Note del Polo
-Ricerca-

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Experiments on new contrast patterns

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Abstract

The appearance of two identical gray patches on black or white surround can vary according to the spatial distribution of the patches. This kind of illusions is very common (e.g. the well-known simultaneous contrast effects) and any theory of visual perception has to deal with them. In this work we want to present some new contrast patterns that show unexpected effects with respect to other known ones and to discuss possible explanations of this visual effects. We consider three main explanation hypothesis that reduce the interpretation to different visual tasks: center-surround low level visual tasks, higher level visual tasks and multi resolution processing. The new configuration proposed, a checkboard configuration with a gray square surrounded by black or white vertical and horizontal squares, cannot be explained by the first two hypothesis. Moreover it is not clear if multi resolution processing alone can explain this effect or other low level tasks should also be taken into account. We have applied a multi resolution analysis to the basic configuration and to some new variants, observing contradictory results. We have performed an observation test with 20 students, to check the effectiveness of the appearance shift.

1. Introduction

The appearance of two identical gray patches on black or white surround can vary according to their spatial distribution.

In this work we have examined some new patterns, that show contrasting effects with respect to other known ones. We consider three main hypothesis that aim at explaining these effects:

?? simultaneous contrast: can be explained with low level visual tasks (center surround)

?? Gestalt higher level visual tasks: psychological and image interpretation tasks

?? multi resolution processing by low level visual tasks.

The new proposed configuration cannot be explained using only one of the above hypothesis and it is open if a combination of them can justify these effects, or other vision tasks should be taken into account.

We have considered separately the three explanations to the basic known configuration and to some new patterns, obtaining contradictory results. We have also performed a quick appearance test, by asking to 20 students the perceived effect, trying, in this way, to confirm our subjective judgement.

2. Different approaches to explain lightness illusion

Various methods have been developed so far, trying to give a coherent explanation and a sound base for lightness illusion and for other type of visual effects. In this work we consider three approaches, representative of three very different points of view. In our opinion, they are not able to justify autonomously the proposed patterns, leaving the problem open to the use of other approaches or to particular combination of the considered ones.

Simultaneous contrast approach

In the classical simultaneous contrast, equal gray zones vary their appearance according to the background. In the example of Fig. 1 the central gray spot is brighter on the black background and dimmer on the white.

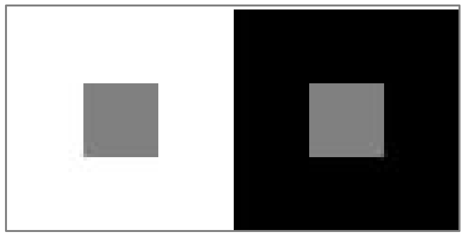


Fig. 1 – Simultaneous contrast

A low level explanation based on the human visual system reaction to the contrast is widely accepted [1]. In this case what affect the lightness perception is the neighborhood of the actual area. We do not consider scattering side effect, that have be proven to affect moderately the contrast phenomena considered in our work [2].

This low level explanation is not able to justify more complex effects like the White's effect (fig.2).

High level approach

An attempt to explain complex images comes from psychological studies. The interpretation of the structural content of the image heavily affects the appearance of identical regions.

In the White's effect [3], shown in Fig.2, the gray stripes on the left are dimmer than the identical ones on the right. This happens despite the fact that they are mainly surrounded by black stripes and the reversal happens to the stripes on the right, contradicting in this way the simultaneous contrast explanation.

This effect can be interpreted as a high order visual process. In fact, it is possible to group the gray stripes and interpret the left part of the image as a white background simultaneous contrast under black bars and the right part as a black background simultaneous contrast under white bars.

This possible interpretation comes from a multi-layer segmentation, typical of high level processes.

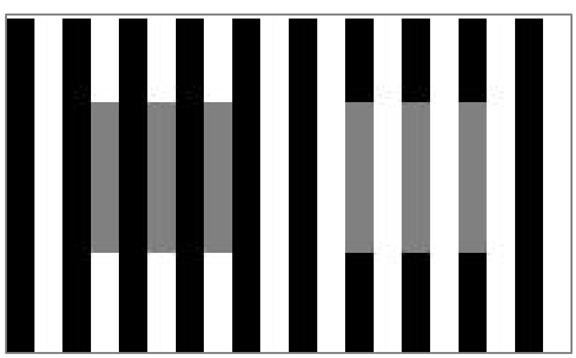


Fig. 2 – White's effect

Multi-resolution approach

The White's effect can also be explained considering its low frequency content [4]. According to this approach, the right gray stripes appear lighter simply because they are lighter when a low pass filter is applied to the image. On the contrary, a low pass filter applied to a simultaneous contrast configuration (fig. 1) fails.

It is possible to divide the lightness illusions into *contrast* and *assimilation*. Contrast is the name of the mechanism that makes gray in white look darker, assimilation is the name of the mechanism that makes gray in white look lighter [5].

The multi-resolution principle seems able to explain assimilation ,but not contrast. This does not hold true in the proposed variants of the following checkerboard pattern.

3. The basic checkerboard pattern

Checkerboard based patterns are not a new idea [6], but in this paper we want to present some new variants able to produce interesting effects.

The basic pattern, due to Rus and Karen De Valois (Fig. 3), is composed by a black and white checkerboard with two identical mid-gray squares replacing a black (upper) and a white (lower) square respectively. The positions of the two gray squares have been chosen in order to avoid any symmetry.

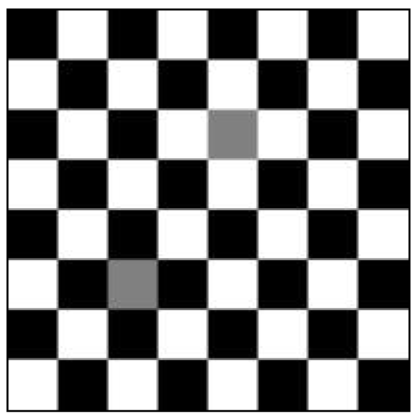


Fig. 3 – The basic checkerboard effect

The lower square appears dimmer than the upper. This is an assimilation effect and can not be explained by the low level simultaneous contrast approach, in fact the lower square is surrounded mainly by black and the upper square vice-versa.

On the contrary, the other two approaches are able to explain this basic pattern. In the case of the high level approach a gray square can be viewed as a "good continuation" of the checkerboard alternance. The effectiveness of multi-resolution approach is shown in Fig 4a (the original image) and 4b (low pass Gaussian filtered - 25 pixel width).

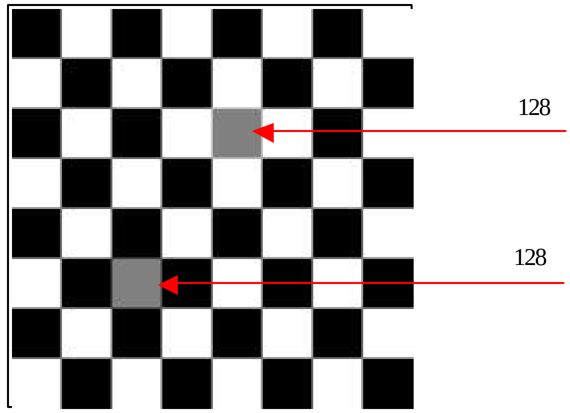


Fig. 4a – The checkerboard basic effect

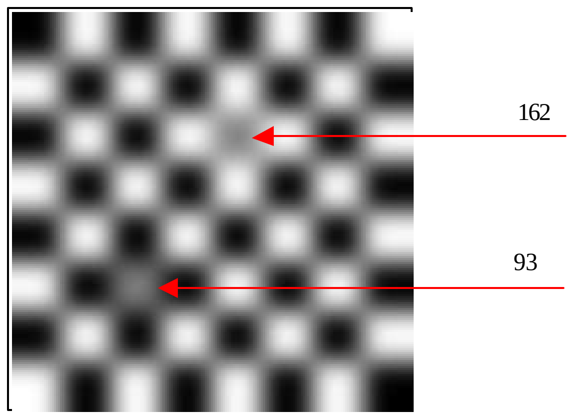


Fig. 4b – Low pass filtered image - mean gray value of the square

4. The proposed pattern

The proposed pattern is a variant of the basic checkerboard effect, shown in Fig. 5. The gray squares are smaller and surrounded by a white or black frame. In this case the appearance of the two gray squares changes in the opposite way: the upper square appears darker than the lower.

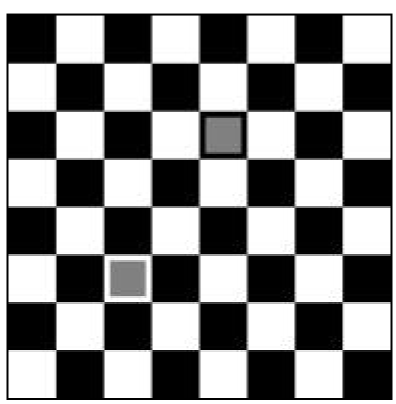


Fig. 5 – The proposed pattern

The simultaneous contrast approach still is not able to explain this illusion, since the lower gray square, surrounded by white, should appear darker and vice-versa.
The high level approach is hardly applicable, since there is no evident structure in the configuration, as in the White effect or in the basic checkerboard pattern. The inserts appear as "intruders". This comment is reinforced by the following variants: with gray circles (variant C) from an Escher picture (variant E). Applying a low pass filter to test the multi resolution approach, it fails (fig. 6).

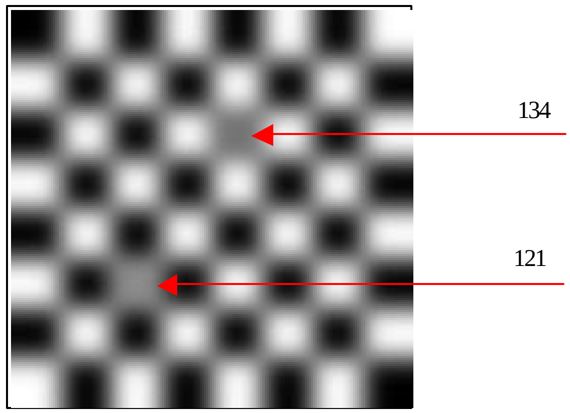


Fig. 6 - Low pass filtered image (gaussian 30 pixel width)

A variant of the proposed pattern

A variant of the proposed pattern is shown in fig. 7 left. In this case the effect is lower, but still the two grays have different appearance: the upper square appears lighter. It is an assimilation effect in line with the multi level interpretation (Fig 7 right).

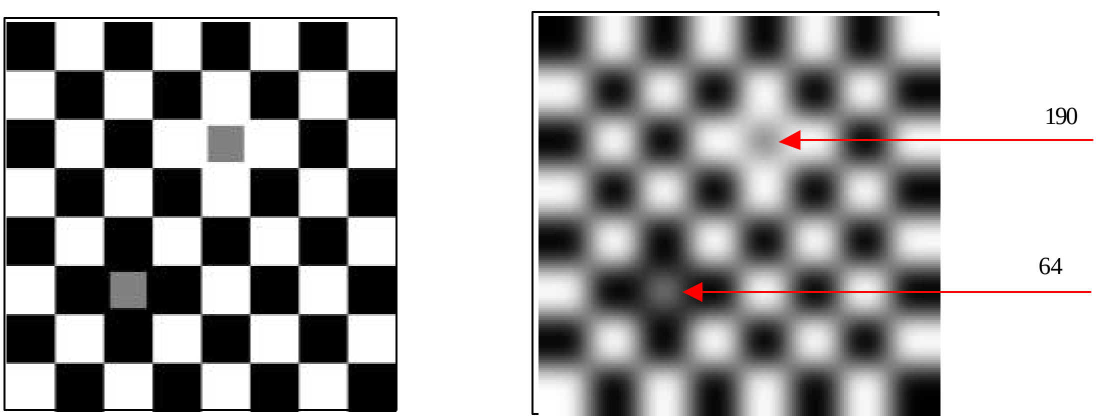


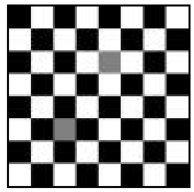
Fig. 7 – *Left* the variant A, *right* its low pass gaussian filtering (30 pixel width)

5. Varying the frame size

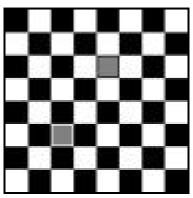
To investigate the effect of the size of the surrounding frame we have prepared different images, shown in the following table of figures (Table 2) The pattern images size is 1024x1024 pixels, each square of the checkerboard is 128x128 pixels and the different sizes of the surrounding frames in the proposed pattern and its variants are reported in the Table 1.

Size	Frame pixel
1	8
2	16
3	32
4	48

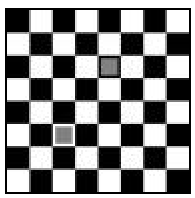
Table 1 – Frame dimensions in pixels



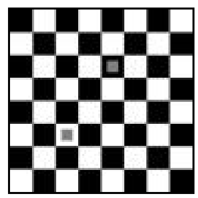
Checkerboard pattern



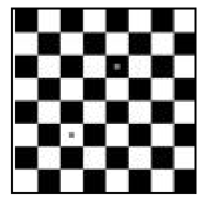
Proposed pattern size 1



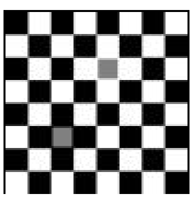
Proposed pattern size 2



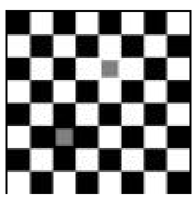
Proposed pattern size 3



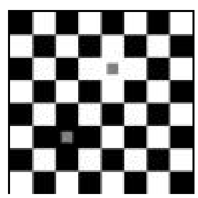
Proposed pattern size 4



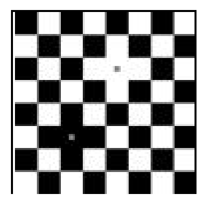
Variant A size 1



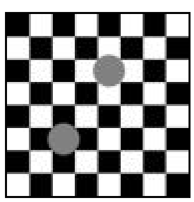
Variant A size 2



Variant A size 3



Variant A size 4



Variant C

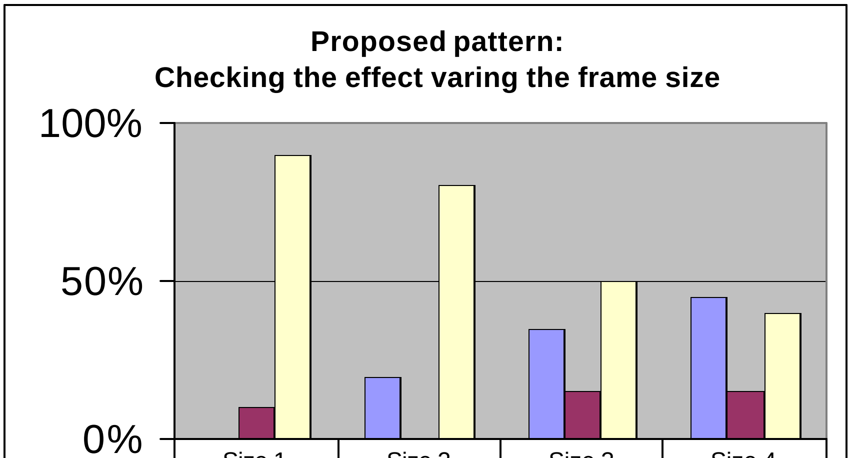
Variant E

Table 2 – All the patterns

6. Checking the effects

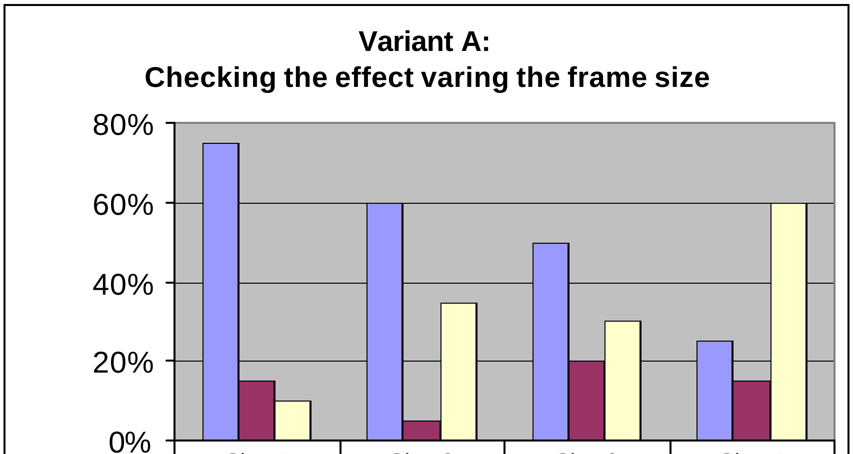
To check the type and the strength of the visual effects, we have performed a quick appearance test with 20 students. During this test, for each image in Table 2, the person has been asked to choose the brighter gray of the pattern under test displayed on a calibrated monitor in a dark room. We have verified that the same effects were observable both on a monitor and on a printed paper, thus we have chosen to perform this test on monitor, to better control the patterns tone mapping.

The result are reported in Table 3. As can be noticed from the values under the graph, the main effect of the proposed pattern is assimilation, since the upper gray square is in a black surround, but the strength of this illusion decreases as the frame size increases.



	Size 1	Size 2	Size 3	Size 4
Brighter up	0%	20%	35%	45%
Equal	10%	0%	15%	15%
Dimmer up	90%	80%	50%	40%

Table 3 – Test of the proposed pattern effect



	Size 1	Size 2	Size 3	Size 4
Brighter up	75%	60%	50%	25%
Equal	15%	5%	20%	15%
Dimmer up	10%	35%	30%	60%

Table 4 – Test of the variant A effect

The same test has been performed also on the variant A; the result are reported in Table 4. In this case the effect is the opposite, but it is still an assimilation, since background of the upper gray square is white. Also in this case, the strength of the illusion changes with the frame size.
In both cases changing the frame size shifts the effect from assimilation to contrast.
In the following section we present some results, testing the capability of each of the considered approaches to explain this property.

7. Overall test results and conclusions

The overall test results of Table 5 allows us to compare the different approaches effectiveness on the presented patterns. For each pattern, the appearance result of the student test is shown. According to the visual effect and for each of the three considered approaches, the capability to explain the relative lightness illusion is reported.

Pattern Name	Test result	Low lev.	Multi Lev.	High Lev.
Basic	Assimilation	No	Yes	Yes
Proposed pattern size 1	Assimilation	No	No	No
Proposed pattern size 2	Assimilation	No	*	No
Proposed pattern size 3	Weak Assimilation	No	*	No
Proposed pattern size 4	Near equal	-	-	-
Variant B size 1	Assimilation	No	Yes	No
Variant B size 2	Weak Assimilation	No	Yes	No
Variant B size 3	Near equal	-	-	-
Variant B size 4	Contrast	Yes	No	No
Variant C	Assimilation	No	Yes	No

Table 5 – Overall test results

The multilevel approach is based on a coarse sampling made by the human visual system receptive fields, with a Gaussian response. The size of the receptive fields and the relative dimension (according to the viewing distance) of the pattern can modify the illusion effect. In our simulation this depends on the Gaussian filter size used to compute the sub-sampled lightness. The "*" symbol indicates that the result vary according to the filter size, as reported in Table 6.
The "-" symbol indicates patterns on which the test results do not indicate clearly a "winning" lightness illusion.
To computes the sub-sampled values, shown in Table 6, the patterns have been low pass filtered using Photoshop Gaussian filter with a pixel radius varying form 16 to 64. From this data we can see that in various cases the low pass filter effect tends to cross over and at very low spatial frequency the pattern illusion is lost. A possible justification of this phenomenon is that more than one low level visual mechanism are involved at the same time (multi resolution as well as a center surround) playing apparently two opponent roles.

		Filter size		
Image	**Squares**	**16**	**32**	**64**
Basic	Upper	150	163	167
	Lower	106	92	87
Proposed pattern size 1	Upper	128	146	158
	Lower	128	109	95
Proposed pattern size 2	Upper	110	128	149
	Lower	146	128	105
Proposed pattern size 3	Upper	83	84	131
	Lower	172	170	123
Proposed pattern size 4	Upper	46	42	116
	Lower	208	212	136
Variant A size 1	Upper	154	172	177
	Lower	102	83	77
Variant A size 2	Upper	155	180	188
	Lower	100	75	66
Variant A size 3	Upper	175	207	207
	Lower	81	48	47
Variant A size 4	Upper	201	235	220
	Lower	41	15	33
Variant C	Upper	142	149	148
	Lower	114	106	106

Table 6 – The multi level approach results

Bibiography:

[1] E.H.Adelson, M.S. Gazzaniga ed., Lightness Perception and Lightness Illusions, in *The Cognitive Neurosciences* Cambridge, MA: MIT Press, pp. 339-351 (2000).

[2] J.J. McCann, "Spatial Contrast and Scatter: Opposing Partners in Sensation", Proc. IS&T/SPIE Conf. on Human Vision and Electronic Imaging IV, San Josè California, January 1999.

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[4] J.J. McCann, "Gestalt Vision Experiments from an Image Processing Perspectives", Proc. IS&T PICS, **4** (2001).

[5] J.J. McCann, "Image Processing Analysis of Traditional Gestalt Vision Experiments"

[6] R.L. De Valois, K.K. De Valois, "Spatial Vision", Oxford University Press, New York, 1988.

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40. Rizzi A., Gatta C., Marini D., ***Experiments on new contrast patterns***