Watercolor illusion

A. Introduction

The “watercolor illusion” is a long-range spread of color (up to 45° visual angle) diffusing from a thin colored line running parallel and contiguous to a darker chromatic contour and imparting a strong figural effect across large regions. Two phenomena can be observed in the watercolor illusion: illusory color spreading and figure–ground organization.

The color spreading effect has some characteristic properties:

(i) The illusory color is perceived as a spreading of some quantity of tint belonging to the lighter line and giving rise to a more diluted coloration;

(ii) The coloration does not appear transparent but opaque and belonging to a solid impenetrable object.

(iii) The coloration appears striking and looks as a surface color.

Watercolor illusion determines figure–ground segregation more strongly than the Gestalt principles of proximity, good continuation, closure, symmetry, convexity, past experience, and similarity. Watercolor illusion includes a new principle of **figure–ground segregation.** The asymmetric luminance contrast principle, stating that, all else being equal, given an asymmetric luminance contrast on both sides of a boundary, the region whose luminance gradient is less abrupt is perceived as a figure relative to the complementary more abrupt region, which is perceived as a background.

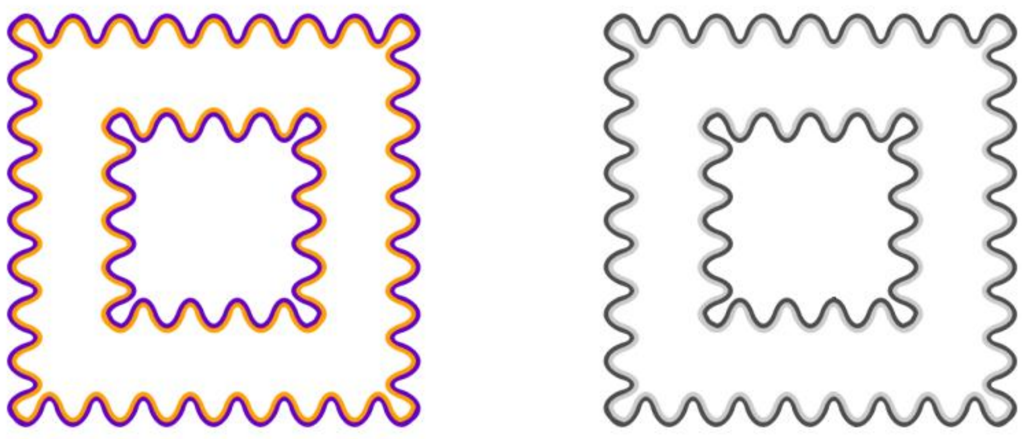


Fig.1 the watercolor illusion: two juxtaposed lines with different colors. The inner part of the rectangular is filled with weak yellow / gray color, despite the fact that the background on both cases is white.

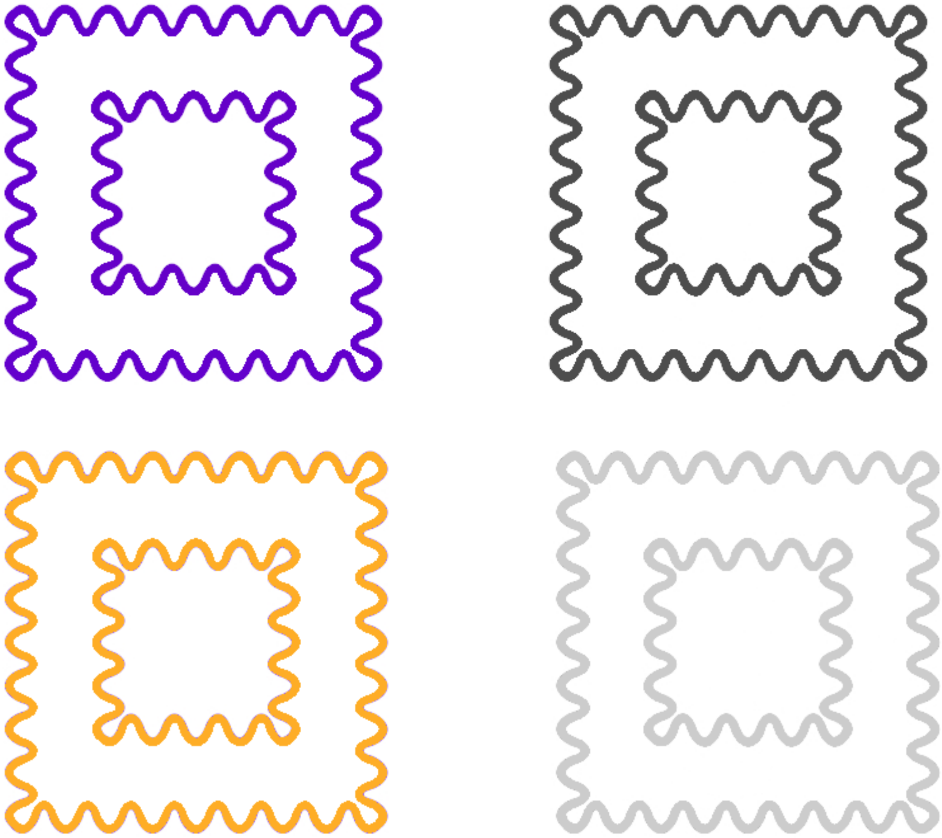


Fig.2 same rectangulars as in fig.1, but instead of two colors for the lines, both lines are colored with only one color (and both colors for each rectangular are presented – dark and light) and no illusion is perceived in any case.

B. HSV

HSV is a different color definition model from the common RGB in which every color is composed from 3 base colors – Red, Green and Blue with a value from 0 to 255 for each. In HSV model a color is also defined by 3 components: **Hue** between 0 - 360 degrees, where 0 corresponds to red. **Saturation** and **Value** between 0 – 100.

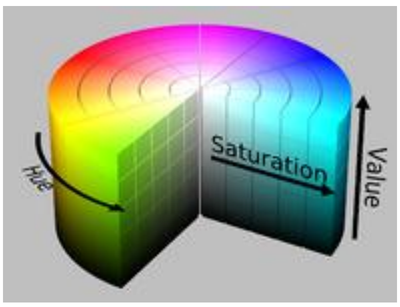


Fig. 3: A 3D model of the HSV

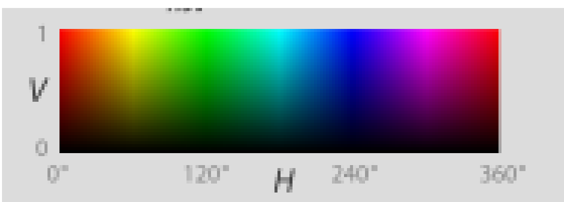


Fig.4: 2D model of Hue and Value (saturation is set to 1)

In the experiments we measured the colors with the HSV model, because the changing of one parameter (the hue) may determine the color component of the lines, so the color difference between the lines can be quantify by angels in degrees.

The HSV model determines that a color is more different from white with the increment of its "Value" component. But looking on the Hue wheel we see that some colors are visible more bright then others. It is caused by different sensitivity of the human eye to different colors. We know that three types of cones exist (short, medium and long), and they have different sensitivity for the colors. Therefore the blue color is seen less bright than green, and the green is seen less bright than red having the same value and saturation values. From the graph we see that deep violet and red-purple colors are the least sensible, and the yellow-green color is the most sensible.

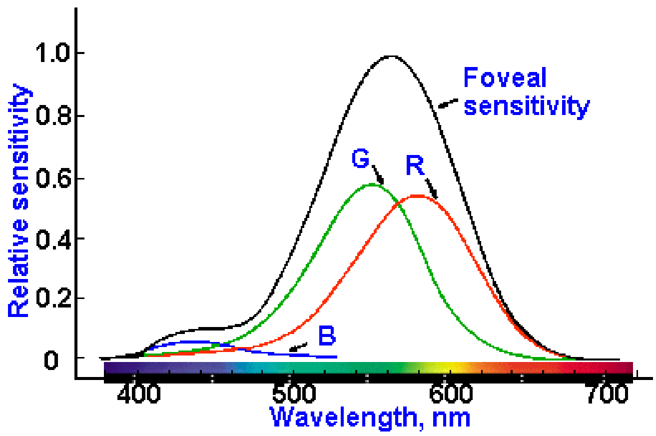


Fig.5 the sensitivity of the human eye to color spectrum

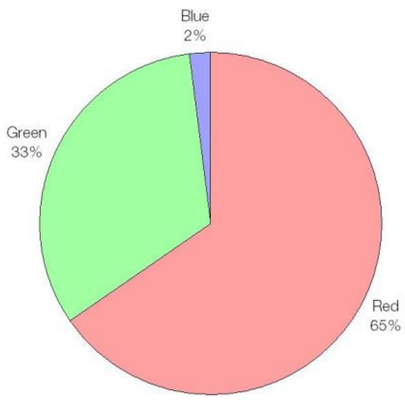


Fig.6: Segmentation of cones in the human eye

The reason for this is that the partition of the 3 cones type isn't symmetric. 65% of the cones are used for the red color, 33% for green and only 2% for blue. Meaning we percept the red color much better than green and blue, and we can see much more hues of this colors than any other.

Experimentation

Experiment 1 – figure-ground duality:

In this experiment we used the same shapes where the contour of the juxtaposed lines was reversed. In Fig.7 we percept the stars as the white background and in Fig. 8 the stars are the figures colored with weak yellow tint.

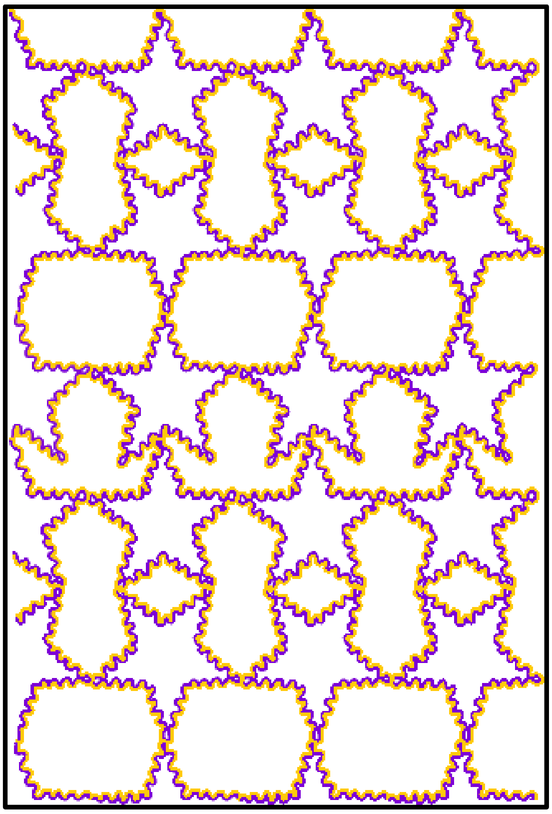


Fig. 7 Stars as background

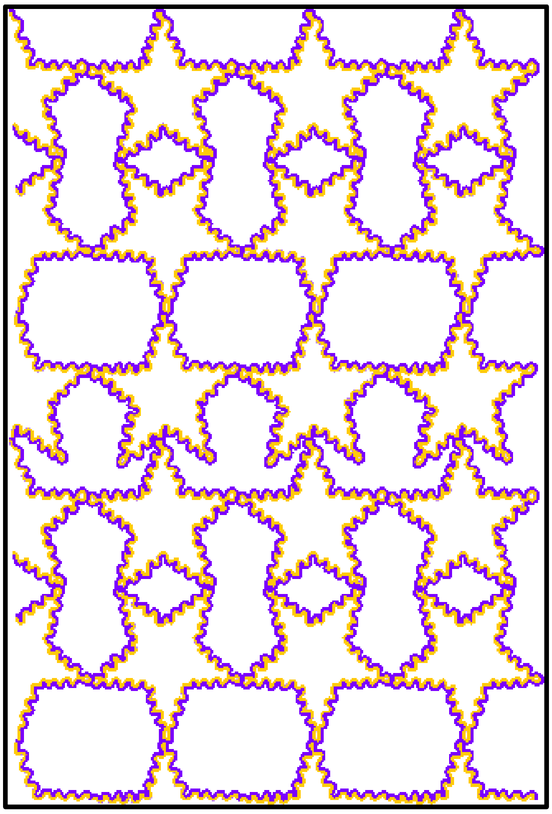
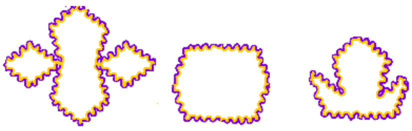
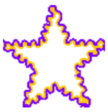


Fig 8. Stars as figure

In fig.7 the perceived figures are  while the white stars are the background.

In fig.8 the perceived figures are 

The **effect of figure-ground duality** is presented since the border between the background color (white) and the figure color is calculated in our brain as the border between areas with the highest color difference (white and purple). And when a darker color is perceived as the border of the figure, the light color (yellow) is perceived as the filling color of the figure.
And when we switch the lines colors, the perception of the border is inversed.

The **effect of color spreading** is presented when the gradient between the background color and the light line color is low, so we perceive the figure is filled with a tint of the light color, and the darker line color is perceived as border line.
Our explanation for the effect color spreading:
The brain comprehends the filling color of figure from both the border and the inner areas, and since the inner border is light color the filling is composed from both colors (background and inner line) and perceived as mixture of the colors.
When there is only one color border line, the "inner border" is of the same color as the background, so their "mixture" is the background color, hence no watercolor illusion observed.

Experiment 2 – **dependency of illusion strength on the Hue component**:

In all our tests we used a white color as the general image background. To generate a watercolor illusion we have tried to find the colors that are correspondently more and less abrupt with white color, and find out which combination of two colors generates the strongest illusion effect and why.

The HUE component is sorted by its angle on the "Hue wheel", where 0 corresponds to red. We took the violet color for the dark outer border line (270/100/84 in HSV), and examined the watercolor illusion for each inner border line (light) differing from the violet by steps of 30°.

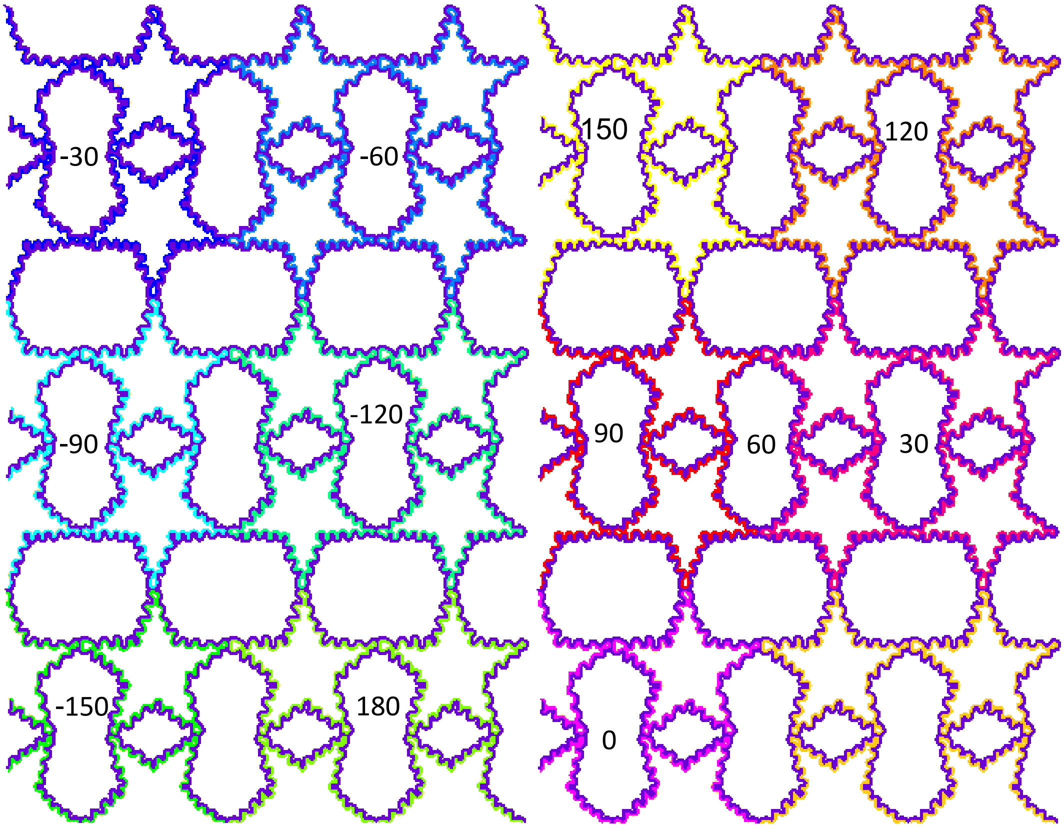


Fig.9 variations of inner line color, varied in gaps of 30° from on Hue wheel from outer border - purple 270°

Experiment 3 – effect on illusion in straight lines

We presented to subjects the same shape in two variations, snake lines and straight lines. Subjects reported a slight higher effect of the illusion with snake lines. Our explanation for this effect is that cells in V1 react to line in a certain orientation, and since the lines are shaped as snake line instead of straight more V1 cells are been activated,(due to constant change of the line orientation) and magnifying the intensity of color-spreading effect.

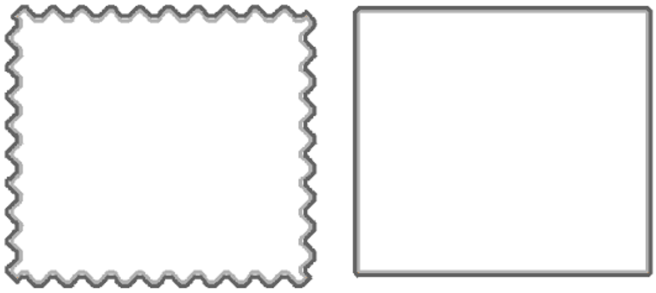


Fig.11 rectangular shaped with snake and straight lines

Conclusions

- The color-spreading occurs in any combination of dark and light border lines.
- Swapping the line colors reverse the figure-ground perception.
- The effect of color spreading with snake line is stronger than straight line.
- The strongest watercolor illusion with deep-purple as dark color and light color in the range of 120°-180° from purple – probably because this range of color is the most sensitive to the human eye (see fig.5 – human eye sensitivity to the color spectrum). High sensitivity causes low gradient between the given light color and the white.
- Figure–ground segregation principle of the Watercolor illusion surpasses Gestalt principles like closure, symmetry, convexity and past experience…
- Intensity of the illusion is subjective and changes for different people.

Additional Information

- Full project report (or download it in PDF)
- Oral presentation slides (or download it in PDF)

References

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Michael D. Mann [2003] - The Nervous System In Action chapter 7

Wikipedia - HSL and HSV

Wikipedia - RGB color model