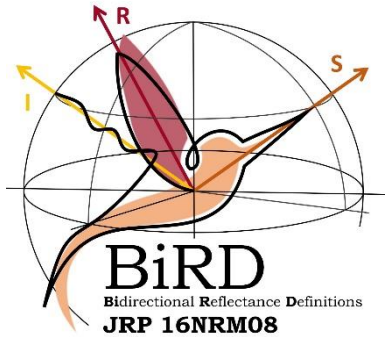


Bidirectional Reflectance Definitions

Workshop on Sparkle and Graininess

VISUAL EXPERIMENTS ON SPARKLE AND GRAININESS

Esther Perales

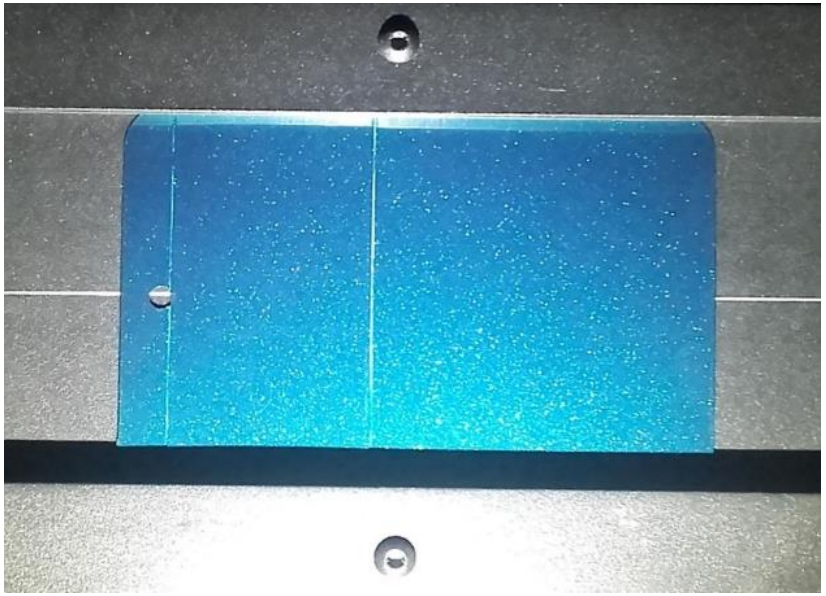
Universidad de Alicante

INTRODUCTION

SPARKLE: **micro-brightness, glints, diamonds**

- **Observation conditions:**
  - **Bright direct illumination (specific illumination angles)**
  - **Close distances**

- **Grade depends on:**
  - **Pigment concentration**
  - **Pigment size**
  - **Pigment orientation**

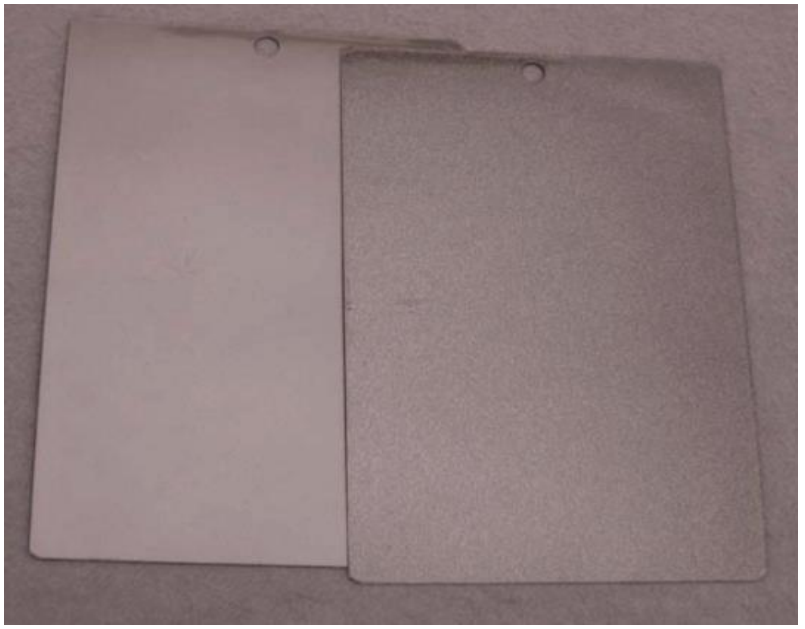


INTRODUCTION

<u>GRAININESS:</u> Salt and pepper appearance. Perceived contrast of a light/dark irregular pattern (<100 μm)

- **Observation conditions:**
  - **Diffuse illumination**
  - **Close distances**

- **Grade depends on:**
  - **Pigment concentration**
  - **Pigment size**
  - **Pigment orientation**

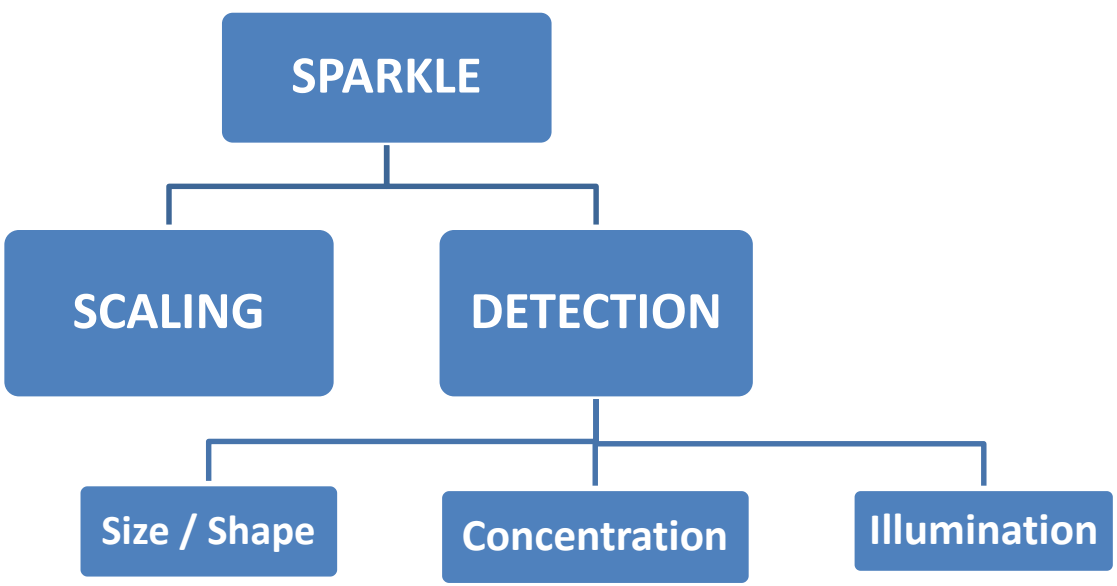


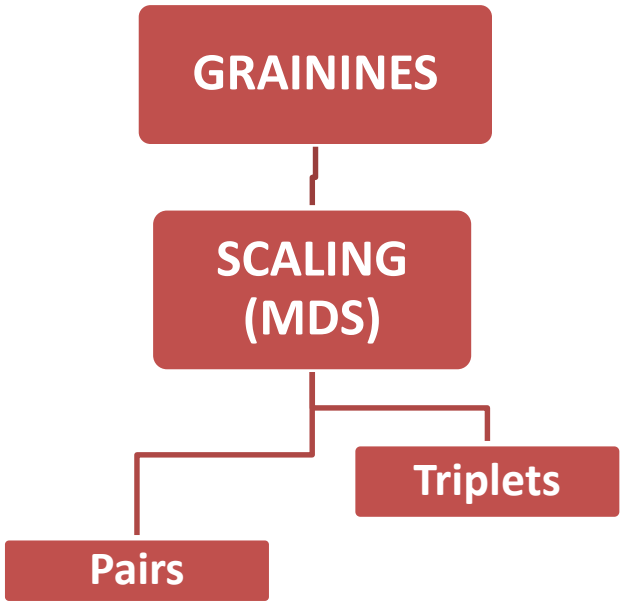
INTRODUCTION

There are **no standards** like ISO, ASTM or DIN that propose the mathematical and optical algorithms to **measure** and calculate the **sparkle** or **graininess**

Visual validation of texture effects by means of psychophysical experiments since these texture effects are important for the visual discrimination of many materials and the **quality control**

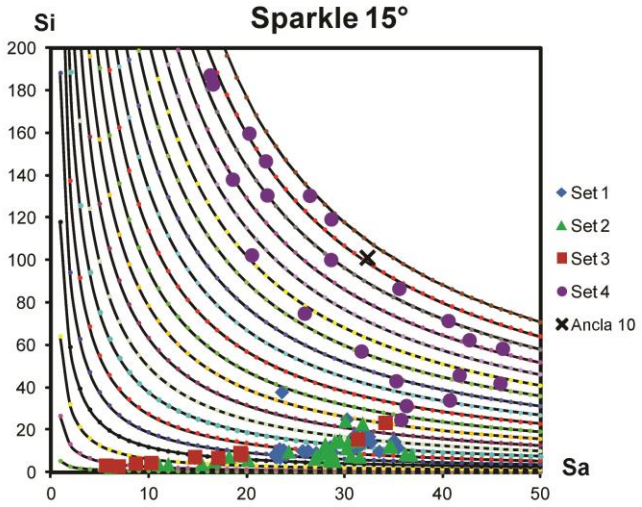
VISUAL EXPERIMENTS

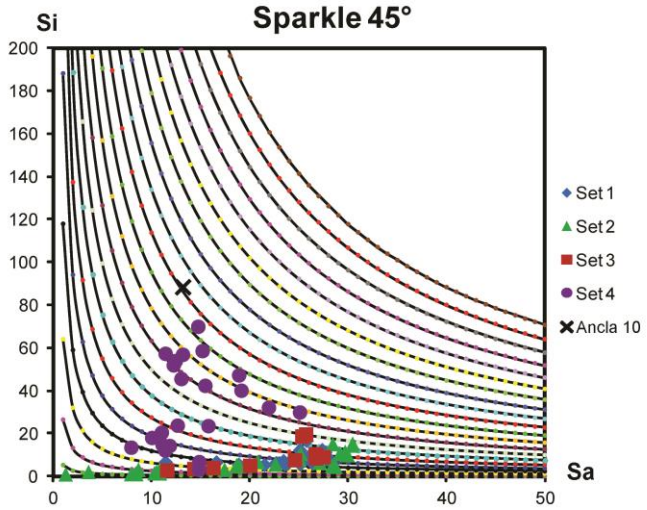




SPARKLE: SCALING

- **SAMPLES: 91 samples divided into 4 sets:**
  - **Set 1: BASF, interference pigments.**
  - **Set 2: Merck, interference pigments, (D50 = 9-25,5 µm)**
  - **Set 3: Merck, metallic pigments, (D50 = 9-35 µm)**
  - **Set 4: Eckart, synthetic mica (D50 = 25-92,5 µm)**

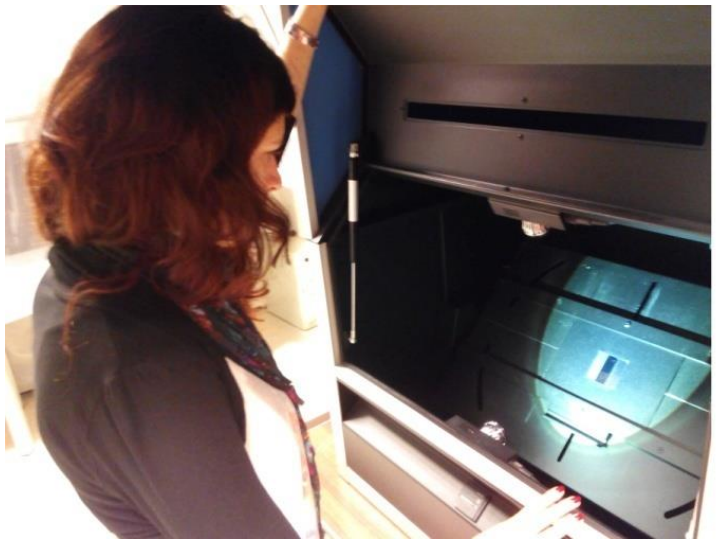


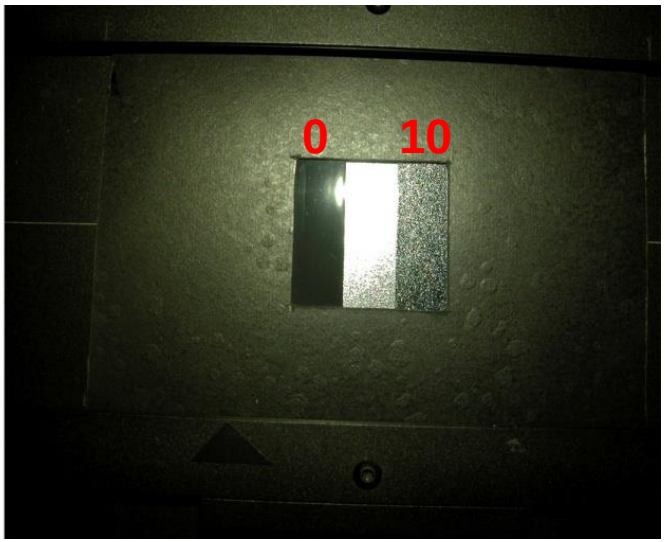


SPARKLE: SCALING

- **Methodology**: magnitude estimation method

Observers are asked to assign numbers in proportion to the magnitude of the stimulus (anchor).

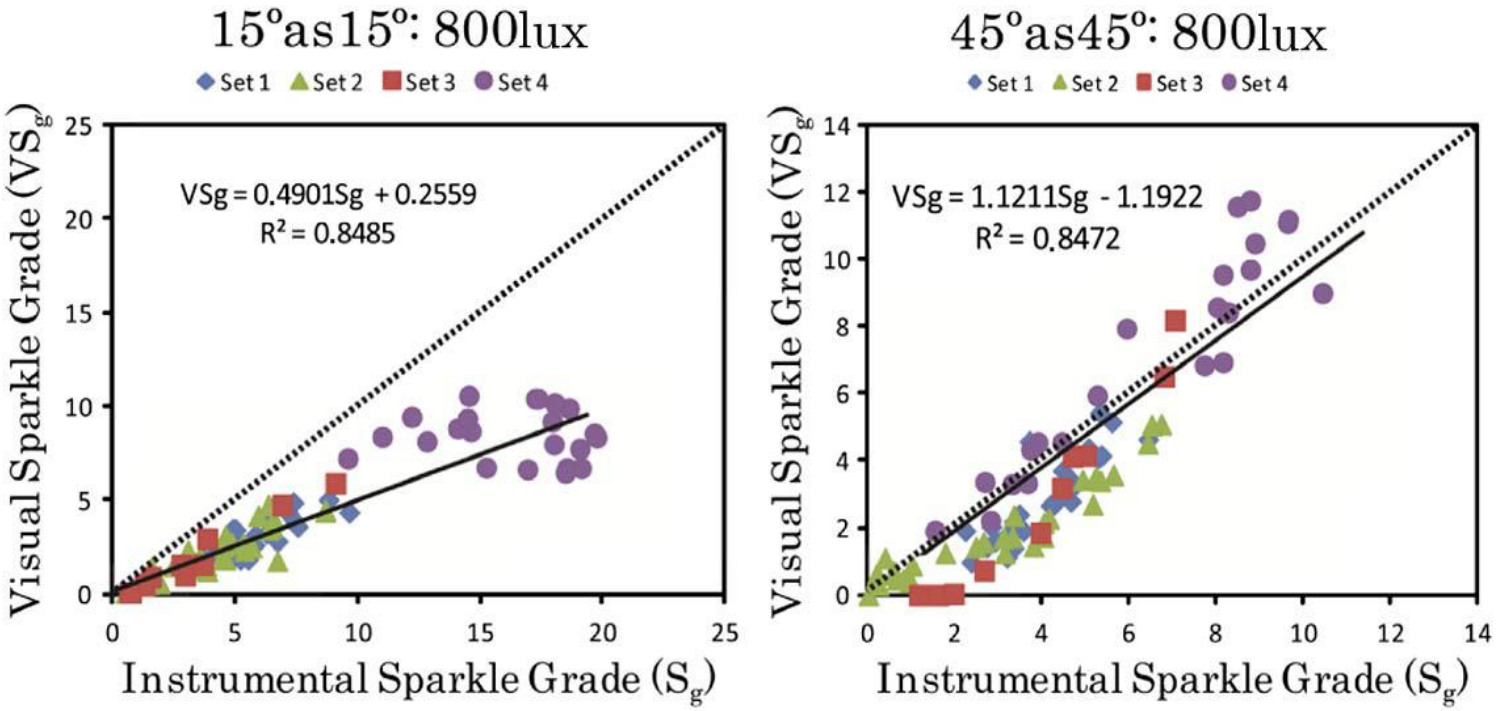




Byko-spectra viewing booth

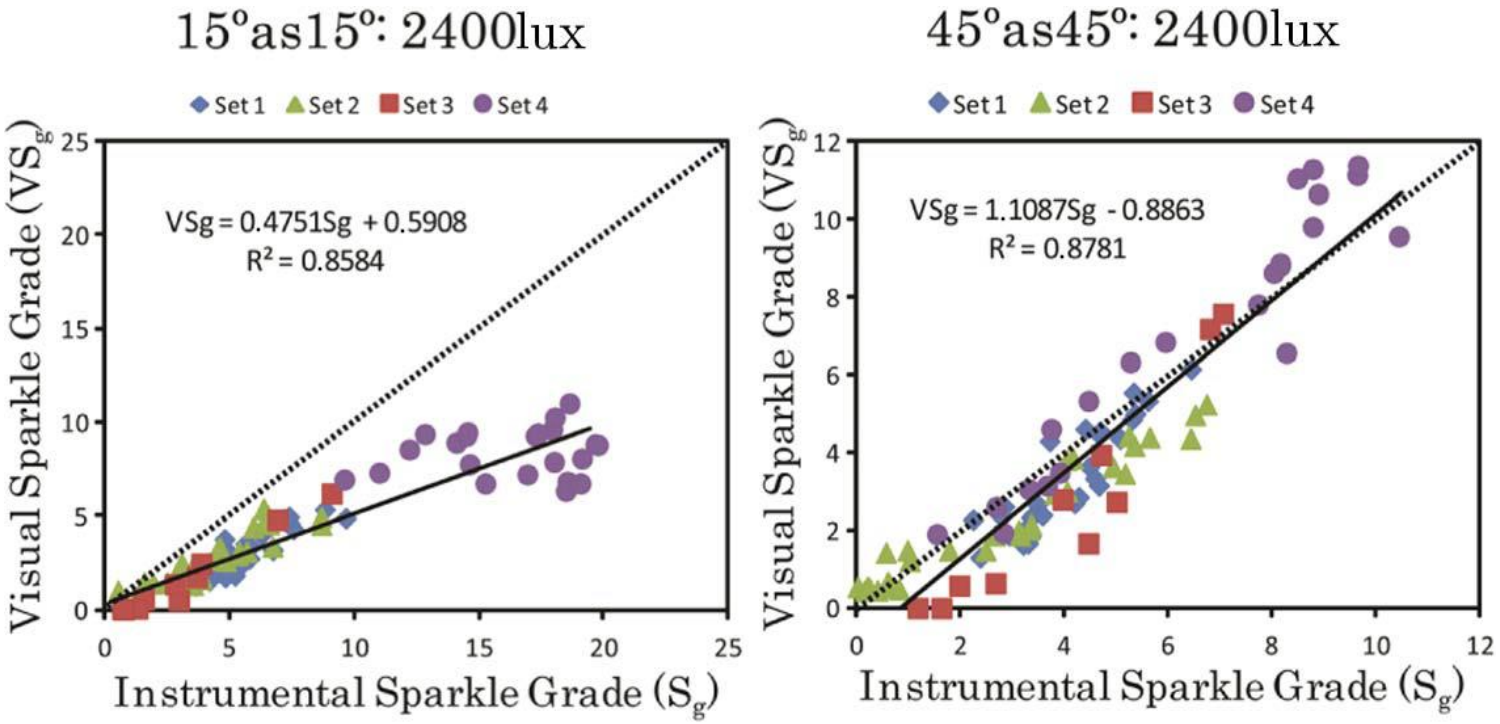
SPARKLE: SCALING

Sparkle grade correlation for the low illuminance conditions (800 lux) for the 15°as15° (left) and 45°as45° (right) measurement geometries.

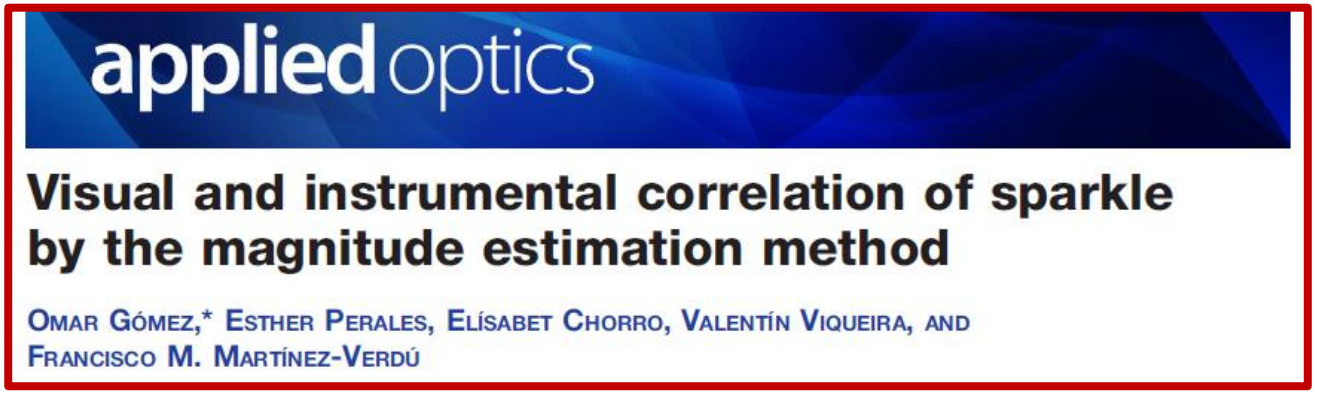


SPARKLE: SCALING

Sparkle grade correlation for the high illuminance conditions (2400 lux) for the 15°as15° (left) and 45°as45° (right) measurement geometries.



SPARKLE: SCALING



- A visual experiment was applied to verify the correlation between instrumental data (S_G) and the visual sparkle estimation
- S_G correlated well with the human visual perception despite using new special-effect pigments (i.e., synthetic mica)
  - Performance was slightly better for the 45°as45° measurement geometry than for the 15°as15°
  - Similar performance for different illumination levels

SPARKLE: DETECTION

- **<u>Purpose</u>: to determine the sparkle visual detection distance and to establish a relationship with qualitative and quantitative variables.**

  - **Size**
  - **Shape**
  - **Concentration**
  - **Sample lightness**

  Structural

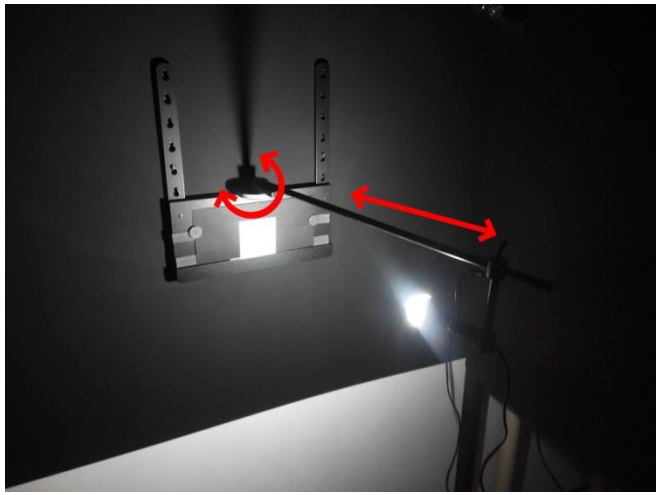
  - **Light source**
  - **Illumination level**

  Environmental

SPARKLE: DETECTION

- **Methodology**: adjustment psychophysical method

Observers are asked to adjust or manipulate the stimulus intensity (sparkle) by changing the distance to the sample.



A new lighting booth designed for this purpose.

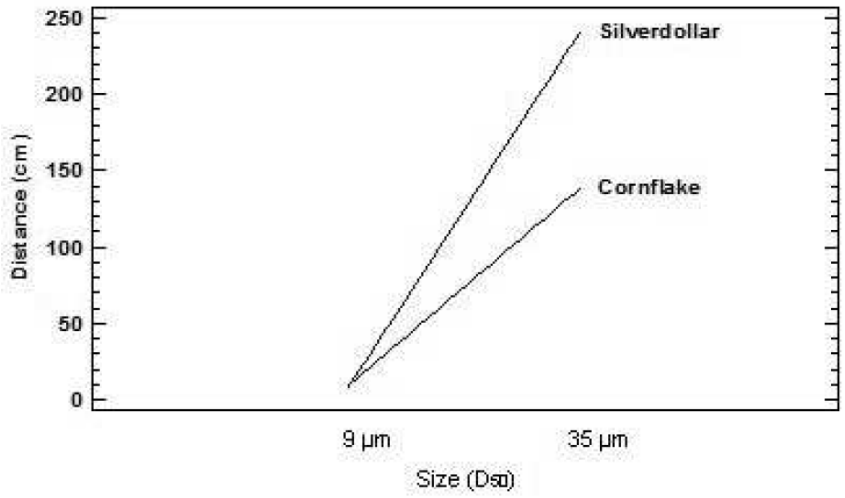
SPARKLE: DETECTION

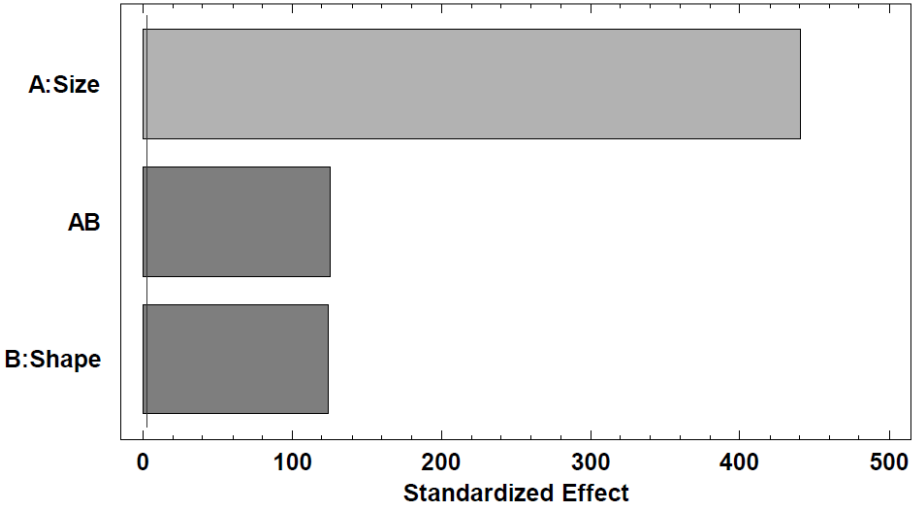
1) SIZE AND SHAPE ANALYSIS

- **SAMPLES**
  - Metallic samples. D_{50} =9-35 µm. Silverdollar, Cornflake.
- **Observation conditions**
  - E(lx): 800 lx – 2400 lx
  - Tc: daylight (6500K)
  - Geometry: 15ºas15º, 45ºas45º
- 540 visual evaluation by observer (12): 6.480 visual evaluations

SPARKLE: DETECTION

1) SIZE AND SHAPE ANALYSIS





- for small pigment size there is no difference between types of pigment
- Silverdollar pigment type is detected at a greater distance for large pigment size

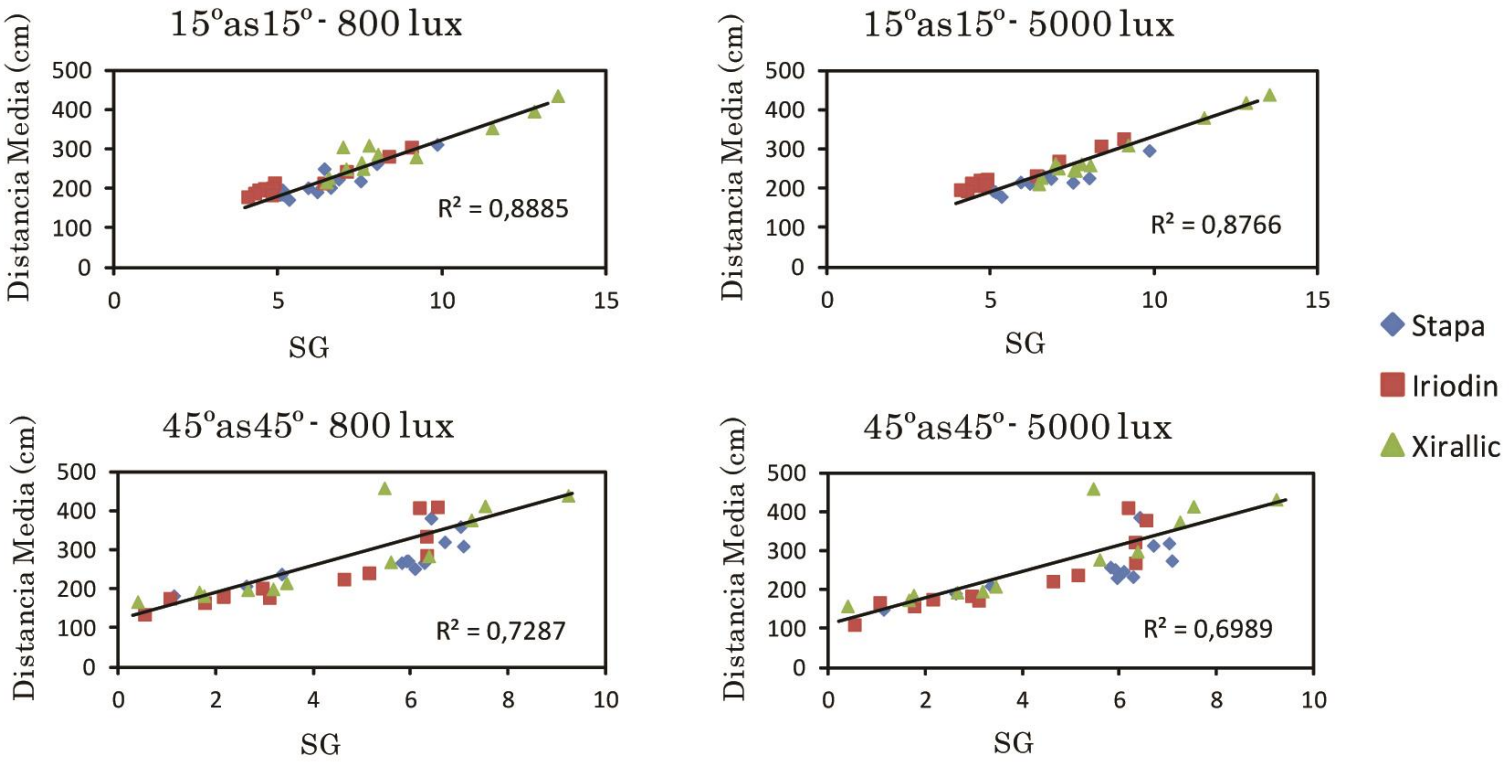
SPARKLE: DETECTION

2) CONCENTRATION ANALYSIS

- **SAMPLES**
  - The pigment size and type was fixed (Stapa, Iriodin, Xirallic)
  - Pigment concentration: from 1% to 26%,
  - Two achromatic backgrounds (black and white)
- **Observation conditions**
  - E(lx): 800 lx – 5000 lx
  - Tc: daylight (6500K)
  - Geometry: 15ºas15º, 45ºas45º
- 864 visual evaluation by observer (6): 5184 visual evaluations

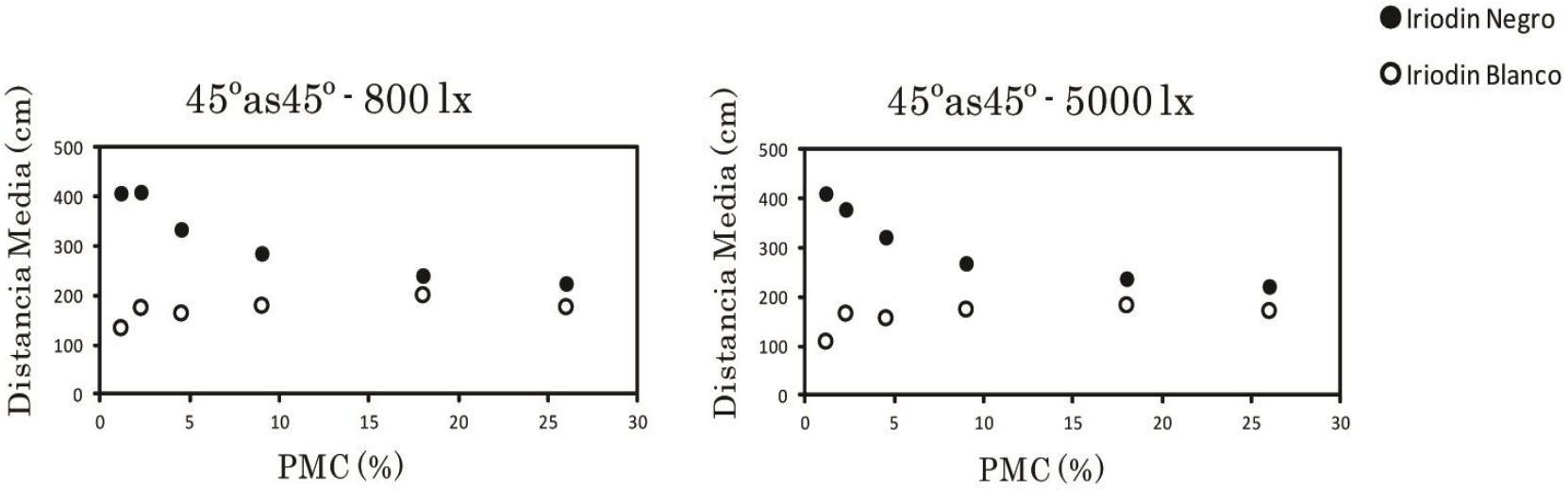
SPARKLE: DETECTION

2) CONCENTRATION ANALYSIS



SPARKLE: DETECTION

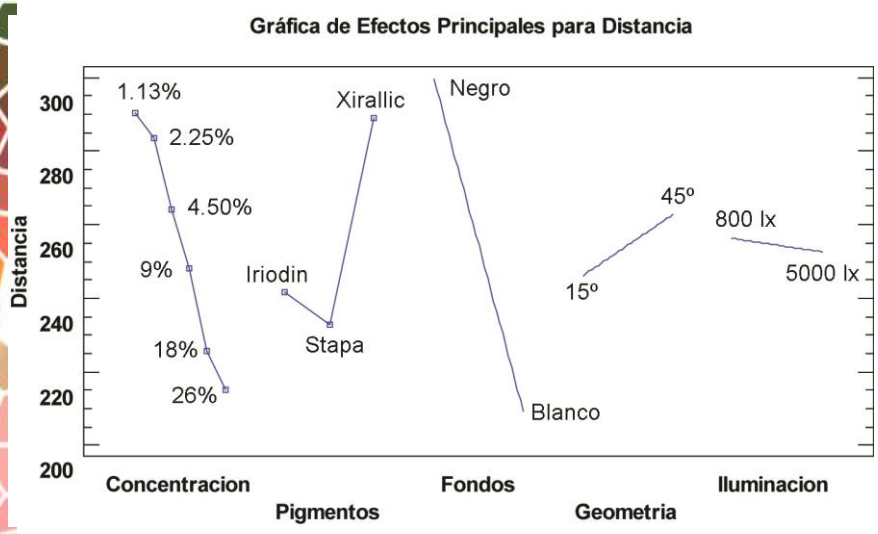
2) CONCENTRATION ANALYSIS

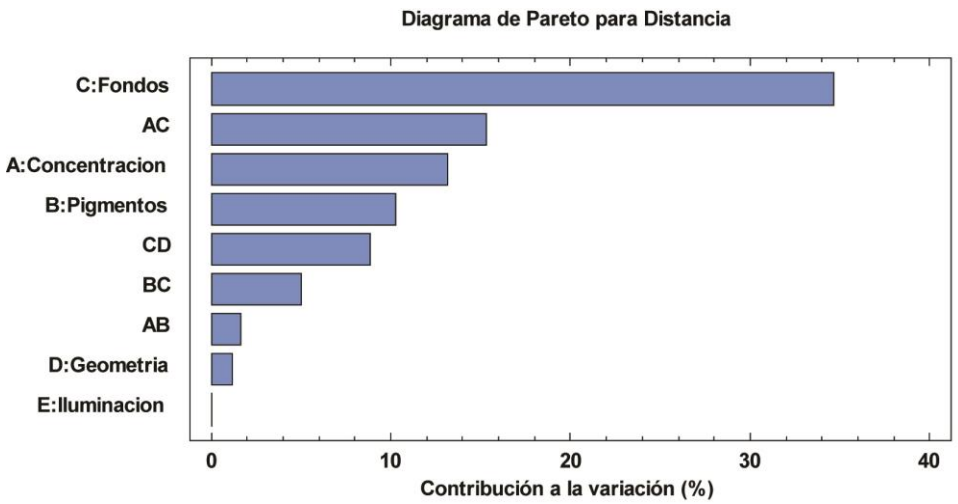


- **On black background at lower concentrations higher detection distance**
- **On white background, as the concentration is increased, the detection distance increases**

SPARKLE: DETECTION

2) CONCENTRATION ANALYSIS





- **Significant variables: background, concentration, pigment type, geometry**
- **Strong interaction between concentration and background**

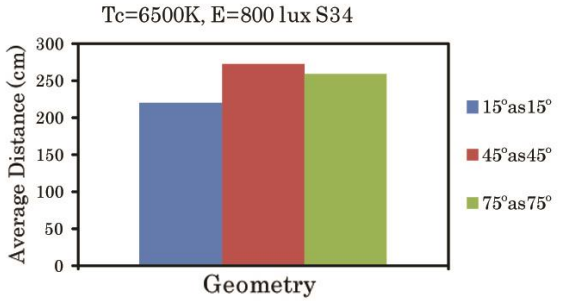
SPARKLE: DETECTION

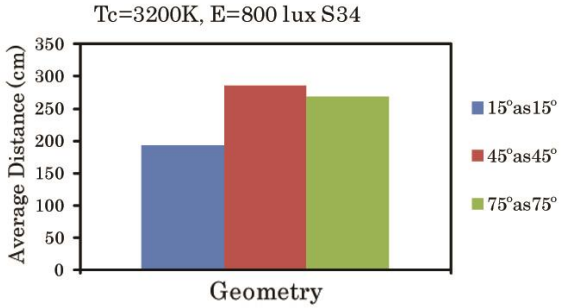
3) ENVIRONMENTAL CONDITIONS ANALYSIS

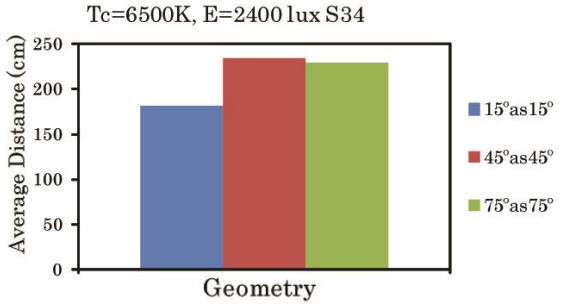
- **SAMPLES**
  - Stapa pigment: D_{50} = 34 µm; Concentration = 3.25%
  - Xirallic pigment: D_{50} =15-21 µm; Concentration = 1.13%
  - Luxan pigment: D_{50} =92.5 µm; Concentration = 2%
- **Observation conditions**
  - E(lx): 800 lx – 2400lx – 5000 lx
  - Tc: 6500K – 3200K
  - Geometry: 15ºas15º – 45ºas45º – 75ºas75º
- 972 visual evaluation by observer (12): 11664 visual evaluations

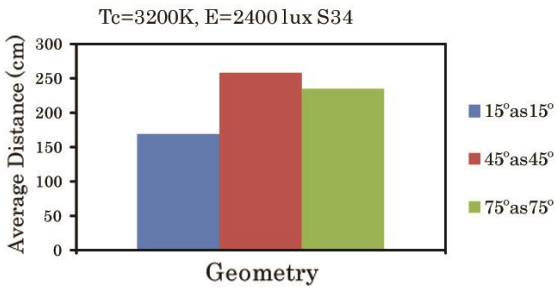
SPARKLE: DETECTION

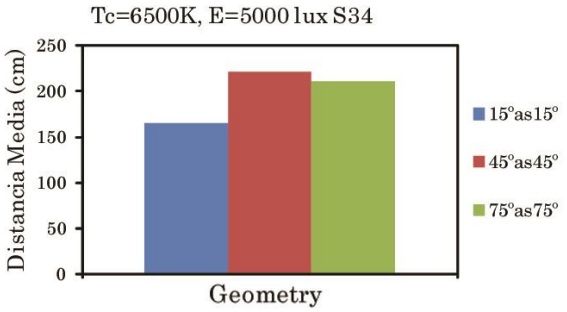
3) ENVIRONMENTAL CONDITIONS ANALYSIS

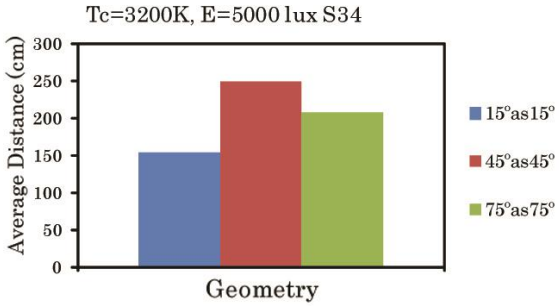






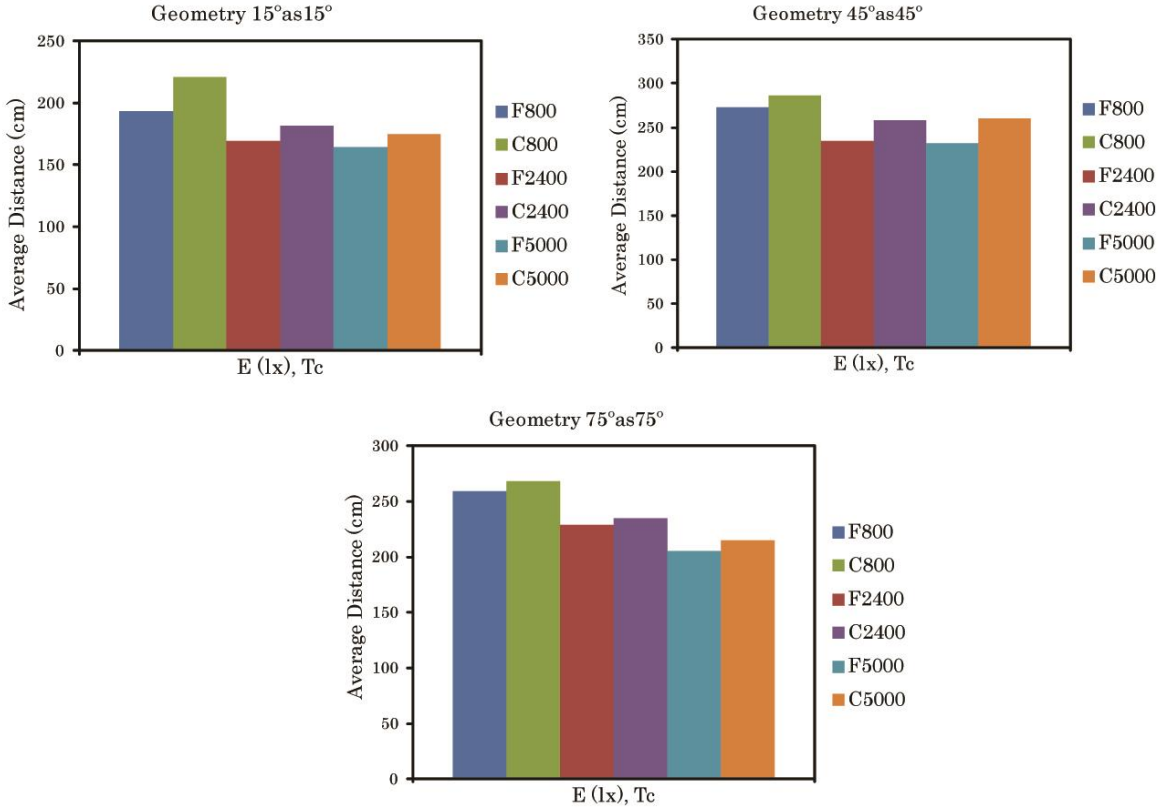






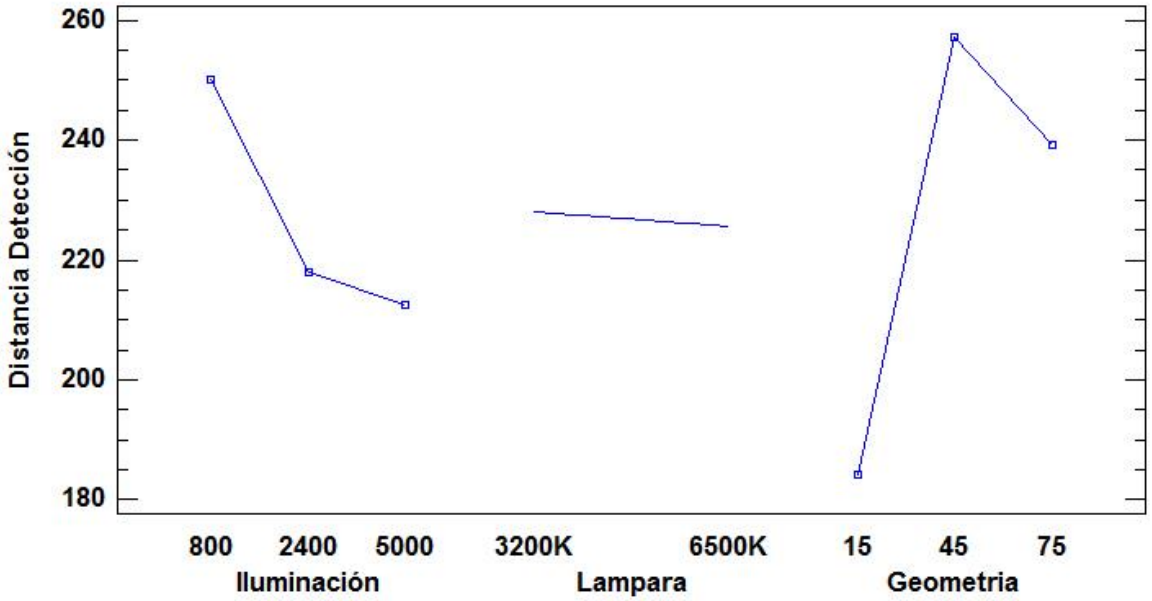
SPARKLE: DETECTION

3) ENVIRONMENTAL CONDITIONS ANALYSIS



SPARKLE: DETECTION

3) ENVIRONMENTAL CONDITIONS ANALYSIS



- for low illumination levels, a greater distance
- for the same illumination level and for the 45ºas45º geometry, sparkle is better detected
- there is no influence on the CCT

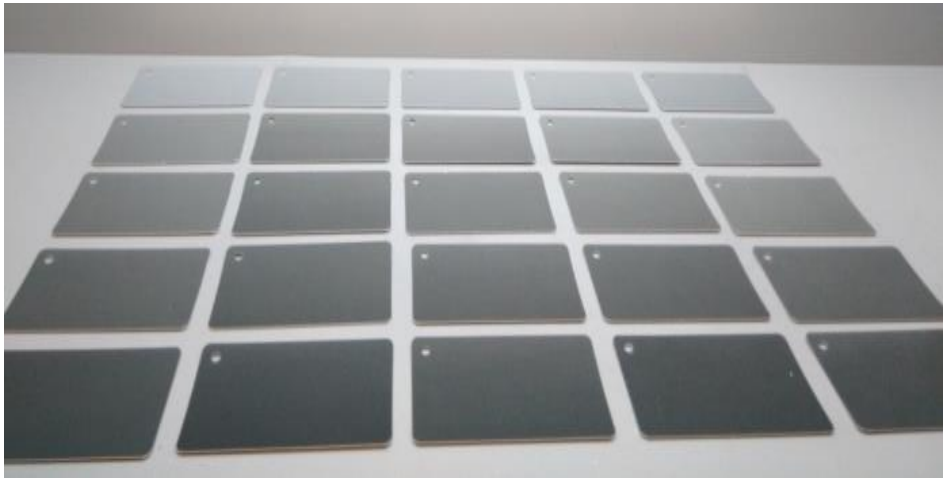
GRAININESS: SCALING

- **PURPOSE: Evaluation of the graininess effect in order to find how many dimensions are necessary to totally characterize this texture effect by means of multidimensional scaling taking into account the visual perception of observers**

- **METHODOLOGY: Two different psychophysics experiments**
  - **point rating scaling**
  - **method of triads (ordinal method)**

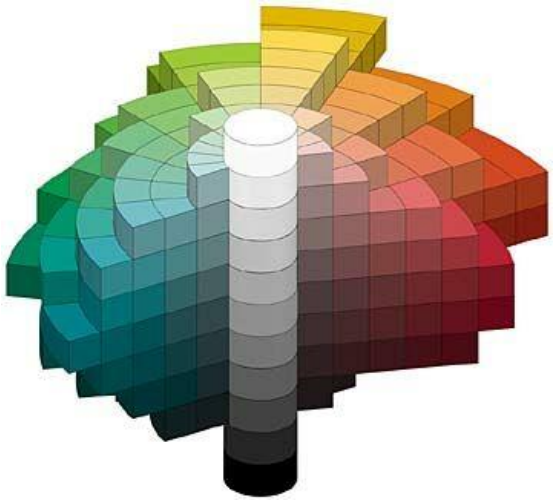
GRAININESS: SCALING

- **SAMPLES: Effect Navigator® chart (Standox)**
  - **Designed to select the exact pigment size (texture effect) for the color matching in the car refinishing industry**
  - **Painted in cardboard with a size of 70 x 120 mm**
  - **Achromatic samples ($C^*_{ab} < 10$)**



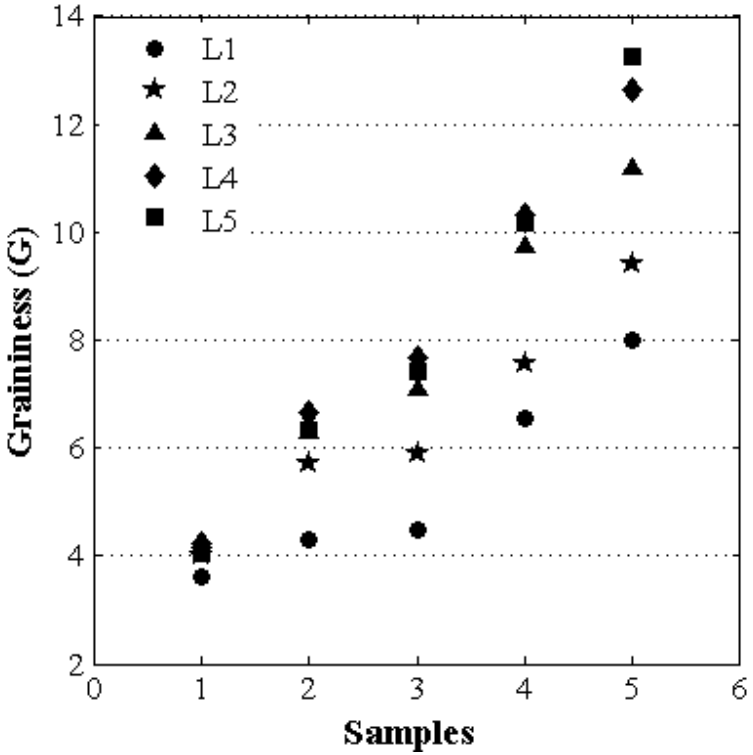
GRAININESS: SCALING

- SAMPLES: Effect Navigator® chart (Standox)
  - 5 different grades of lightness and texture effect
  - BYK-mac-i multi-angle: CIELAB values and G
    - L1: L* = 60, G ϵ [3.5, 8]
    - L2: L* = 45, G ϵ [4, 9.5]
    - L3: L* = 35, G ϵ [4, 11]
    - L4: L* = 25, G ϵ [4, 12.5]
    - L5: L* = 15, G ϵ [4, 13]



GRAININESS: SCALING

- **SAMPLES: Effect Navigator® chart (Standox)**



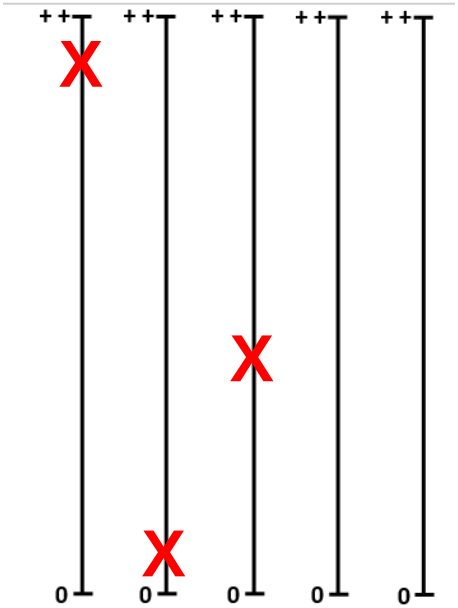
GRAININESS: SCALING

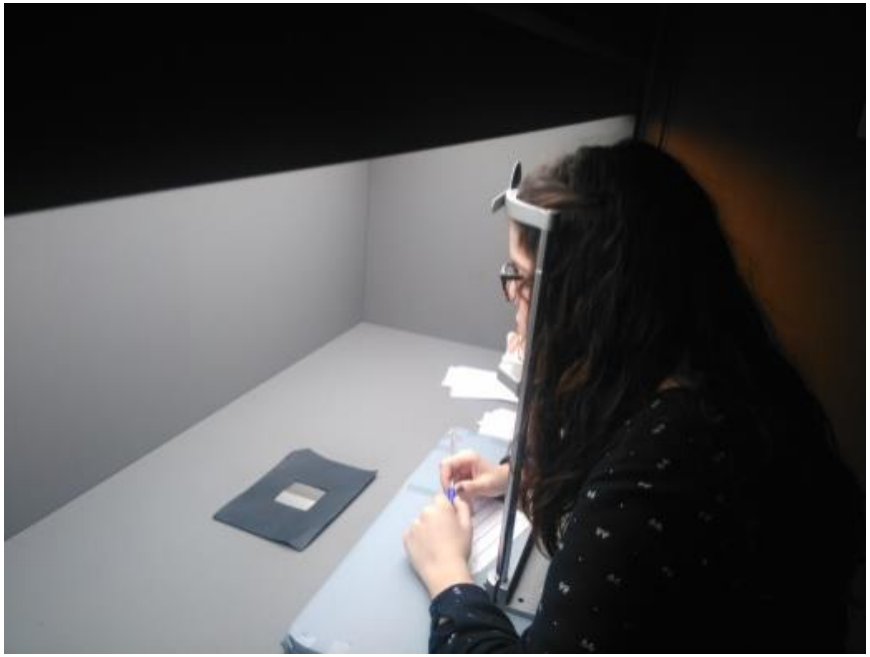
- VeriVide CAC-150 viewing booth
  - Diffuse illumination: not possible to perceive sparkle on the samples
  - Illuminance level = 1415 lx
  - D65 fluorescent simulator:
    - x = 0.3127 and y = 0.3383
    - CCT = 6439 K
    - Ra = 95 units

GRAININESS: SCALING

1) Point rating scaling method

how much these two samples differ in graininess?





GRAININESS: SCALING

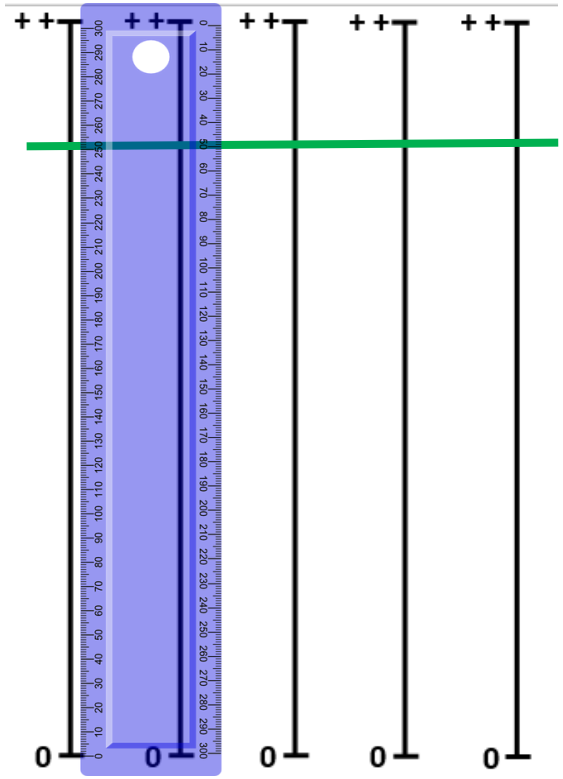
1) Point rating scaling method

- Training session + three repetitions
- 17 observers participated in the experiment
  - 11 males and 6 females
  - Average age: 32 ± 10 years old
  - Best-corrected visual acuity of 1 (decimal scale)
- 50 visual (10 x 5) assessments in a session of 30 minutes to avoid fatigue:
- 2250 visual assessments

GRAININESS: SCALING

1) Point rating scaling method

- **MDS: *mdscale* function (Matlab®)**



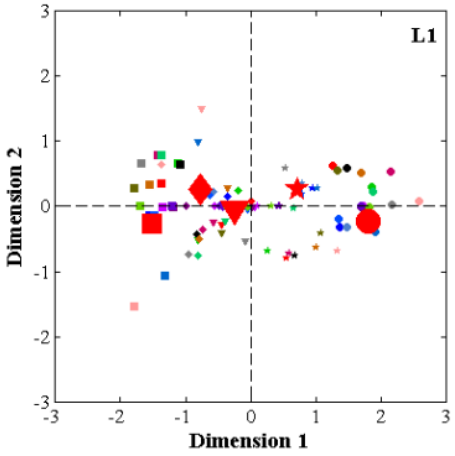
250 mm

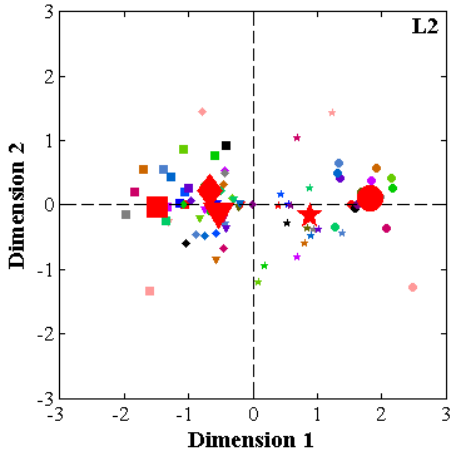
$$D = \begin{array}{c} \\ m_1 \\ m_2 \\ m_3 \\ m_4 \\ m_5 \end{array} \begin{array}{c} \begin{array}{ccccc} m_1 & m_2 & m_3 & m_4 & m_5 \end{array} \\ \begin{bmatrix} & x_{12} & x_{13} & x_{14} & x_{15} \\ & & x_{23} & x_{24} & x_{25} \\ & & & x_{34} & x_{35} \\ & & & & x_{45} \\ & & & & \end{bmatrix} \end{array}$$

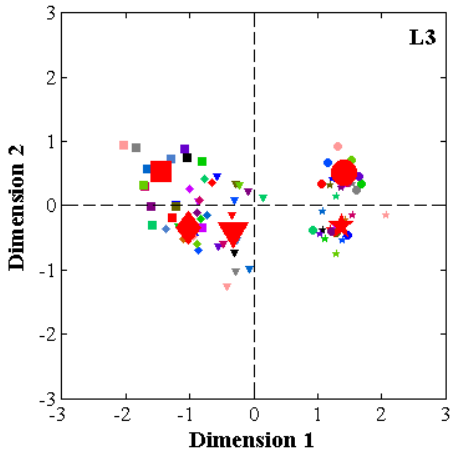
Perceived visual differences on graininess: input matrix (D)

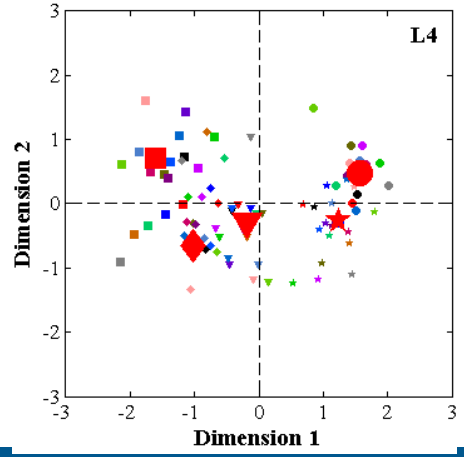
GRAININESS: SCALING

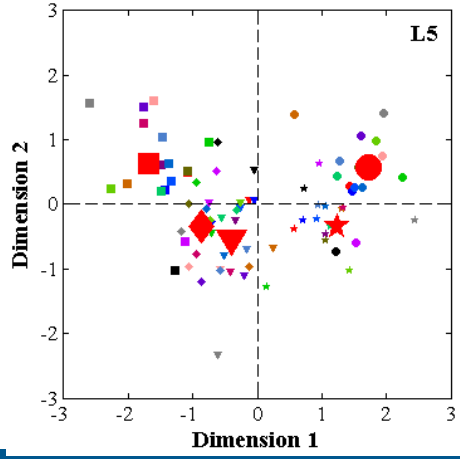
1) Point rating scaling method









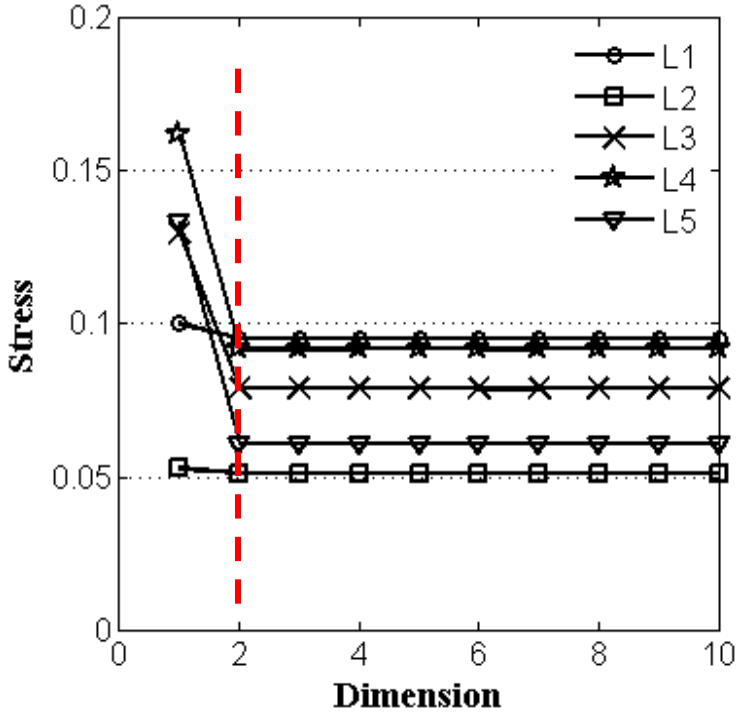


Dark samples → 2 dim
Light samples → 1 dim

GRAININESS: SCALING

1) Point rating scaling method

- **Screeplot (MDS-Dimension vs Stress)**



GRAININESS: SCALING

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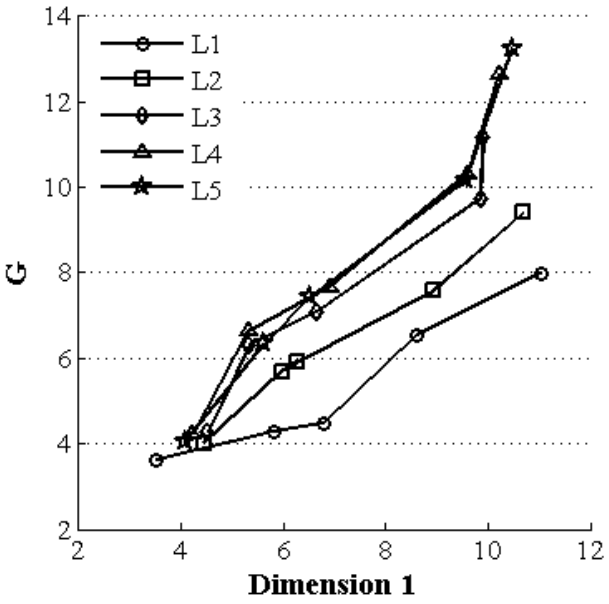
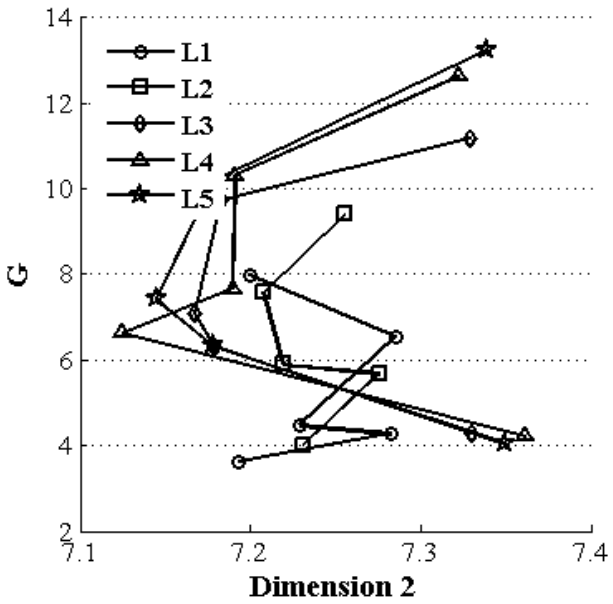
Graininess characterization by multidimensional scaling

E. Perales[a], F. J. Burgos[b], M. Vilaseca[b], V. Viqueira[a] and F. M. Martínez-Verdú[a]

1) Point rating scaling method

- ***Relationship between mathematical dimensions and physical attributes (BYK-mac-i)***





$r^2 = 0.9566$

GRAININESS: SCALING

2) Triads method

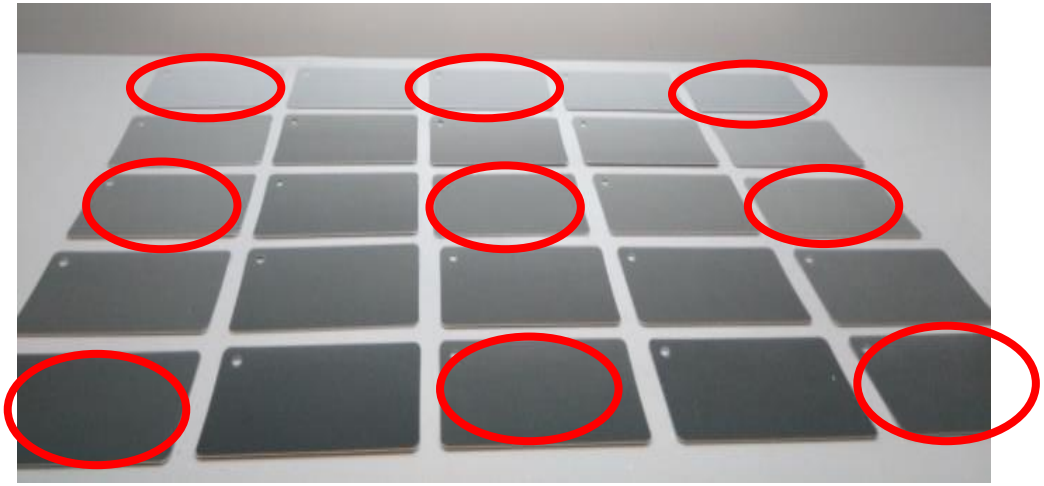
<u>Visual experiment</u>: method of triads (ordinal method)

"Which pair is more similar? Which pair is least similar?"

GRAININESS: SCALING

2) Triads method

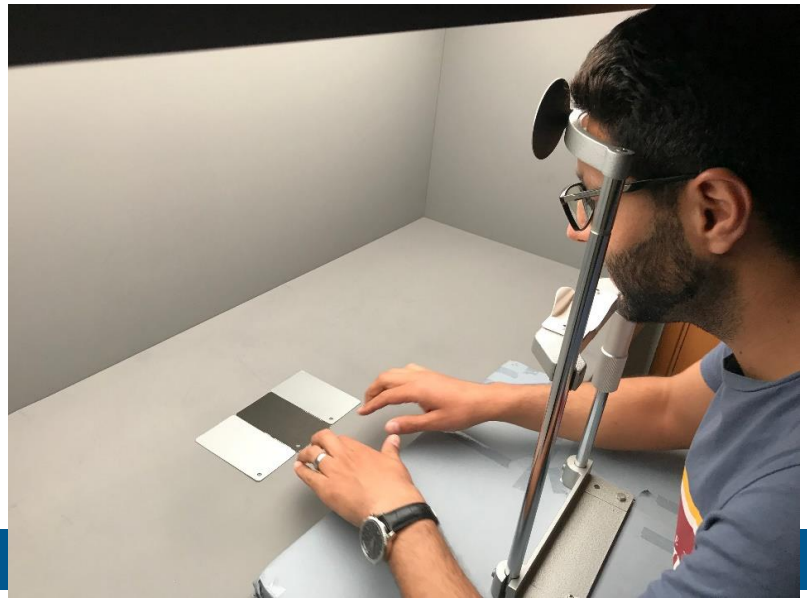
- **Number of samples: n = 9; N = 84**
- **Number of observers → 30**
- **84 visual assessments in a session of 30 minutes to avoid fatigue (3 repetitions)**



GRAININESS: SCALING

2) Triads method

- 3 different sets of combinations → to know the triad influence on the results (group 1, 2, 3)
- Observer is asked to say which sample (left or right) is more similar to the center sample



GRAININESS: SCALING

2) Triads method

- Training session + three repetitions
- 30 observers participated in the experiment
  - 13 males and 17 females
  - Average age: 32 ± 10 years old
  - Best-corrected visual acuity of 1 (decimal scale)
- 84 visual assessments in a session of 30 minutes to avoid fatigue:
  - 2520 visual assessments (7560)

GRAININESS: SCALING

2) Triads method

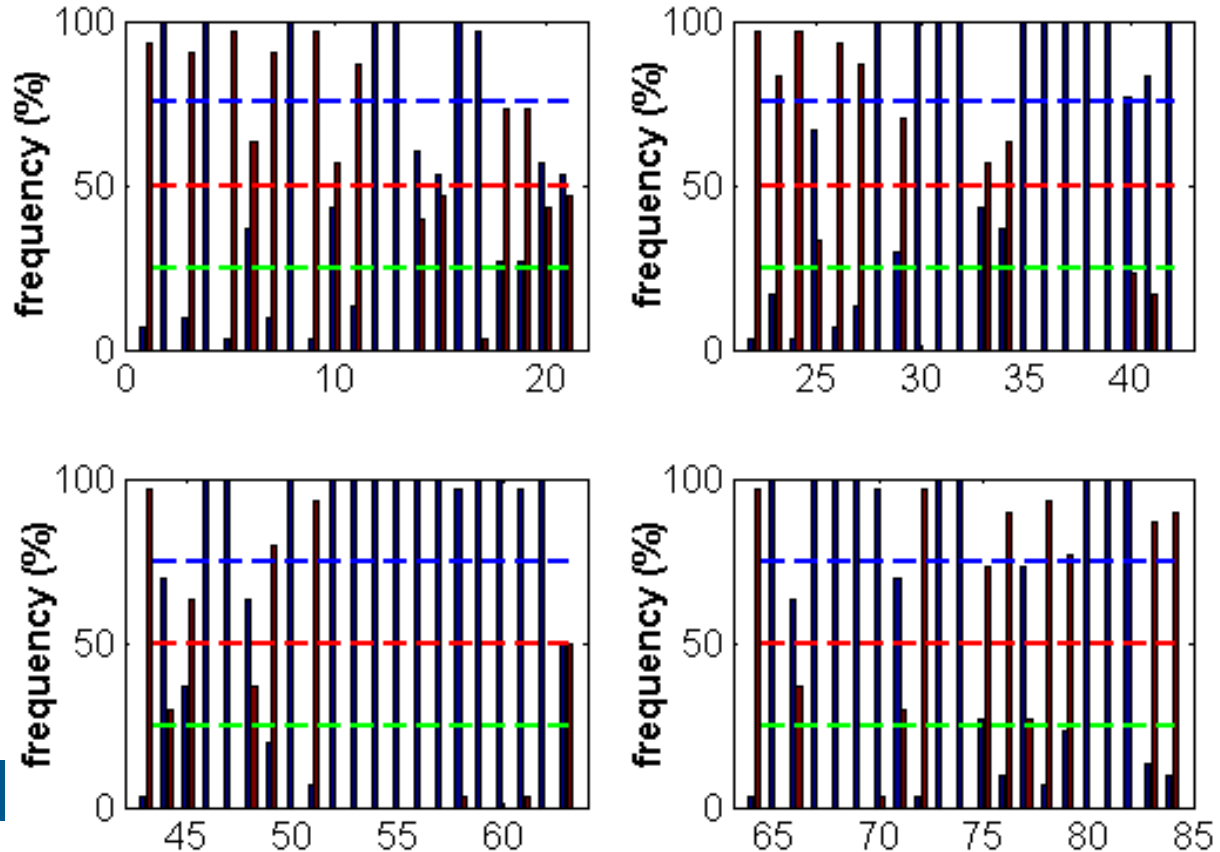
- **The set of dissimilarities is obtained for the triad comparison following the procedure described in [Wills 2009]**

WILLS, Josh, et al. Toward a perceptual space for gloss. ACM Transactions on Graphics (TOG), 2009, vol. 28, no 4, p. 103.

GRAININESS: SCALING

2) Triads method

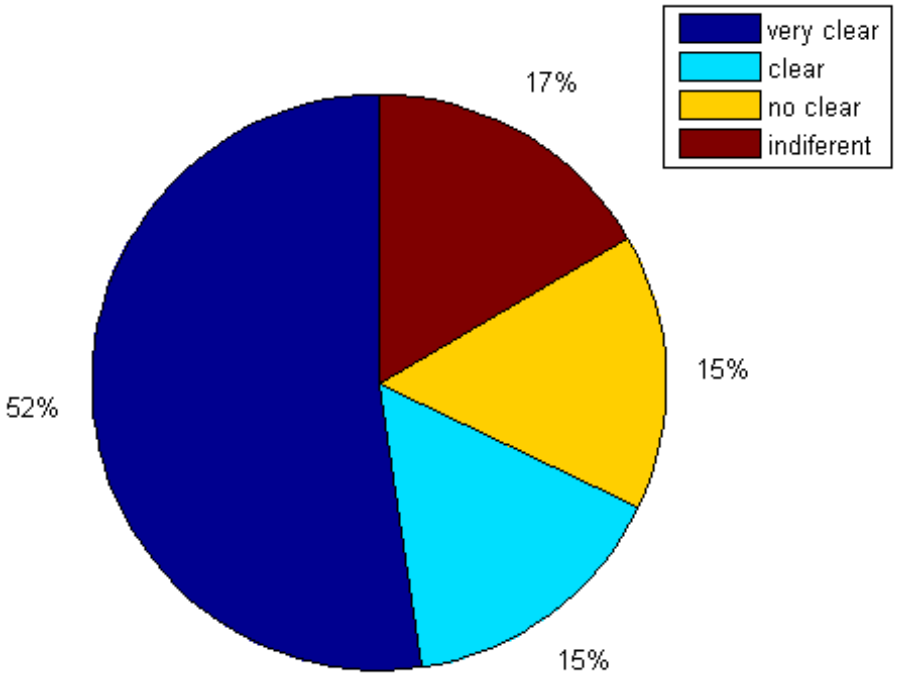
- **Triad selection analysis:** ***frequency calculated as how many times observers give the same answer for the different combinations***



GRAININESS: SCALING

2) Triads method

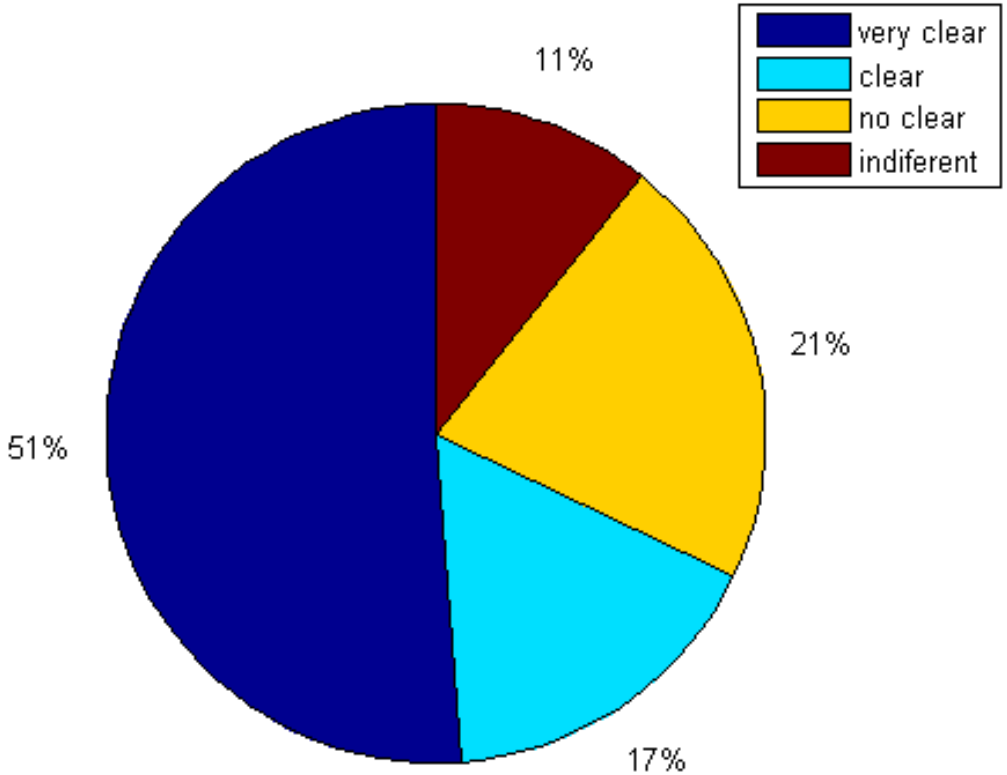
- **Triad selection analysis:** ***frequency calculated as how many times observers give the same answer for the different combinations***
  - **Combination distribution in the different quartiles for the group 1**



GRAININESS: SCALING

2) Triads method

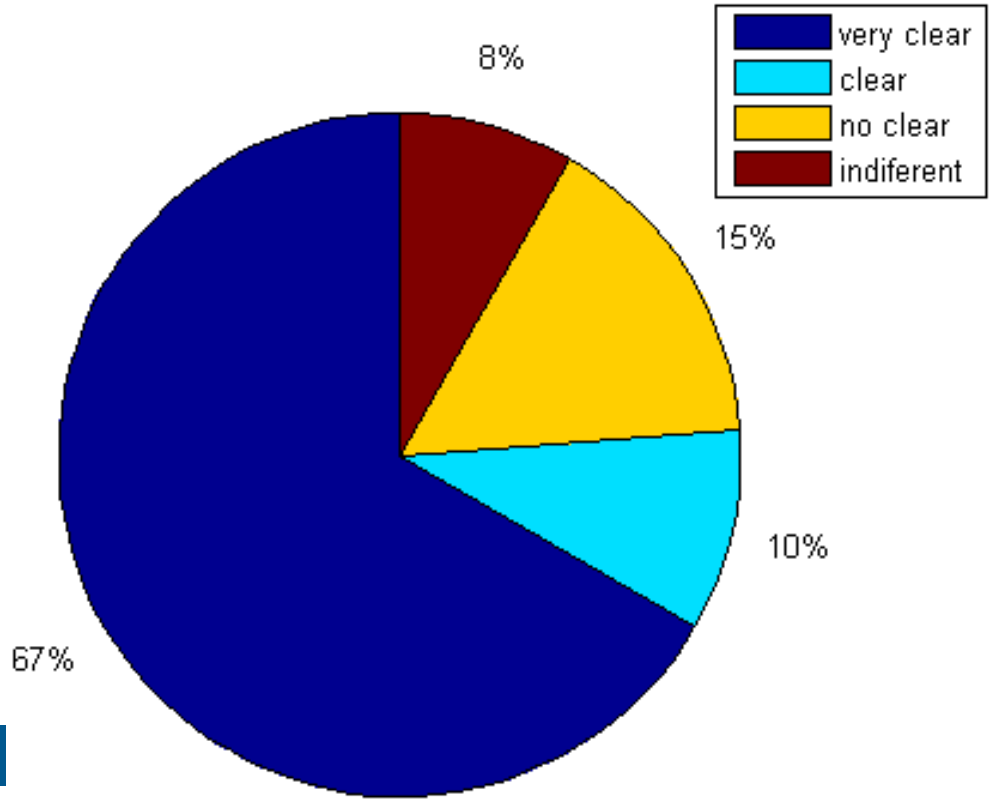
- **Triad selection analysis:**
  - **Combination distribution in the different quartiles for the group 2**



GRAININESS: SCALING

2) Triads method

- **Triad selection analysis:**
  - **Combination distribution in the different quartiles for the group 3**



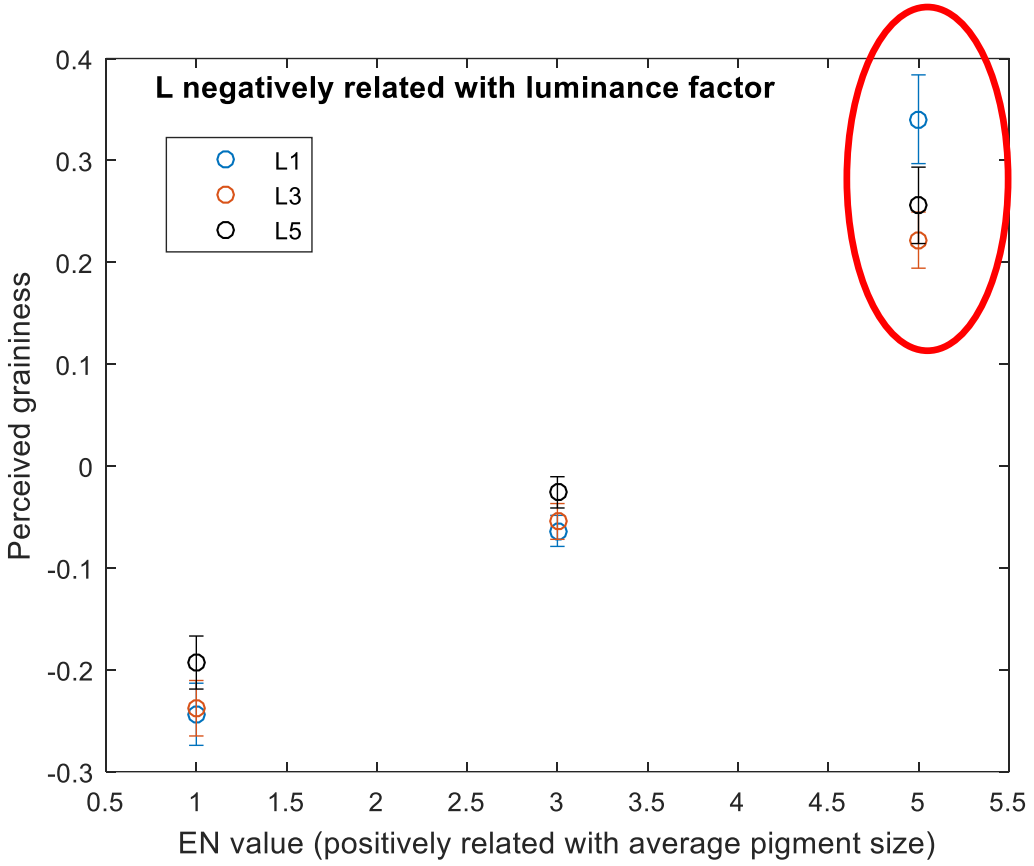
GRAININESS: SCALING

2) Triads method

- **Triad selection analysis:**
  - **A high percentage of combinations are evaluated in the same way for all the observers (> 50%)**
  - **For a 10% of combinations, the observer answer is random**
  - **These results can reduce the number of evaluations for next visual experiment**

GRAININESS: SCALING

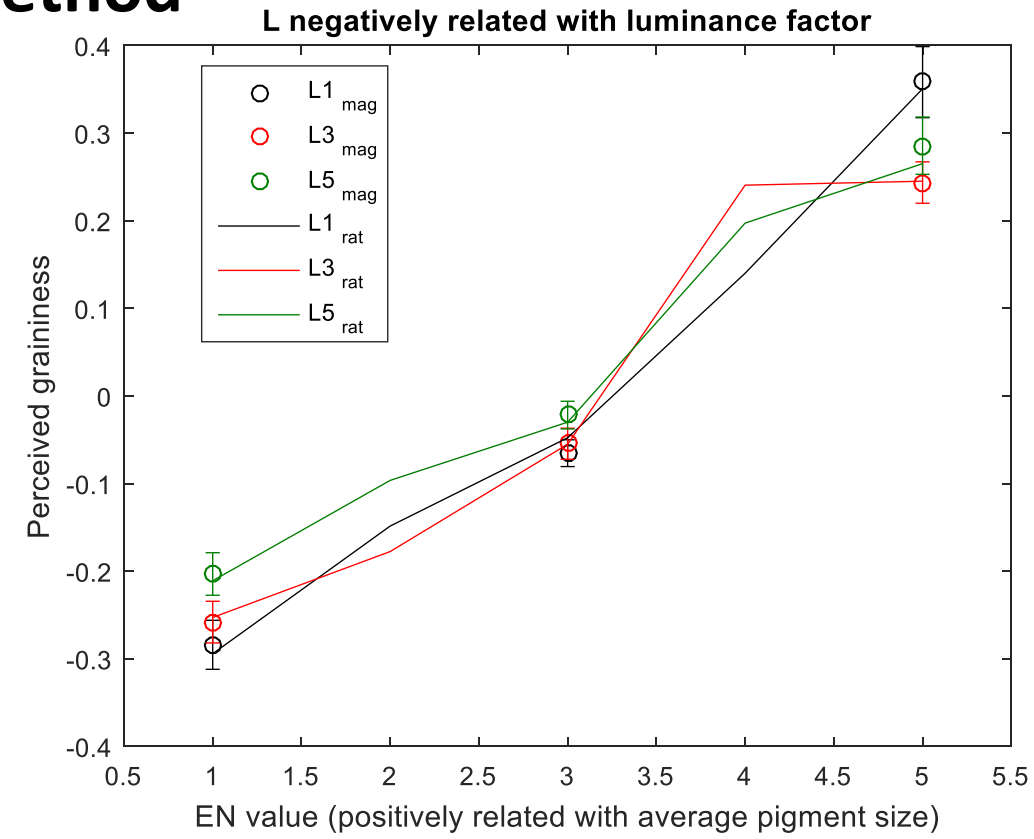
2) Triads method



- **High dependence on pigment size** (the larger it is, the larger the perceived graininess).
- **Very little dependence on lightness and pigment concentration**
- **Only for high pigment size/graininess levels, it seems that lightness/concentration favours graininess perception.**

GRAININESS: SCALING

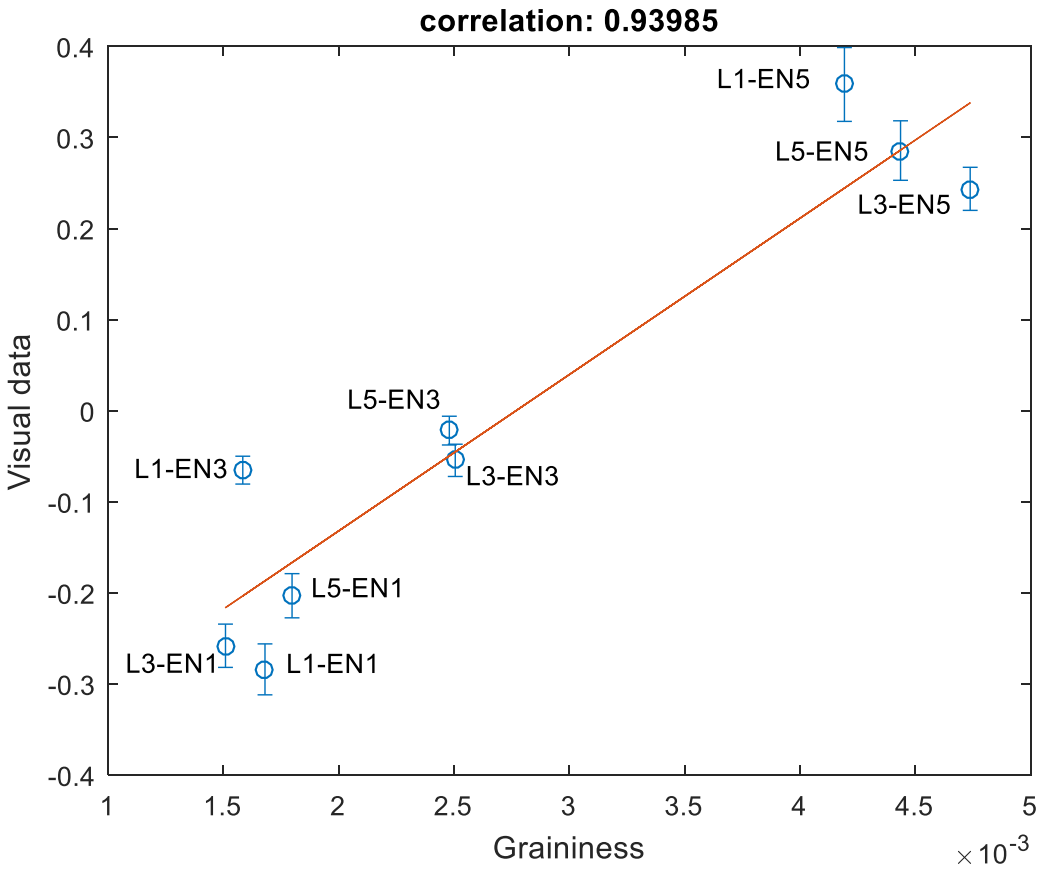
2) Triads method

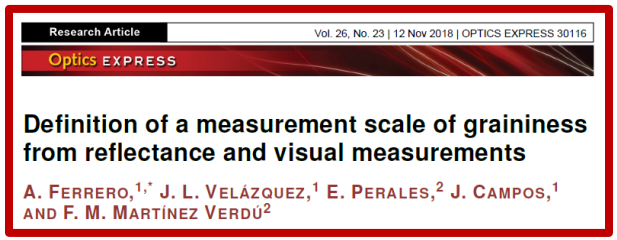


- **Very good match with results from rating experiment.**

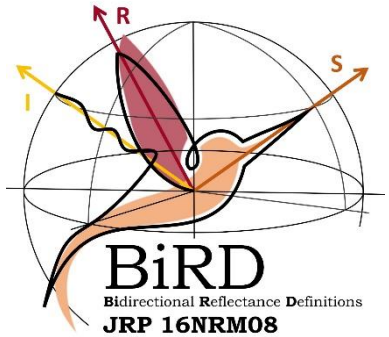
GRAININESS: SCALING

2) Triads method





- 30 observers
- 3 subsets of triplets



Bidirectional Reflectance Definitions

Workshop on Sparkle and Graininess

VISUAL EXPERIMENTS ON SPARKLE AND GRAININESS

Esther Perales

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