ESTÍMULO DE MOSAICO MOTEADO COMBINANDO CONTRASTES DE LUMINANCIA Y COLOR PARA LA EVALUACIÓN VISUAL

VARIEGATED MOSAIC STIMULUS COMBINING LUMINANCE AND COLOR CONTRASTS FOR VISUAL EVALUATION

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La información de color y luminancia son atributos visuales importantes para detectar e identificar objetos en sus entornos. El presente artículo revisa cómo se tiene investigado con estímulos de mosaico moteado para la evaluación del proceso de color y luminancia y cómo podrían ser un modelo de imágenes naturales.

Palabras clave: Color, Luminancia, Visión de color, Visión Espacial, Sensibilidad al contraste.

Color and luminance information are important visual atributes to detect and identify objects on their environments. The present paper reviews how have been studied using variegated mosaic stimuli for evaluation of the color and luminance process and how they could be a model of natual images.

Keywords: Color, Luminance, Mosaic, Color Vision, Spatial vision, Contrast sensitivity.

I. INTRODUCCIÓN

The objects reflect a different number of photons traveling through a wavelength variety in space and time domains. The creation of the perception of a visual scene starts with the absorption of the photons by the photoreceptor cells in the retina, and the electrical signal of the photoreceptors are the inputs for complex neural processing along the visual system[1-4].

For one object to be visible, it is necessary to have a contrast between this object and the background of its surroundings, and the contrast should be among at least one out of the five attributes of the visual scene: luminance, texture, movement, color, and binocular disparity[5]. The better camouflage of an object in the surrounding environment occurs when all these attributes between the object and the environment are quite close.

A mixture of luminance and color information composes naturalistic images. There is a wide variety of ways in which both types of information are distributed in the visual scene. Figure 1 shows two kinds of luminance distribution on naturalistic images. Figure 1A shows an example of an object (flower) that differs from its background mainly due to the difference of luminance, while Figure 1B shows an image in which the object (set of central flowers) has few differences in luminance compared to the background (leaves), indicating that other visual attributes would be contrasting between the target and the background; in this case, the color is the main attribute of contrast.

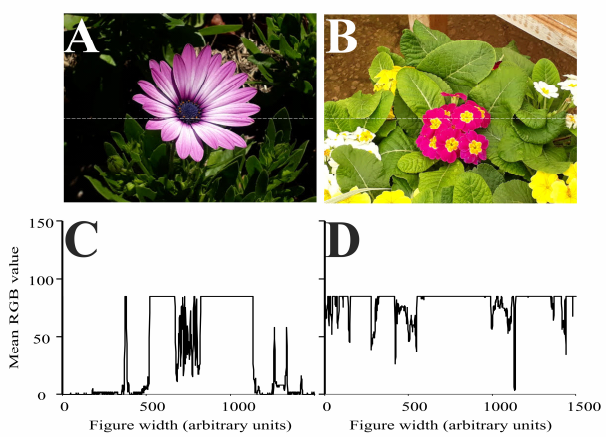

Figure 1. Luminance spatial profiles of naturalistic images. (A) and (B) represent two targets (flowers) that differ from their backgrounds mainly due to luminance and color, respectively. (C) and (D) show the luminance values in the height of the white dashed lines in the images (A) and (B), respectively. The luminance values were represented by the mean of RGB values at each pixel of the image.

II. NEUROPHYSIOLOGY OF COLOR AND LUMINANCE CONTRAST PROCESSING

The first stage of luminance and color neural coding occurs in the ganglion cell layers of the retina[6]. The mechanism that codes color and luminance information is based on the comparison of photoreceptor inputs to some ganglion cell types. This comparison transforms the task of the counting of photons in the photoreceptors in a calculation of contrast[7] of different inputs in the

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ganglion cell layer level. In primates, three ganglion cells act mainly in color and luminance contrast coding: M-, P-, and small bistratified cells[8].

The nature of the contrast is dependent on the receptive field properties of these ganglion cells. Some of these cells (P- and small bistratified cells) receive inputs coming from different cone types in the center and periphery of the receptive field. They are named color opponent cells due to the cone signals that are going to their receptive field carrying information of different spectral content. P-cells or midget cells receive L-and M-cone inputs separately in the periphery or the center of the receptive field[9]. Small bistratified cells receive S-cone input in the centers of their receptive fields and the sum of L-cone and M-cone inputs in the peripheries of their receptive fields[10]. P-ganglion cells and small bistratified cells are considered the substrate of the beginning of the neural mechanisms of the red-green and blue-yellow psychophysical channel, respectively. Each M-cell receives the same inputs (summed M- and L-cone inputs) in the center and periphery of its receptive field[9]. This cell is called a luminance opponent cell because it calculates the amount of contrast between information about the number of photons absorbed by the photoreceptors regardless of their wavelengths. This cell is the basis for the luminance psychophysical channel.

The signals about contrasts in color and luminance travel parallelly throughout the axons of the ganglion cells towards the lateral geniculate nucleus and from there to the primary visual cortex[11-12]. In the primary visual cortex, there are different types of neurons that respond to information about luminance, color, and both of these together[13]. After the primary visual cortex, new channels with a different contribution of luminance and color information seem to travel to the ventral and dorsal parts of the brain[11].

III. BASIC STUDIES USING VARIEGATED MOSAIC STIMULUS

The perception of the luminance and color contrast between objects and their environment is fundamental for several behavioral tasks carried out by the primates (including humans). Examples of such tasks are searching for fruits, finding their partners, and occupational services[14-15]. The loss of the contrast discrimination would impair our ability to perform them and subject us to some ecological prejudice. The development of tests for luminance and color vision evaluation is essential for early diagnosis and possible intervention.

Stiling[16] was a pioneer in design stimulus that combined a mixture of luminance and color. He introduced what would later be named pseudoisochromatic stimulus. The purpose of this kind of stimulus was that a target was perceived just by chromatic difference compared to the surround field. The pseudoisochromatic design consists of a mosaic of small patches (spatial noise), in which the luminance of each patch was randomly distributed across the stimulus (luminance noise) (Figure 2). The spatial noise excluded border artifacts between the target and the remaining field and prevented luminance clues from being able to be used to detect the target. During a long period, the use of pseudoisochromatic stimulus was restricted to the development of diagnostic methods of congenital and acquired color vision losses. The Ishihara test and Hardy-Rand-Rittler pseudoisochromatic test are examples of widely used tests that implemented the pseudoisochromatic design to diagnose color vision deficiencies[17-18]. The implementation of pseudoisochromatic design to computerized procedures allowed basic questions about the chromatic discrimination masked by the luminance noise to be investigated[19-20]. Many reports observed that the changes in the luminance noise could have influence on the color vision perception[21-23]. They observed that the low number (or levels) of luminance in the luminance noise impaired the chromatic discrimination compared to the conditions with higher luminance levels[21]. Moreover, they also observed that changes in the mean luminance of the stimulus should be accompanied by changes in the range of the luminance noise to keep the chromatic discrimination constant[22]. The chromatic discrimination was dependent on the Weber contrast between the maximum and minimum values of the luminance noise. Figure 3 shows the luminance noise of mosaics with different luminance noise levels and mean luminance. For both cases, probably the increase of the luminance level or/and mean luminance, without any other change in the other parameters of the luminance noise, increases the homogeneity of the luminance noise, making it less effective. The homogeneity of the luminance noise is associated to an increase of the chromatic discrimination[21-22]. Linhares et al.[23] observed that dynamic luminance noise had no influence on the chromatic discrimination of normal trichromats, but it improved the chromatic discrimination of anomalous trichromats.

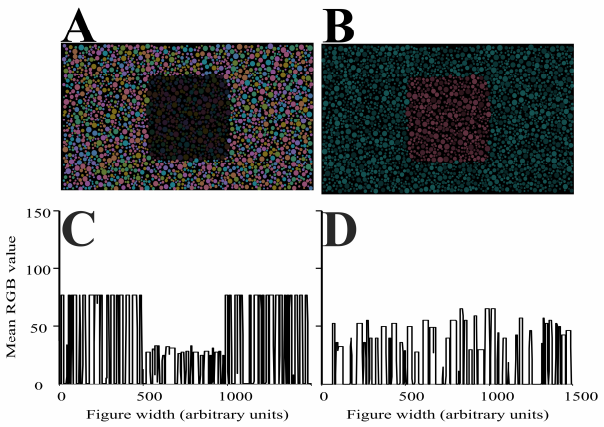

Figure 2. Luminance spatial profile of variegated stimulus. (A) represents a stimulus with a target that differs from the field by luminance contrast masked by chromatic noise. (B) represents a stimulus with a target that differs from the field by chromatic content masked by luminance noise. (C) and (D) show the luminance values in the height of the white dashed lines in the

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images (A) and (B), respectively. The luminance values were represented by the mean of RGB values at each pixel of the image.

Miquilini et al.[24] introduced a new design that combined luminance and color information in a mosaic of patches. The design also is featured by a spatial noise with different colored patches. A subset of the mosaic patches differed of the remaining field by the luminance contrast. Figure 2 shows an example of this novel stimulus. It is the opposite rationale of the pseudoisochromatic design. They observed that the chromatic information of the noise impaired the luminance discrimination on the threshold level. They suggested an inhibitory influence of color on luminance discrimination.

Figure 2 shows luminance spatial profiles of both variegated stimuli similar to the naturalistic images of Figure 1. The use of variegated stimuli for luminance and chromatic discrimination could simulate some patterns of luminance and color distribution of naturalistic images.

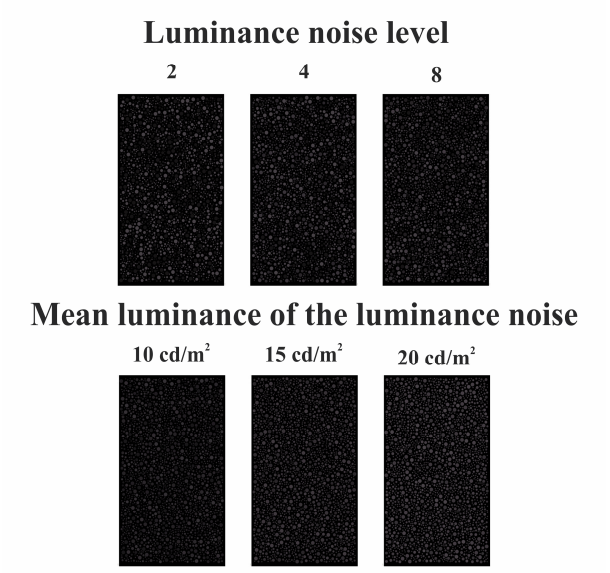

Figure 3. Mosaics with different configuration of the luminance noise. Upper panels show mosaics with different luminance levels, and lower panels show mosaics with different mean luminance of the luminance noise. The higher homogeneity of the spatial luminance in the noise is associated to the impairment of the effectivity of noise and increase of the chromatic discrimination.

III. CONCLUSIONS AND FUTURE PERSPECTIVES

Future investigations should clarify how other spatial and temporal parameters of variegated stimuli influence luminance and color perception. Moreover, better comprehension of the physiology that underlies luminance and color perception in variegated mosaic stimuli enables us to build standardization to optimize clinical tests for luminance and color vision loss diagnosis and to enable research laboratories to compare adequately their results.

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