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Preliminary measurement scales for sparkle and graininess

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Abstract: Large effect pigments, widely used in various fields of industrial applications, produce characteristic visual textures known as sparkle and graininess, which need to be quantified by objective or subjective methods. The development of preliminary measurement scales for sparkle and graininess, whose recommendation is now under discussion in the International Commission on Illumination (CIE), is described in this article. These scales are absolute, linear and traceable to standards of optical radiation metrology. The main purpose of this article is to justify the convenience of adopting these preliminary measurements scales, showing clear evidence that they correlate well with subjective evaluations. Before standardization, these scales need to be validated with more experimental data, including different specimens and experimental systems from other research groups.

1. Introduction

Some surfaces exhibit spatial inhomogeneities caused by strong variations in their reflection characteristics which are apparent by visual examination. The appearance related to these objective variations in the surface may greatly depend on the illumination geometry. Visual textures due to these spatial inhomogeneities are widespread phenomena in human perception of the natural surround. Two visual textures can be observed in many cases. One is observed under directional illumination as point light sources distributed on a dark background, similarly as stars on the night sky or the Sun's glitter on the wavy surface of the sea [1]. This is known as sparkle, although other terms can be found in the literature, such as glint, glitter or brilliance. Sparkle is produced because some elementary areas on the surface behave as isolated microscopic mirrors or perfect refracting elements, causing light to scatter into one specific direction [2,3]. Sparkle is defined by *ASTM E284-17 Standard Terminology of Appearance* [4] as "the aspect of the appearance of a material that seems to emit or reveal tiny bright points of light that are strikingly brighter than their immediate surround and are made more apparent when a minimum of one of the contributors (observer, specimen, light source) is moved."

Sparkle decreases when the illumination changes gradually from directional to diffuse illumination, and disappears completely under purely diffuse illumination. Under partial or

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complete diffuse conditions of illumination, a second visual texture is observed, a granular appearance referred to as graininess. Other terms can be also found in the literature, such as diffuse coarseness [5] or simply coarseness. It has been shown to be the most important visual texture parameter for many materials [6–8]. In 1920, in the field of photographic materials, the term "graininess" was defined as "the sensation or impression of non-uniformity in a photographic deposit produced on the consciousness of the observer when such a deposit is viewed" [9]. This subjective or psychophysical quantity is the counterpart of the "granularity", which was considered the objective quantity in that field. The relation between "granularity" and "graininess" was studied for several decades using different smart methods to measure "granularity" [10], before the invention of the charge-coupled device (CCD) in 1969 [11], which allowed a more efficient image processing. Similarly as in the field of photographic materials, the term *graininess* is used in the context of this article as *the sensation or impression of non-uniformity produced on the consciousness of the observer when a surface with effect pigments is viewed under diffuse illumination*.

Large effect pigments, even when embedded in binders as in effect coatings [12–16], are capable of producing sparkle and graininess. Since they allow an appealing appearance in products, their use has become very popular in automotive, cosmetics, coatings, inks, flooring, textile or decoration. In order to control their visual texture, it must be quantified by objective (image-based reflectance measurements) or subjective (visual assessments) methods. To provide traceable measurements in industry, it is convenient to develop well-defined measurement scales by psychophysical experiments [17], with magnitudes calculated using exclusively objective methods.

Cameras have lately improved in great extent their accuracy and precision in optical radiation measurements [18], with uncertainties below 2% mainly limited by stray light, and they are widely-used as traceable radiance or luminance measurement devices in lighting applications. It notably favors the accuracy of the texture assessment by objective methods. Although the present technological state of imaging technology is adequate for traceable reflectance measurements with spatial resolution, until 2018 the only commercially-available instruments able to quantify sparkle and graininess have been the BYK's spectrophotometers for metallic colors (BYK-mac models) [19], which provide sparkle and graininess indexes. In 2018, the company X-Rite introduced two new portable multiangle spectrophotometers in the market (MA-T6 and MA-T12) [20], also capable of quantifying sparkle and graininess. Both BYK and X-Rite opted for defining their own sparkle and graininess scales, because to date there is no standard procedure to obtain correlates from reflectance measurements. Therefore, although developed to be well-correlated with the visual perception, their texture indexes are not traceable to international standards. Standard measurement scales must be defined to improve the appearance control of sparkle and graininess.

The development of preliminary measurement scales for sparkle and graininess, whose recommendation are now under discussion in the International Commission on Illumination (CIE), is described in this article. It is the result of previous reflectance measurements, performed by national metrology institutes (PTB, METAS and CMI) and a designated institute (CSIC), and visual assessments performed at the University of Alicante. These scales were conceived to be traceable to optical radiation standards [21–23]. The main purpose of this article is to justify the convenience of adopting these preliminary measurements scales, showing clear evidence that they correlate well with subjective evaluations.

2. Experimental methods

Similar experimental methods were followed to develop these preliminary measurement scales for sparkle and graininess. In both cases, a set of 9 achromatic samples (8 cm × 13 cm), belonging to the Effect Navigator set of 25 samples produced by Standox [24], was used. The set provides five different levels of lightness. Each sample can be identified with an *L* number and an *EN* number, both varying from 1 to 5, whose permutation makes 25 samples in total. We know from Axalta Coatings that the *L* number is related to the concentration of effect pigments, whereas the *EN* number is related to the average size of the pigments. However, the exact relation between the identifying *EN* and *L* numbers and the size of the underlying physical parameters is not disclosed. But this is not crucial for the objective of this work, as no relation of measurements with physical parameters of the specimens is attempted to be given.

The sample set can be regarded as five groups of samples with fixed concentration of pigments and variable pigment sizes, or, reciprocally, as five groups of fixed pigment sizes and a variable concentration of pigments. The set of the 9 selected samples is composed by those with odd numbers for both *EN* and *L*. Visually, it is evident that the larger the *L* number, the lighter the sample, which means that the luminance is related to the concentration of effect pigments. In addition, for a fixed *L* number, the visual texture is more apparent for larger *EN* numbers. It is expected because this texture partially depends on the luminous flux reflected by the effect pigments, which is proportional to their areas.

The reflectance properties of the specimens of the selected set were evaluated by three national metrology institutes (PTB, METAS and CMI) and one designated institute (CSIC), according to procedures already presented in previous papers [21–23]. To sum up, these procedures are based on measuring the luminance factor of the specimens with spatial resolution (luminance factor images), by the use of calibrated cameras or imaging luminance measurement devices (ILMDs).

On one hand, when sparkle correlates are to be obtained from these luminance factor images, they need to be acquired at bidirectional geometries, where the specimen is irradiated from specific directions and the reflected light evaluated at specific directions. In that case, goniospectrophotometers were used for the characterization, as described in Ref. [23]. Due to the high contrast between the bright sparkle points and the background, high-dynamic-range images were required.

On the other hand, when graininess correlates are to be obtained, these luminance factor images have to be acquired under diffuse illumination, as shown in Ref. [21]. The measurements of the set of samples were performed using four different measuring systems, all of them based on integrating spheres. When the specimen is glossy, it is recommended to acquire the luminance factor images in a geometrical configuration for which no specular image of features of the integration sphere (port or baffles) on the surface of the specimen is observed by the camera [25]. This usually happens for the standard $d : 0^{\text{o}}$ geometry (that is, diffuse illumination and frontal observation, and consequently the specular image of the camera port is observed by the camera). Therefore it is recommended to use instead the standard $d : 8^{\text{o}}$ geometry (diffue illumination and observation angle of 8^{o} with respect to specimen surface), as it was done in this work.

The measurement scales for sparkle and graininess must be developed by comparing objective data (luminance factor images and measuring conditions) with visual data, in order to find a mathematical function relating them. Two visual experiments were carried out at University of Alicante to obtain visual data corresponding to the selected set of specimens, one for sparkle and another for graininess. They were identically designed, except for the light booth used for the assessment.

In the case of sparkle, the byko-spectra-effect booth [26] was used, which provides directional illumination on the specimen. A wLED lamp, slightly color-filtered with yellowish nuance is implemented with chromatic coordinates of $x = 0.3415$ and $y = 0.3821$, with a color temperature of 5208 K, and with a color rendering index, R_{a}, of 71.5 units. The illuminance on the sample plane is 2700 lx.

In the case of graininess, the VeriVide CAC 150 light booth [27] was used. This booth has good diffuse illumination; therefore, sparkle perception is canceled and only the graininess is perceived. The selected illuminant was the D65 illuminant with chromatic coordinates of

$x = 0.3127$ and $y = 0.3383$, with a color temperature of 6439 K, and with a color rendering index, R_a, of 95 units. The illuminance on the sample plane is 1415 lx.

The geometry $45^o : 0^o$ (angle of incidence of 45^o and frontal observation) was used in the case of sparkle. Sparkle can change notably with the bidirectional illumination-observation geometry, mainly because the sparkle luminous points are produced by mirror-like reflections in the effect pigments, whose orientations with respect to the surface of the specimen are not uniformly distributed. In consequence, the density of sparkle luminous points is usually larger at smaller aspecular observation angles (angular distance to the specular direction). Therefore, the exact geometry must be clearly specified in the assessment.

Before starting the visual assessment, observers were well-instructed about sparkle and graininess appearances. To illustrate the textures to the observers, a solid sample without effect pigments was placed together with a test sample in the corresponding lighting booth. Afterwards, sparkle was introduced as glints or bright dots on a uniform background, similar to stars on the night sky. Graininess was introduced as a light/dark pattern leading to a granulated appearance. In this way, observers could identify these features on the samples placed in the lighting booth (by difference between solid and effect sample) and to distinguish both textures. The observers were informed about the purpose of the visual experiment.

The visual experiment was designed to accomplish Multidimensional Scaling (MDS) [28], according to the procedure explained in Ref. [29]. For both cases, sparkle and graininess observation, it would allow to notice the presence of a second dimensional dependence, if there was any. A method of forced choice was used. In these methods, the question to the observer is clear and simple, and forces him to make a decision between a limited number of possible options. Each judgment is totally independent of the previous one, and if the samples are well chosen, usually very solid experimental results are gained.

Triplets of specimens were shown to the observers, and their only task was to decide if the specimen on the left or that on the right had a more similar texture to the anchor specimen between them. 84 triplets were made at random by combining the 9 selected samples and making non-repetitive combinations of the 9 samples in groups of 3. The presentations followed a pre-established disordered criterion, so that there was no sequence that could be detected by the observer and influence the observer's responses. Each observer performed three repetitions of the same experiment in three different sessions. The sessions lasted approximately 30 minutes to avoid observer fatigue and ensure better response. At the beginning of each session, the observer remained 3 minutes with only the cabinet light on, in order to adapt to the measurement conditions. In total, 252 visual observations were made per observer.

30 observers participated in each visual experiment with a total of 7560 visual observations . Observers were checked for their suitability before starting the first session. Accordingly, their visual acuity was measured with a Snellen test to guarantee a visual acuity test higher or equal to 20/20. In addition, the color vision of participants was evaluated by an Ishihara test. In particular, in the sparkle experiment twenty people participated in this study (16 females and 14 males) with an age ranging from 23 to 58 years, with an average value of 27.8 ± 9.5 years. For the graininess experiment, thirty people participated in the experiment (13 males and 17 females) with an age from 20 to 57 years, with an average value of 32 ± 10 years. One of the authors participated in each visual assessment.

Visual data (referred here as visual sparkle or visual graininess) are obtained from the visual experiments. They are relative values and depend on the design of the visual experiments, but their tendency allows conclusions to be drawn on the appearance or on measurement scales.

3. Measurement scales

3.1. Sparkle

Quantities related with the sparkle texture are obtained from the luminance factor images by identifying visible luminous points on the sparkling surface. To identify them, the contrast at which a luminous source is distinguishable on a background (contrast threshold) was accounted, as determined by the procedure outlined by Richard Blackwell [30] in the largest and most authoritative psychophysical study on contrast threshold. According to this study, the contrast threshold depends on the source luminance, the background luminance, the size of the source, and the observation distance.

As explained in detail in [23], the visibility of each luminous point in the luminance factor image, V_p, is quantified as the relative positive difference between contrast, C_E, and contrast threshold, $C_\mathrm{E,th}$:

$$V_\mathrm{p} = \frac{C_\mathrm{E} - C_\mathrm{E,th}}{C_\mathrm{E,th}} \tag{1}$$

where C_E is calculated as the ratio between the integrated value of the background-subtracted luminance factor on a elementary area at the sparkle luminous point and the luminance factor of the background [23].

The contrast threshold is calculated as:

$$C_\mathrm{E,th} = \frac{d_\mathrm{ST}^2 R}{A_\mathrm{e}} \tag{2}$$

where d_ST is the observation distance, A_e is the elementary area used to spatially integrate the luminance factor around the sparkle luminous points, and R is the factor in the Ricco's Law [31–33], defining the product between the contrast threshold and the solid angle subtended by the luminous source when it is lower than the Ricco's area (expressed in solid angle units).

R is calculated, for a given luminance background $L_\mathrm{V,bg}$, as [32]:

$$R = \left(\sqrt{a_1 L_\mathrm{V,bg}^{-1/2} + a_2 L_\mathrm{V,bg}^{-1/4} + a_3} + a_4 L_\mathrm{V,bg}^{-1/4} + a_5\right)^2 \tag{3}$$

where:

$$a_1 = 5.949 \times 10^{-8},\ a_2 = -2.389 \times 10^{-7},\ a_3 = 2.459 \times 10^{-7},$$
$$a_4 = 4.120 \times 10^{-4}, \quad a_5 = -4.225 \times 10^{-4},$$

$L_\mathrm{V,bg}$ must be given in cd/m^2 and calculated as:

$$L_\mathrm{V,bg} = \frac{E_\mathrm{V} \times \beta_\mathrm{bg}}{\pi} \tag{4}$$

where E_V is the illuminance on the sample and β_bg the luminance factor of the background.

The explicit dependence on E_V, β_bg and d_ST makes this scale conceptually absolute, in the sense that sparkle measurements at different observation and illumination conditions can be compared.

Once the visibility of each luminous point in the luminance factor image is quantified, sparkle quantities can be calculated by considering as "visible" only those sparkle luminous points with visibilities above zero. The quantities are defined as the first, second and third quartiles (V_Q1, V_Q2 and V_Q3) of the visibility values of the visible sparkle luminous points (to describe the visibility distribution in the image), and as the sparkle density (d_s, number of visible luminous points per square millimeter).

Note that these quantities are already founded on visual experiments by Blackwell's study, but they must be still visually validated, because for sparkle there is a spatial distribution of luminous points, and not simply a well-defined source on a background. The advantage of these quantities is that their measurement can be traceable, and that they explicitly include the dependence on the illuminance on the evaluated surface and on the observation distance.

The procedure to obtain these sparkle quantities from a luminance factor image is thoroughly described in [23]. Therein the results obtained from measurements at PTB, METAS, CMI and CSIC are given. They were adapted for the observation conditions in the visual assessment, according to the proposed definitions. These results (second quartile of sparkle visibility and density), with a very acceptable compatibility among the participating institutes, were used as candidate sparkle correlates in this study. A very high correlation was found between the second quartile of the sparkle visibility V_{Q2} (linear correlation coefficient $r = 0.992$), hereafter *sparkle quantity*, and the first dimension of the visual data (hereafter *visual sparkle*) obtained through the visual assessment described in section 2.

This relation and the linear fitting results are shown in Fig. 1. The error bars represent the inter-observer standard deviation for each specimen. Intra- and inter-observer variations are shown in Fig. 2.(a) for each specimen, as a percentage of the standard deviation with respect to the total range of the visual sparkle. Note that the uncertainty of the visual sparkle, the inter-observer standard deviation of the mean, corresponds to the value shown in Fig. 2.(a) reduced by the square root of the number of observers, but this uncertainty was not used in the bars in Fig. 1 to make their relative size more obvious. Also note that no fitting parameters were required to obtain the resulting linear dependence.

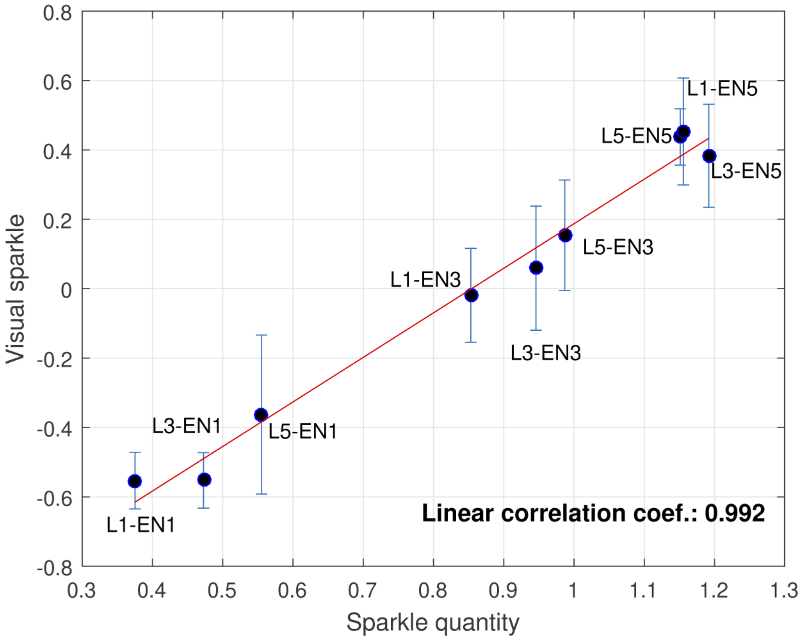
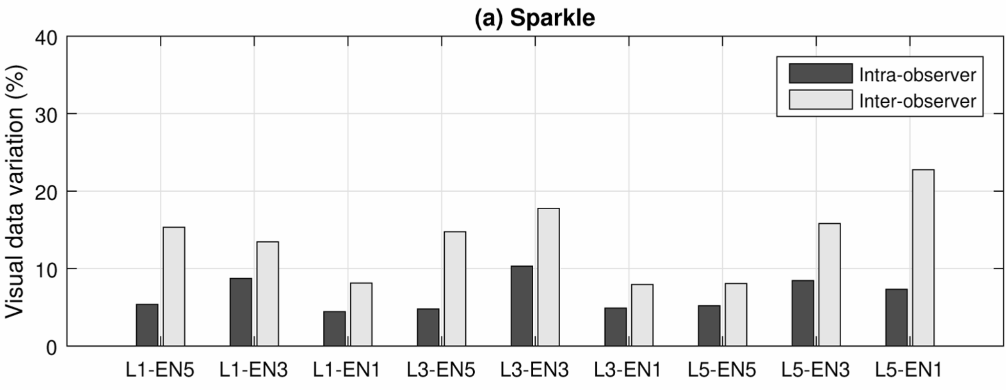
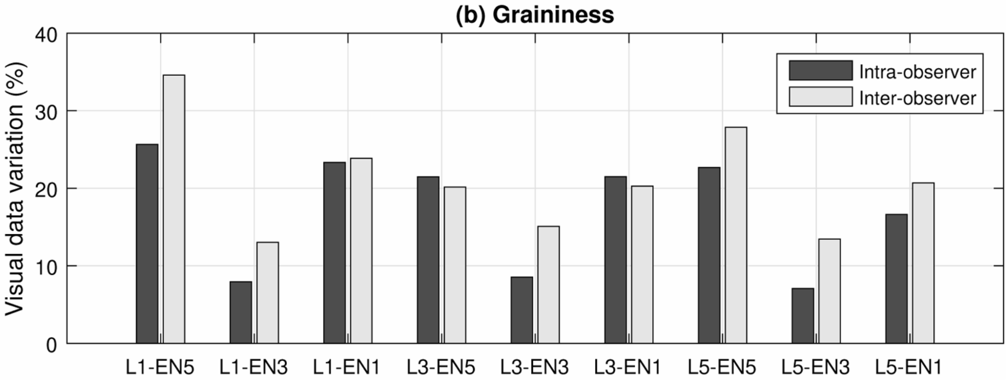


Fig. 1. Relation between visual sparkle and the calculated sparkle quantity as derived from absolute measurements. The error bars represent the inter-observer standard deviation. Note that the values of visual sparkle can only be interpreted in relative terms, and they can be negative.

The visual assessment confirmed two main features of the sparkle mechanisms. Firstly, that the larger the average size of the sparkle pigments (the larger *EN* numbers in the labels in the figure)



(a) Sparkle



(b) Graininess

Fig. 2. Intra- and inter-observer variations for (a) sparkle and (b) graininess, as a percentage of the standard deviation with respect to the total range of the visual sparkle (a) and graininess (b).

the more apparent the sparkle [2,3], and, secondly, that the larger the luminance background (the lower L numbers of the labels in figure) the less apparent the sparkle is [30,32]. Whereas the first feature is very well proven by the visual assessment for all specimens, the second one is better observed at intermediate levels of sparkle.

The sparkle density is also correlated with the visual sparkle, although slightly worse than V_{Q2} (see Fig. 3, first column of plots). The values of V_{Q1} and V_{Q3} correlate also slightly worse than V_{Q2}, although better than sparkle density. The correlation of the four quantities is acceptable for the studied specimens. Other dimensions of the visual data from multidimensional scaling analysis are found to be completely uncorrelated with any of these quantities (Fig. 3, second column of plots). Note that it does not mean that they cannot be related with other visual attributes. If some relation between these additional dimensions and other visual attributes could be identified, such information might be used to improve the description given to the observers before the visual experiment, in order to avoid their judgments relying on those visual attributes. This might help to decrease the inter-observer inconsistency.

The analysis shows that V_{Q2} can be regarded as the sparkle correlate. However, the other sparkle quantities (V_{Q1}, V_{Q3} and d_{s}) might also be relevant for more precisely describing the sparkle appearance. Note that these sparkle quantities are defined using concepts from optical radiation measurement and the psychophysical data from Blackwell [30].

It must be noticed that the proposed measurement scale of sparkle is restricted to the visual texture. The dynamic attribute given by *ASTM E284-17 Standard Terminology of Appearance* [4]

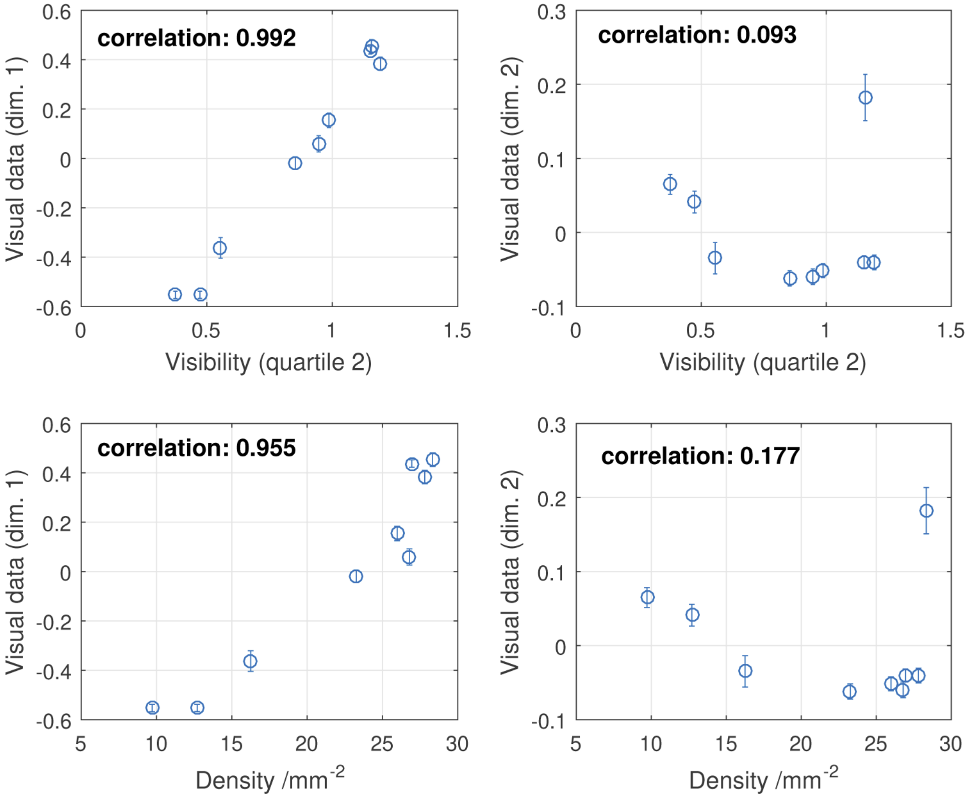


Fig. 3. Relation between the two first dimensions of visual sparkle and the sparkle visibility (second quartile, V_{Q2}) and the sparkle density. The error bars represent the inter-observer standard deviation of the mean. The linear correlation coefficients are given for comparison.

("more apparent when a minimum of one of the contributors (observer, specimen, light source) is moved") is not considered. This must be defined with another quantity, describing the constancy of specific sparkle luminous points under slight geometrical variations.

3.2. Graininess

As in the case of sparkle, quantities related with the graininess are obtained from the luminance factor images. As shown in Ref. [21], the graininess quantity should include the spatial variation at intermediate spatial frequencies (including exclusively those variations due to local reflectance) and the average luminance factor. In Ref. [21], the proposed measurement scale was based on BYK-mac measurements and on visual data, where only specimens with similar luminance factors were compared, so that it was not possible to obtain the accurate relation of graininess with the luminance factor in order to define an absolute scale. This issue was avoided in the visual assessment described in section 2., where very different levels of luminance factor were compared. Luminance factor images from PTB, METAS, CMI and CSIC were used to obtain a measurement scale correlated with the visual data from that assessment. This measurement scale for graininess is expressed as:

$$G = \frac{1}{(\beta_0 - \langle\beta\rangle)} \frac{\sqrt{V_G(f_1, f_2)}}{\langle\beta\rangle}, \tag{5}$$

with

$$f_1 = 1\ \text{mm}^{-1},\ f_2 = 5\ \text{mm}^{-1},\ \beta_0 = 0.76,$$

where $\langle\beta\rangle$ is the spatially-averaged luminance factor, β_0 is the fitting parameter, and the graininess variance (V_G) is given from a Fourier transform as:

$$V_G(f_1,f_2) = 2\int_{f_1}^{f_2} \text{PSD}(f)\text{d}f, \tag{6}$$

where f is the spatial frequency (the inverse of the spatial interval), and f_1 and f_2 (fitting parameters) are the spatial frequencies defining the integration range of the Power Spectral Density (PSD) of the luminance factor image. Note that, in the so-defined variance, the variations at spatial frequencies below f_1 and above f_2 have been filtered.

It must be noticed, that the luminance factors of the examined specimens range from 0.057 to 0.68. For larger luminance factors, we recommend to use a constant factor $1/(\beta_0 - \langle\beta\rangle)$ of 12.5 [1/(0.76-0.68)] to avoid very large or negative values of G. However, the correlation with visual graininess will be poorer the more the luminance factor exceeds 0.68.

If it is expected that the only spatial variation of the luminance factor in the specimen is due to graininess, the factor $\sqrt{V_G(f_1,f_2)}/\langle\beta\rangle$ can be approximated as the relative standard deviation of the luminance factor image, as long as the low- and high-spatial-frequency noises are properly reduced, by correcting the irradiation and pixel-responsivity spatial variations [34–39], and by averaging to increase the signal-to-noise ratio, respectively. This way, the factor is regarded as the relative inhomogeneity exclusively produced by the local variation related with graininess. The first factor of the equation, $1/(\beta_0 - \langle\beta\rangle)$, is very critical, since it includes the weight of the relative inhomogeneity as a function of the luminance factor. It is important for an acceptable

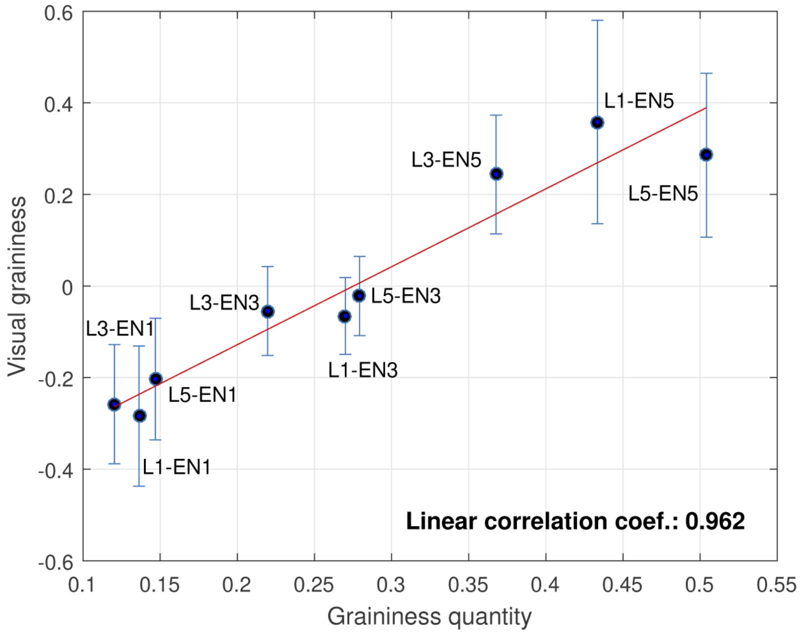


Fig. 4. Relation between visual graininess and the graininess quantity calculated from METAS's reflectance measurements. The error bars represent the interobserver standard deviation. Note that the values of visual graininess can only be interpreted in relative terms, and they can be negative.

correlation between Eq. (5) and the visual data when specimens with very different luminance factors are studied.

The visual data (*visual graininess*) are shown in Fig. 4 as a function of the graininess quantities calculated from METAS's luminance images. Intra- and inter-observer variations are shown in Fig. 2.(b) for each specimen. The goodness of the correlation of METAS's data with the visual graininess ($r = 0.962$) is representative of the other institutes, ranging from $r = 0.946$ to $r = 0.986$. The variation in the correlation coefficients should be due to the different spatial resolutions and in the different realization of the diffuse illumination (different integrating-sphere systems), which has ports and is never completely ideal. The figure shows that the larger the average pigment size (larger *EN* number) the larger the graininess texture.

A first validation of the presented preliminary measurement scale was carried out by using four visual scales provided by Audi (with visual data obtained by Maximum Likelihood Difference Scaling [40]) and luminance factor measurements from CSIC. Each of these visual scales is composed of eight specimens with similar luminance factors (for each scale: $\approx 0.47 \pm 0.08$, $\approx 0.20 \pm 0.05$, $\approx 0.10 \pm 0.01$ and $\approx 0.08 \pm 0.01$). The values calculated by Eq. (5) correlated with the visual data with $r = 0.958$. However, the value of the parameter β_0 in the factor $1/(\beta_0 - \langle\beta\rangle)$ could not be validated, since the Audi's visual data do not include comparisons between specimens with very different luminance factors.

4. Discussion and conclusions

Preliminary measurement scales for sparkle and graininess have been developed, in order to be proposed as CIE recommendation. The scales are linearly correlated with visual data and traceable to standards of optical radiation metrology. The dependence on the average luminance factor has been explicitly included in the case of graininess, and the dependence on the observer distance and the illumination on the surface in the case of sparkle. Before standardization, and in order to identify limitations and to address them if possible, the here proposed preliminary measurement scales for sparkle and graininess need to be contrasted with more experimental data, including different specimens (chromatic, with other kind of pigments...) and experimental systems of other research groups by applying e.g. other spectral power distributions of the light source, different illuminance levels and methods for visual assessment.

However, there are already remarkable features in these scales:

- The sparkle and graininess quantities are traceable to standards of optical radiation measurements, and they are not indexes exclusively related to specific instruments.
- They are absolute scales, allowing a comparison of specimens with very different luminance factors or a comparison of specimens at different illumination and observation conditions.
- They are linear, at least for the set of specimens so far studied.

The adoption of standard measurement scales of sparkle and graininess would facilitate the definition of standard measurement conditions or restrictions on instruments, and recommendations for a good measurement practice. Important questions to be addressed are the minimum degree of directionality (or diffusivity) of the illumination required for characterizing sparkle (or graininess).

The sparkle quantities are derived from the Blackwell's psychophysical study, where well-defined and uniform light source on a dark background was used instead of a distribution of luminous points, as it is the practical case when evaluating sparkle. This difference might affect the contrast threshold when the number of luminous points is very large. This effect only can be revised with a more extensive psychophysical experiment.

The preliminary measurement scales here described were conceived for defined situations where only directional (sparkle) or diffuse (graininess) illumination is present. In practical lighting conditions, specimens can be observed under both directional and diffuse illumination. In such cases, the mixed appearance, with simultaneous sparkle and graininess contributions, might be evaluated by using the measurement scales proposed here, providing visibilities and densities of sparkle luminous points, and variances of the texture in the given spatial frequency range for graininess. However, the performance of the scales in this situation has not been explored in and is outside the scope of this work. As another option, sparkle and graininess measurements at the conditions specified in this article can be used to find the physical parameters for effect coatings in models as those proposed in the literature [2,3], allowing the texture in mixed conditions to be estimated by rendering methods.

It must be noticed that the proposed measurement scale of sparkle is not applicable to the sparkle produced in displays by anti-reflection coatings [41]. In this field, the irradiation on the pixels of the display is not directional and the texture cannot be considered strictly as "sparkle" in the terms here defined. In lighting, the term "sparkle" is sometimes referred to "pleasant glare" [42–44]. The measurement scale discussed in this article does not distinguish between pleasant or unpleasant effect, and it is not applicable here either, at least in the present form.

Note that chromaticity is not to be considered in these scales, in the same way that texture is not considered in the definition of the CIE 1931 colorimetric standard. The impact of the color in the texture perception is evident and also the impact of texture in the color perception, and well-accepted measurements scales for texture are very beneficial for progressing in this field, by studying the relation between both visual attributes to improve color appearance models.

As in colorimetry, the next step after the standardization of the scale should be the development of texture difference formulae.

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Disclosures. The authors declare no conflicts of interest.

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