An order system based on material perception which adds dimensions to surface color perception

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Introduction

The word “color” is a term that carries multiple meanings for various disciplines of color research, and even for the visual nature of color, what properties included is subject to be inspected semantically and perceptually. The present study aims to go beyond the basic three properties of color – hue, saturation, and brightness – but to explore the appearance of materials, which is unignorable for describing a complete meaning of surface color.

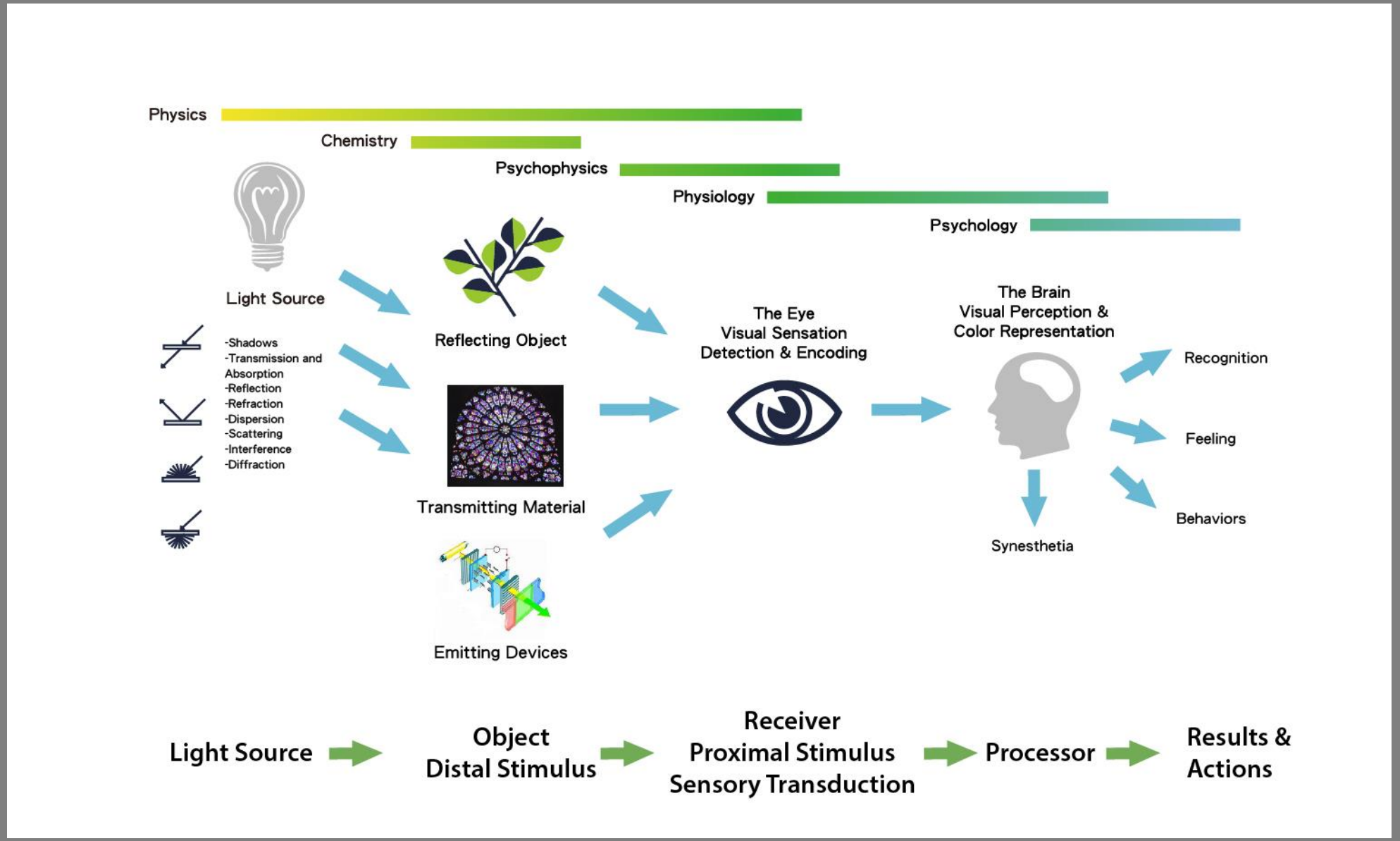
Introduction

The present study applied a three-dimensional system developed by Argentinian scholar Jose Caivano to describe these supplementary appearance qualities. The system "cesia" uses three axes to define and quantify three significant properties of material perception and further extend the description of color appearance into material properties:

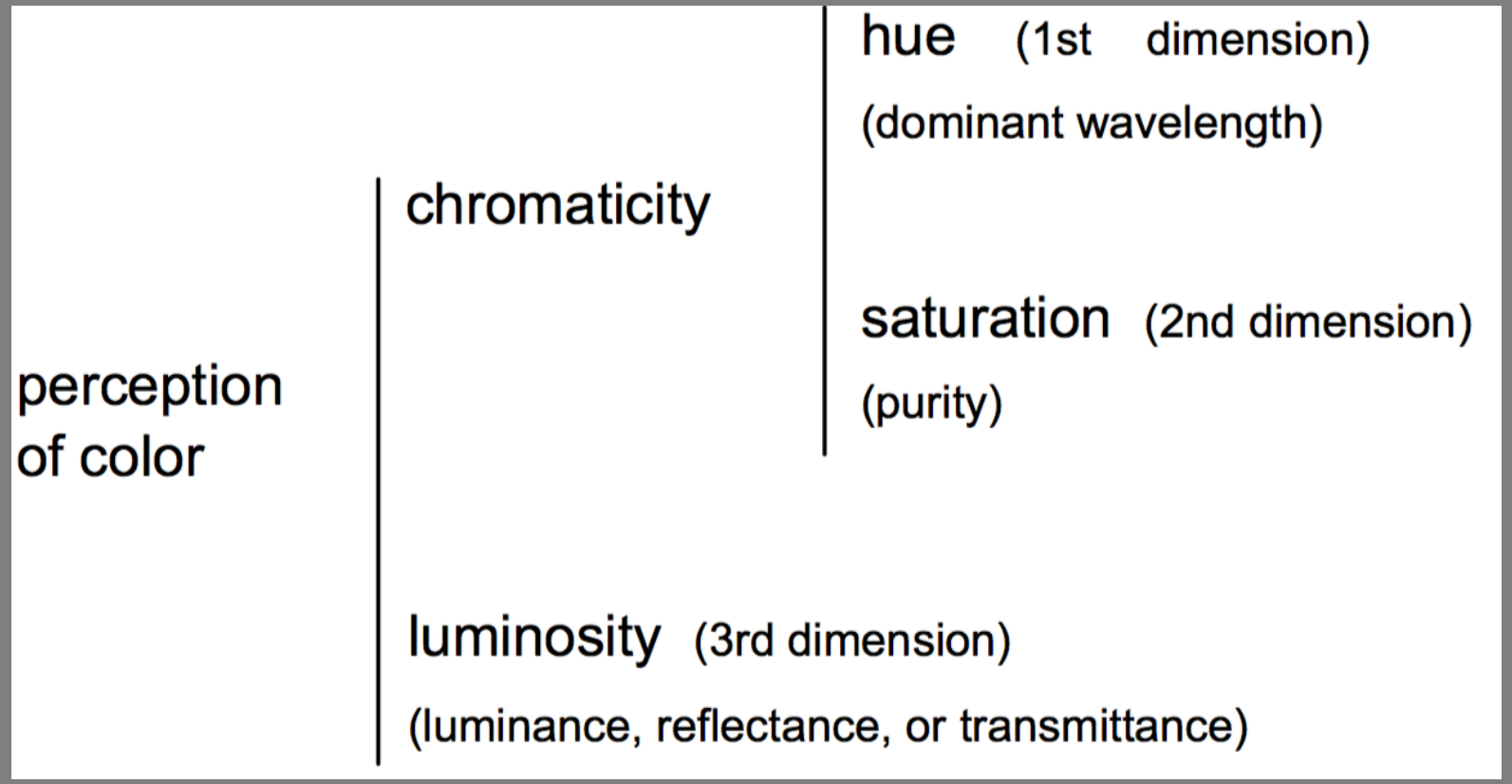
P – Permeability, D – diffusivity, and A – Absorption. The plausibility of the cesia system was supported by earlier studies.

How do we perceive the Colour?

Path of seeing color



Categories in the perception of color



(Caivano,1996)

Material Perception

The visual judgement of surface properties, such as roughness, smoothness, thickness, undulations, glossiness, matt, puffiness, transparency, hardness, etc.

The perceived surface properties through merely visual perception for images of materials.

Cesia

The word “cesia” has been coined to refer to the visual sensations aroused by different spatial distributions of light:

sensations of transparency, translucency, matte opacity, specularity, glossiness, darkness, etc.

Color sensations are always accompanied by sensations of cesia; the same opaque color may have a glossy or matte aspect.

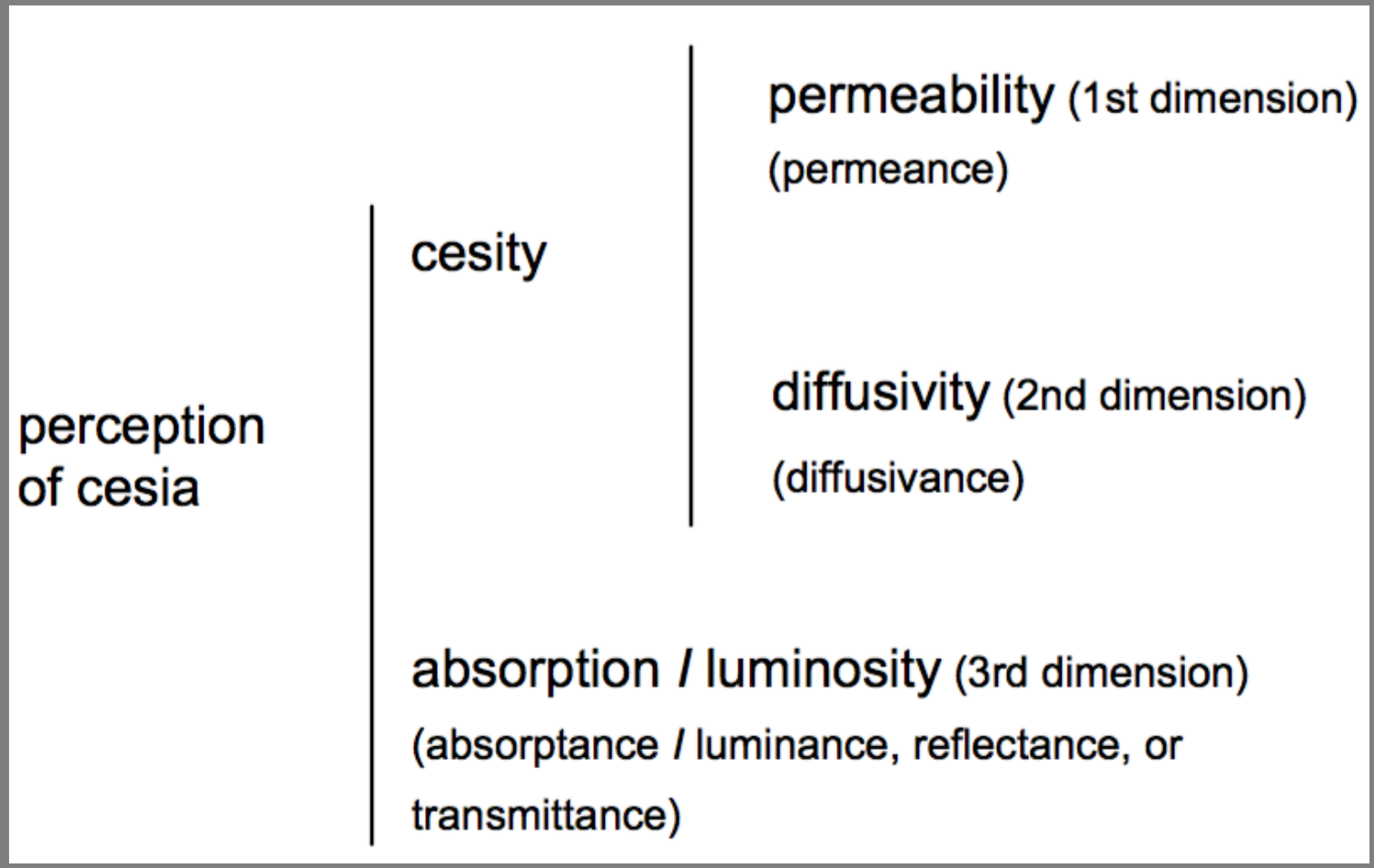
Cesia

Cesia properties appear associated with color due to the fact that all the spatial modalities of light transfer may be selective as regards wavelength; if they are nonselective, then we have achromatic or colorless cesias.

The explanation arises from the analysis of the possibilities of transmission and reflection (whether they are diffuse or regular), as well as absorption of light, splitting the light stimuli into each primary component.

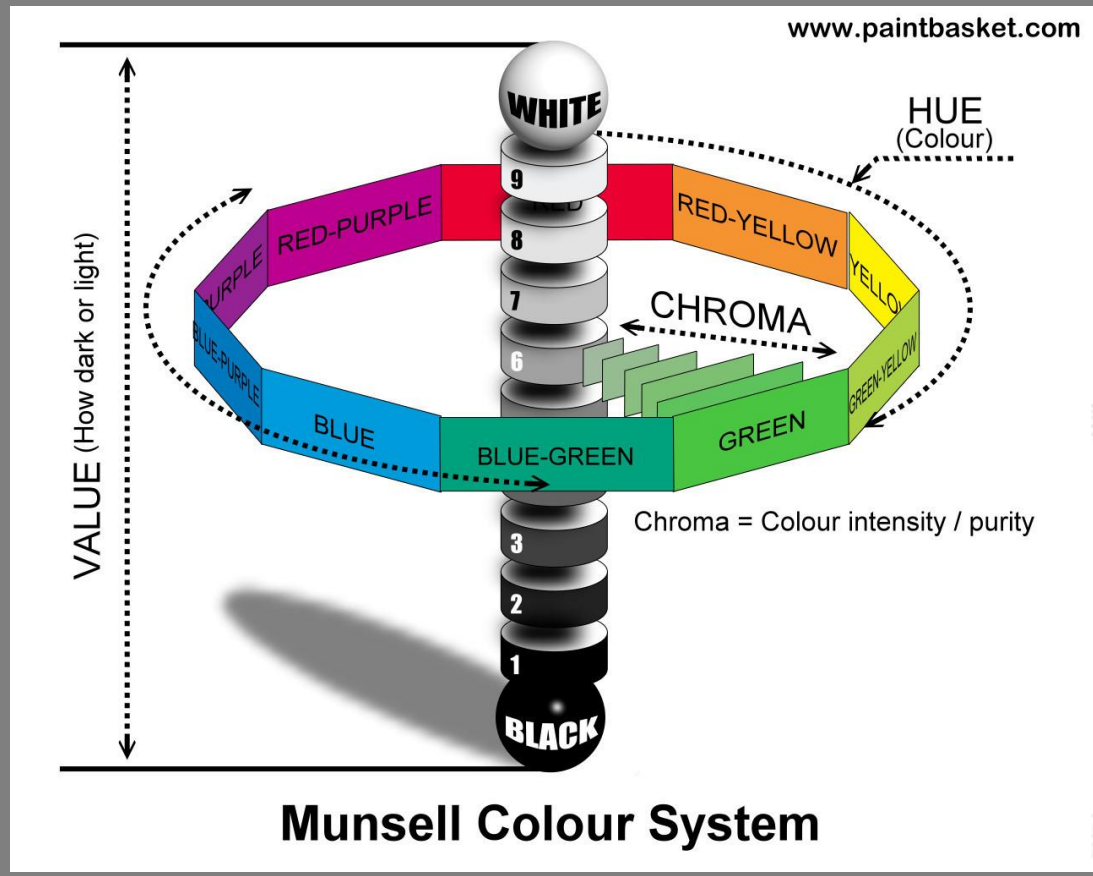
Caivano (1991)

Categories in the perception of cesia

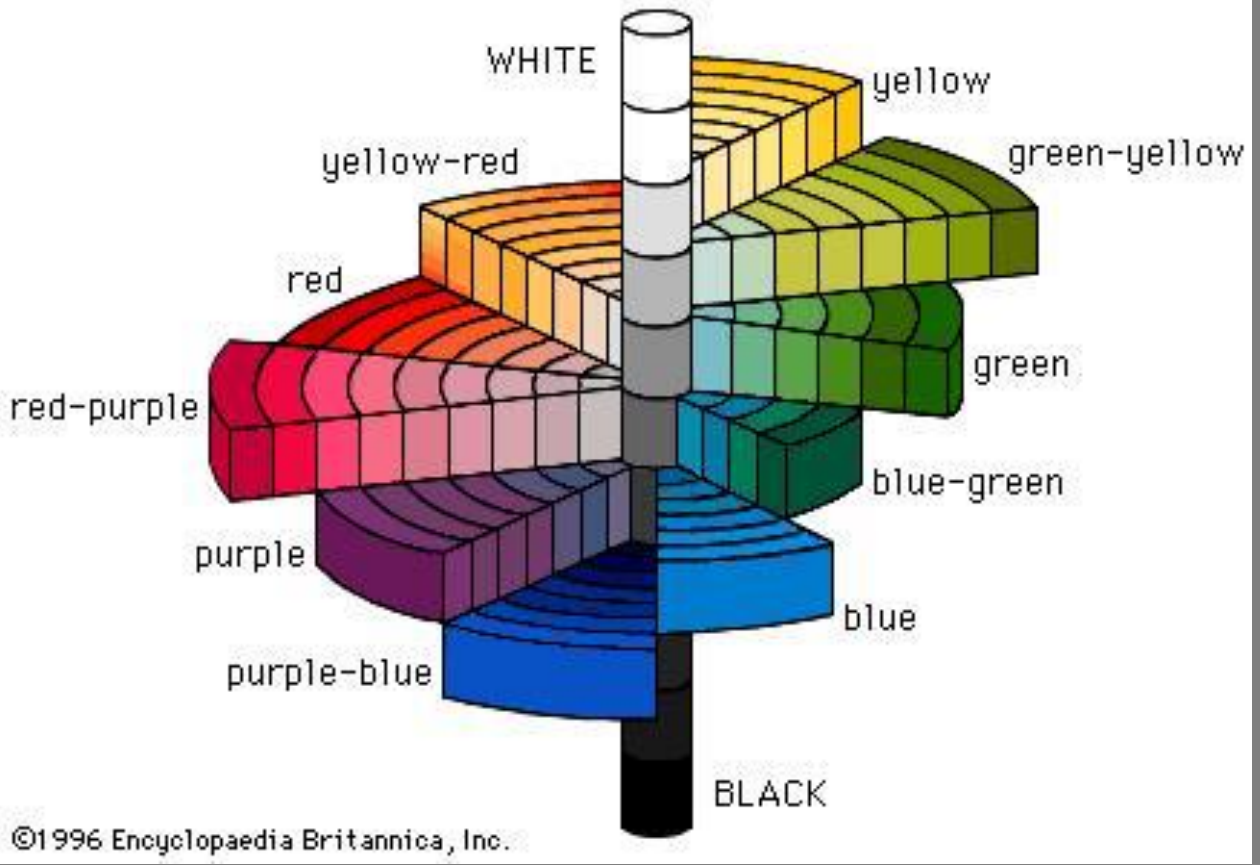


(Caivano,1996)

Can we add more dimensions to a color order system?



Munsell Colour System



Based on Hale (1990), the technical committee of the International Organization for Standardization, ISO/ TC187 (Colour Notations), has defined a color-order system as “a set of principles for the ordering and denotation of colors that defines: (a) an arrangement of colors according to attributes such that the more similar their attributes, the closer are the colors located in the arrangement, and (b) a method of denoting the locations in the arrangement, and hence of the colors at these locations.”

The purpose of a color-order system determines the number of attributes that must be considered, each attribute defining one dimension of the system.

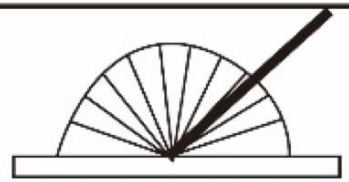
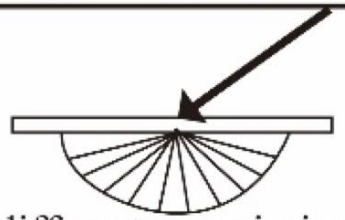
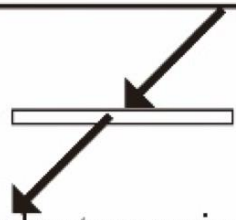
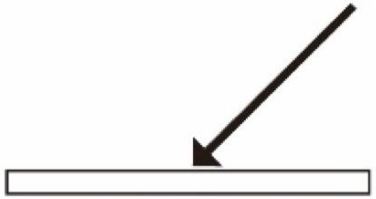
Following the definition of a color order system, the present study suggests to build up an order system that arranges colors according to material perception attributes, and applies a method of perceptual magnitude estimation to construct the scales of cesia to denote samples on locations of arrangement.

The purpose is to build a three-dimensional order system to describe the perceived material surface attributes, as the way a color order system describing color appearance attributes. The material perception order system can be used to denote material samples with their perceived surface appearances, and is valuable for both science and industry.

The present study applied a three-dimensional system developed by Argentinian scholar Jose Caivano to describe these supplementary appearance qualities.

Caivano (1991)

Five primary interactions between matter and light (physical stimulus)

Absorbed	Re-emitted	
	Diffusely	Regularly
Reflected	 1 diffuse reflection(matte)	 2 Regular reflection (mirror-like)
Trans-mitted	 3 diffuse transmission (translucent)	 4 Regular transmission (transparent)
different distribu-tions of light in space 5 		

By Caivano (1991)

- **P (permeability): 3, 4**


Light passing through the object so that incident and emerging radiation are in opposite semispaces divided by the object.

- **D (diffuseness): 1**

Light scattered in infinite directions, or re-emitted regularly in only one direction so that the emerging ray is as even and direct as the incident one.

- **A (absorbability): 5**

The incident radiation does not emerge from the surface or body in any visible way.

- **R (reflectance): 2**

Incident and emerging radiation are in the same semispace in relation to the object.

- **L (lightness):**

The degree of light emitting from a surface from the direction of observation.

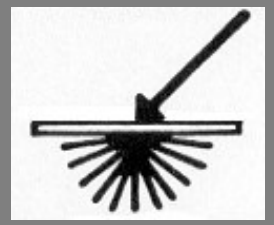
By Caivano (1991)

Four different cesia types in the same color

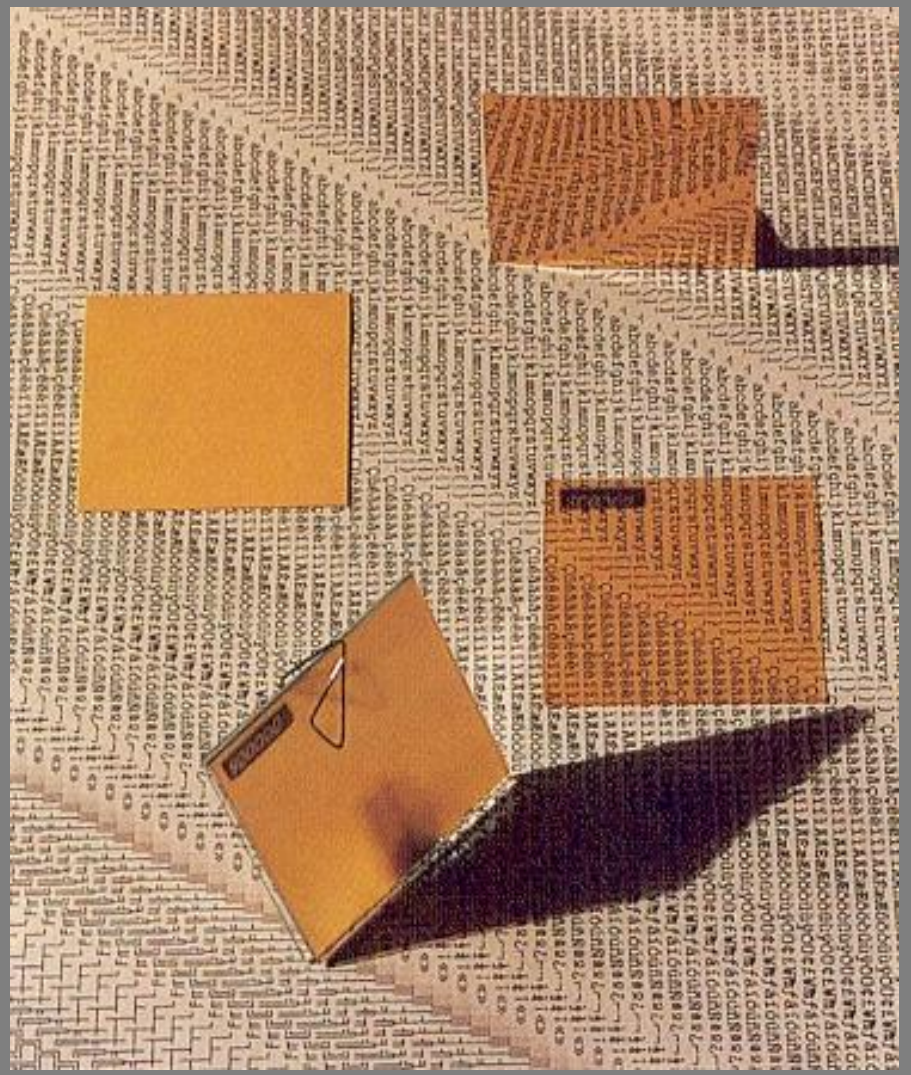
1

diffuse reflection
(matte)

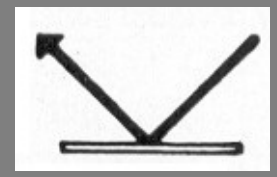
3



diffuse transmission
(translucent)

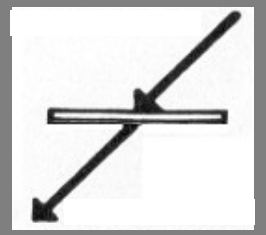


cesia



2

Regular reflection
(mirror-like)



4

Regular transmission
(transparent)

P D L example

P: permeability
D: diffusivity
L: lightness

inherent cesia:
P 95, D 0, L 95

perceived cesia:
P 50, D 0, L 95

perceived cesia:
P 5, D 5, L 95

The window looks transparent during the day, when the most intense source of light is outside the room, and turns specular as night advances, when the artificial light inside the room becomes the most intense source.

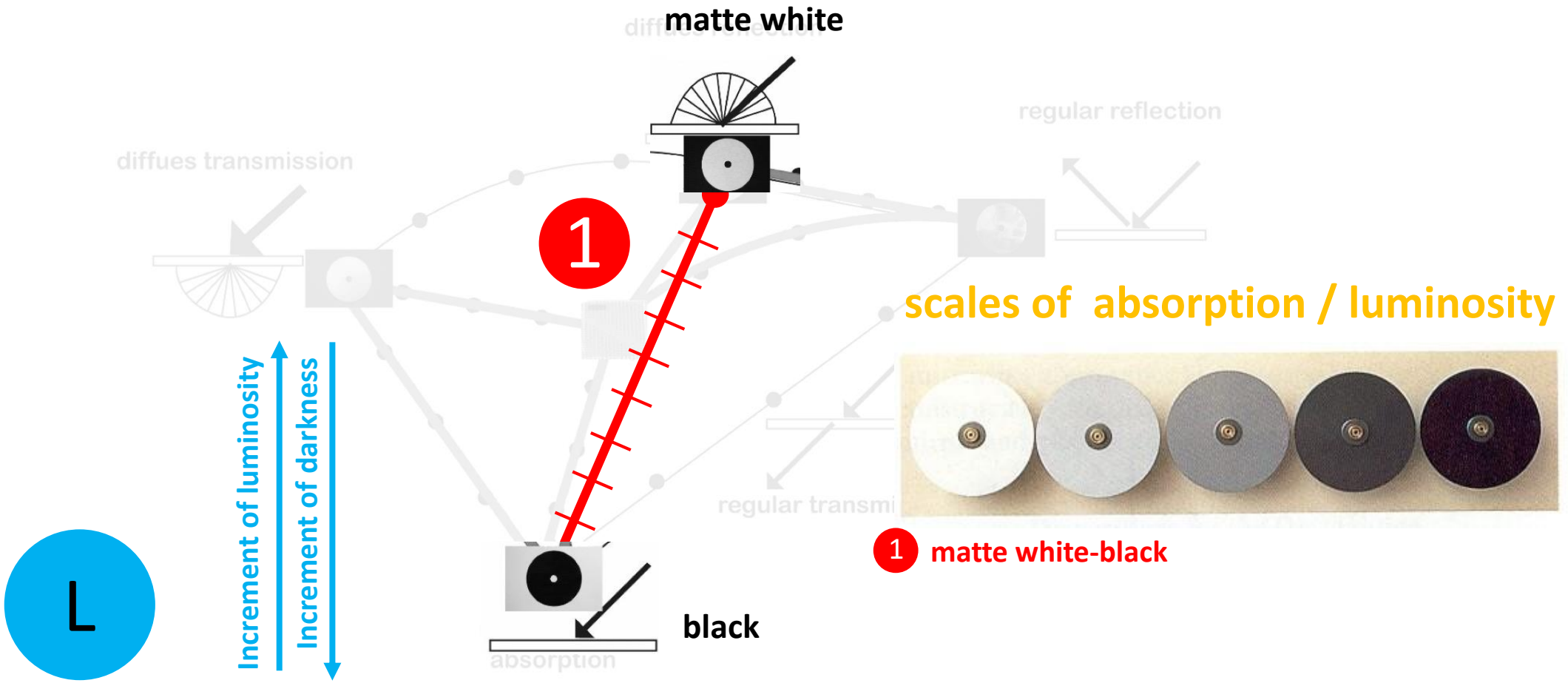
Other types of scales of cesia, In this case made by the mixture of liquids.
(1). Transparent - white. This is a scale where a variation of permeability / opacity (from transparent to opaque) and a variation of diffusivity / regularity (from regular to diffuse) occur simultaneously.

(2). Transparent blue- opaque blue. A scale of the same kind as the previous one but with color (selectivity in regard to wavelength).

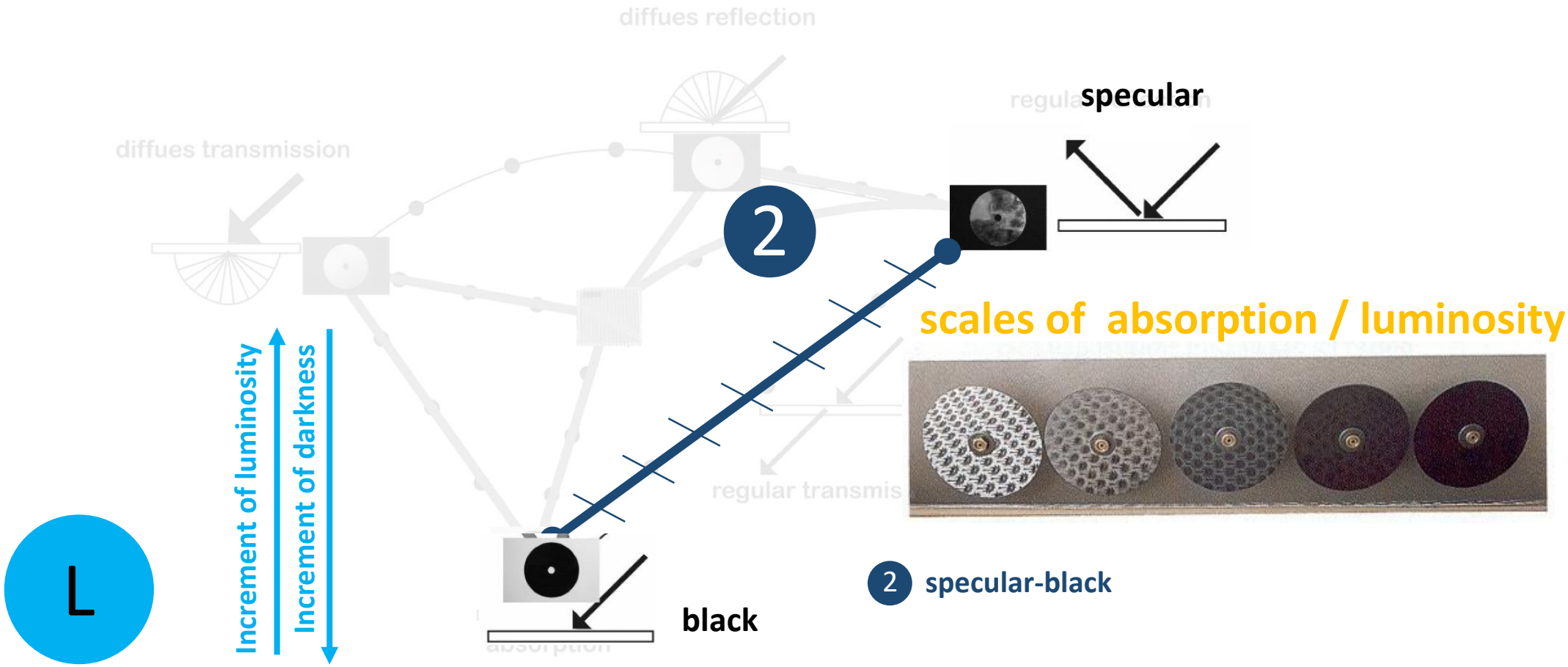
The five primary interactions between matter and light in turn generate five material properties (PDARL), and in turn five primary cesia stimuli and sensations.

Then a solid model of cesia was suggested.

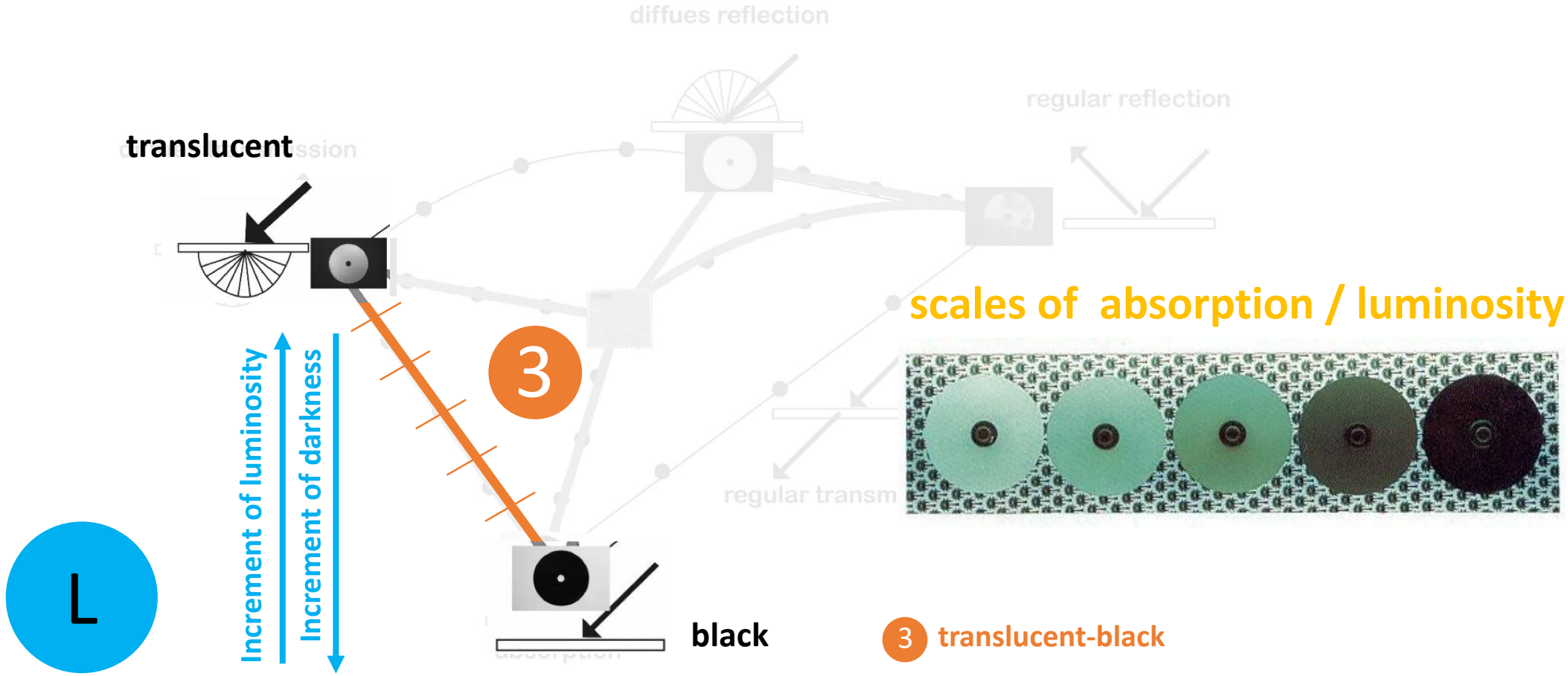
The solid model of cesia with the five primary sensations and the eight kinds of variation



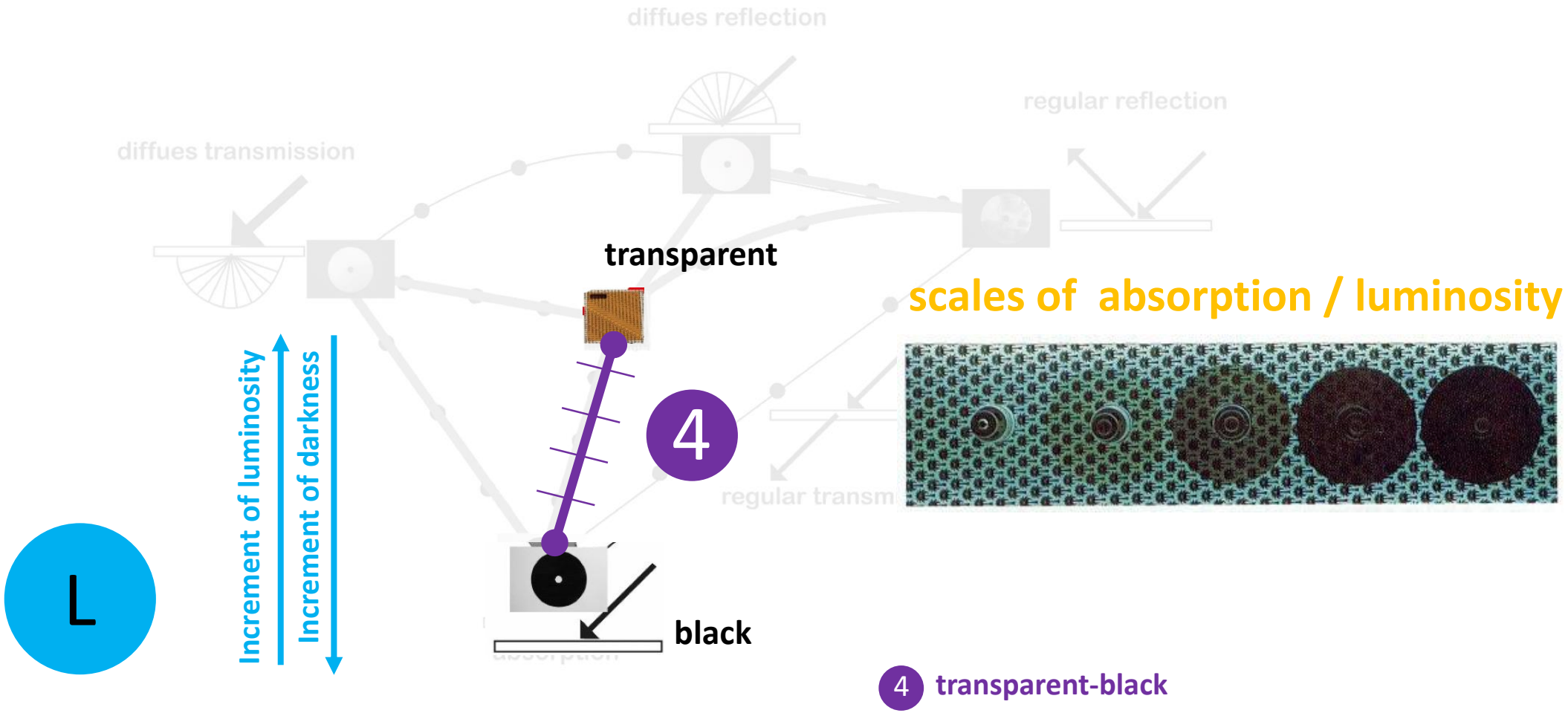
The solid model of cesia with the five primary sensations and the eight kinds of variation



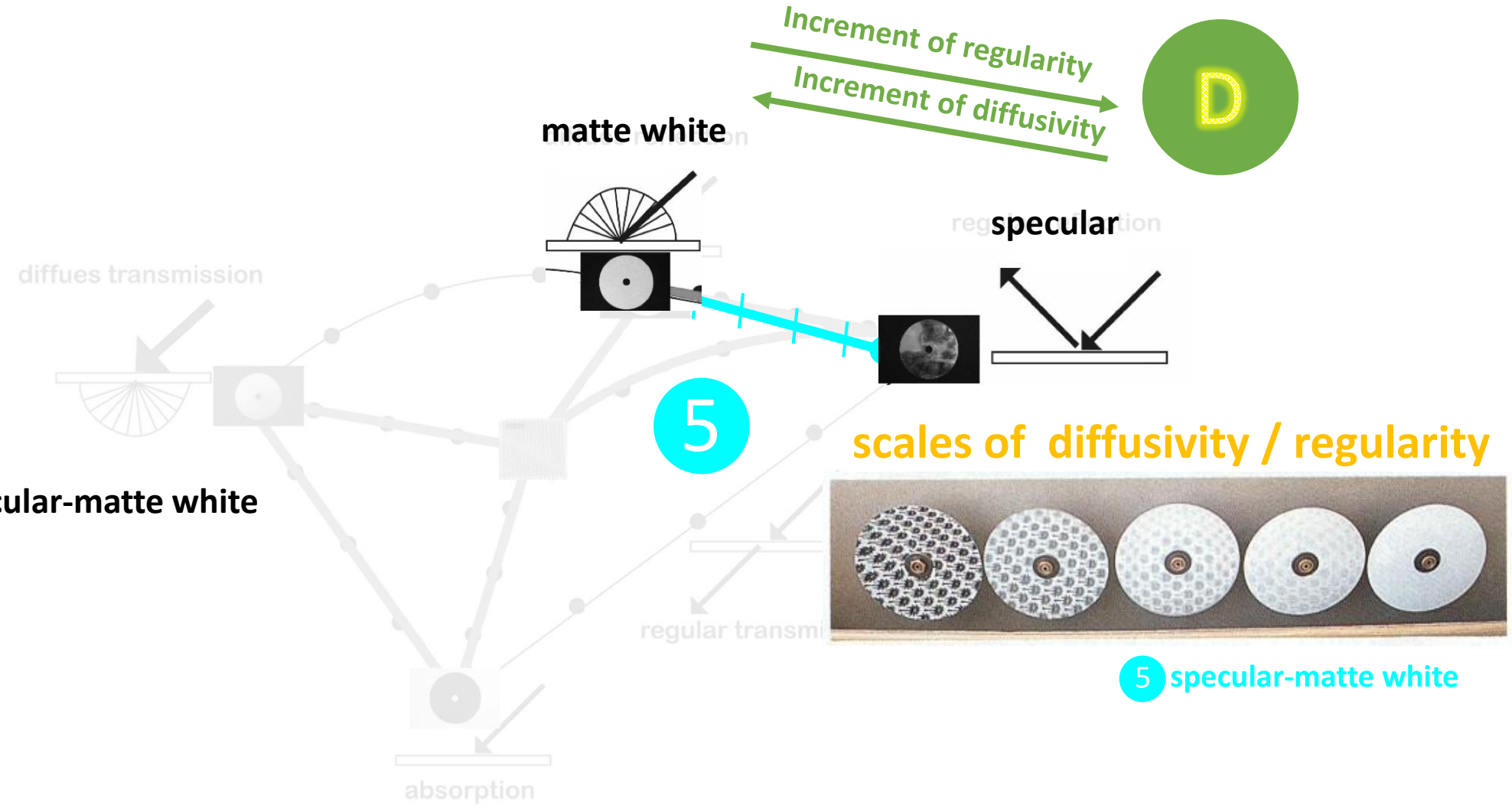
The solid model of cesia with the five primary sensations and the eight kinds of variation



The solid model of cesia with the five primary sensations and the eight kinds of variation



The solid model of cesia with the five primary sensations and the eight kinds of variation



5. specular-matte white

The solid model of cesia with the five primary sensations and the eight kinds of variation

Increment of regularity

Increment of diffusivity

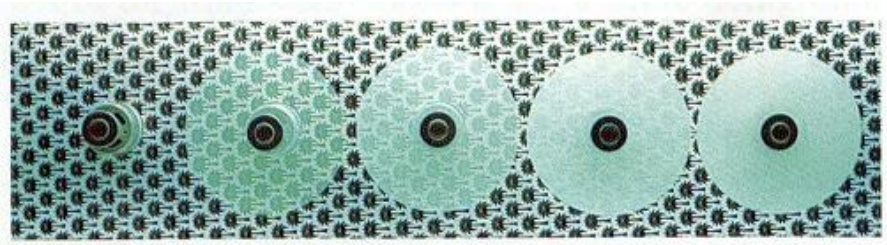
D

translucent

transparent

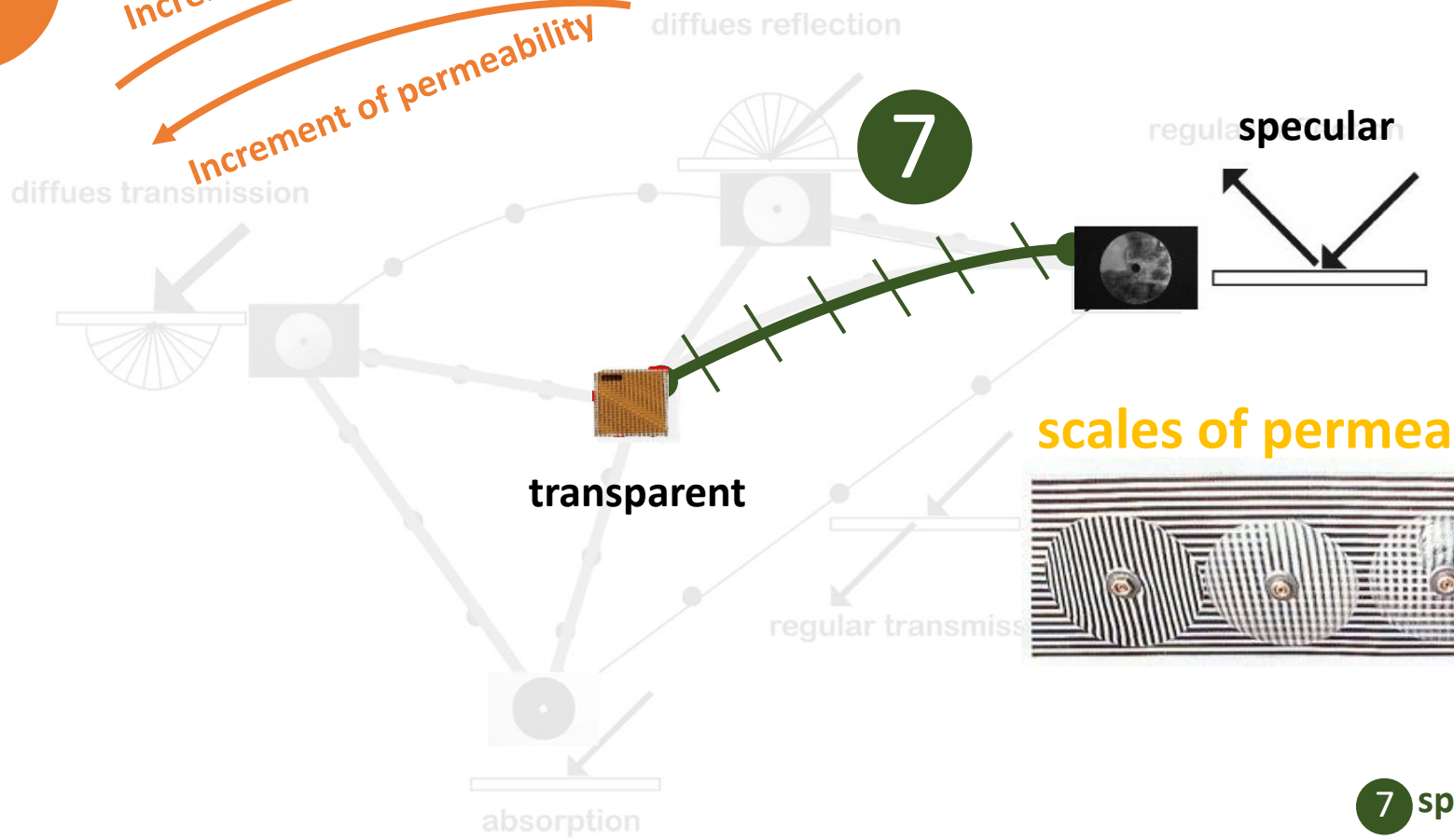
6

scales of diffusivity / regularity



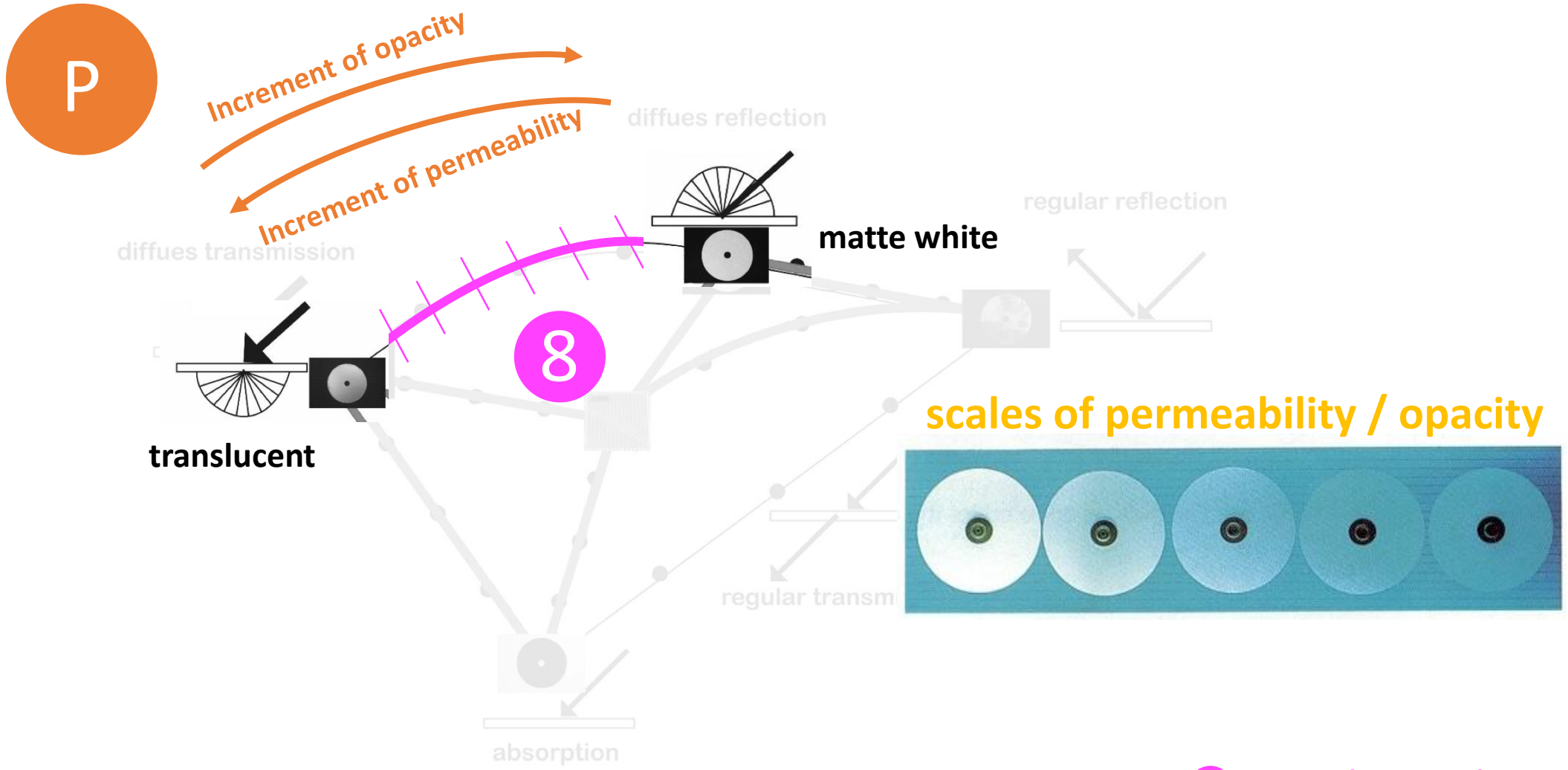
6 transparent-translucent

The solid model of cesia with the five primary sensations and the eight kinds of variation



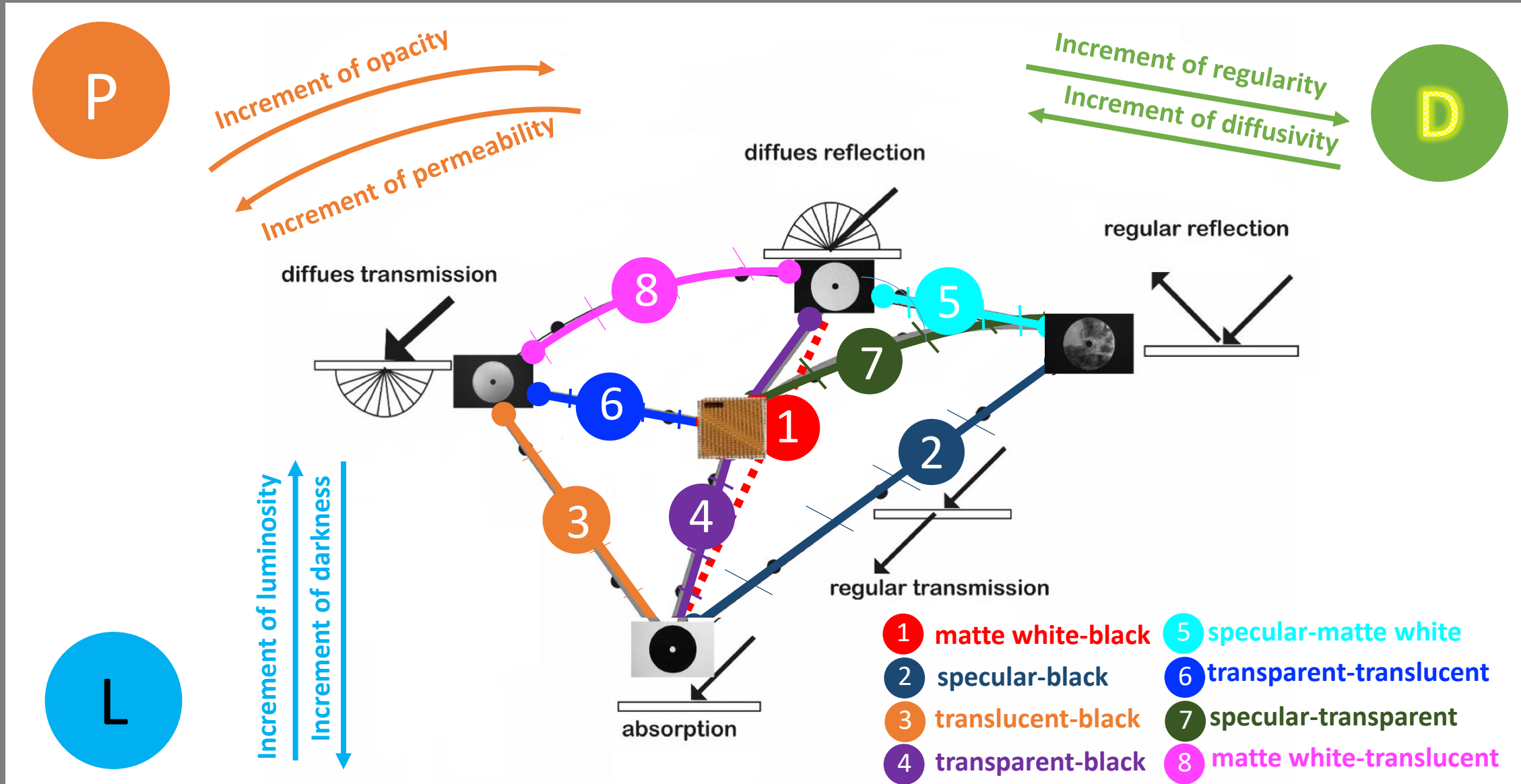
7 specular-transparent

The solid model of cesia with the five primary sensations and the eight kinds of variation



8 matte white-translucent

The solid model of cesia with the five primary sensations and the eight kinds of variation



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However, the original cesia scales are based only on physical properties of material,

and lack of psychophysical scaling data to relate the physical cesia values and perceived psychological sensations.

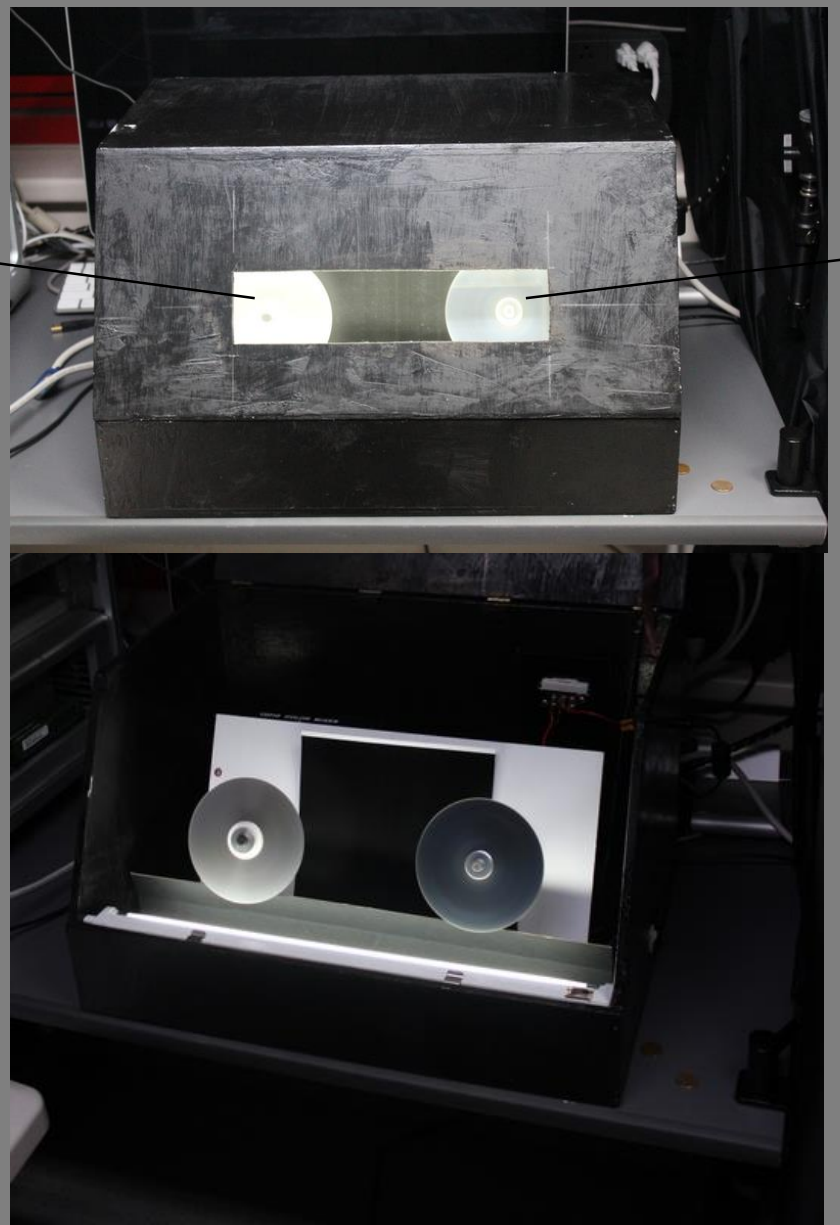
What we were and are doing?

Experiment 1

This experiment was to find the perceived PDL values in accord to physical values, that is, to find the psychophysical relationship between physical and perceived cesia values.

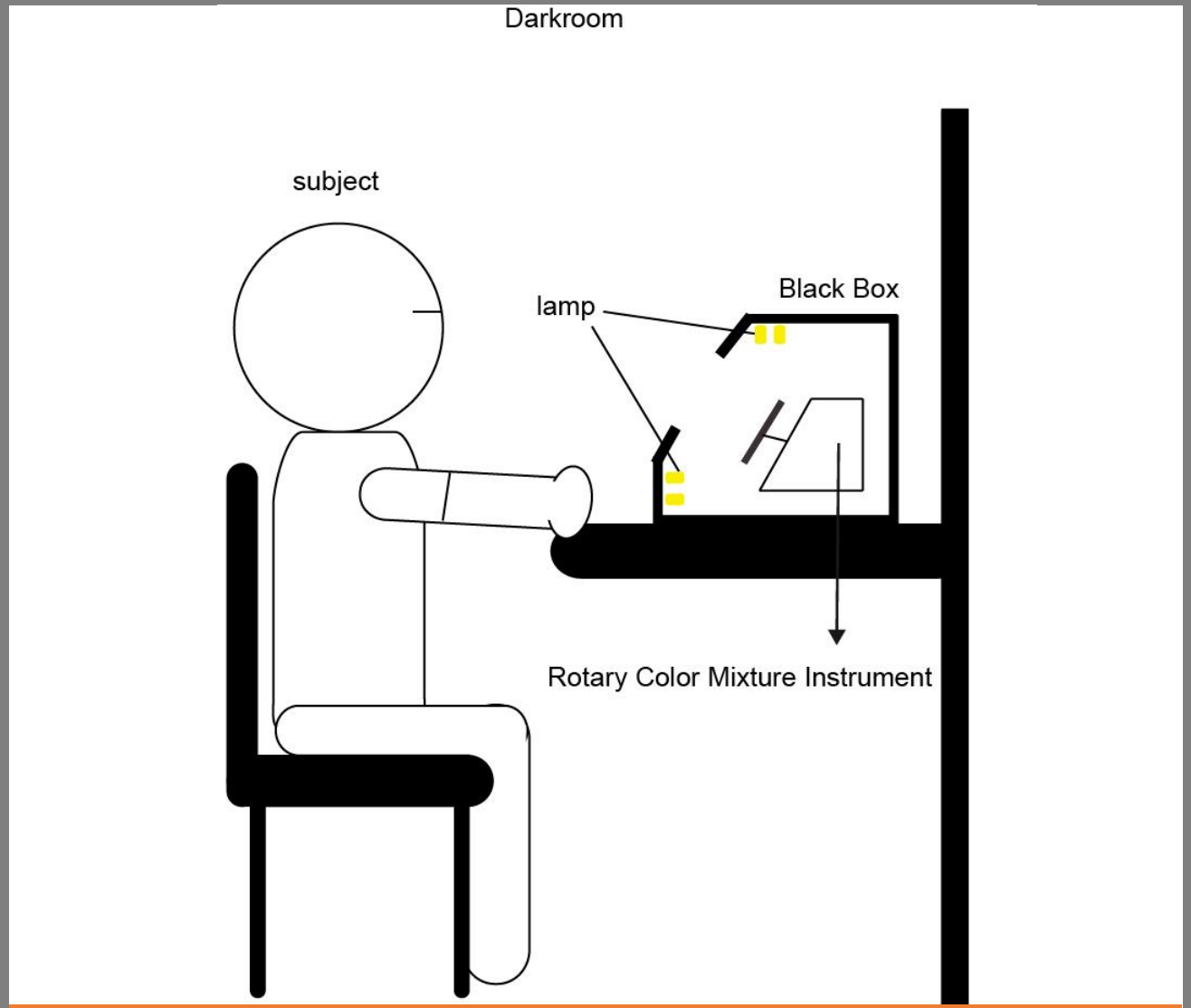
Jose Caivano (1994) suggested the method of using spinning disks with variable sectors to generate different PDL values in physical scales, which was used here to made the stimuli.

Stimulus materials



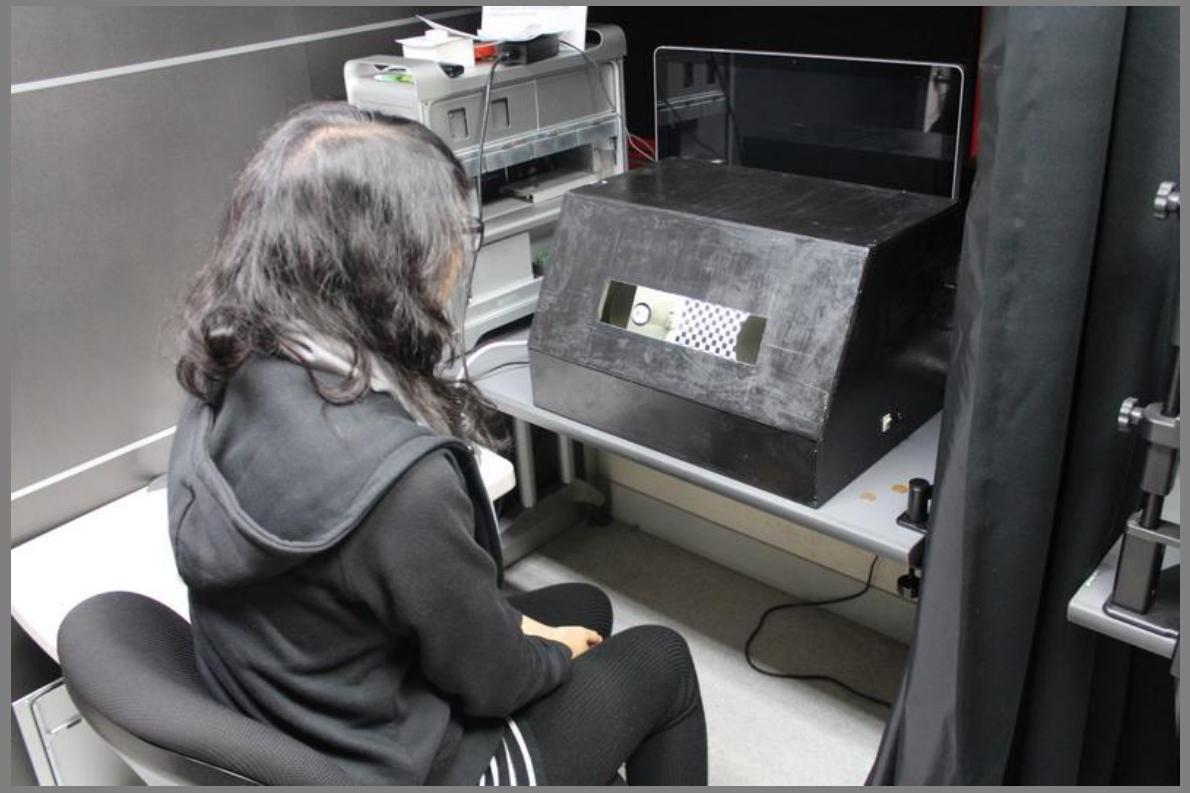
Lan, Lee, and Sun (2015)

Experiment environment



Lan, Lee, and Sun (2015)

Experiment environment



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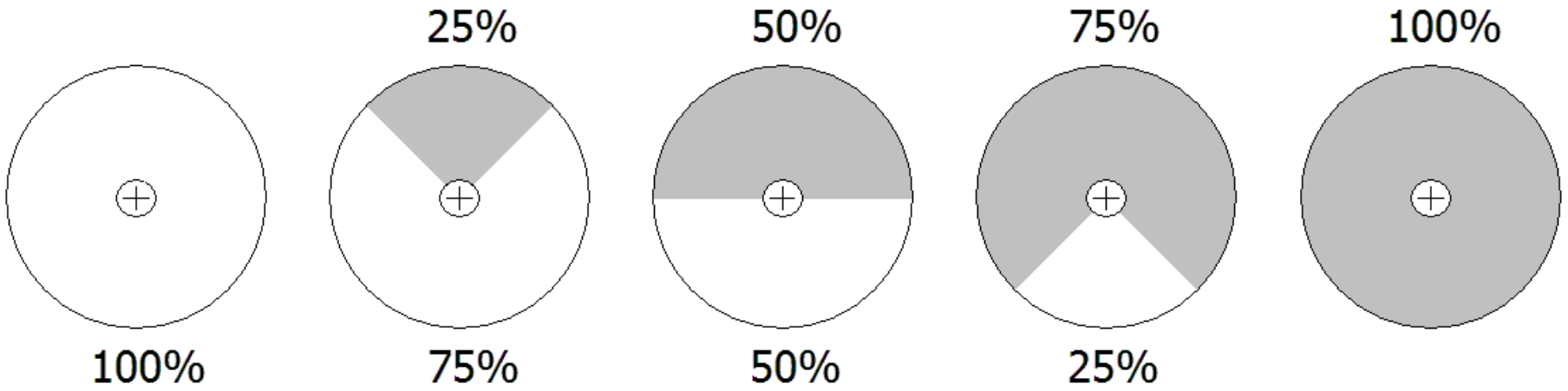
Lan, Lee, and Sun (2015)

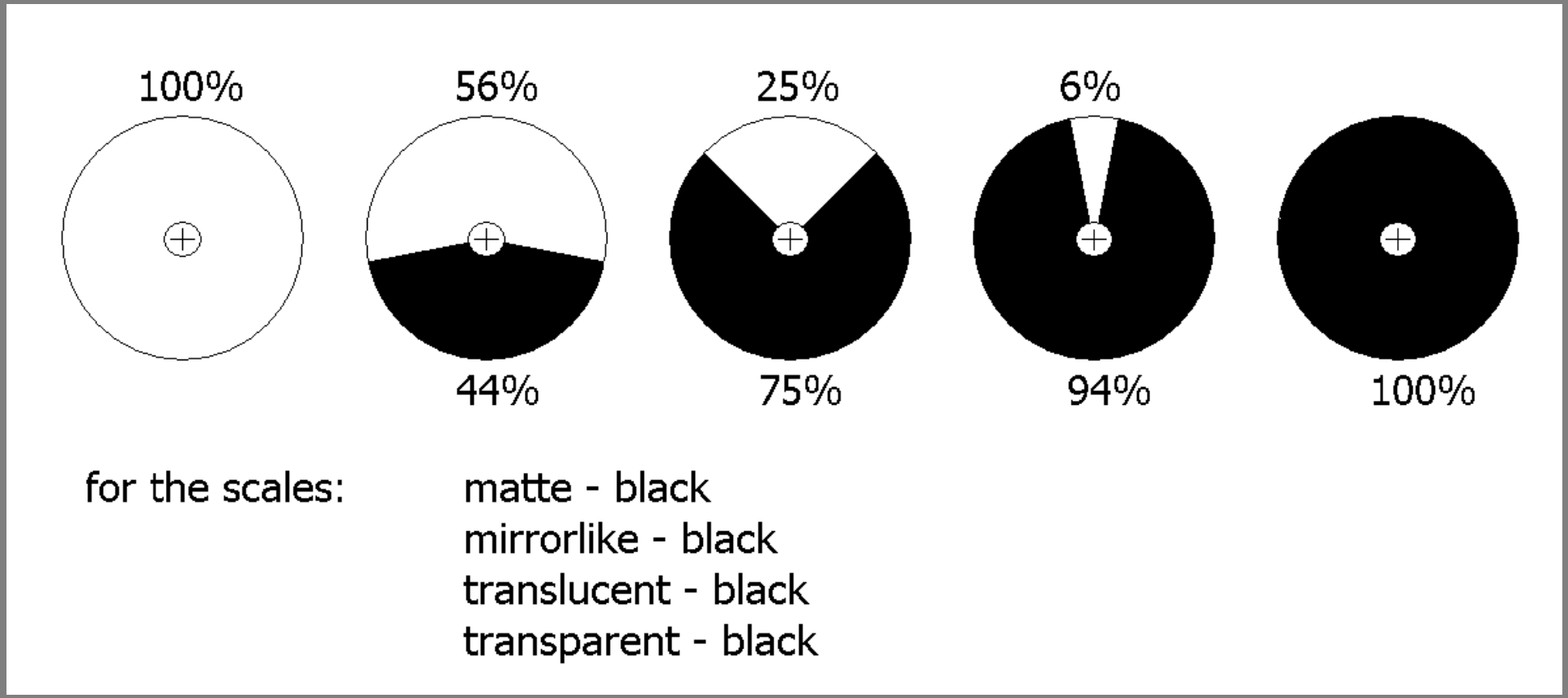


for the scales:

mirrorlike - matte
transparent - translucent
mirrorlike - transparent
matte - translucent

Lan, Lee, and Sun (2015)

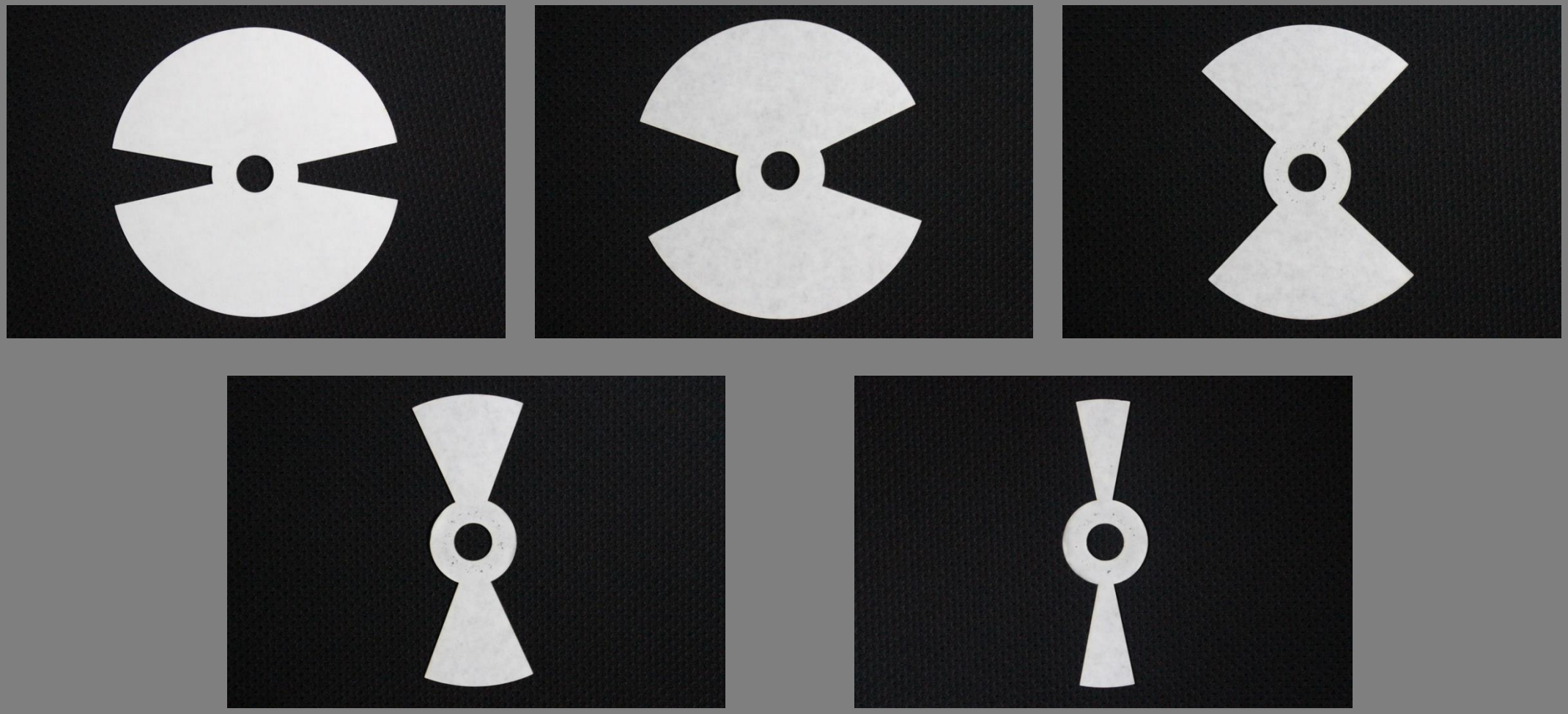
The disks were cut from printed CD disks available, and the percentages were determined in a negative exponential of 2.



Lan, Lee, and Sun (2015)

Diffuse reflection: matte white-transparent disks

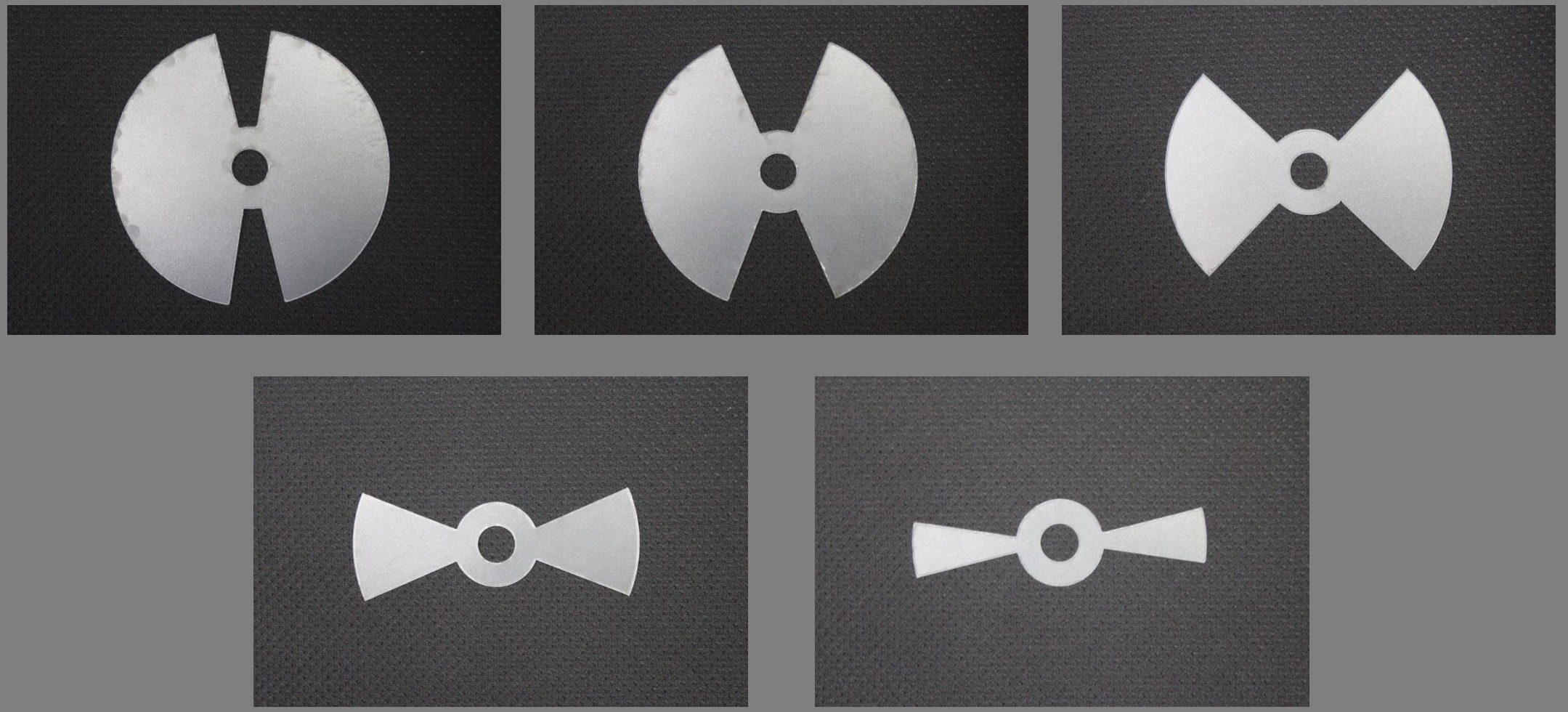
Lan, Lee, and Sun (2015)



White paper on resin

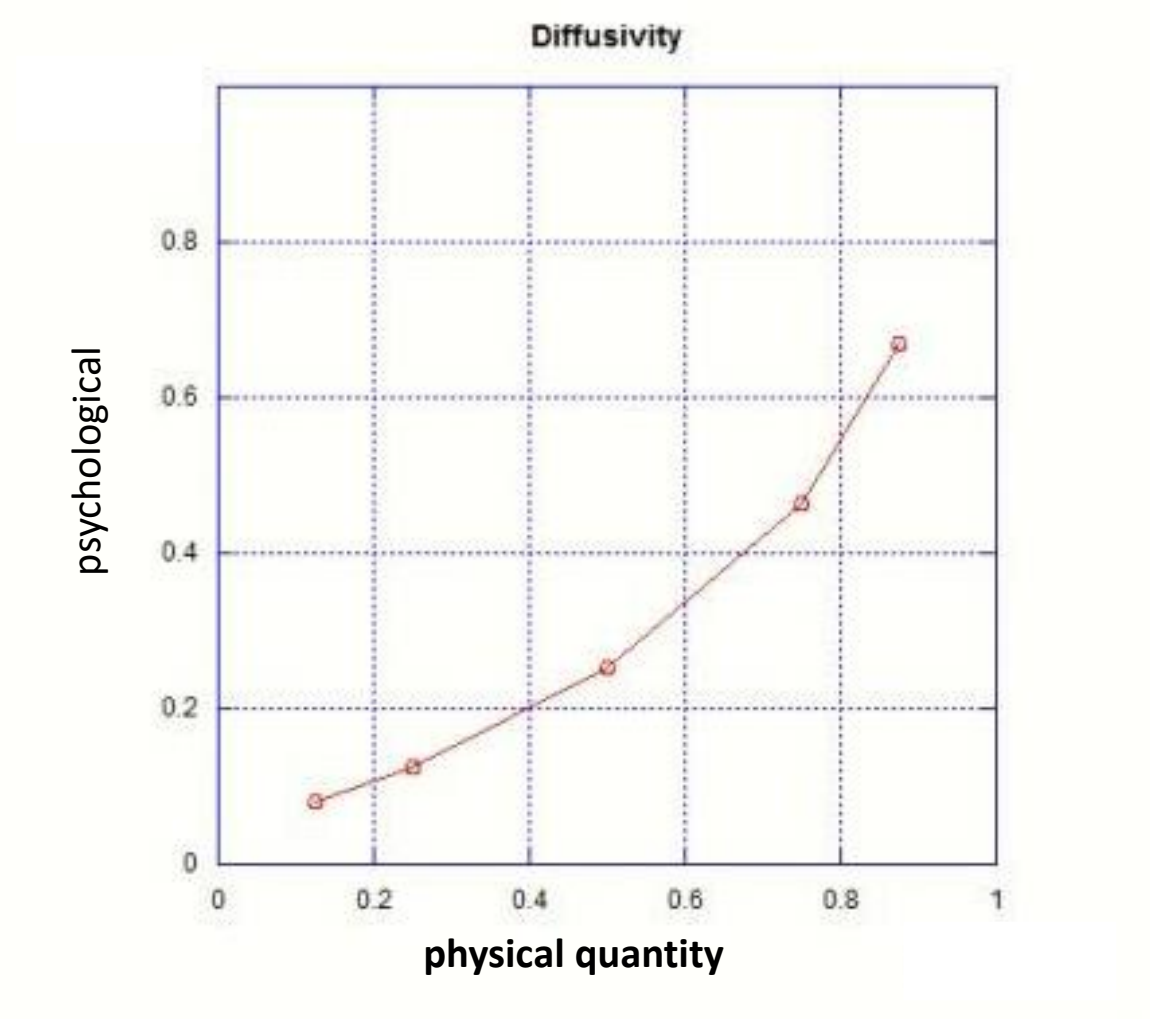
Diffuse transmission: translucent-transparent disks

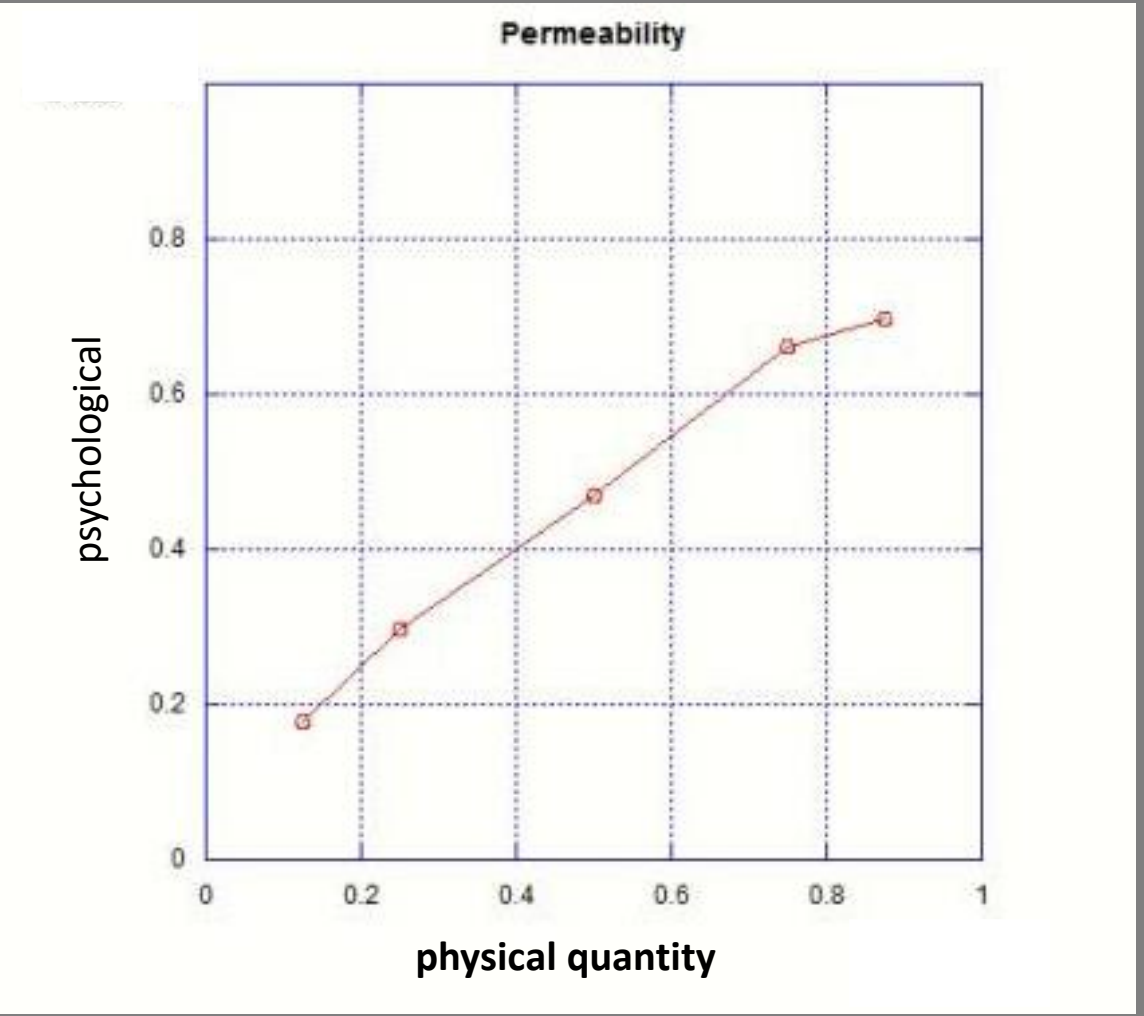
Lan, Lee, and Sun (2015)



Diffusive Gelatin Film

Part of the resultant data from (Lan, Lee et al. 2015)





Experiment 2

Based on the previous experiment, we used the spinning disks as anchors for the maximum and minimum scale values, to test the perceived cesia values with real construction material samples, mostly glass plates. The physical parameters of those construction material samples were also measured to observe the relationship between perceived cesia scale and physical properties.

In the present study, the samples used to be rated are 23 glass plates provided by Taiwan Glass Inc., and five selected representative samples.

Those glass samples have various permeability, surface reflectance, and translucency on physical scales as given by the manufacturer.

They are chosen based on availability.

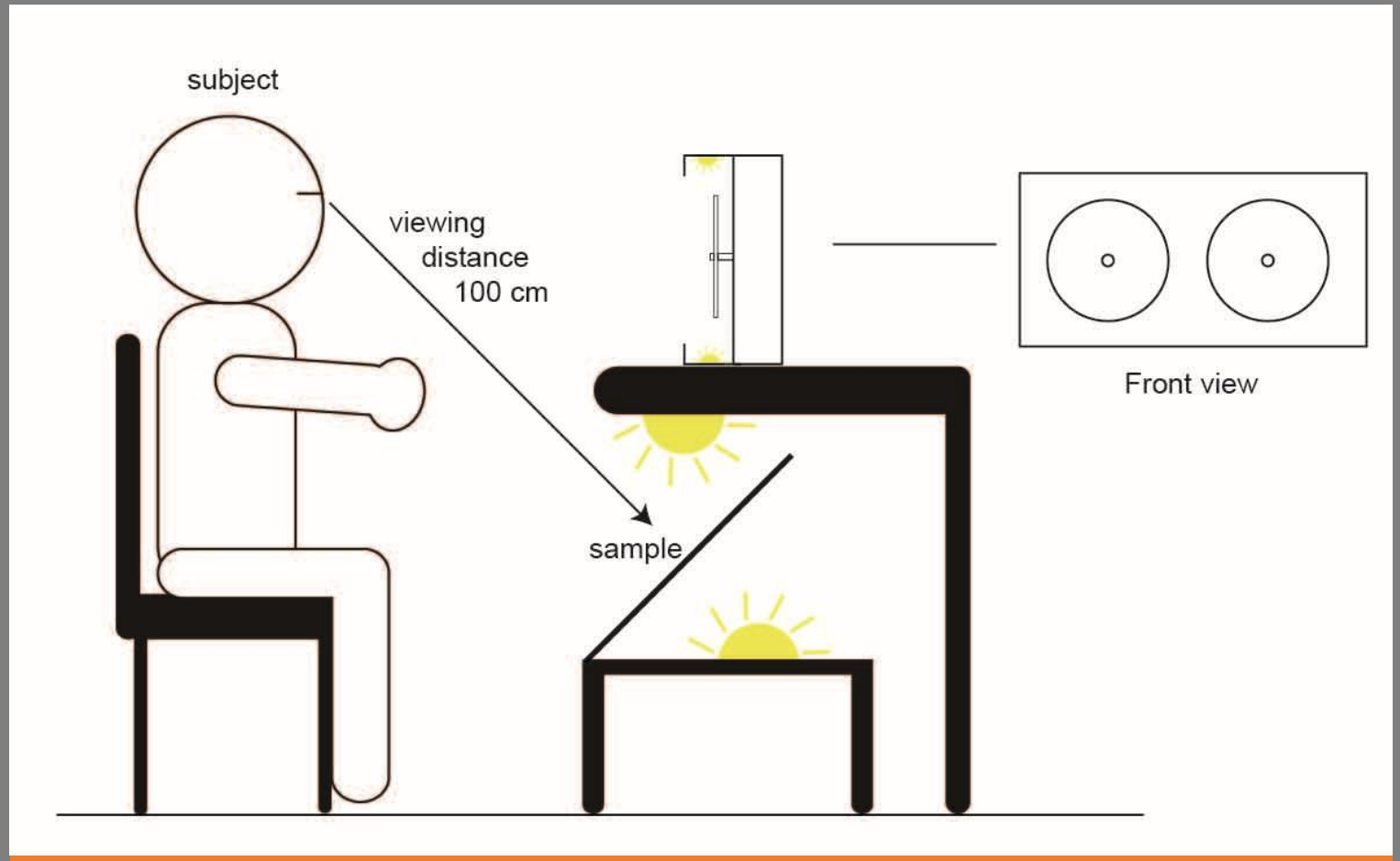
The experiments were conducted in a room with reduced illumination. The test samples and the references were illuminated by lamps positioned to generate the necessary effects for cesia rating purpose.

The experiment set-up

The test samples (plate glass) was placed on an slanting shelf (45°), covered by an black cardboard with an 3”x3” square opening, where samples can be observed.

Observers were instructed to rate their perceived glossiness, mirror-ness, and transparency to the samples they looked through the square opening. Two spinning disks on the table used as anchors for minimum and maximum references. The observers simply rate their perceived sensation by answering percentage values (0 – 100%) for the samples presented. Four observers joined the experiment, two of them rating all samples twice.

Experiment environment



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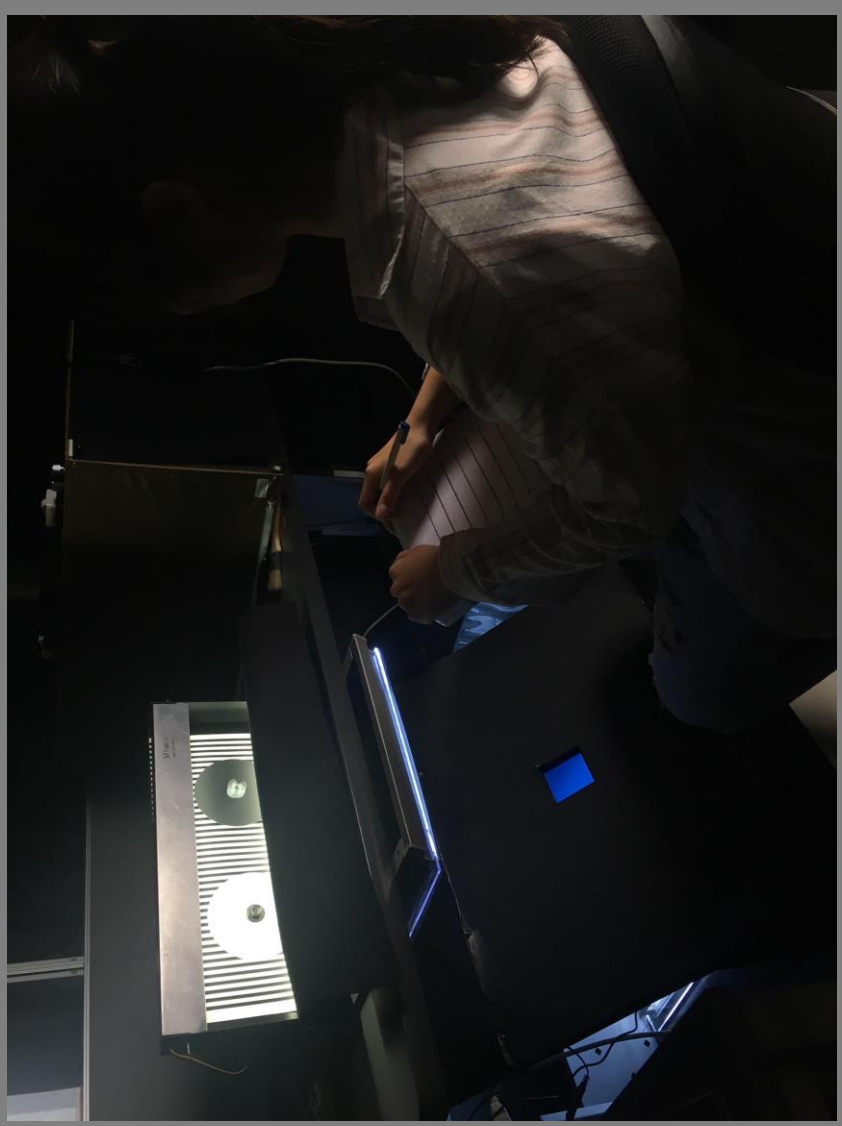

Results

The observers showed evidence that they could understand what the terms glossiness, matt-ness, mirror-ness, translucent and transparency mean, and made correspondent and relatively consistent ratings.

Totally eight scales were used for rating the 28 samples. However, participants did NOT show consistent and agreeable ratings on all scales for each samples respectively.

Only the ratings on scales agreeable among participants were averaged and displayed in the following plots for each of the 28 samples.

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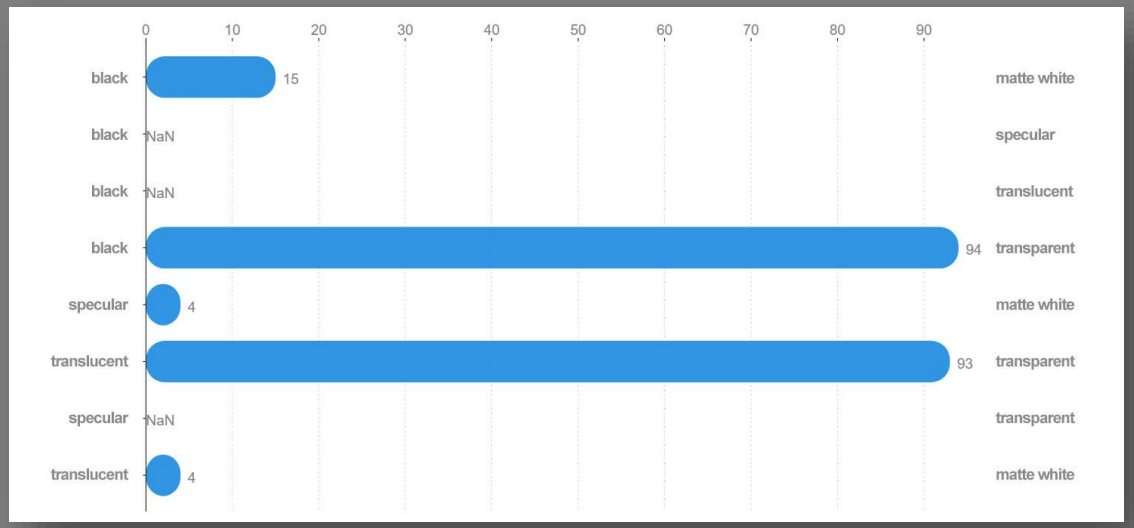
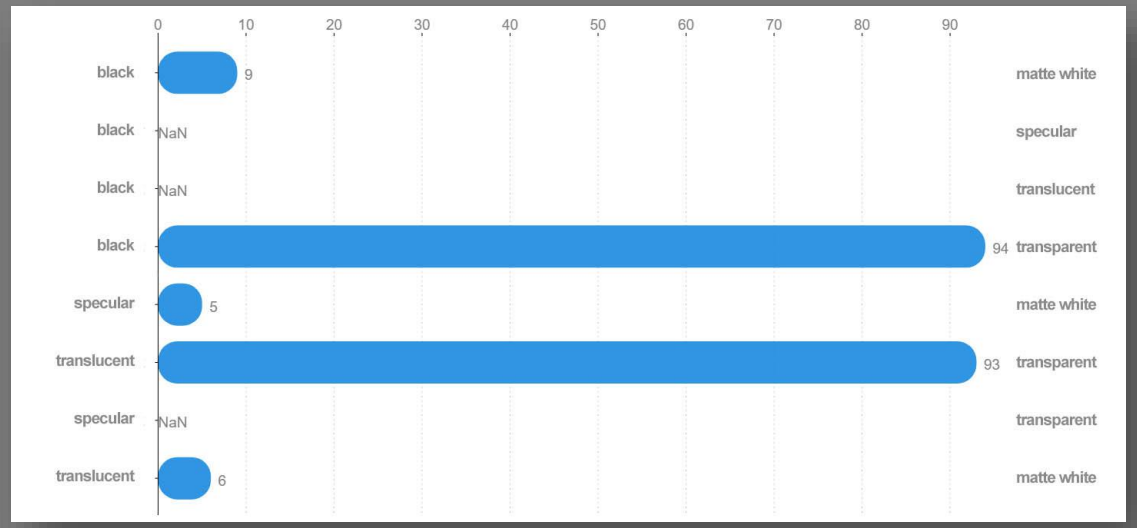
The Resultant Ratings for the 28 Samples

- **Reflective Plate Glasses 微反射玻璃**



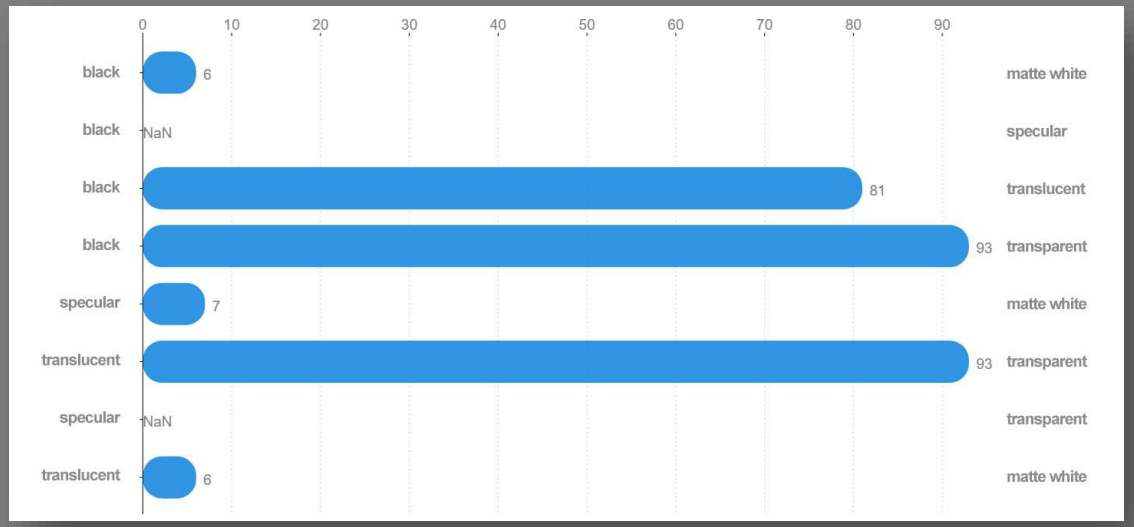
CL-PTS40-6mm-T 6mm



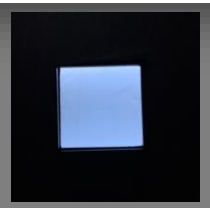
CL-PGY40-6mm-T6mm

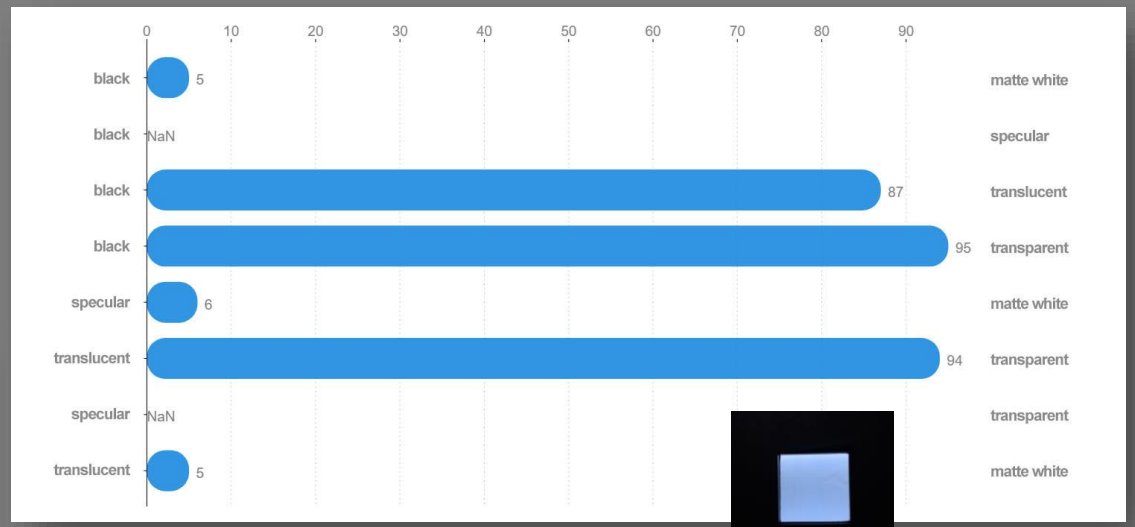
The Resultant Ratings for the 28 Samples cont.

- **Reflective Plate Glasses 微反射玻璃**

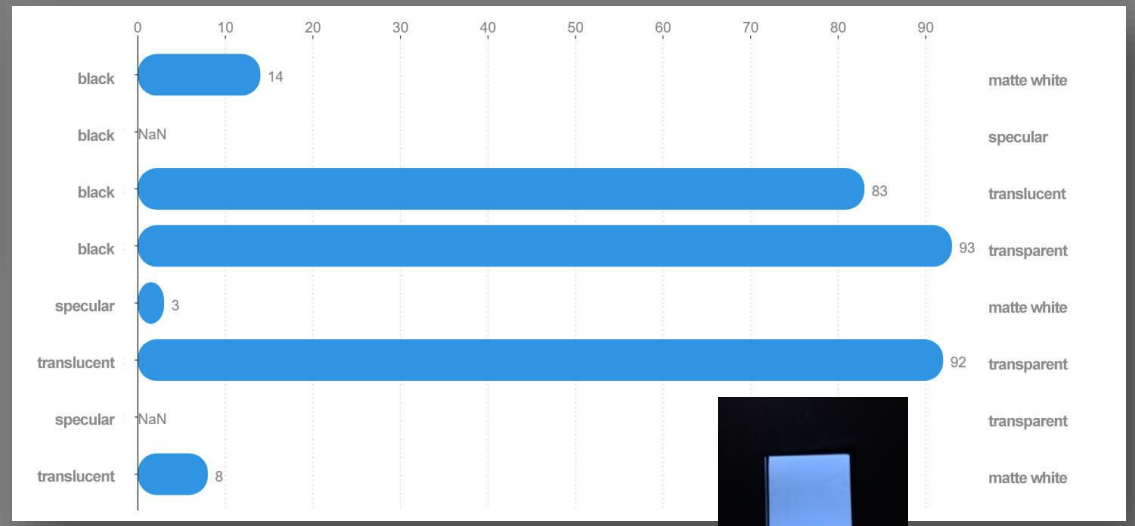


CL-PGY50-6mm-T 6mm





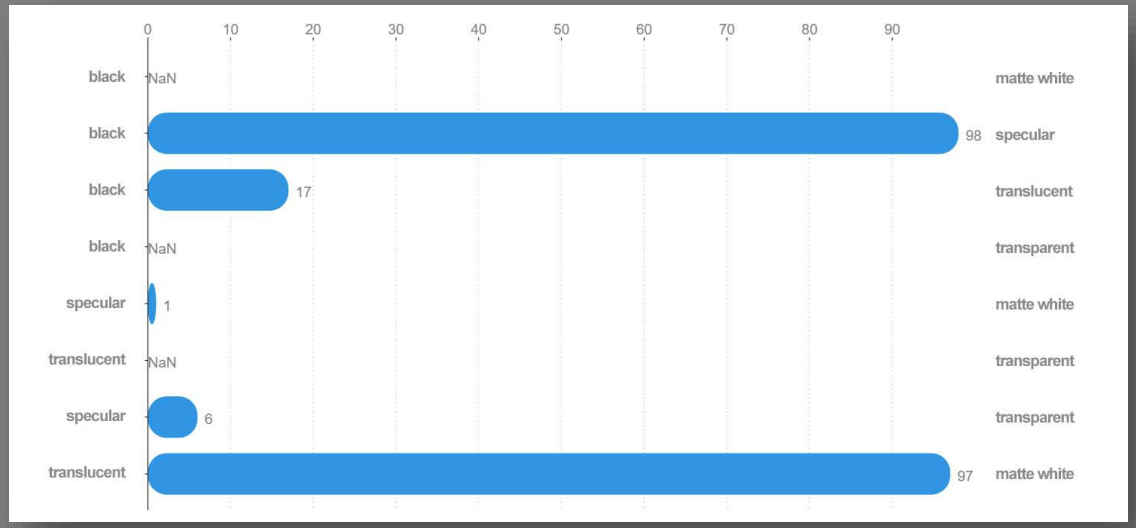
CL-PGY60-6mm-T 6mm



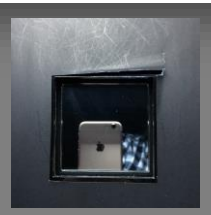
CL-PSS40-6-T 6mm

The Resultant Ratings for the 28 Samples cont.

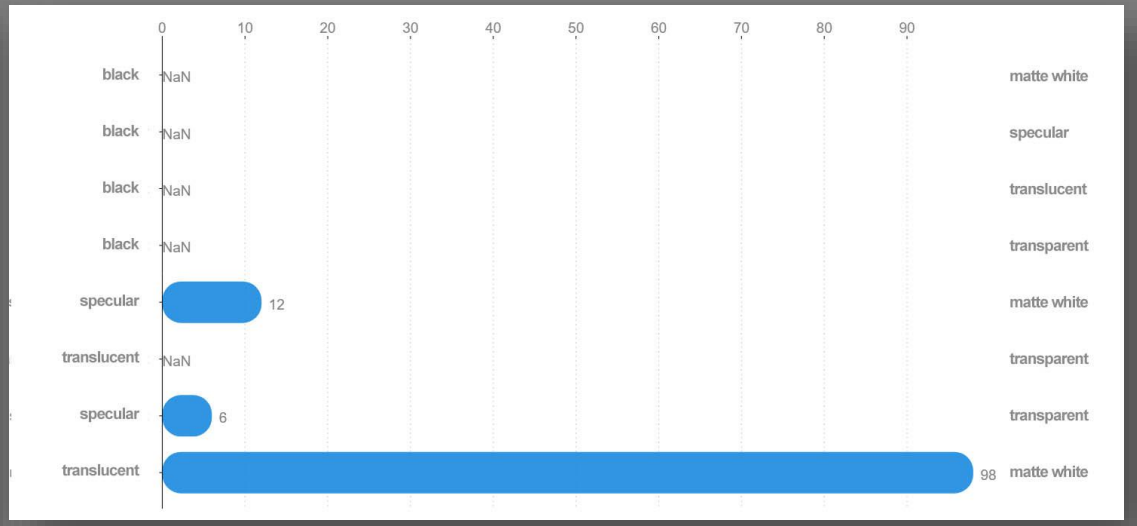
- **Mirror Plate Glasses 鏡面**



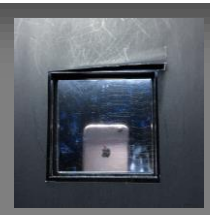
鏡板玻璃 浮式鏡板



Silver Foil

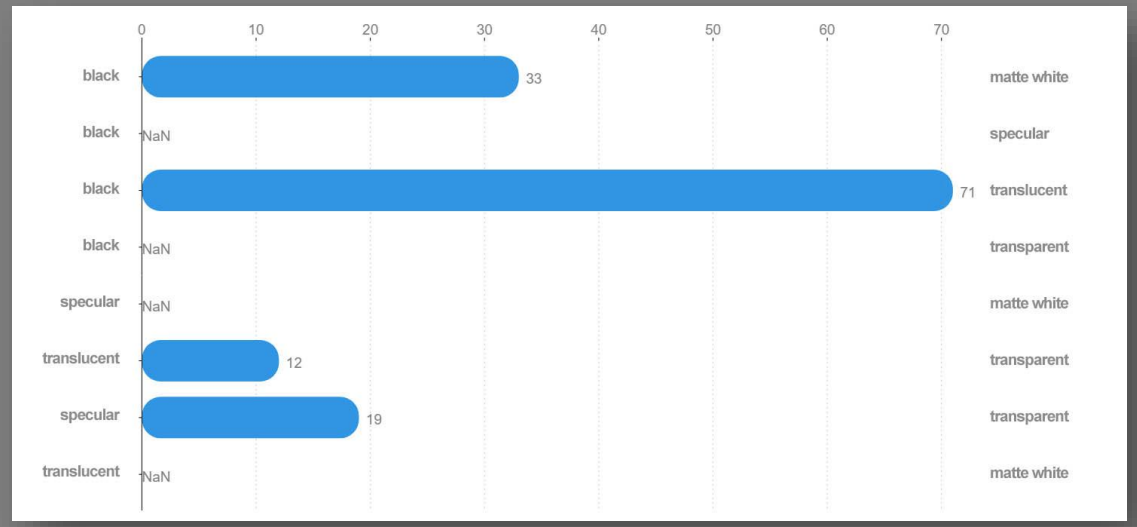


specular

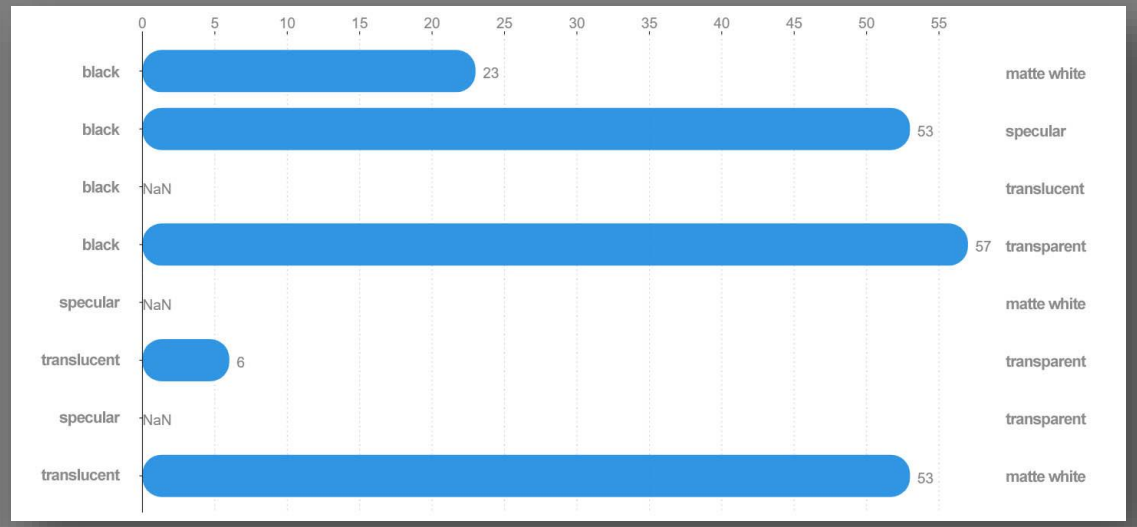


The Resultant Ratings for the 28 Samples cont.

- **Painted Plate Glasses 強化漆板玻璃**



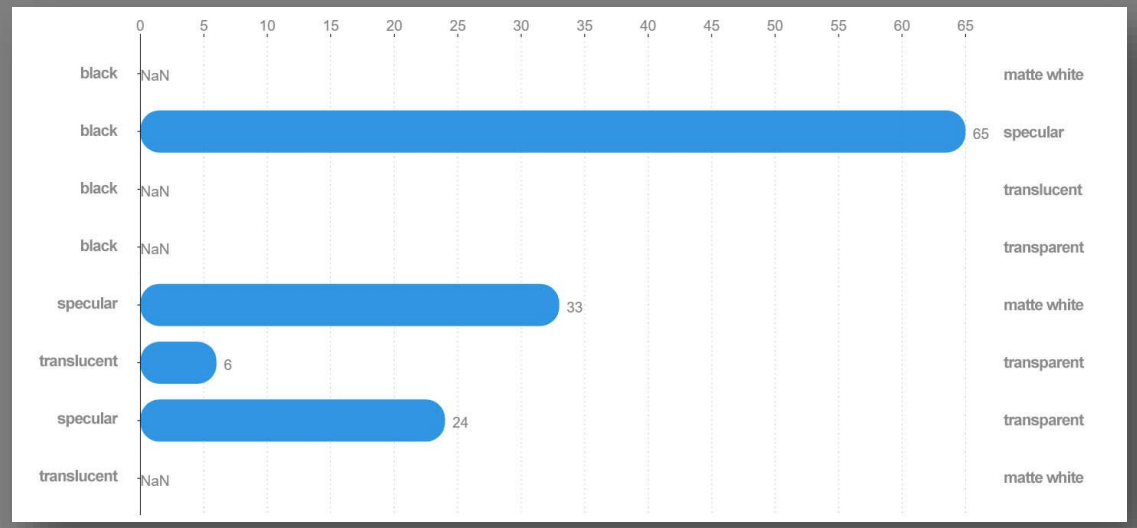
CL-SPAND.#001-6mm-T 6mm



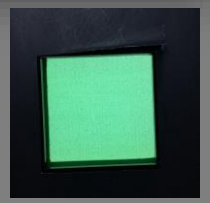
CL-SPAND.#003-6mm-T 6mm鈷藍色

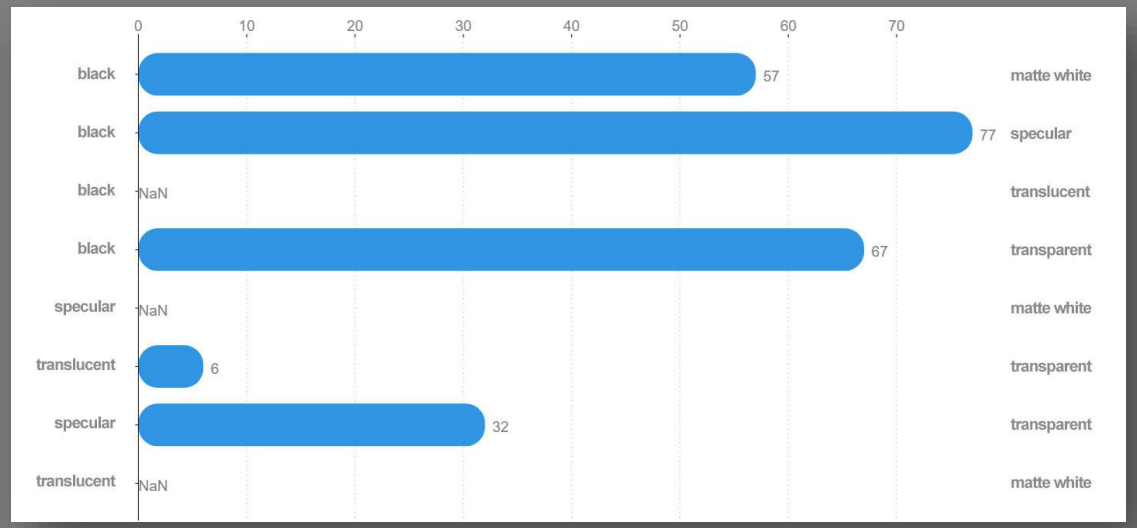
The Resultant Ratings for the 28 Samples cont.

- **Painted Plate Glasses 強化漆板玻璃**

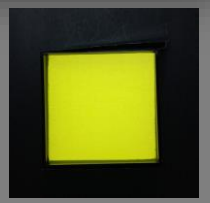


CL-SPAND.#004-6mm-T 6mm鮮綠色



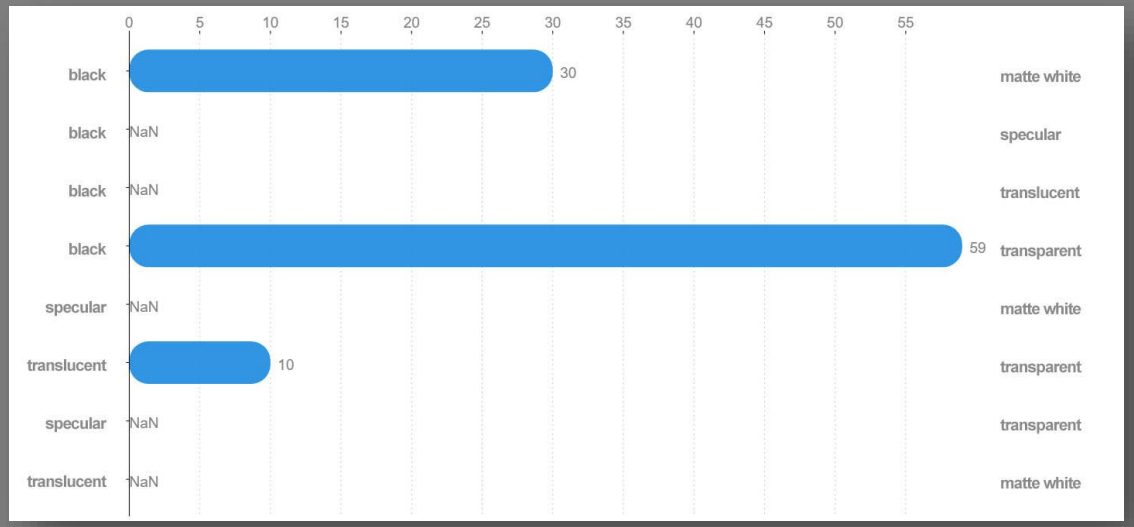


CL-SPAND.#005-6mm-T 6mm黃色

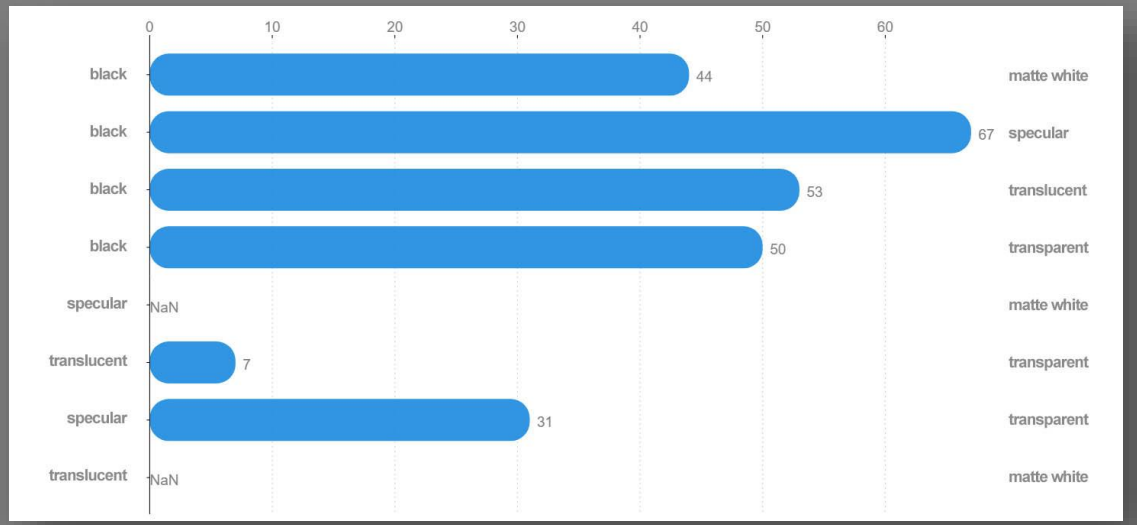


The Resultant Ratings for the 28 Samples cont.

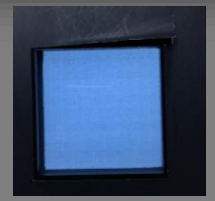
- **Painted Plate Glasses強化漆板玻璃**



CL-SPAND.#008-6mm-T 6mm

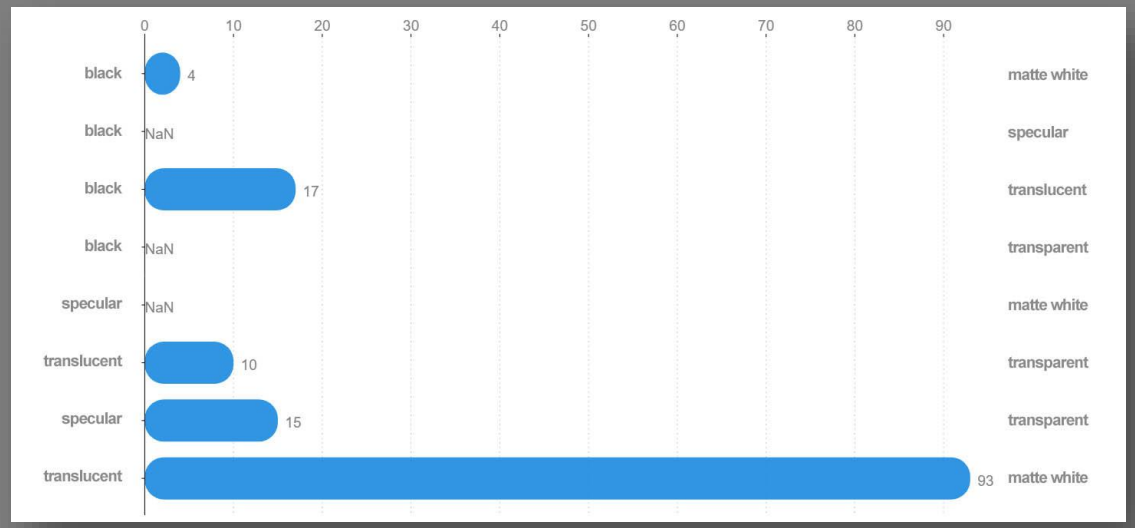


CL-SPAND.#009-6mm-T 6mm

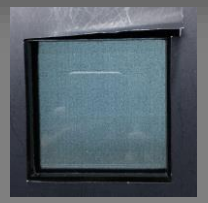


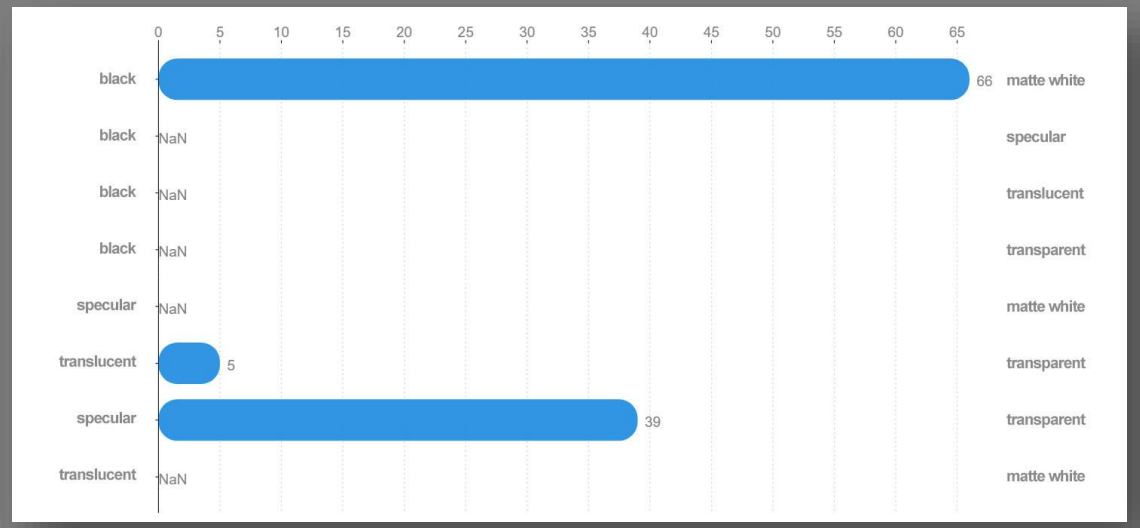
The Resultant Ratings for the 28 Samples cont.

- **Painted Plate Glasses 強化漆板玻璃**



CL-SPAND.#009-6mm-T 6mm





CL-SPAND.#012-6mm-T 6mm

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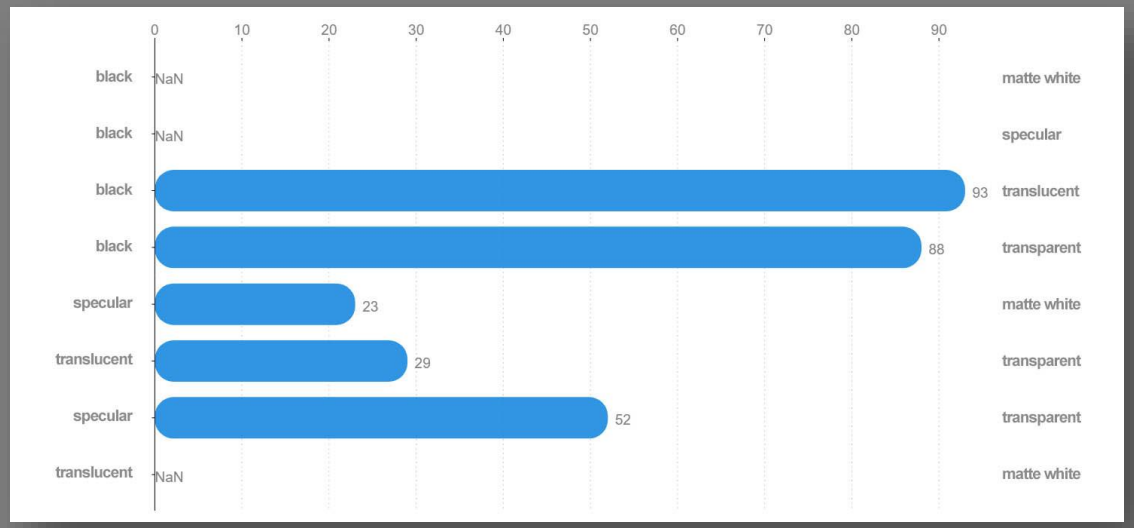
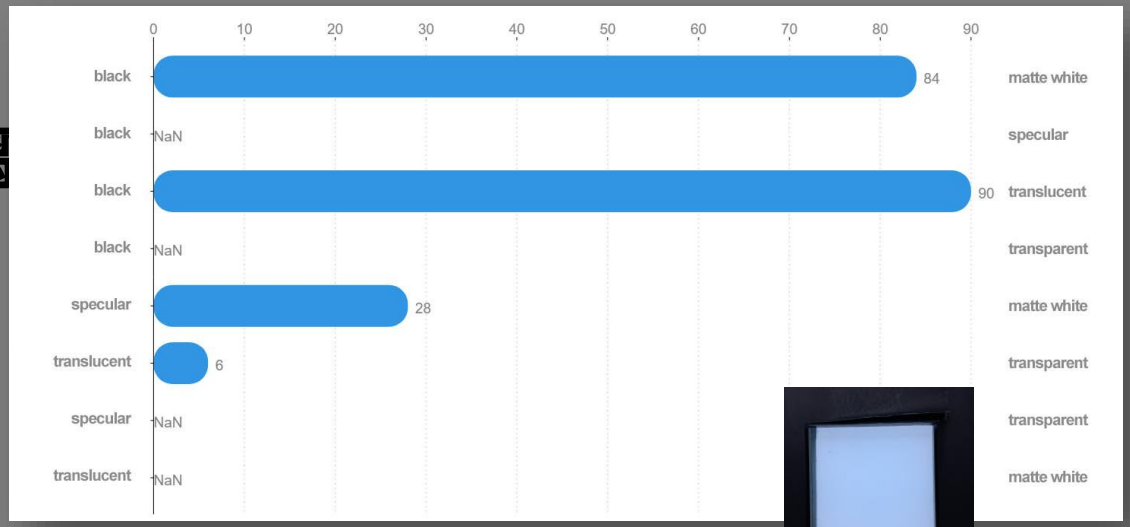
The Resultant Ratings for the 28 Samples cont.

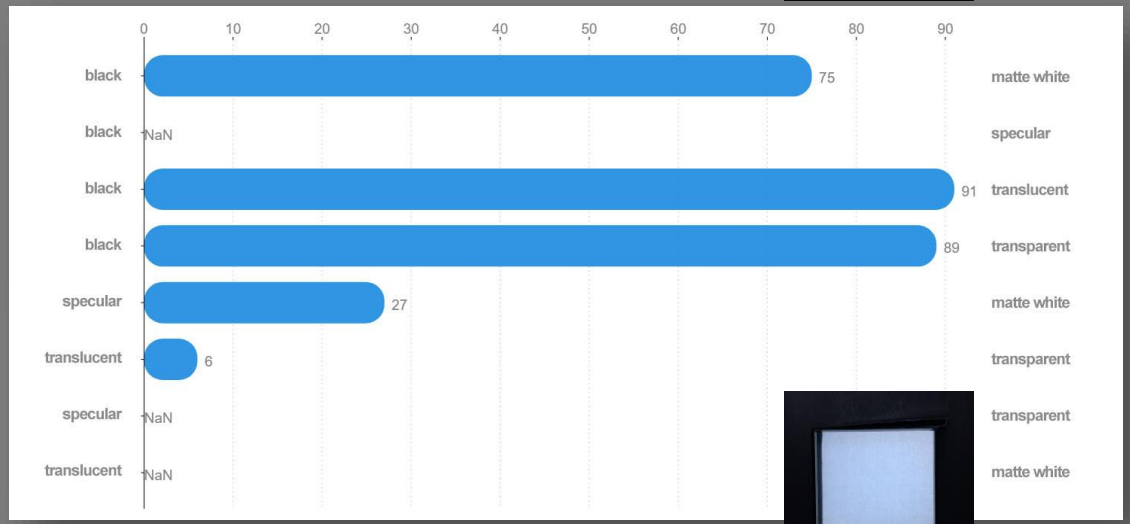
- **Painted Plate Glasses 強化漆板玻璃**



CL-SPAND.#014-6mm-T 6mm 磨砂色



CL-SPAND.#015-6mm-T 6mm 深白色



CL-SPAND.#016-6mm-T 6mm

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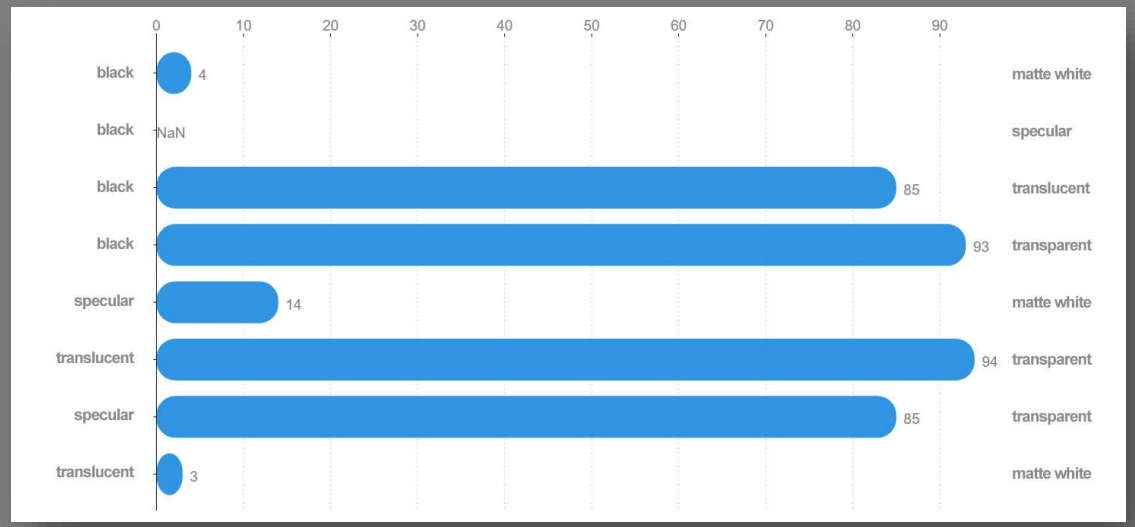
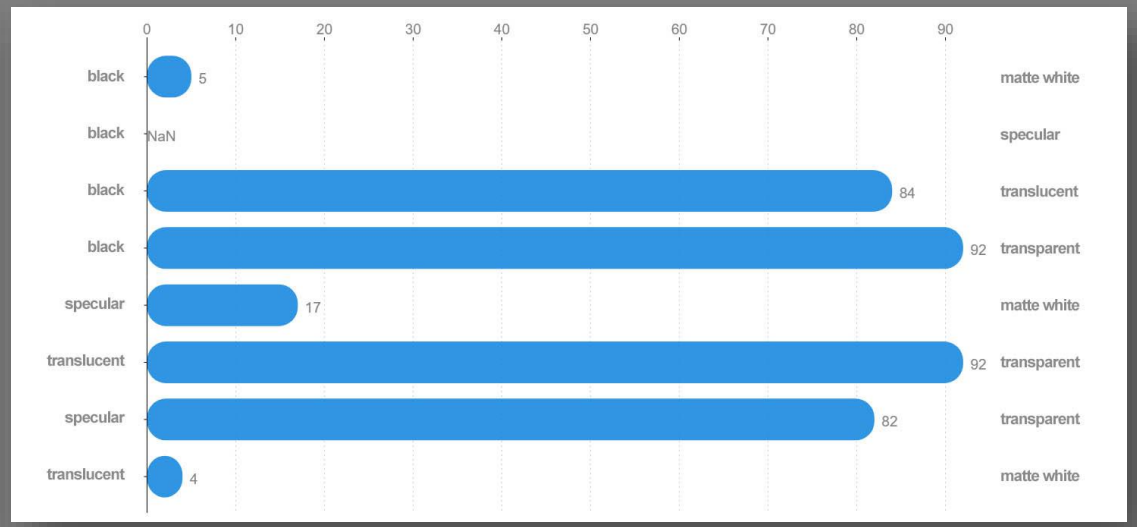
The Resultant Ratings for the 28 Samples cont.

- **Tinted Plate Glasses 色板玻璃**



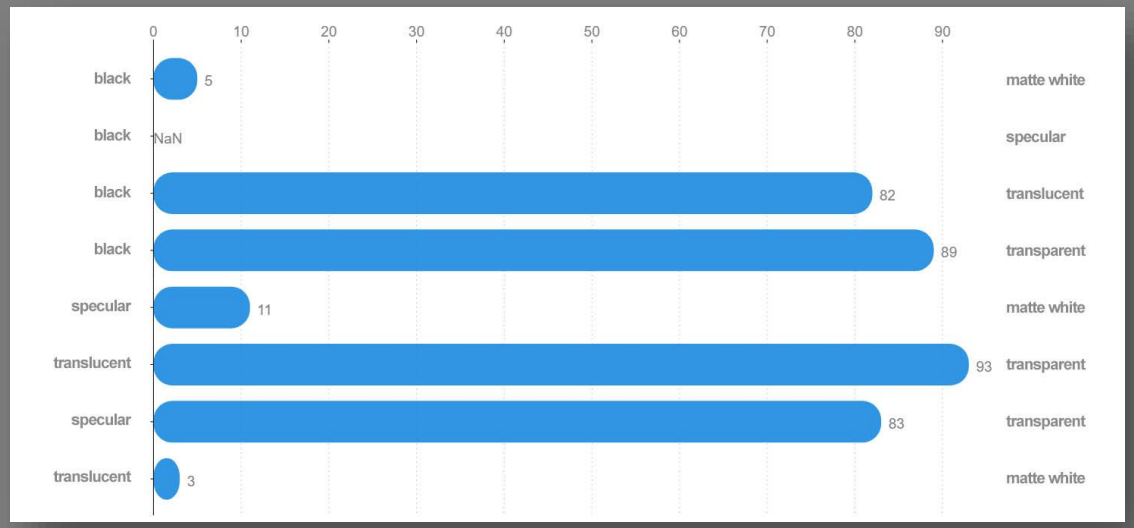
TG-S.CL-6 GY-6mm 6mm 灰色



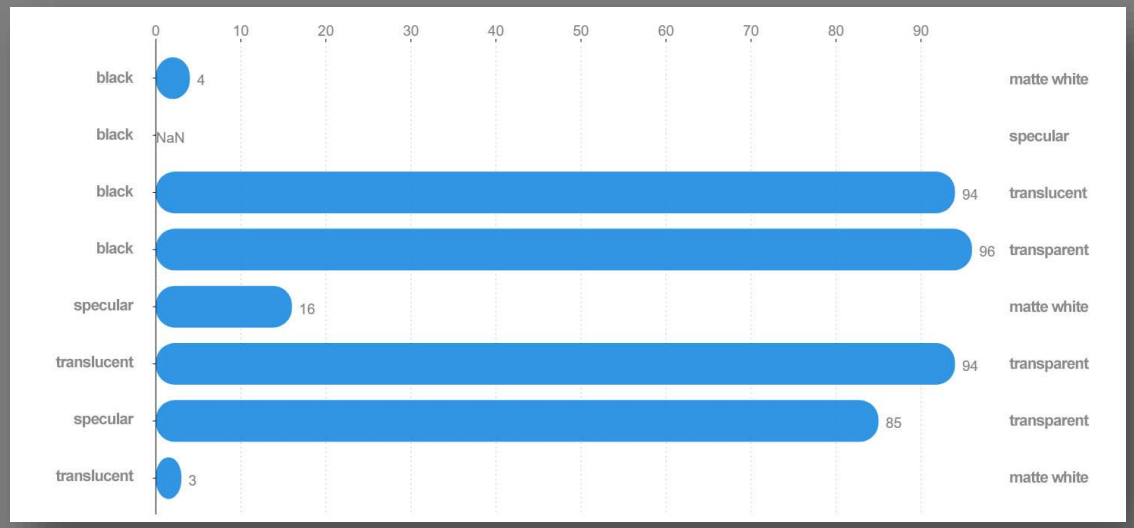
TG-GY-6 F.GR-6mm 6mm 法國綠色

The Resultant Ratings for the 28 Samples cont.

- **Tinted Plate Glasses 色板玻璃**



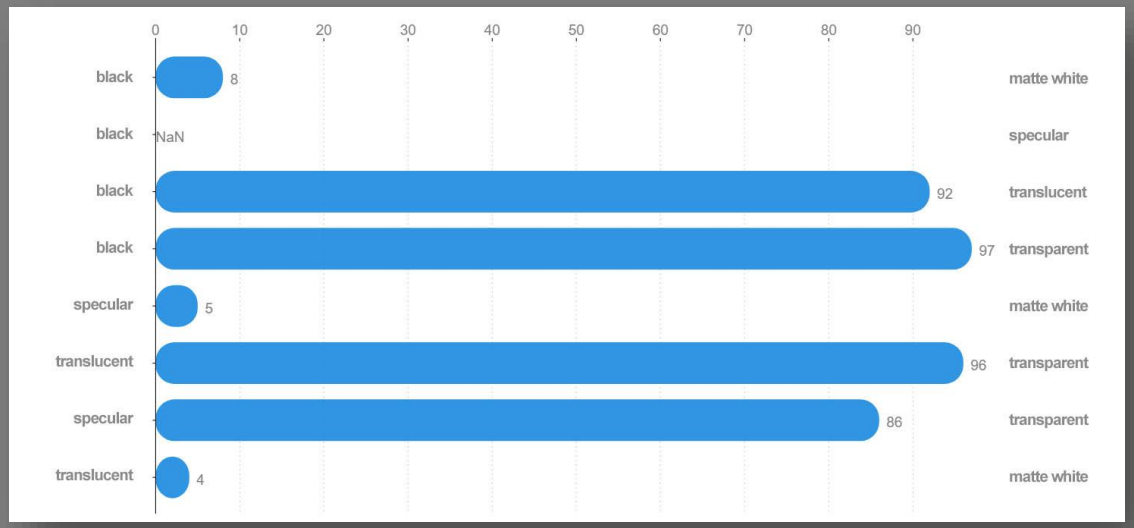
TG-F.GR-6 O.BL-6mm 6mm 海洋藍色



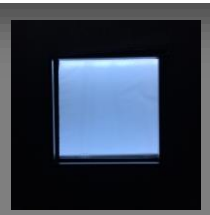
TG-CL-6 BR-6mm 6mm 茶色

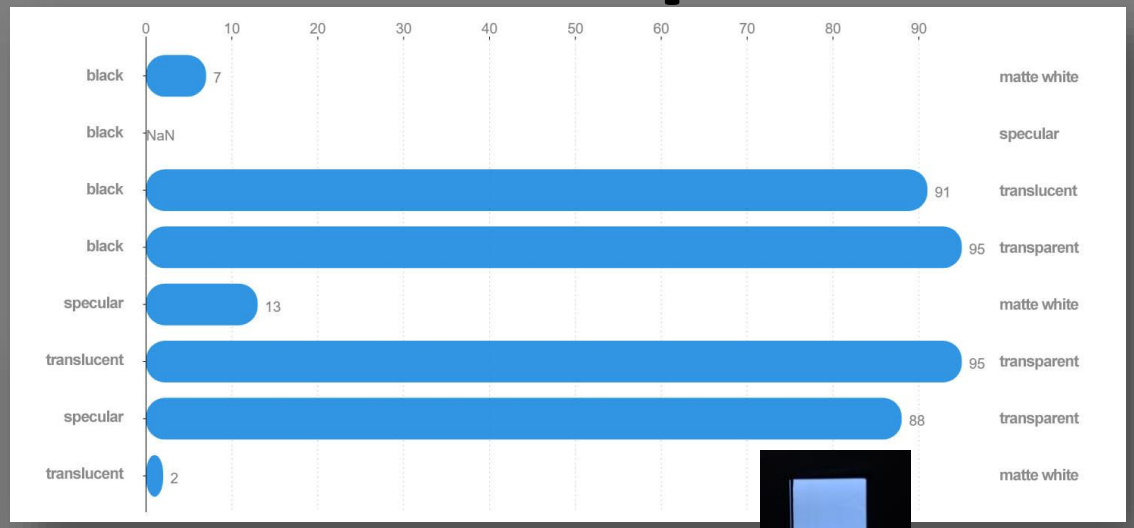
The Resultant Ratings for the 28 Samples cont.

- **Clear Plate Glasses 透明玻璃**

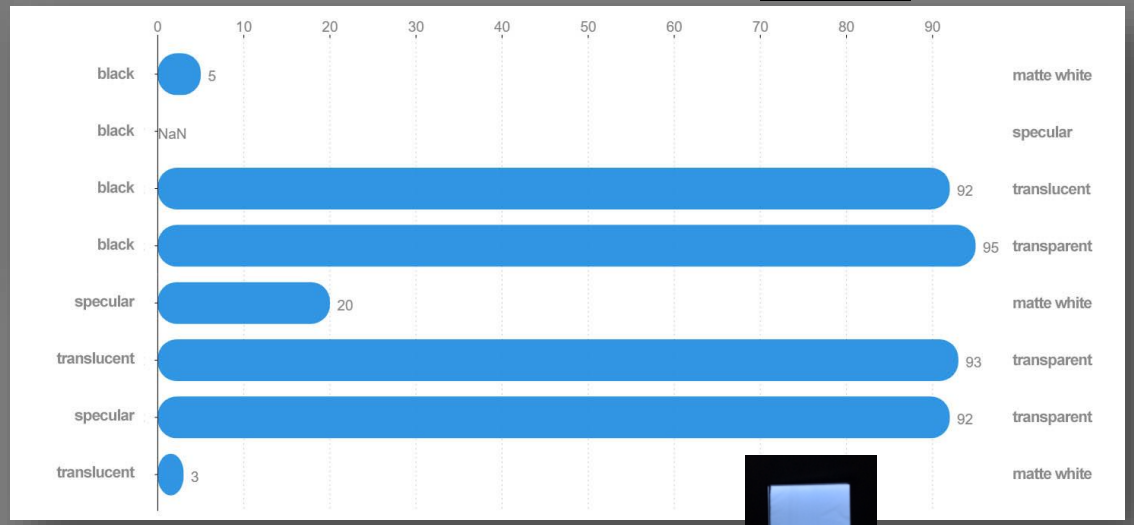


S.CL-6mm





TG-O.BL-6 CL-6mm



CL-8mm

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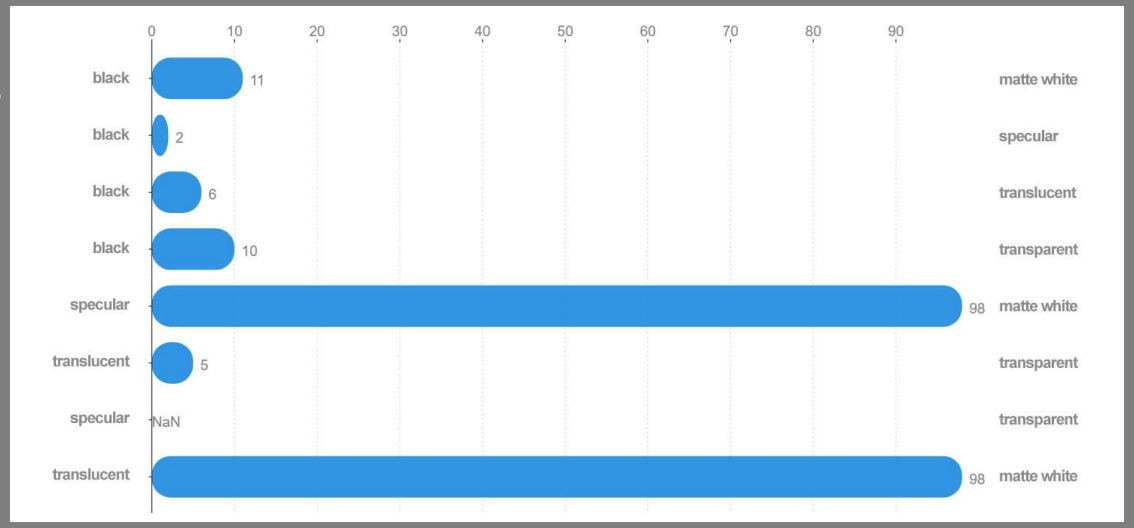
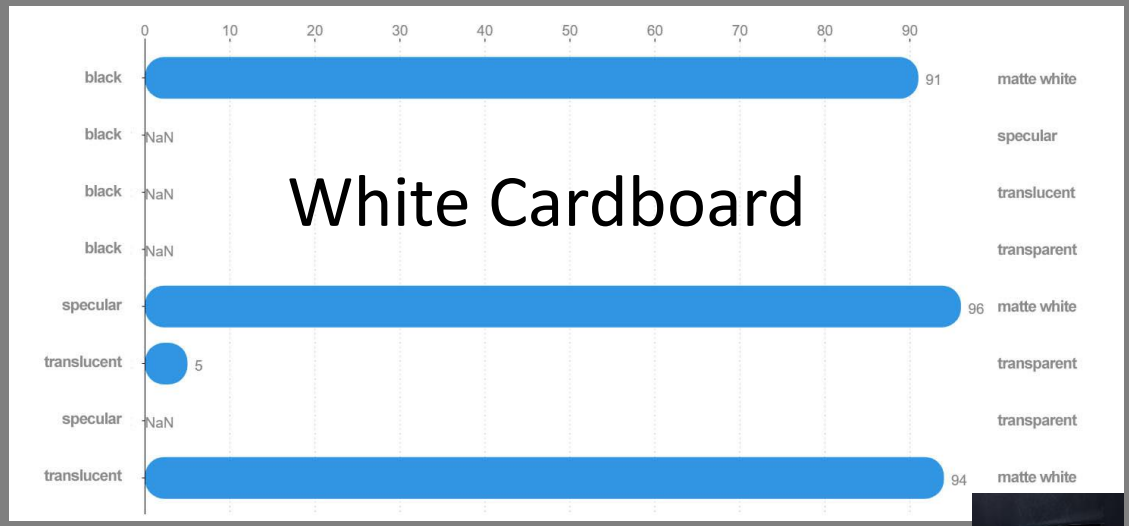
The Resultant Ratings for the 28 Samples cont.

- **Diffusive Gelatin Film**

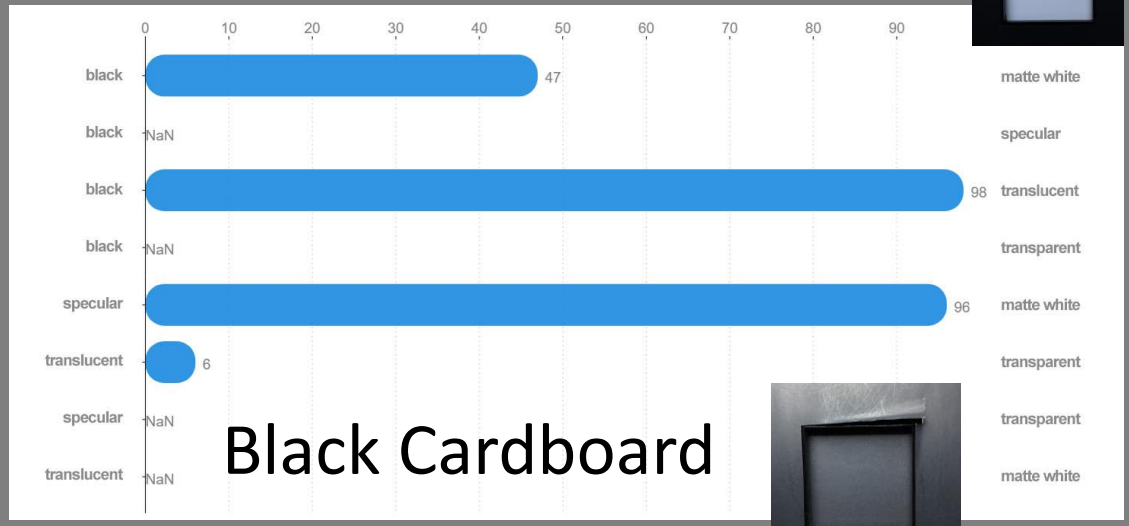


translucent



White Cardboard

matte white



Black Cardboard

black

Conclusions

The present study provides practical data for Cesia, on both the system and theory.

The study shows that the indexes in the Cesia system are understandable for human observers, and can generate rather consistent results for Cesia indexes.

Conclusions

The present research suggests that even for solid samples, such as the plate glasses used in experiments,

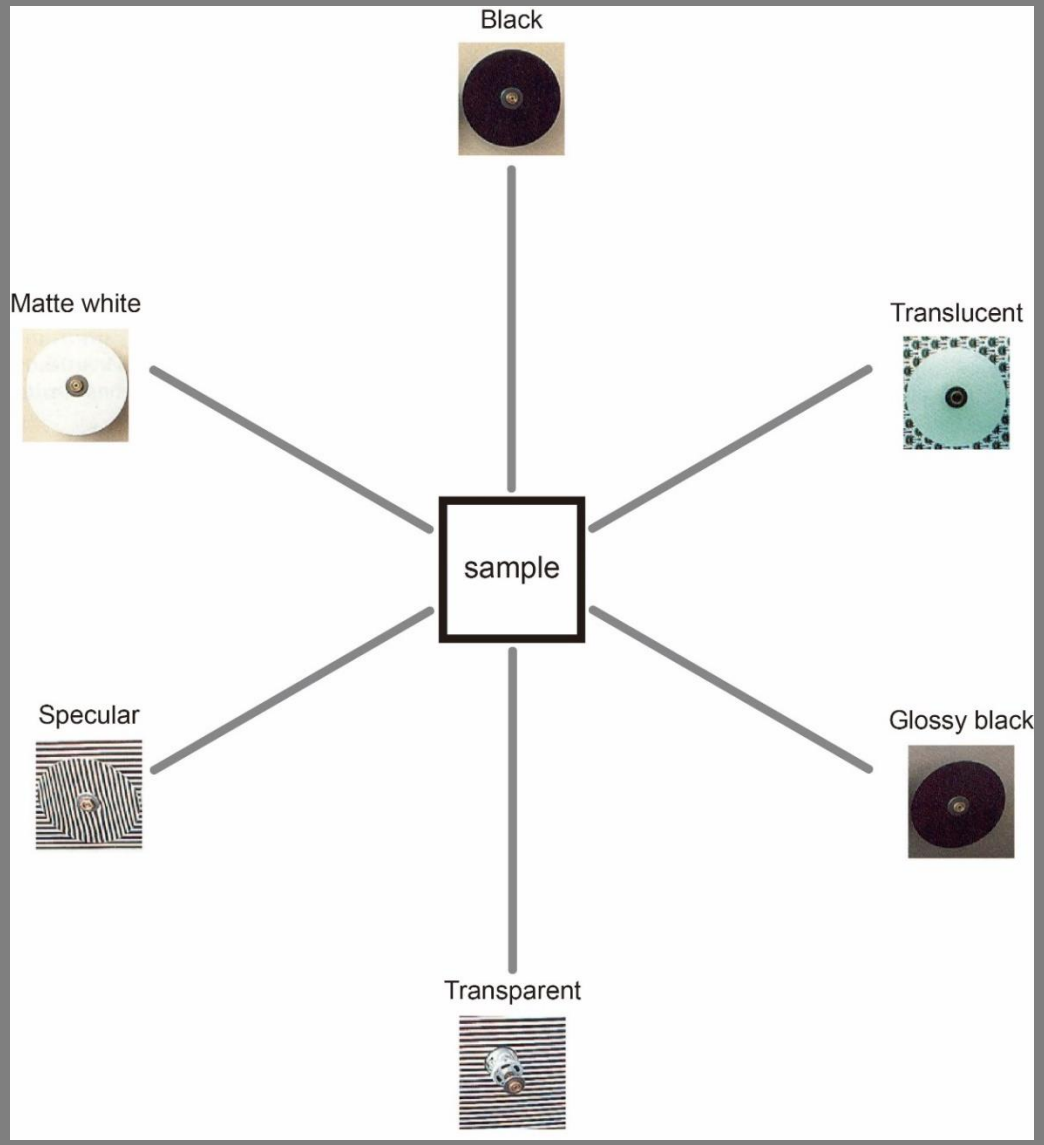
Cesia is still a valid system to describe the material texture perception, and the use of spinning disks can also serve as a standard references for Cesia indexes.

Due to the material properties of various samples, only certain cesia scales are available for rating a specific sample and generating consistent results.

Conclusions

During the rating processes of the experiment, we noticed that observers could perceive all scales of cesia for a given sample. That is, we can provide references all together and ask the observer to rate all suitable cesia scales at a time. A improved rating procedure and display geometry are suggested, as shown in the following.

d/8 viewing geometry



- **The subject just rates how similar the central test sample to the 5 cesia reference stimuli on the board, respectively. An additional glass black reference is suggested due the observation of experiment.**

Conclusions

Though the current study was mainly based on the cesia measurement executed in the laboratory, the results are useful for understanding the appearance of those material samples in natural environment. The 0/45 sample viewing geometry simulates a natural perspective where a tile viewed at eye level under diffuse skylight, which is common in everyday environment. The cesia data obtained in the present study will provide empirical reference for environmental color designers.

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