve this objective, a unidimensional gloss scale has been used. Observations were done on real samples, in real environment. Two types of illuminations, that is, specular and diffuse, and two types of environment, simple and complex, have been used. It gives four illuminations covering extreme cases that can be found in real life. Psychometric scales are established through a maximum likelihood difference scaling (MLDS) method[28] in order to provide values with associated uncertainty. The work is reported in 3 sections. First section reports on the effect of the lighting on gloss perception in simple environment. Second section reports on the effect of the lighting on gloss perception in a complex environment. Last section is the discussion.

3 | EXPERIMENT 1: GLOSS PERCEPTION ACCORDING TO DIFFUSE AND SPECULAR LIGHTING IN A STANDARD LIGHTBOOTH

3.1 | Protocol

3.1.1 | Pairs comparisons

We use a comparison of pairs protocol. It implies that samples are to be presented by quadruples. We consequently built planks able to hold 4 samples. These holders are made from gray plastic, samples are manually placed in it, a pair above the other. The spacing between each sample is less than 1 mm. Each pair is identified by a color on the plank (yellow or green). Original coated paper samples were cut to reach a size of 70 mm by 50 mm and glued to a 4 mm-thick flat plastic plate. The total number of nonoverlapping quadruples to be tested in the case of a seven-level scale is 35. To compensate for observer's learning and fatigue effects, the order of presentation of quadruples is scrambled for each observer. The position of a pair on the plank (yellow/green) as well as its location inside the pair (left/right) are randomized.

Because of gloss constancy, we think that it is not necessary to impose illumination and observation angles. It is more comfortable in both configurations to let the observer hold sample planks in their hands. He/she is moreover encouraged to orientate them in various directions before stating his/her gloss judgment. This mode of presentation ensures that they can exhaustively analyze the specular peak region under different viewing angles.

3.1.2 | Training

Before the first experiment, observers must go through training. This stage consists in evaluating key quadruples, extremal stimuli of our experiments, in different order. They were presented with the following question:

"Which of these two pairs exhibits the highest difference between its constituting samples?"

As the samples we use only differ by gloss, we chose to remove this word from the paradigm rather than confusing observers with discussions of mattness vs glossiness.

3.2 | Samples

The coated paper samples we use are from a commercial gloss scale developed by NCS company. In this scale, perceived surface gloss is expressed through seven gloss levels ranging from full matt to high gloss. The specular gloss at 60° of each sample was measured by the manufacturer according to ISO 2813[2] and are reported in Table 1. We arbitrarily chose to use the medium gray scale (NCS S5000-N) in order to avoid extremal reflective behavior of black samples, whose reflection has a minimal diffuse component or white samples, where this component is at its maximum.

3.3 | Observers

Twenty-nine observers, 14 men and 15 women, took part in our experiments. They are all between 18 and 42 years old. All of them have normal or corrected to normal vision and are naïve with respect to the experimental objectives. On their first participation, subjects undergo an interview aimed at establishing whether their vision is normal or corrected to normal. They are also screened for colour vision using the D16 Farnworth-Munsell test.

3.4 | Data processing: MLDS

We used a MLDS algorithm based on generalized model (GLM) as proposed by Knoblauch and Maloney.[29] To apply this method, we chose to use the MLDS library version 0.4.5 in R© developed by Ken Knoblauch. This library also implements the calculation of estimated SD of the obtained psychometric values, through bootstrapping methods. Practically, the probabilities of response associated with each quadruple are calculated based on real answers of observers. Other responses following these probabilities are randomly generated according to a binomial law. These new answers are analyzed through MLDS algorithm. An average value and a SD are calculated for all resampled data and respectively considered as estimators of the mean value and associated uncertainty of the real observation properties.

3.5 | Experimental setup

3.5.1 | Lightbooth illumination

A modular light-booth is adapted for this experiment. The cabinet is a cubic volume of 1 m^3. It is rigged with two different light sources, diffuse and collimated as shown on Figure 1. We use either the diffuse or a combination of both collimated and diffuse sources in our experiments.

Diffuse

The light source consists of six D65 fluorescent tubes of colour temperature 6500 K. These are placed behind two diffusers (a frosted diamond glass plate and a PMMA sheet, both 6 mm thick). Above the fluorescent tubes, a reflective coating is used to send the light back into the cabinet. Under the last diffuser, we place a rectangular mesh of characteristic length 50 mm, intended to help the observer in its evaluation. We used "Osram HO24W/965 Lumilux de luxe" T5 fluorescent tubes, dimmable and driven by an electronic controller Osram Qti2*14/24DIM. The colour rendering index (CRI) of such light source was given to be superior to 90 by the manufacturer. We controlled the illuminance of this configuration with a Hagner E2 luxmeter. We adjust an average value of 1600 lx over ten measurement points in the working area of the light booth. The homogeneity of ±86.5 lx is not perfect, mainly because of the interreflections between the walls of the booth. The maximum is at the middle, the lowest values are in the corners. The gradient is below

TABLE 1 NCS S5000-N sample scale optical properties.

Sample name	Description	Gloss index 60° (GU)	SD (GU)	Normalized luminous reflection factor specular excluded (SPEX)	Normalized luminous reflection factor specular included (SPIN)
NCS1	Full matt	1.8	0.1	1.000	1.000
NCS2	Matt	9	0.3	**0.940**	0.993
NCS3	Semi-matt	11.5	0.4	**0.955**	0.989
NCS4	Satin matt	26.3	0.4	0.936	0.975
NCS5	Semi-glossy	44.1	1.2	0.903	0.974
NCS6	Glossy	71.2	1.7	0.837	0.970
NCS7	High gloss	93.5	0.2	0.814	0.956

Bold values enhance the inversion of samples regarding to descending order in flux.

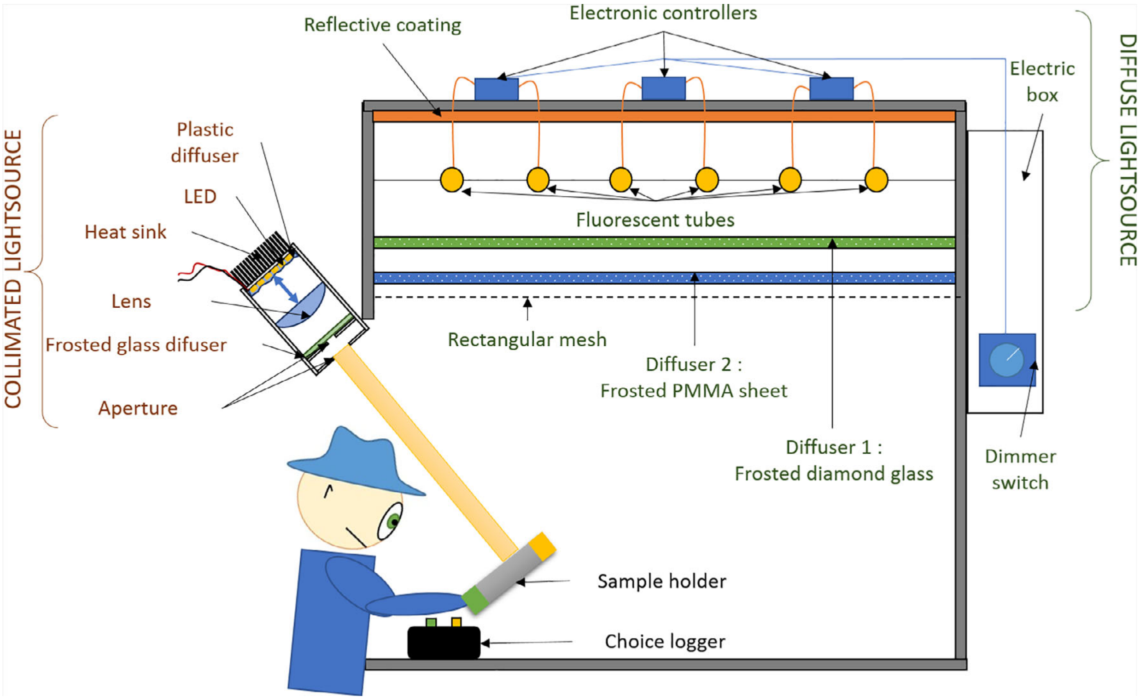

FIGURE 1 Lighting conditions in the lightbooth

200 lx m^{-1}. Using a Konica-Minolta CS-2000 spectroradiometer, we measure a colour temperature of 6685 K with a deviation to the blackbody locus of Duv = 0.05. We consider that in this configuration, at the sample location the observer evaluates the samples as if he/she was under a cloudy sky.

Combination of diffuse and collimated

In this configuration, we use a combination of diffuse and collimated light sources. The latter consists of a seven LEDs Luxeon CoolWhite 6500 K cluster with a CRI superior to 80 located at the focal point of a lens of focal length 18 mm. The beam goes through a frosted diamond glass diffuser and a series of apertures to obtain an angular aperture of the same magnitude as the angular size of the sun (circa 0.5°). We use the diffuse light from the fluorescent tubes to mimick the diffuse part of the sky light. We adjust the illuminance level under these conditions to 1600 lx. The level of inhomogeneity in the light booth is of ±96.5 lx because of the directional flux of the LED cluster. The spectroradiometer measurement indicate a color temperature of 6214 K with a deviation to the blackbody locus of Duv = 0.007. We consider that in this configuration, the observer assesses the samples as he/she would under a clear diffuse sky with a solar disc. The difference between the two lighting configurations in colour temperature can be explained by both the type of light sources (LED Light-Emitting Diode vs fluorescent tubes) and the transmittance of the diffusers used on the set-up (Polymethylmethacrylate (PMMA) and diamond glass). However, such a discrepancy is not critical as the observer performs the experiment on different days and thus does not perceive the colour changes between the diffuse and combined configurations. The illumination dynamic reached by this setup is consistent with natural illumination levels, slightly inferior to one decade. A cloudy sky produces an illumination of 15 000 lx when a sunny sky generates 100 000 lx. Our lightbooth illumination level is inferior but it is located in the middle of the photopic range. Rods are not activated and we believe that visual adaptation will put the observer in a similar state to the one he would be in outdoor illumination conditions. The spatial frequencies for both lighting conditions are consistent with diffuse sky behaviors and with the angular aperture of the sun. In this regard, the ratio of diffuse vs collimated illumination on the sample surface would be of the order of 1:10. We also acknowledge that the collimated illumination coverage is not the one of direct sunlight, this aperture of 0.5° is solely intended to produce a plausible image of the sun on the sample surface.

3.5.2 | Lightbooth environment: standard conditions

This environment is close to the one depicted in the ASTM standard.[30] The inside of the light booth is covered in black diffuse curtains. A mesh of 50 mm by 50 mm squares is placed underneath the diffusers in order to ease the discrimination of high gloss samples. A photograph of

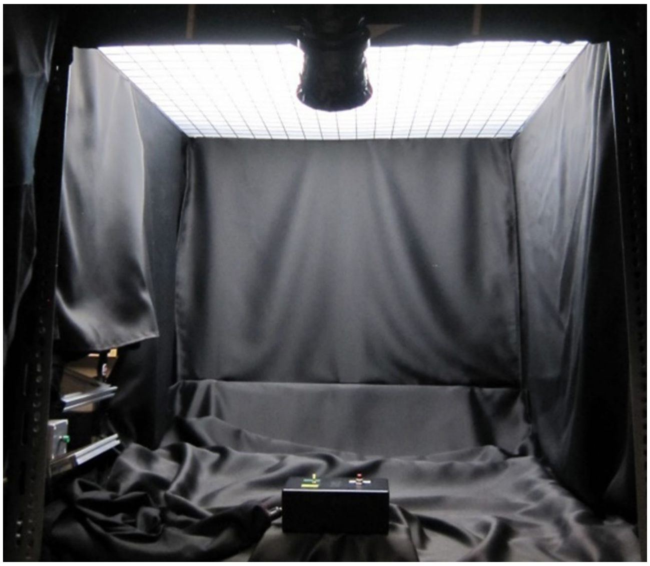

FIGURE 2 Standard black lightbooth environment for gloss evaluation

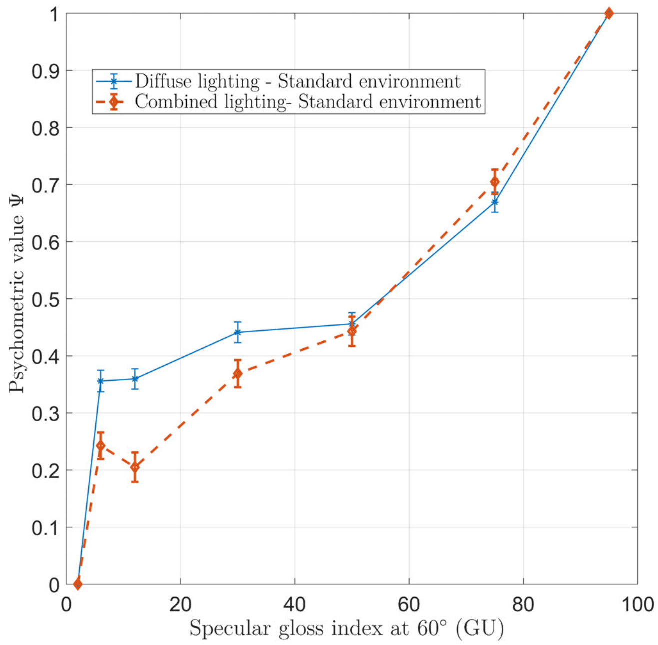

FIGURE 3 Psychometric scales according to gloss index obtained under two lighting conditions in a standard environment

the lightbooth interior in standard condition is shown in Figure 2.

3.6 | Results

From evaluations of sample quadruples by our 29 observers, we establish the psychometric scales for both lighting conditions (Figure 3). The determined scales are normalized and stretch between 0 and 1, respectively, attributed to NCS1 and NCS7. These scales are listed in Table 2. Our results agree with previous findings of the literature regarding the observer sensitivity to gloss:

- Regarding the global aspect of the scales produced under a complex lighting, we recognize the classical shape of gloss perception curves as they were measured by Hunter, Obein and Ji. The slopes of each segment between perceptive values are indicators of the global observer's sensitivity with respect to the 60° specular gloss index.
- For both lighting conditions, observers exhibit a higher sensitivity for very matt samples (<7 GU) and very glossy samples (>70 GU).
- For diffuse lighting, the observer has no sensitivity within the middle of the available gloss range between NCS2 and NCS5. From sample NCS5 to NCS7, he recovers his ability to evaluate gloss and confidently ranks the artefacts. In this task, he relies on the DOI gloss to build his gloss perception. The average estimator of the uncertainty associated with the measurement under diffuse lighting is 1.9%.
- In the case of the combined lighting, all the samples are easily discriminated by the global observer. The scale is roughly linear with the glossmeter values except for samples NCS2 and NCS3, which present an inversion of their psychometric values with respect to their 60° gloss index. The average estimator of the uncertainty associated with the measurement under combined lighting is 2.6%, slightly higher than under diffuse lighting.

In the case of diffuse lightings: NCS1 is alone at the bottom of the scale. It is clearly identified as the mattest of the seven artefacts. For this sample, observers claim to use two criteria in their judgments: hue and gloss. From a metrological point of view, all samples present the same hue. NCS1 because of its extreme mattness appears darker than all the other samples. This "perceived different hue" criterion is present only for this sample.

4 | EXPERIMENT 2: GLOSS PERCEPTION ACCORDING TO DIFFUSE AND SPECULAR LIGHTING IN A COMPLEX LIGHTBOOTH

4.1 | Method, protocol, and observers

Protocol, samples, and data processing were identical to the ones described in 1.1, 1.2, and 1.4. Twenty observers

TABLE 2 NCS S5000-N samples normalized psychometric scales under different lighting and environments

Sample name	Diff. light. std. env.	Assoc. uncertainty	Comb. light. std. env.	Assoc. uncertainty	Diff. light. real. env.	Assoc. uncertainty	Comb. light. real. env.	Assoc. uncertainty
NCS1	0.000		0.000		0.000		0.000	
NCS2	0.340	0.018	0.223	0.020	0.250	0.017	0.201	0.033
NCS3	0.347	0.018	0.214	0.025	0.314	0.018	0.121	0.042
NCS4	0.426	0, 018	0.363	0.022	0.407	0.019	0.335	0.034
NCS5	0.447	0.019	0.445	0.024	0.416	0.020	0.403	0.040
NCS6	0.661	0.018	0.696	0.020	0.651	0.018	0.673	0.031
NCS7	1.000		1.000		1.000		1.000	

took part to this experiment, 10 women and 10 men. All of them have normal or corrected to normal vision and are naïve with respect to the experiment problematic. On their first participation, observers undergo an interview aimed at establishing whether their vision is normal or corrected to normal. They are also screened for colour vision using the D16 Farnworth-Munsell test.

4.2 | Experimental setup: complex lightbooth

4.2.1 | Lightbooth illuminations

Experiment 2 relies on the exact same consecutive lighting conditions as in Experiment 1, described in 1.5.1.

4.2.2 | Lightbooth environment: realistic conditions

In this experiment, we change the lightbooth appearance to a more realistic one mimicking an office cubicle. The walls of the light booth are replaced by wooden planks covered by a wallpaper presenting repetitive geometric shapes. The base of the cabinet is covered with a white diffuse cloth and a colored desk blotter. We add basis classical elements that can be found in an office: bookshelves, pictures in frames, notes, stationery, plant, … We also paid attention to adding several kinds of materials in viewable range of the observer: wood, metal, plastic, and ceramic. This environment is represented in Figure 4.

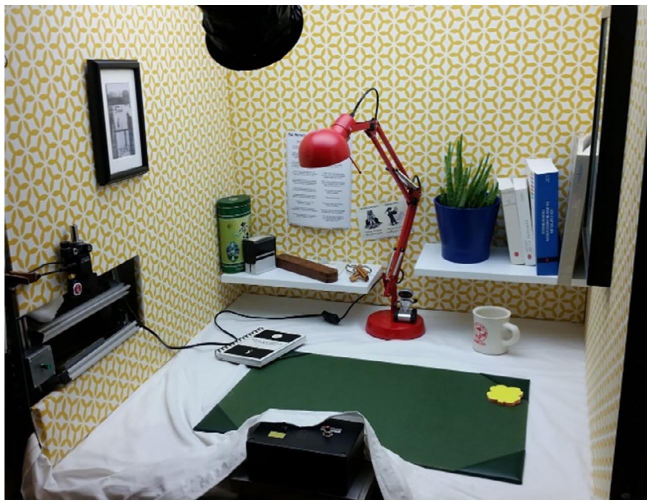

FIGURE 4 Realistic office environment for gloss evaluation

4.3 | Results

From evaluations of sample quadruples by 20 observers, we establish the normalized psychometric scales for both lighting conditions (Figure 5). We remark that the global aspect of the functions determined in a realistic environment is quite similar to the curves obtained in a standard lightbooth. In terms of uncertainty associated to the office-like environment, the estimated average value for both scales under diffuse and combined light source is of the same order of magnitude (as measured in experiment 1 circa 3% for combined lighting and below 2% for diffuse lighting). These scales are listed in Table 2.

The following significant differences were found under realistic environment:

- The inversion between NCS2 and NCS3 psychometric values under combined illumination is still present and exhibits a higher magnitude difference between the two samples.
- Samples NCS2 to NCS4 under diffuse illumination are now perceived as rankable by the observer, when they were not in the standard environment.

5 | GENERAL DISCUSSION

5.1 | Result comparison per lighting conditions

Graphs in Figure 6 represent the previously obtained psychometric values curves vs 60° gloss index plotted as function of the two lighting conditions under two environments. The psychometric scale determined in the office-like cubicle is quite similar to the scale determined in standard black light booth. The effect of the spatial distribution of illumination, described in the previous experiment is still valid in the office environment. For both lighting conditions, the psychometric scale determined in the black light booth exhibits higher values than the scale determined in the cubicle.

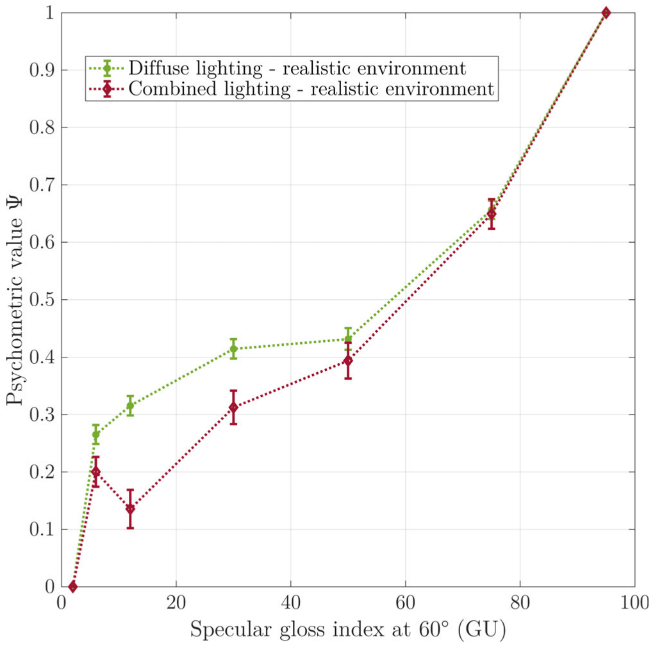

FIGURE 5 Psychometric scales according to gloss index obtained under two lighting conditions in a realistic environment

5.2 | Visual gloss and solid angle of illumination

The first point to acknowledge is that gloss perception varies with the solid angle of illumination. Obein has shown that the observer has the capacity to compensate the effect of the direction of illumination and keeps constant the gloss of the sample (Obein et al, 2004). We find on the one hand that gloss constancy is maintained when the convergence of illumination is modified. However, it is lost in standard environment. This effect is particularly significant for matt samples; the Weber-Fechner's law of perception described by Ng et al (2003) no longer stands. On the other hand, for glossy to high gloss samples, the sensitivity is not modified with the light source and the gloss constancy is maintained. These observations are partly in agreement with Sève's remark on the switch of appearance from glossy to matt (Sève, 1993).

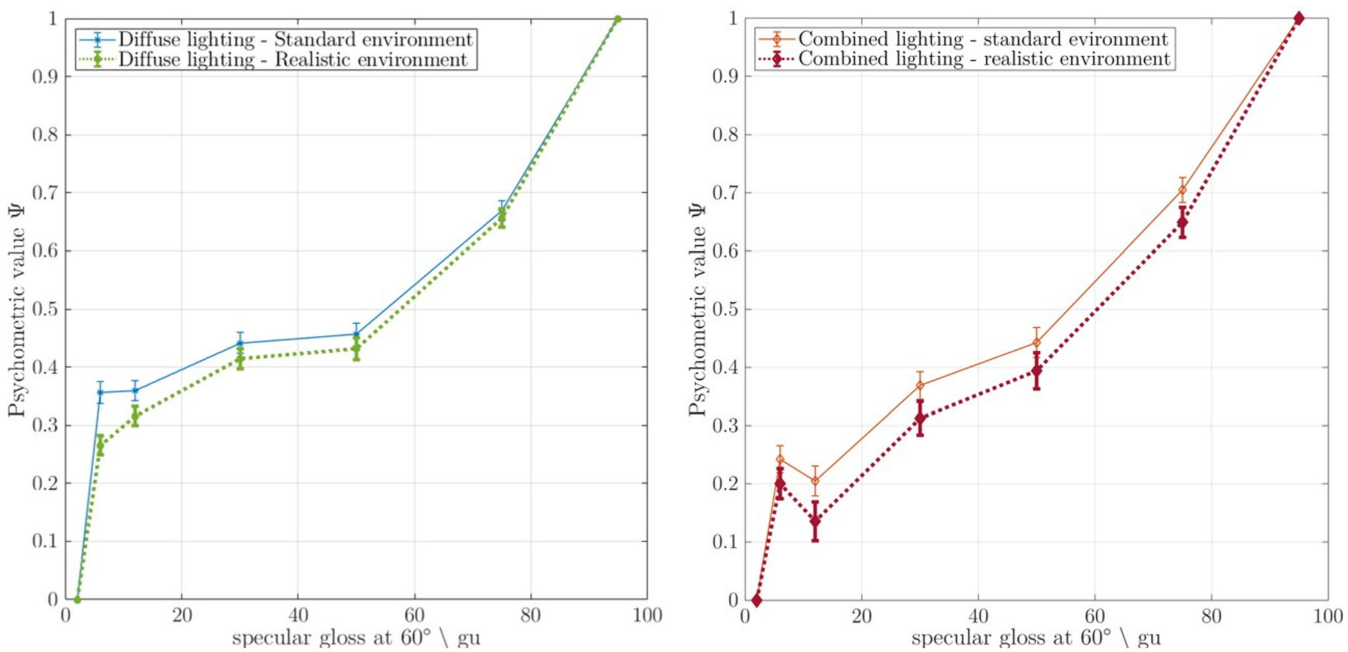

FIGURE 6 Psychometric scales according to gloss index obtained under two different environments presented per lighting conditions

In the case of matt surfaces, subjects declare that their judgments are based on the hue of the sample. However, NCS samples are all made of the same hue. Observers must then have used another criterion to build their choices. Such a cue could possibly be lightness. In order to get more insight on this point, we realized complimentary measurements. Spectral reflectance factors measured with specular peak included (SPIN) or excluded (SPEX) were determined using a commercial spectrophotometer Perkin Elmer Lambda 900. The measurement geometry is a standard configuration 8:d, which consists in illuminating the samples with a 8° incidence and to detect the reflected signal with an integrating sphere bearing a mobile aperture that allows to include or exclude the specular peak. The reflectance curves are measured spectrally in the visible range. These data, integrated over $V(\lambda)$ curve, are normalized to obtain luminous reflectance factors specular included or excluded. These last factors are presented per sample in Table 1.

SPIN factor is almost constant according to the gloss level. This is explained by the fact that the samples are all made from the same ink. SPEX factor decreases when specular gloss increases. It is also logical regarding the fact that the higher the specular peak, the lower the diffuse reflection. Subjects from our visual experiments might have used a criterion associated with diffuse reflection. This parameter is indeed almost constant in the case of cloudy sky lighting, because of the lack of a collimated light source. Matt samples cannot consequently be told apart. In the case of sunny clear sky lighting, this parameter is now variable and our results correlate with it and even predict the inversion of samples NCS2 and NCS3 when the glossmeter fails to do so. Such an inversion could come from the nature of the coated paper scale, which relies on the mixture of several layers of pigments and binding agents. Further investigation on the microscopic structure of these two samples may lead to a better understanding of the inversion.

In the case of glossy surfaces, the divergence of the light source has no effect. Gloss constancy prevails. It seems that the observer uses recognizable reflections on the samples' surface. From 50 GU, the observer manages to acquire clues regarding the light source, diffuse or combined. This analysis could be built on the study of the DOI of the reflected images of either the grid beneath the diffuser or the black curtains of the light booth. From this point, we have to wonder about the attributes of these two configurations that improve the gloss sensitivity of observers. We must stress on the fact that the major difference between the two lighting conditions is the presence on the samples of the image of the collimated source mimicking the sunny clear sky case. Such an image seems to play a part as a cognitive cue to establish the visual gloss sensation. In a recent study,[31] perceptual gloss scales produced in similar conditions in two facilities were compared. The cabinets were identical apart from a difference in the luminance ratio between diffuse and punctual light sources, which was 460 times more important in one setup according to the other. Despite this difference, the perceptual curves were overlapping in the case of the sunny clear sky configuration. Consequently, the ratio between diffuse and punctual light sources contribution might be less important than the presence of the reflected image to build the gloss perception. Our measurements indicate that a complex lighting reproducing a clear sunny sky clearly allows a better perception of the whole scale than a diffuse lighting imitating a cloudy sky.

5.3 | Visual gloss and environment realism

By comparing perceptual scales obtained in both an office environment and a standard environment, we investigated the effect of surrounding realism over gloss perception. The observation of the results determined in the office environment indicates that the global observer's sensitivity is the same for each segment apart from the last one (NCS6-NCS7) which is higher in the office configuration. Our scale being normalized, the NCS1 to NCS2 segment is smaller to compensate for the increase in sensitivity for high gloss. We hypothesize that without this normalization constraint, the two scales may be superimposed, apart from sample NCS7 which will present a higher perceptive value in the cubicle environment than in the standard environment, as depicted in Figure 7. Therefore, NCS7 value in realistic ambient can be higher than the value presented here. The office-like cubicle environment increases the dynamic range of the gloss perceptive scale.

This observation agrees with results described by Fleming et al. in the case of gloss judgments carried out under realistic lighting.[23] For Fleming, the dynamic was constant and constrained by the dynamic of the screen. Realism increased the resolution of gloss. In our case, the dynamic is not restricted because the environment is real. Realism then increases the dynamic range of gloss perception We also hypothesize that realism puts the observer at ease to realize the comparison task. Consequently, in the case of a diffuse lighting (Figure 6, left) he can grab cues in the environment to discriminate NCS2 and NCS3 a task that he/she did not manage to achieve in a black standard environment. The criterion remains the same as in the first experiment: from the inversion between samples NCS2 and NCS3, the observer is using

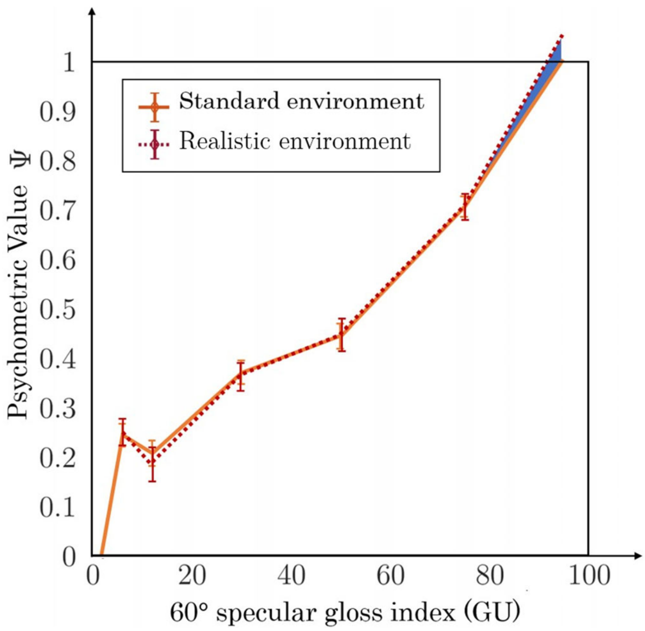

FIGURE 7 Transposition of the scale obtained in realistic office environment over the black light-booth standard environment scale. The scale is translated towards higher values. The increase in dynamic range is indicated in blue

an indicator linked with the diffuse reflectance. He/She however finds in his environment other clues that allow him/her to accomplish the gloss discrimination better. Could that clue be the colored reflects from the yellow walls? Is it the secondary reflections from the objects inside the light booth? We cannot answer these questions from our results. In these realistic conditions, the estimated uncertainty is paradoxically higher. This increased variability can be explained by the more complex nature of the data the visual system has to treat in such an environment. Our results are in a favor of gloss constancy as long as either environment or lighting are realistic. Under cloudy sky lighting, in the office-like cabinet, observers are able to recover the glossy appearance that was lost for matt samples in the black cabinet lit under the same conditions. The presence of multiple reflections, of reference materials inside the light booth possibly helped the observer to discriminate two matt samples difficult to differentiate otherwise. Many gloss classes coexist on a sample in realistic conditions; they can also be clues on which the observer could build his judgment. In this regard, the higher uncertainty obtained in a realistic environment could be an indicator of gloss multidimensionality.

6 | CONCLUSION

Our objective was to quantify the effect of the illumination on gloss perception and to test under what types of illumination conditions—varying the degree of convergence and the use of environmental clues—gloss constancy was valid. To answer to these concerns, we realized visual experiments in a dedicated light booth. We used two lighting conditions and two types of environment.

The first experiment was dedicated to testing the effect of the solid angle of lighting. It indicates that the perceptive scales are different when the type of light source used for the measurement is changed. In the case of a matt surface, observers could lay their judgment on a parameter similar to the SPEX diffuse reflectance. For intermediary samples (above 50 GU), they could be using DOI as ranking criterion. The second experiment was dealing with the effect of environment realism over visual gloss scale. This experiment confirms the result of the first one and indicates an increase in the visual gloss dynamic. This effect is particularly sensitive in the realistic environment, opposed to the black standard one. This increase in dynamic could be explained by the presence in the realistic environment of supplementary clues that the visual system can interpret. The use of realistic environment of evaluation, lit by a combination of diffuse and specular sources should be encouraged. The GLM MLDS is a good candidate to build psychometric scales. However, multidimensionality of gloss must not be neglected in our future measurements. We noticed the joint presence of data regarding gloss and hue. The use of a multidimensional method such as Maximum Likelihood Conjoint Measurement MLCM should be the logical sequel to this work.

The visual system tries to maintain gloss constancy in the same way it does for colour. As the perceived colour of an object is kept constant under light sources of different colour temperatures, its glossy appearance is perceived identically despite changes in the lighting divergence. This adaptation is to be associated with the natural variations of illuminations we can meet in everyday life (colour temperature of the natural light at sunset or at noon and changes of divergence induced by meteorological conditions). Similarly, to colour constancy, the link between gloss and light source can be broken. Considering for instance a diffuse lighting over a scene deprived of environmental clues, observers are facing a difficult task. They no longer have a specular reflection to base their judgment particularly for matt samples below 50 GU. As a consequence of that, gloss constancy is lost for these samples. A striking result is that when more environmental clues are given to the observer, as for instance the geometrical wallpaper on the wall of the office cabinet, he uses these to restore gloss constancy. In real-life, we always have lateral references in our field of view (trees, buildings). These may help to maintain gloss constancy over long time. We show that the realistic environment increases the gloss perception dynamic and consequently allows a better evaluation of gloss. Polar explorers, evolving in a cloudy, white, and desertic ambient are often complaining about the impairment of perceptual constants in their travels (Jean-Louis Etienne, marcheur du pôle, edited by Robert Laffont 1986).

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