

PSYCHOLOGICAL CONNECTION BETWEEN COLORS AND CERTAIN CHARACTERISTIC TERMS

Nedim Smailović

Pan-European University APEIRON, Banja Luka

Case study

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Abstract: This paper presents results of a research on psychological connection between 40 offered colors and 91 terms from everyday life. Similar researches have been conducted and published in a number of instances in domestic and foreign bibliography, but this research has certain particularities that are not often present in other articles. For one thing, colors whose associativity with certain terms is being analyzed are shown in a table, their name and code in the RGB system of color marking are provided. Colors were not merely described, e.g. blue, green, yellow, etc., as it may be confusing or lead to misinterpretation of answers since there are many degrees of blue color, for example. In the second part of the poll, the subjects answered the Ishihara test, in order to check the ability to correctly interpret the colors. The third specific is triple visual interpretation of received results using colored graphs.

Keywords: color, Ishihara test, psychology, visualization of data.

INTRODUCTION

The electromagnetic waves spectrum spreads in a large range of frequencies i.e. wavelengths. At one end of the spectrum is gamma radiation (gamma particles) with wavelength $< 0,02$ nm and frequency $> 15 \cdot 10^{18}$ Hz, and at other end are radio waves with wavelength of 1 mm – 100 km and frequency 300 GHz – 3 kHz. The electromagnetic spectrum can be divided into seven bands, which are the following (from highest to lowest frequencies i.e. shortest to longest wavelengths):

1. Gamma rays,
2. X – rays,
3. Ultraviolet radiation,
4. Visible light,
5. Infrared radiation,
6. Micro-waves,
- and 7. Radio waves.

Visible light is only the segment of electromagnetic spectrum containing waves of wavelength 390 nm – 750 nm and frequency 770 THz – 400 THz. Humans have receptors (eyes) for these waves and at their detection after passing through optical nerve, the brain creates the sense of receiving the light.

The eye retina contains two types of cells sensitive to light, rod and cone cells. Rod cells react even

to the small quantity of light, but do not differentiate colors. That is why at night we only see the shapes of objects. Poets say: “Dawn is the birthtime of colors”. That is when the light gets stronger and is received by cone cells. There are three kinds of cone cells and each recognizes one of three primary colors – red, green or blue. These signals are combined in the brain, enabling recognition of a whole spectrum of colors. Retina has about 130 million rod cells and 6,5 million cone cells. They are mainly all situated in the area called the macula lutea, where an up-side-down image of the observed scene is created.

Wavelengths of the visible part of electromagnetic spectrum are mixed in many combinations, and human eye can differentiate over 10 million colors. When a Sun light passes through a transparent glass prism, certain wavelengths diffract differently, creating a spectrum of colors.

Larousse encyclopedia interprets colors in this way:

“A color is an impression created by electromagnetic waves as they pass through our eye; a property

ascribed to light or objects to create a special visual impression.” [9]

crvena	~ 620 - 740 nm	~ 400 - 495 THz
narančasta	~ 590 - 620 nm	~ 480 - 500 THz
žuta	~ 580 - 590 nm	~ 510 - 516 THz
zelená	~ 530 - 545 nm	~ 550 - 553 THz
plava	~ 435 - 500 nm	~ 600 - 690 THz
ljubičasta	~ 380 - 440 nm	~ 700 - 680 THz

Picture 1. Names of colors, their wavelengths and frequency ranges

The word “color” (in the sense of a matter or a visual feeling) was not separately defined in the *Leksikon stranih reči i izraza*, by Milan Vujaklija, Prosveta – Belgrade, 1980, (Lexicon of Foreign Words and Expressions), or in *Rječnik stranih riječi: tuđice, posuđenice, izrazi, kratice i fraze* (Dictionary of Foreign Words) by Sima Anić, Nikola Klaić, Želimir Domović - Zagreb: Sani-plus, 1998. As if it were not of foreign origin, while it is. In the dictionary “Turkish Words in Serbo-Croat Language” by Abdulah Skaljic, it states that the word color (boja) has its origin in Turkish (boya) in the sense of farba (paint), though that word is Germanism. Such a frequent word in everyday speech, and we do not have our own term for it. Only in Russian and Bulgarian language we can still find Slavic words ‘cvet’ and ‘краска’. The notion of colors may be connected with old words ‘mast’ (‘masnica’ – bruise) and ‘шаръ’ (colorfulness, to draw). However, the word color has stayed unchanged from Turkish in everyday speech, just as there are no adequate substitute for some other words of Turkish origin: bakar, čarapa, česma, dugme, jastuk, jogurt, kaiš, limun, makaze, testera, tavan, kreč, šećer, sapun, majmun, rakija, čelik, kičma, pare, puž, komšija, kesa, kašika, đubre... (eng. copper, socks, tap, button, pillow, yogurt, belt, lemon, scissors, (wood)saw, attic, chalk, sugar, soap, monkey, spirit drink, steel, spine, money, snail, neighbor, bag, spoon, rubbish...).

From a wider perspective, the notion of a color has several different meanings:

1. color as a psychological phenomenon, i.e. as a stimulus in an eye and a subjective perception;
2. color as an optical phenomenon;
3. color as means of expression;
4. color as a matter.

In everyday speech the word color is often accompanied with attributes such as: (of) light color, dark color, calm color, dead color, vivid color, joyful color, etc.

Isaac Newton (1642 -1727) experimentally proved in 1676 that white light separates into seven different colors, if passed through a glass prism. White and black are not among those colors. White color is obtained by mixing all the colors of that spectrum.

Newton also experimented with associations of colors and tones of a musical scale, while a century later Johann Wolfgang Goethe (1749-1832) studied psychological effects of colors. Colors are inseparable from everyday life situations. In business world, colors are often an important segment of presenting and doing business. Well selected colors or their combinations may be an important factor of market success, while a bad choice may produce negative effect, fully opposite from the desired one. It is particularly important when planning an appearance on markets of different cultural, religious or geographic communities. Observers of different age, ethnicity, gender or local communities have different perceptions of particular colors. Often the symbolic meaning (‘the language’) of colors is changing.

SYSTEMATIZATION OF COLORS

Thomas Young and Hermann von Helmholtz established in early 19th century that any color of light may be obtained by mixing the three primary light sources. That meant that colors first needed to be systematized. Many great scholars wrote about systematization of colors, and among them were: Leonardo da Vinci (1452.-1519), Sir Isaac Newton (1642-1727), Johann Wolfgang Goethe (1749-1832), James Clerk Maxwell (1831-1879), Albert Henry Munsell (1858-1918), Wilhelm Oswald (1853-1932).

There are several different interpretations of primary colors (primaries), which is a consequence of the fact that colors may be observed from different standpoints: psychological, physics, chemical, etc. The science of colors is a true example of interdisciplinary area.

Physics standpoint interprets behavior of colored rays of light and their mixing. In that sense the primaries are additive: red (R), green (G) and blue (B), or subtractive: cyan (C), magenta (M) and yellow (Y). Subtractive primaries are complementary colors to corresponding additive primary colors.

Psychological standpoint interprets colors based on their noticing and perception of color.

Hence, the psychological primaries colors were defined: red, green, blue, yellow, white and black.

The painters will emphasize, among their primaries, those colors they use as a matter (paint in a tube) to mix and get all other colors. **Painters' primaries** are red, blue, yellow, white (noncolor) and black (noncolor). White and black noncolors are used to obtain the desired degree of saturation of mixed colors.

The Art primaries are the same as Painters' primaries, excluding white and black noncolor.

The theory is even more complicated by the fact that painters' primary "red" is not necessarily the same as the additive primary "red".

Mixing the primaries gives secondary colors, while further mixing of secondary colors produces tertiaries, etc.

Colors rarely appear isolated in nature and almost always combine mutually next to each other. There we have harmony of colors. Just as some paired sounds may be in harmony or disharmony, two or more colors next to each other may look nice but they can also produce a completely different feeling. All this is, of course, subjective, as something that looks nice to some may not look like that to others, since the perception of colors is very complex.

INTERNATIONAL ASSOCIATIONS FOR LIGHT AND COLORS RESEARCH

For the purpose of interpreting all aspects of color research, the AIC – The International Color Association (<https://www.aic-color.org/>) was established. The AIC aims to have close cooperation with existing international organizations, such as Associations with topics relating to light: CIE, Commission internationale de l'éclairage; ICO, International Commission for Optics; ISO, International Organization for Standardization; SPIE, The International Society for Optical Engineering; AISV, Association internationale de semiotique visuelle; Applied Vision Association (Great Britain); Royal Photographic Society (Great Britain); IS&T, Society for Imaging Science & Technology (USA); ICC, International Color Consortium; ICVS, International Colour Vision Society; IACM, International Association of Color Manufacturers, Centre d'information de la couleur (France); Fédération française de la cou-

leur (France), Ad chroma (France); SDC, Society of Dyers and Colourists (Great Britain); Color Marketing Group (USA); China Fashion Colour Association (China).[1]



Picture 2. Logo of the AIC



Picture 3. Logo of the International Color Day

In 2009 the AIC accepted founding the International Color Day, which is commemorated in many countries around the world. The establishing of the international color day (ICD) is considered justified as the color, thanks to the visual perception, is one of the most influential phenomenon in life of people and one of ways that contribute most to the perception of reality. It could be said that the contemporary world communicates through colors.

The ICD was proposed by the Portuguese organization for colors in 2008. The proposal was agreed in 2009 among members of national associations in more than 30 countries.

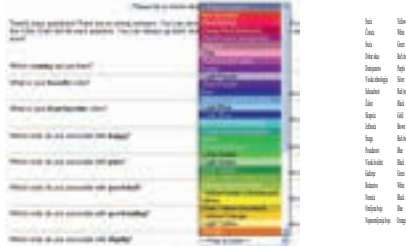
Some of the activities and events that take place on ICD day are: art exhibitions, architectonic projects, design, decoration, fashion, meetings, discussions, scientific events, workshops on the use of color and light for children and adults, competitions, etc.

SUBJECTIVE PERCEPTION OF COLORS

The Internet address <http://express.colorcom.com> until recently held a comprehensive interpretation about colors, dealing with topics such as: colors and science, colors and computers, colors and the world, etc. There also was, inter alia, a survey where site visitors could say something about associativity of a term – notion and a color. There were 18 questions asked. Colors for answers are shown visually (as displayed in the picture) in order to avoid misunderstanding regarding which color it is in the words

description. The same color may be associated to different terms.

The authors stated that over 30.000 persons took part in the survey, and they published the following results on associating colors with terms:



Picture 4. An Internet research on associating colors with certain terms

SURVEY ON SUBJECTIVE PERCEPTION OF COLORS

The polled subjects had 40 concrete colors in front of themselves, which belong to Microsoft standard palette of colors with a unique code to differentiate the colors among themselves. For example, one green-blue color was titled teal, it was number 14 and a code in the RGB system was 000 255 204. The subject saw exactly that color, and not some abstract green-blue. According to the opinion of the polled subjects, that color best corresponds to some of the offered 92 terms.

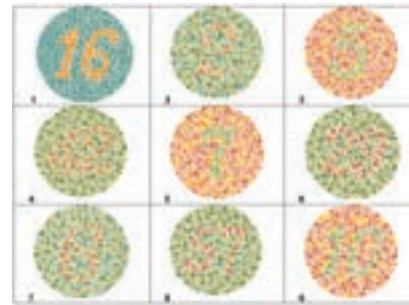


Picture 5. A survey form with colors and associating terms

The second part of the survey was Ishihara test.

Dr. Shinobu Ishihara (1879 - 1963) was a Japanese military surgeon and an ophthalmologist who created a test for color-blindness, called after him afterwards. The test comprises of recognizing a number or a pattern in a set of differently colored circles.

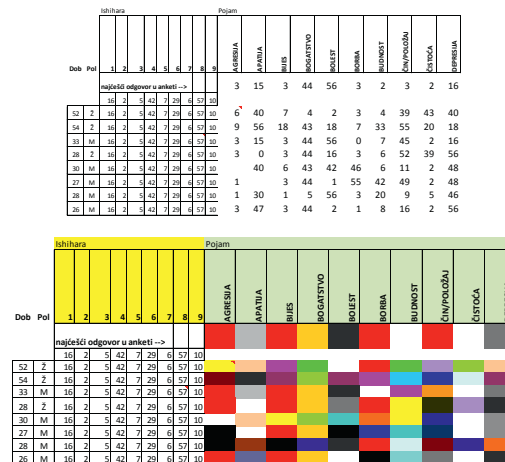
The subjects were tasked to recognize the number in the given circles and write down the result in the provided table.



1	2	3
4	5	6
7	8	9

Picture 6. Ishihara test

The third specific of this work is the processing of the obtained results. The survey results were imported in the Excel table. The subjects wrote down the color under its given number, and in Excel that number in the table was again presented in the same color of the color from the answer. In that way the research results were visualized. We used the opportunity of visualization by chart type Treemap, which was presented only in the latest version of the program MS Excel 2016.



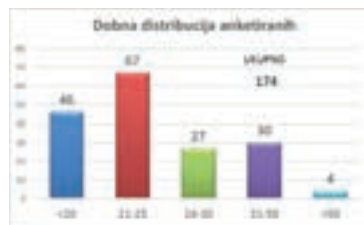
Picture 7. Data in the Excel table and their transforming into corresponding colors

SURVEY RESULTS

Average age of the polled subjects	25,8 years
Total number of polled subjects:	174
No. of men	147
No. of women	27
Incorrect answers in Ishihara test (dichromatism)	12 (7%)

Dischromatism (Greek dys-, chroma, color, opsis – vision, seeing), medically – color blindness, inability of the sense of vision to perceive all specter colors equally. [10].

Normal color vision is technically called normal trichromacy.

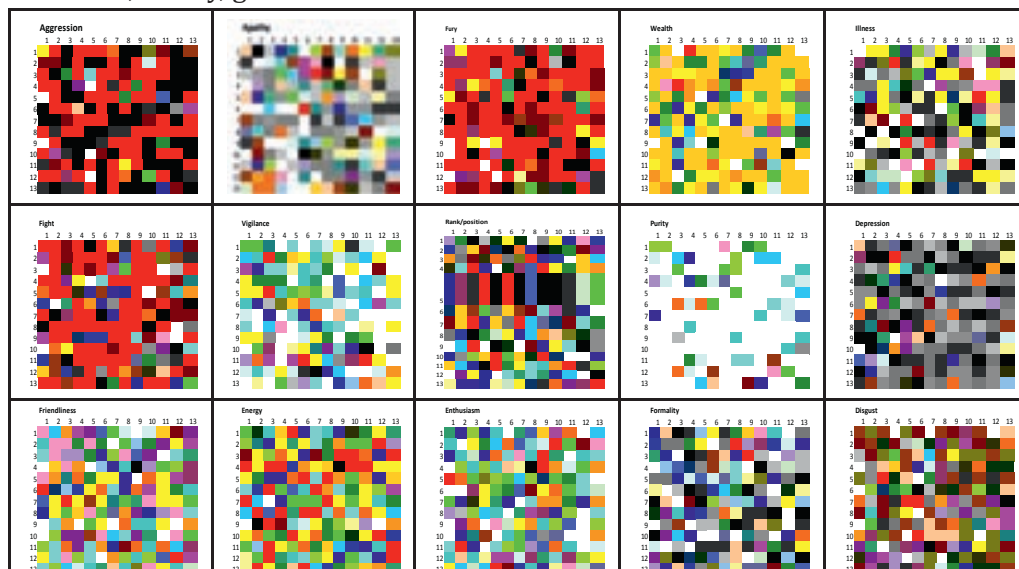


Picture 8. Chart and a table of age distribution of subjects

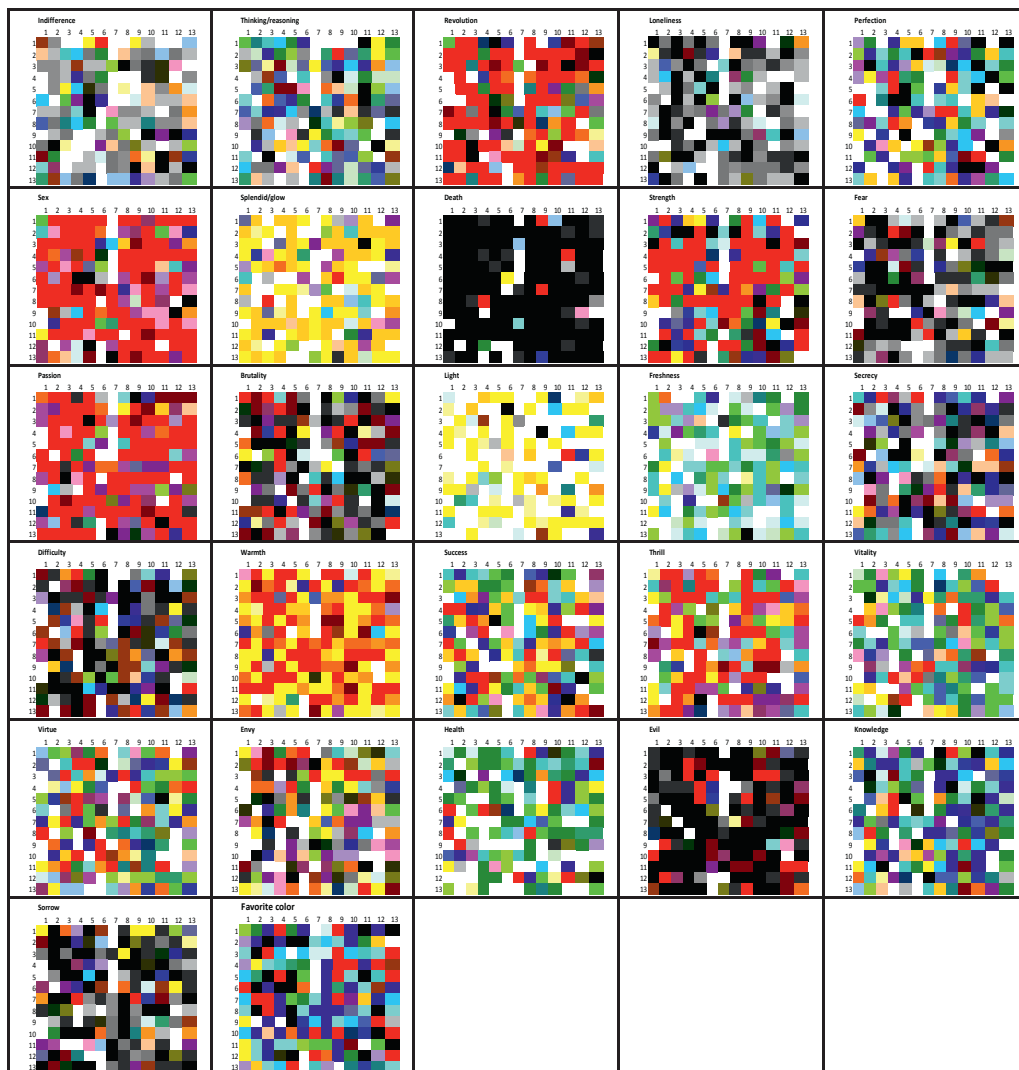
The following picture shows answers received in the survey, each in the 13x13 square. Every square presents 169 color associations with a certain term. Even in such a relatively small sample, we could notice interesting results. Domination of certain colors are very present with certain terms. The most prominent examples are with terms: anger (red), wealth (yellow), hygiene (white), nature (green), revolution (red), death (black) ...

There also are surprising examples, where terms such as aggression, anger or death are associated with yellow color, or terms isolation, death and fear are associated with green, or cleanliness is associated with brown or dark-blue color. A detailed analysis showed that one person that did not answer correctly to Ishihara test (does not recognize colors properly) unexpectedly associated terms of negative connotation (apathy, illness, disguise, stupidity, fear, deceit, poison, infertility...), as a rule, with yellow color.

Survey results were obtained used the features of MS Excel (cell format and conditional formatting). Graphic designers might find an inspiration in these examples, e.g. combination of colors with the term energy, concentration, luxury, gentleness...



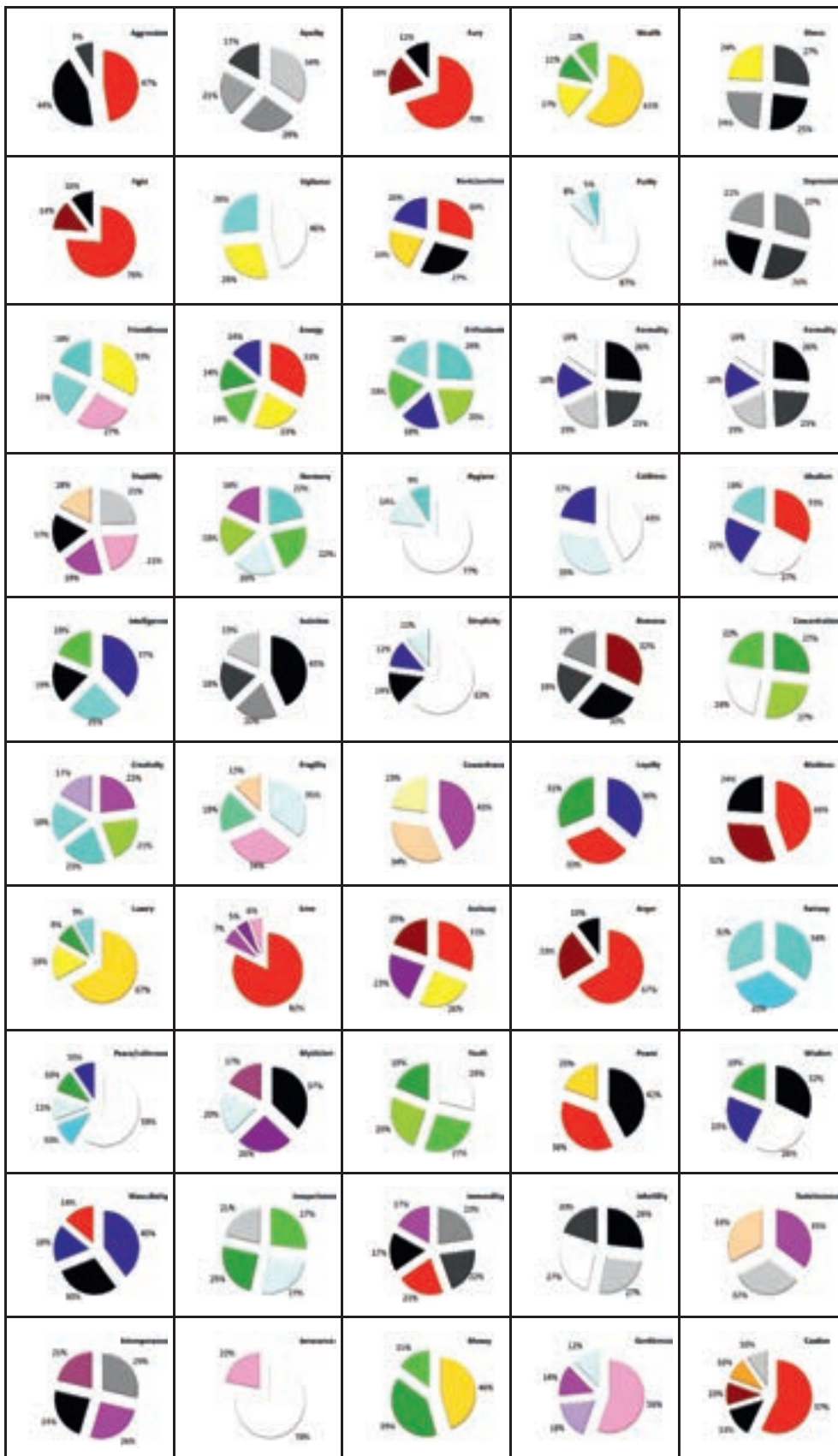


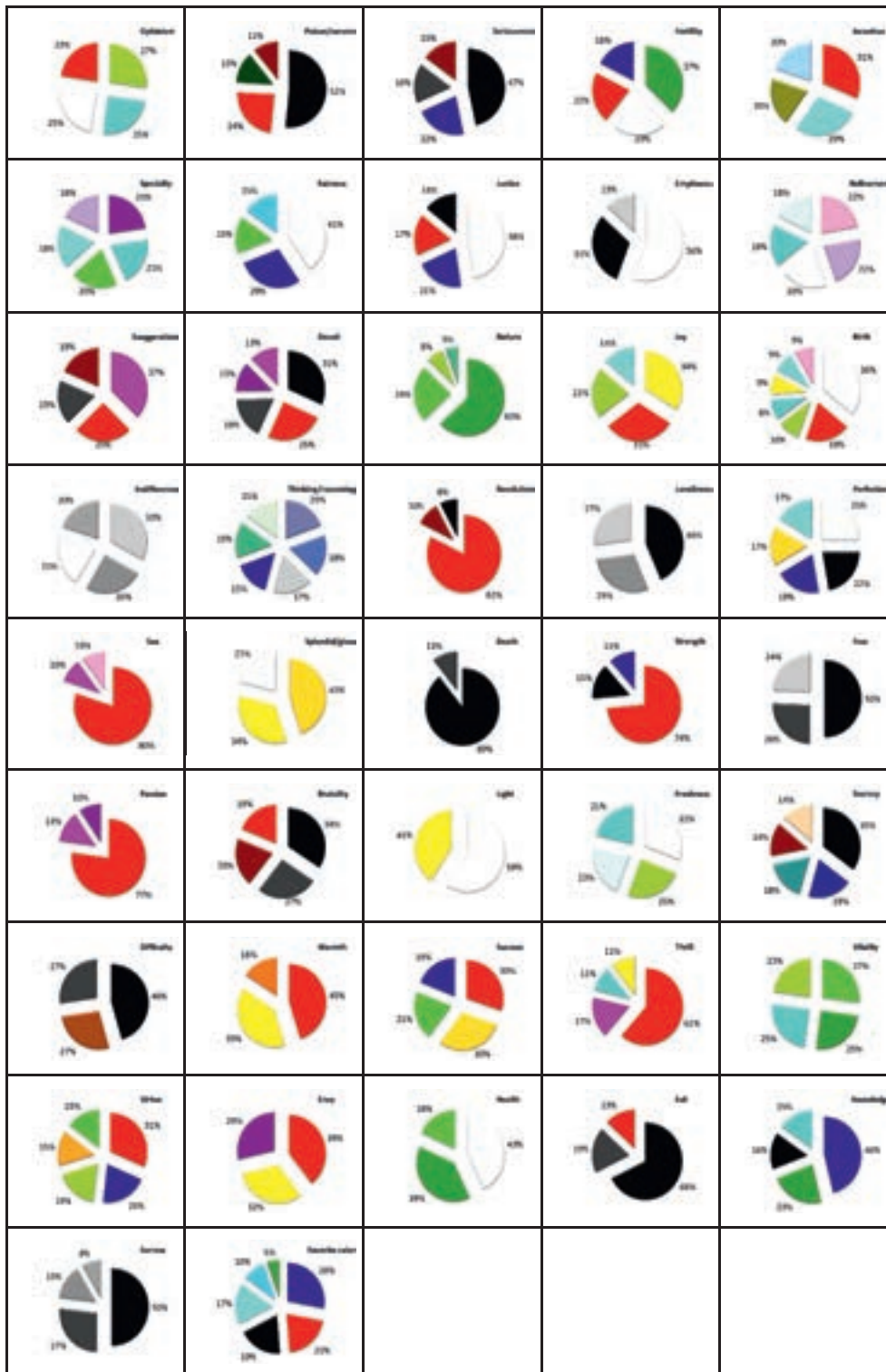


Picture 9. Overview of all answers to the associating colors with certain terms

The following picture shows the results of the same survey in the Pie Chart type of chart. For each term the most associated colors were presented, from two to six dominating ones. The given percentages show only the mutual relation of dominant colors. It is noticeable that terms with negative psychological prefix: apathy, depression, isolation, infertility, emptiness, loneliness, death, fear, remorse, had only shades of grey among dominating colors. Some terms with clearly understood meaning have only two or three dominating color associations, such as: aggression, anger, fight, purity, hygiene, innocence, emptiness, revolution, death, light, while other colors were very scarce. More (four to six) dominant color associations have terms of less specific meaning, such as: enthusiasm, immorality, thinking, birth, etc.

One of the most interesting results in this reserach is the analysis of the answer to the question about the favorite color. It could be expected it would be blue. That color was among the most popular ones in other works as well. The second place went to red color, which could also be expected. The surprise was that the third color per affinity was black (noncolor). From a total of 174 surveyed subjects, blue was the favorite color for 31 of them (18%), red for 23 (13%) and black for unexpected 21 (12%). Looking at it in a different way (see the last round chart), the order among the six most favorite colors is the following (Microsoft names of colors): Blue 28% (0, 0, 255), Red 21% (255, 0, 0), Black 19% (0, 0, 0), Aqua 17% (0, 255, 255), Turquoise 10% (0, 204, 255), Dark Green 5% (0, 128, 0).

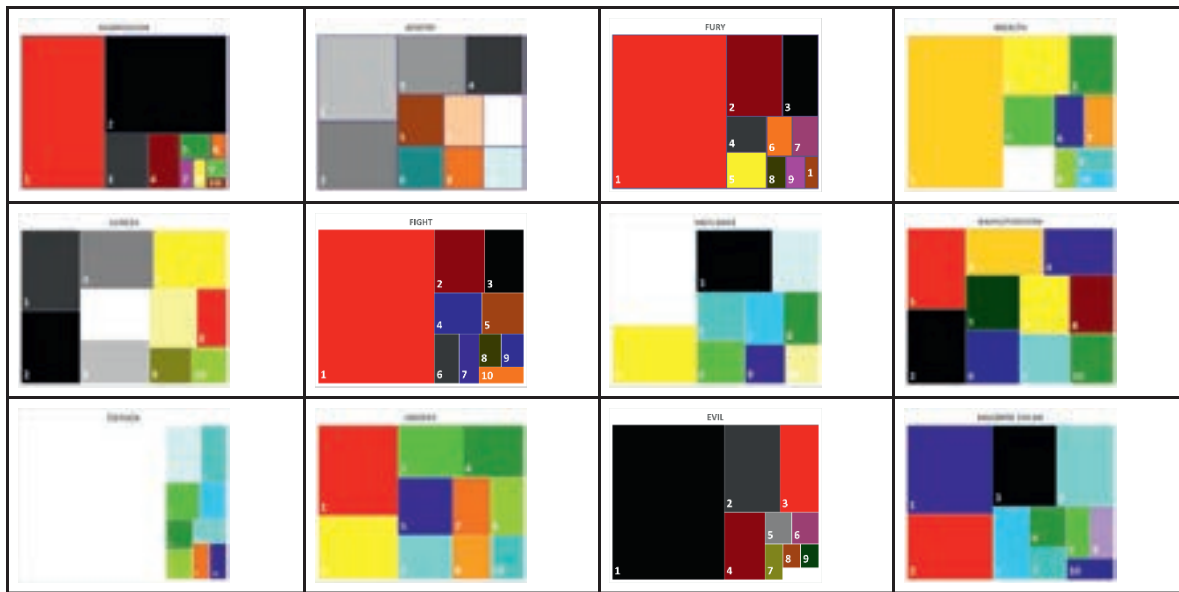




Picture 10. Overview of percentage participation of most frequent colors associated with certain terms using the Pie type of chart

A chart of Treemap type shows the data in a specific way, using rectangles that fully fill a certain surface.

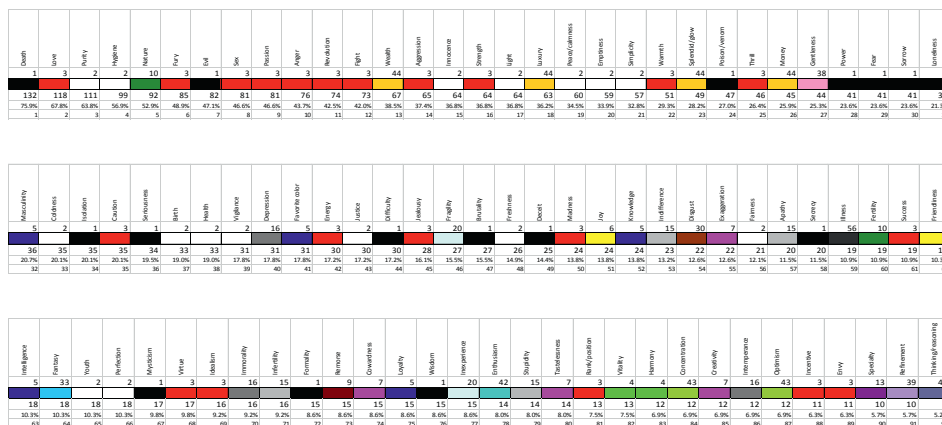
The largest rectangle presents the largest set of data, and to the right of it there are smaller rectangles with lower values in the descending order. This chart type does not have sub-types and may be used in Office 2016. It did not exist in earlier versions. The picture shows some characteristic results of processing answers using the Treemap type chart.



Picture 11. Overview of ten most frequent colors associated with certain terms using the Treemap type of chart

Table 1. Overview of colors with most associations with certain terms

Color	RGB code	Most frequently associated terms
	255 000 000	love, fury, sex, passion, anger, revolution, fight, aggression, strength, warmth, thrill, caution, energy, jealousy, madness, success, virtue, idealism, rank/position, incentive, envy
	000 000 000	death, evil, poison, power, fear, sorrow, loneliness, isolation, seriousness, difficulty, brutality, deceit, secrecy, mysticism, formality, wisdom
	000 000 255	masculinity, favorite color, knowledge, intelligence, loyalty
	128 128 128	depression, immorality, intemperance
	000 128 000	nature, fertility



Picture 12. The order of the most prominent connection between a color and a term

CONCLUSION

In this paper we analyzed psychological connection between 40 offered colors and 91 terms from everyday life. The answers were provided by 147 men and 27 women who were asked, besides the color-term associations, also to fill out the Ishihara test that checks the ability of correct perception of colors and to state their favorite color. A part of received results was expected, so even the result of Ishihara test, showing that 7% of subjects (12 polled, 10 men and 2 women) do not recognize colors properly (dichromatism) – do not differ significantly from the results of other research. Color blindness (color vision deficiency, or CVD) affects approximately 1 in 12 men (8%) and 1 in 200 women in the world. In Britain this means that there are approximately 2.7 million colorblind people (about 4.5% of the entire population), most of whom are male. [6] The biggest surprise for the author was high position (third place) of black on the list of favorite colors, given that 80% of the polled subjects were 30 or under 30 years of age. The answers suggest that light colors caused mainly positive emotional associations, while dark colors caused mainly negative emotional associations. The analysis was not made separately for men and women. We will leave it for the future survey that should be posted onto a website, where a far larger number of participants will be able to take part in the survey.

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ABOUT THE AUTHORS



Nedim Smailovic was born in Tuzla. He has been living in Banja Luka since 1973. He graduated from the Faculty of Electrical Engineering, department of Telecommunications. Since 1982 he has worked in RO PTT traffic of Bosnia and Herzegovina, and a series of organizational transformation

it is now called Mtel doo Banja Luka. His first work experience was in designing and maintaining the PTT capacities. He obtained his Master's degree from Pan European University

'Aperion' Banja Luka, in 2005. There he also defended his doctoral thesis titled: Computer information graphics in presenting Bosnia and Herzegovina on the road to accessing the European Union. He was elected Associate Professor in 2013 and he has been teaching since in three universities in Bosnia and Herzegovina subjects relating to computer technology. He is an author and co-author of several books from the field of information technology and mathematics. He is married, father of two daughters.

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