Variation with the contrast and modulation ratio of an achromatic grating on the view of a chromatic periodic test

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1. INTRODUCTION

Daily experience shows that with certain spatial conditions, alternated or surrounding colours (adaptation field) are added to the object, a phenomenon described by Bezold[1] and known as Bezold effect, assimilation effect, spreading effect or merely, inverse contrast.

Our laboratory started to quantify this effect six years[2] ago, by studying the influence of a Ronchi grating on the chromatic perception of a recurrent sequence and focusing on how this perception was influenced by the grating's orientation and critical frequency [3, 4].

This paper uses achromatic gratings to analyse, depending on the frequency of the grating, the influence of the following factors on the perception of colour in a recurrent sequence (sequences/degree):

1º.- The modulation ratio of the grating, that is the ratio between the space occupied by the white strip and that occupied by the period.

2º.- The contrast of the grating (the white strips are always white, but the luminance factor –β- for grey strips is modified).

2. DISCUSSION

Notwithstanding the possibility of a physiological justification for the spreading effect - Hurvich and Jameson[5]- due to the presence of receiver units of different dimensions in the area in which the retinal image is formed, we believe that this effect can be psychologically explained within the framework of Gestalt theory. According to this theory, sight is a consequence of the brain's interpretation of the light received from the whole visual field; objects are perceived as part of their surrounding and in accordance to it (in a marine landscape, any distant object will always be a boat).

Simultaneous contrast (direct spatial contrast) can also play a role, although a weaker one, in the study of the chromatic variance of the recurrent sequence by adding its effects to those of spreading contrast in cases in which, as the one exemplified, the adaptation field is an achromatic grating.

In this particular case, a set of three parallel lines can be seen, the two lines on the sides (red, black = blackened red) and the middle line (red, white = whitened red). This theory justifies the lessening of Bezold effect as the frequency of the grating decreases, until reaching a limit value (critical frequency) in which it disappears. We have gone from seeing black or white lines with small red specks inside (Bezold effect) to seeing clear red squares on a black or white background.

Direct contrast (simultaneous spatial contrast) with more quantitatively different effects to those of Bezold effect could also play a role, although a proportionally minimum one, in the variation of the perception of red in those sequences in which each red square (forming altogether a vertical stripe) is superimposed on a white stripe of the grating, and this is due to this particular horizontal stripe.

3. EXPERIMENTAL TECHNIQUE

The test used consists of three parallel straight lines with a width equal to the separation among them (1 cm.), sequences that have a Ronchi grating, with the horizontal orientation, as background with a 2 cm period over a 22 cm sideways square.

Figure 1: Test models for the study of the effect of the modulation ratio on the adaptation field. The figure on the left shows a Ronchi grating with a ¼ modulation ratio, while the figure on the right is a Ronchi grating with a ¾ modulation ratio.

The central sequence is superimposed on the black stripes of the grating and the lateral sequences are superimposed on the white stripes of the grating (fig.1). From a 7-metre distance, observers gradually approach the test until no difference is perceived between the central sequence and the lateral ones[2].

Using a scale from 0 -unseen on the central whitened sequence- to 10 -colour perceived on the darkened lateral sequence- the observer indicates as he approaches, the value (V) that on his/her opinion the central sequence has on the scale. This value is used to determine the chromatic contrast between the central and lateral sequences, the contrast with which the Bezold effect is quantified

$$\frac{10-V}{10} = \text{Bezold Effect} \tag{1}$$

12 observers were used and a total of 108 readings grouped in 36 sessions and divided into 2 observations per week. With a constant illuminance (750 luxes) two trios of sequences were used, one of them red ($x=0.58$; $y=0.35$) and the other one green ($x=0.34$; $y=0.51$) while maintaining the same luminance factor ($\beta = 0.20$).

No significant differences in the Bezold effect were found with respect to the red and green colours of the central and lateral sequences[2], although our laboratory is currently working on specific studies to corroborate this fact.

The same can be said about illuminance, since significant differences were not found either[2], which explains the constant illuminance values used for this work; however, there are works stating that the direct/inverse effect ratio decreases as the illuminance of the sample increases[3]. Therefore, future works should study the possible influence of the illuminance of the adaptation field on the Bezold effect.

4. RESULTS AND CONCLUSIONS

Summarising the most relevant results obtained, the vision of colour in a red rectangular recurrent sequence depends, besides the grating's spatial frequency, on the contrast (a) and modulation ratio (b).

4.1. RELATION BEZOLD EFFECT - GRATING CONTRAST. B_E= F (C_G) (TABLE 1, FIGURE 2)

The correlating decrease of the Bezold effect and the grating contrast (keeping a constant modulation ratio –r_m-) is easily explained, since the difference between the whitening and darkening of colour caused by the grating decreases as the contrast decreases, and thus, Bezold effect decreases as well, given that its value mainly depends on the difference above.

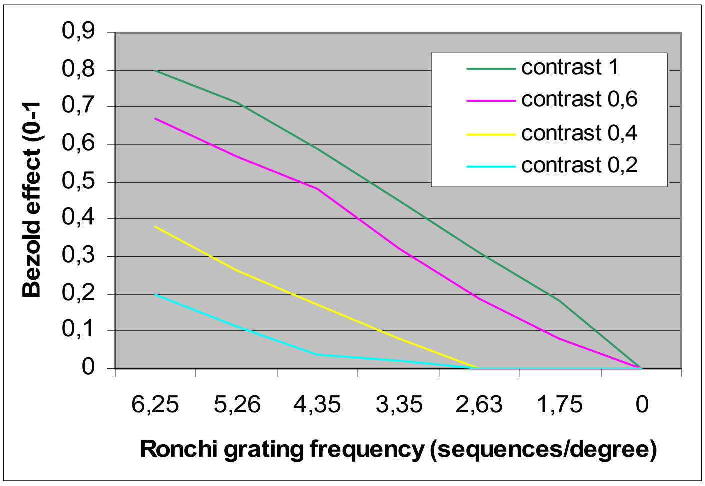

Figure 2: Graphic representation of Bezold effect with modulation ratio constant (1/4) and differents contrasts.

1/4 modulation ratio				
Seq/degree	**C=1**	**C=0.6**	**C=0.4**	**C=0.2**
6.25	0.80	0.67	0.38	0.20
5.26	0.71	0.57	0.26	0.11
4.35	0.59	0.48	0.17	0.04
3.35	0.45	0.32	0.08	0.02
2.63	0.31	0.19		
1.75	0.18	0.08		
0				

Table 1: Quantified difference of Bezold effect when analysing a modulation ratio

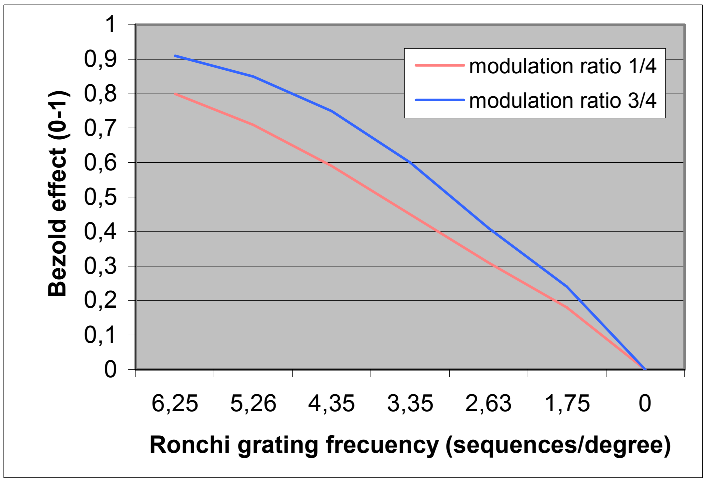

Figure 3: Graphic representation of Bezold effect for a test with modulation ratio ¼ and ¾ and maximum contrast.

Contrast = 1		
sequences/degree	**r_m=1/4**	**r_m=3/4**
6,25	0,80	0,91
5,26	0,71	0,85
4,35	0,59	0,75
3,35	0,45	0,60
2,63	0,31	0,41
1,75	0,18	0,24
0	0	0

Table 2: Quantified difference of Bezold effect when analysing a modulation ratio 1/4 and 3/4.

4.2. RELATION BEZOLD EFFECT - MODULATION RATIO. B_E= F (R_M) (TABLE 2, FIGURE 3)

Using high-contrast gratings (the influence of the simultaneous effect –direct spatial effect- with a high-contrast is negligible compared to Bezold effect) the difference in Bezold effect between a r_m =3/4 grating (white strips wider than grey strips) and a r_m=1/4 grating (grey strips wider than white strips) is a consequence, on our opinion, of the higher "colour masking effect" caused by white colour (which acts on luminosity and saturation) than by black colour, which only affects luminosity.

Therefore, an r_m=3/4 shows a greater difference between whitening and darkening, and thus a higher Bezold effect, than a modulation ratio of ¼.

Using weaker contrasts in which Bezold effect is minimum and difficult to specify, quantifying the $r_m 3/4 - r_m 1/4$, difference could be uncertain, and although it should still physically exist, its value, with certain experimental conditions, could be lower than that of the chromatic threshold and thus difficult to determine, as can be seen with the luminance and with red and green in this paper.

4.3. FINAL OBSERVATION

The expression (1) with which Bezold effect is quantified has been used as base for the mathematical processing of Bezold effect.

The real value of Bezold effect should be obtained, not from the differences between the whitened and blackened colour, but from the difference between the whitened or blackened colour and the undistorted colour; thus obtaining two values, one for whitening and one for blackening, whose mean value could be given as Bezold effect value in order to simplify the calculations and arguments involved in the process.

References

1.W. Bezold, "The theory of color" (United States edition) Prang and Company (1876).

2. M. Aguilar, C. Urtubia, "Direct and Inverse Contrast interaction in a periodic test wieving", IX Congreso Internacional de AIC Rochester (USA), 2.001.

3. M. Aguilar, R. Lopez, C. Urtubia, "Visión de un test periódico con una red de Ronchi como fondo", V Congreso Nacional de Color, Tarrasa, 1.999

4. M.L. Martínez, J. Irigoyen, I. Tortajada, M. Aguilar, "Variación en la percepción del color con la orientación de una red de Ronchi como campo de adaptación", VII Congreso Nacional de Color, Pamplona, 2.003.

5. L. Hurvich, "Color Vision". Sinauer Associates inc. Massachussets, 1.981

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