Investigating of Memory – Colors of Intellectually Disabled Children and Virtual Game Addict Students

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Abstract. We describe an investigation of memory colors. For this investigation Flash test software was developed. 75 observers used this test software in 4 groups: average elementary school children (aged: 8-9 years), intellectually disabled children (age: 9-15), virtual game addict university students (average age: 20) and university students who play with VR games rarely or never (average age: 20). In this pilot test we investigated the difference of memory colors of these 4 groups.

Keywords: memory colour, intellectually disabled, virtual game addict

1 Introduction

One of the most influential aspects on the quality of our lives is color. Our use of memory color occurs so often we usually don't even realize it is happening [1]. Another important impact color has in our lives is on our learning processes. Disorders such as dyslexia are sometimes affected by color. According to a web page on the testing of dyslexia the 'glare' of the white paper makes it hard for some dyslexic children and adults to read the page (Dyslexia, 2002) [2].

Many books and articles deal with the question of how colors influence the mood of people seeing them and how, e.g. in a picture the mood of a person can be expressed in colors. For artists, color was always a vehicle to express moods [3]. Panton, as an artist, even gave the title of his booklet: “Choosing colors should not be a gamble. It should be a conscious decision. Colors have meaning and function” [4]. Hutchings discussed the use of colors during the ages, and pointed out that there are cultural differences that should be taken into consideration [5]. Robertson and his colleagues [6] found evidence of cultural and linguistic relativity, among others in color categorization. Duncan and Nobbs [7] investigated the interrelationship between human emotions induced by colors and their psychophysical stimuli, and found differences between emotional color scales established in Europe and the Far East.

Virtual Environment (VE): A synthetic, spatial (usually 3D) world seen from a first-person’s point of view. The view in a VE is under the real-time control of the user. Virtual Reality (VR) and Virtual World are more or less synonymous with VE [8].

Multi-sensory VEs are closed-loop systems comprised of humans, computers, and the interfaces through which continuous streams of information flow. More specifically, VEs are distinguished from other simulator systems by their capacity to portray three-dimensional (3D) spatial information in a variety of modalities, their ability to exploit users' natural input behavior for human-computer interaction, and their potential to "immerse" the user in the virtual world [9].

Virtual reality games are popular among children and young people all over the world. According to Steinkuehler, the current global player populations of the three game titles (of dozens) that she has studied over the past few years (Lineage I, Lineage II and Word of Warcraft) totals over 9.5 million - a population which rivals, e.g. most US metropolises [10].

"The computer gaming industry has now surpassed the "Hollywood" film industry in total entertainment market share, and in the USA sales of computer games now outnumber the sale of books." (Doug Lowenstein, President, Interactive Digital Software Association) [11].

What is computer and video game addiction?

When time spent on the computer, playing video games or cruising the Internet reaches a point that it harms a child's or adult's family and social relationships, or disrupts school or work life, that person may be caught in a cycle of addiction. Like other addictions, the computer or video game has replaced friends and family as the source of a person's emotional life. Increasingly, to feel good, the addicted person spends more time playing video games or searching the Internet. Time away from the computer or game causes moodiness or withdrawal [12].

We are seeing more and more adults and adolescents struggling with real world relationships because of virtual world relationships they have created [13].

The Smith and Jones Wild Horses Center has the very first outpatient addiction treatment program for problem gamers in Europe. *"Computer and video games can be fun and innocent. Most people can play computer games without trouble. However, 20% of all gamers can develop a dependency on gaming. Many of these individuals have neglected family, romance, school, and jobs; not to mention their basic needs such as food and personal hygiene? All for a video or computer game"* [14].

Virtual reality games are popular among children and young people all over the world. There are a lot of 3D games nowadays. The properties of the heroes of these games are, however, very far from those of humans. Sometimes the surroundings are futuristic too. Children play with the computer games longer and longer every day, and thus the games have an influence on the aesthetic sense of the children. In this respect the question might be raised: are the memory colors of virtual game addict people influenced by VR games' color, or not?

We know that the color, shape and the name of objects are storing in different parts of the brain. Brain stores knowledge and color separately [15]. Therefore the other question was to investigate in this pilot study whether a child with some intellectual disability or learning problems has other memory colors as the average children, or not?

2 COLORIMETRIC FUNDAMENTALS

2.1 Color

The electromagnetic radiation reaching our eye and producing there a sensation is called color stimulus. The sensation produces the color perception in our brain. In scientific literature three components of color perception are distinguished: brightness, hue and colorfulness:

- Brightness: the sensation can be almost blending strong, medium or dim and dark.
- Hue is usually shown as a hue circle, where four distinguishable different areas are red, yellow, green and blue. A hue yellow hue can be reddish or greenish, but never bluish; a green hue can be yellowish or bluish, but never reddish, and so on (see: Figure 1) [16]. One can define the hues between two fundamental (or unique) hue, as e.g. green, bluish green, greenish blue, blue. Sometimes for the hues that are somewhere in the middle between two unique hues special names are used:
    - Yellow – red: orange
    - Green – yellow: lemon
    - Blue – green: cyan or turquoise
    - Red – blue: magenta or purple
- Colorfulness has been divided by MacDonald into a five value scale: Starting with gray (achromatic) up to the most brilliant color. If no hue can be determined for a color then it is gray (or white or black). Thus with increasing colorfulness one can speak about a gray, grayish, moderately vivid, vivid and very vivid color perception.

The communication of the color perception can thus be made in the following form: The complexion of the person who stands in front of me is medium bright, moderately vivid and reddish yellow [17].

The color stimulus can be described in a definite way using a color order system. The color solid contains all the realizable surface colors. There are several color systems in use, some of them are the RGB, CMYK, CIELAB, NCS. We performed our measurements using the CIELAB system, because this is – in contrary for example to the RGB or CMYK system a non-device dependent system, it is the system now recommended by international standards [18]. It can be used not only for surface colors, but also for defining colors produced on computer monitor screens. Figure 2. shows this color system as a three dimensional body, with the lightness (the brightness of surface colors), chroma (representing colorfulness) axes and hue circle (or $a*$, $b*$ axes to describe chroma and hue) where the hue is measured as a hue angle. In the CIELAB color system one can describe the color with the $L*$ lightness and the $a*$, and $b*$ co-ordinates (in Figure 2 we show the $a*$, $b*$ sections as two-dimensional planes). The $a*$, $b*$ co-ordinates describe the amount of redness – greenness, and yellowness – blueness.

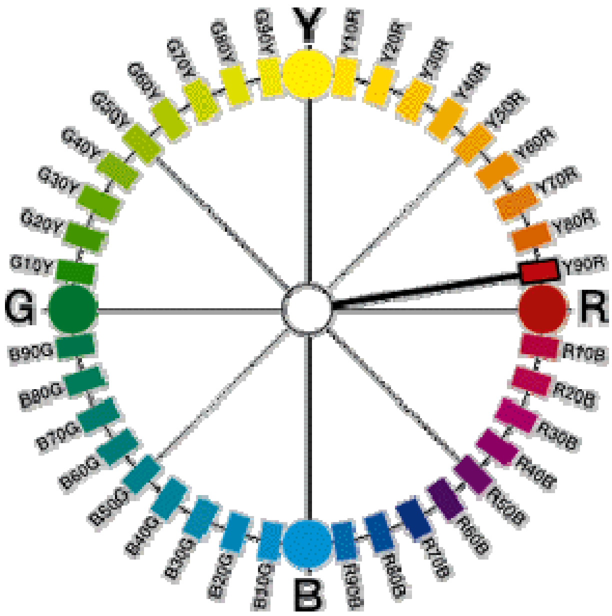

Fig. 1. Opponent colors and color notation in the NCS color system [16].

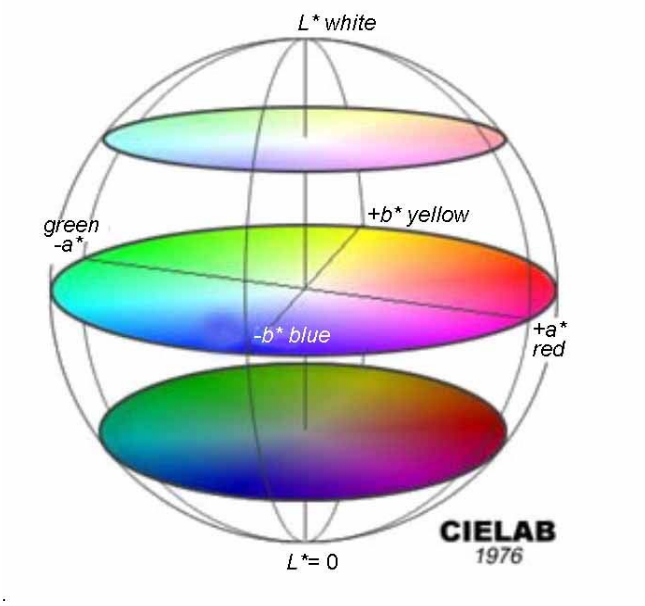

Fig.2. Three-dimensional graph of the real surface colors, in the system of lightness, chroma and hue.

Visually the difference between two colors is described by saying: large, medium and small. In the CIELAB system, the color difference can either be described as the Euclidian distance between the two points representing the colors in the three-dimensional space, or can be described by the lightness difference (ΔL^*), hue angle difference (Δh_{ab}, where h_{ab} = arctan(b^*/a^*), and ΔC^*_{ab}: $\Delta C^*=(\Delta a^* + \Delta b^*)^{1/2}$.

2.2 Memory colours of well known objects

The term memory color is used for the color of well-known, often seen object, as in our brain we attach a color to the given object. One has to distinguish between memory color and color memory, the later is the color we will reproduce after we have seen a colored object. Memory colors are well stabilized products of our memory. They are colors we will pick from a high number of color chips if one is asked to show the color chip resembling the color of human complexion, or sky blue, etc. Table 1 shows the L^*, a^*, b^* values of some memory colors.

Table 1. Memory colors for well-known objects according to different authors

Memory color	L^*	h_{ab}^*	Reference
Caucasian skin	79.5	32.9	[19]
blue sky	54.0	238.8	[19]
green grass	50.0	138.5	[20]
oriental skin	63.9	49.0	[21]
deciduous foliage	33.6	145.3	[19]

3 METHOD

Flash test software was developed for the investigation of memory colors [22]. 75 observers used this test software in 4 groups: 20 average elementary school children (aged: 8-9 years), 10 intellectually disabled children (age: 9-15), 24 virtual game addict university students (average age: 20) and 21 university students who play with VR games rarely or never (average age: 20). The task was coloring pictures using the color palettes introduced below and answering some questions. The experiment was made in a dark room using a laptop computer, the monitor of which was calibrated by an Eye-One apparatus. Every observer has good color vision, we tested them with Colorlite Color Test (see a shorter version of this test:

http://www.colourvision.info/test_color_vision_deficiency.htm)

3.1 The tests

The tests were based on 3 tasks: i. "Extended color palette" (Figure 3), ii. "Given color palette" (Figure 4), and iii. "Answering questions" (Figure 5). The observers first solved the “Extended color palette” tasks. Here the observer could choose from 576 colors. The second task: “Given color palette” was made one week later. There were 7 colour groups, every color group consisted of 4 colors. The last task: “Answering questions” was made one week later after solving the earlier task. At the 3rd task the test software asks some questions, for example: What kind of color is the sky?, What kind of color is the grass?

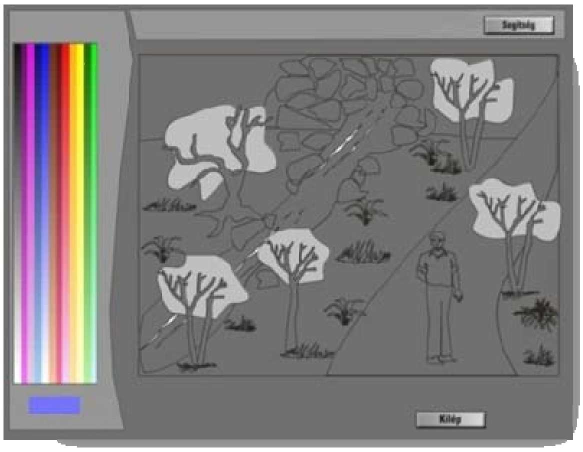

Fig. 3. *Extended color palette task: coloring the foliage*

Fig. 4. *Given color palette task: coloring the sun*

Fig. 5. *Answering questions task: What kind of color has the Caucasian skin?*

4 RESULTS

The test software saved the chosen colors at the coloring tasks and the answers of the observers. So the software saved the L^*, a^* and b^* values of the Caucasian face skin, foliage, sky, tree trunk, cloud, grass, sun, stone, sand, flower, water: stream, sea.

Table 2. Test results of the elementary school children

	Mean			Standard deviation		
form	L^*	a^*	b^*	L^*	a^*	b^*
sky	71.63	6.29	-35.08	9.63	8.91	14.89
tree trunk	44.66	10.69	24.85	5.74	6.44	2.79
cloud	69.75	7.81	-34.58	13.51	9.35	13.84
grass	76.85	-55.19	50.95	4.92	8.58	9.83
sand	83.59	-12.22	44.81	9.58	19.14	13.98
stone	51.02	0.05	0.83	13.67	4.20	5.89
foliage	70.85	-50.64	49.47	7.95	10.88	10.03
sun	94.90	-14.61	73.32	6.01	11.54	5.29
stream	67.95	-2.07	-24.75	9.27	15.50	20.51
Caucasian skin	86.07	4.17	31.90	5.92	11.50	13.24
sea	62.85	7.05	-37.54	7.37	10.92	14.01
flower	58.22	59.86	34.81	7.86	17.95	31.62

Tables 2 and 5 show the average CIELAB *L**, *a**, *b** and the standard deviation. Based on the data of the pilot test, there was significant difference in the memory colors especially of grass and Caucasian face skin.

Table 3. Test results of the intellectually disabled children

	Mean			Standard deviation		
form	*L**	*a**	*b**	*L**	*a**	*b**
sky	65.42	5.26	-36.10	13.44	12.93	14.35
tree trunk	50.19	10.45	27.35	10.96	9.61	4.86
cloud	59.94	3.87	-31.87	15.22	12.51	16.83
grass	72.58	-49.13	45.84	13.07	12.15	9.62
sand	84.84	-10.58	44.65	19.23	16.02	18.40
stone	57.19	0.84	8.65	24.90	10.00	13.82
foliage	67.32	-44.77	44.45	17.03	20.89	11.48
sun	94.00	-12.87	68.52	10.58	18.52	7.73
stream	61.48	3.74	-35.32	14.78	11.75	13.22
Caucasian skin	71.58	8.71	40.39	20.60	15.56	14.89
sea	68.13	-0.71	-29.84	14.25	11.33	29.78
flower	60.84	50.94	46.87	15.34	30.71	23.93

Table 4. Test results of the virtual game addict university students

	Mean			Standard deviation		
form	*L**	*a**	*b**	*L**	*a**	*b**
sky	69.73	9.13	-36.20	7.39	7.43	12.75
tree trunk	40.87	39.13	26.47	7.67	3.49	1.98
cloud	87.93	-1.40	-14.87	6.87	6.56	9.52
grass	19.09	-41.20	14.03	6.84	5.89	5.31
sand	89.27	-14.07	48.87	16.53	15.86	13.76
stone	23.77	-3.07	-1.00	18.25	0.86	0.24
foliage	47.87	-38.60	37.93	2.32	0.68	4.02
sun	99.90	-24.20	71.13	0.45	2.95	14.73
stream	62.53	7.67	-35.27	9.65	7.80	9.58
Caucasian skin	81.47	0.73	28.93	17.51	7.92	8.68
sea	57.93	12.00	-40.53	8.67	7.49	10.16
flower	45.27	67.07	54.47	14.20	22.65	18.01

Figure 6 and Figure 7 show the „bad" influence on memory color of VR games. There is no significant difference between the average elementary school children, intellectually disabled children and university students who play with VR games rarely or never, but the virtual game addict university students' results differ from the other 3 groups significantly. The grass' memory color of the virtual game addict university students is darker. This result agrees with the results we had by investigating the colors found in VR games, studied by game category: the color of the grass of VR games was darker and browner, compared to the cartoon colors and the memory colors found in the literature [23], [24].

Table 5. Test results of the university students who play with VR games rarely or never

	Mean			Standard deviation		
form	*L**	*a**	*b**	*L**	*a**	*b**
sky	66.29	7.53	-34.71	9.07	11.40	11.75
tree trunk	41.35	16.82	31.18	6.31	0.81	7.80
cloud	80.71	0.53	-23.47	15.38	10.10	15.38
grass	64.65	-45.41	43.29	13.77	3.98	3.94
sand	93.00	-13.71	56.47	7.57	7.76	4.13
stone	64.59	-3.76	-0.53	13.37	0.98	0.57
foliage	68.00	-49.94	44.53	12.69	6.72	5.42
sun	99.82	-22.59	66.65	1.89	2.37	3.74
stream	65.18	-0.76	-26.24	9.05	7.29	2.85
Caucasian skin	94.88	-9.35	40.12	4.79	8.46	17.01
sea	66.94	1.94	-30.18	12.54	9.91	10.56
flower	49.12	72.59	38.12	7.29	5.79	30.35

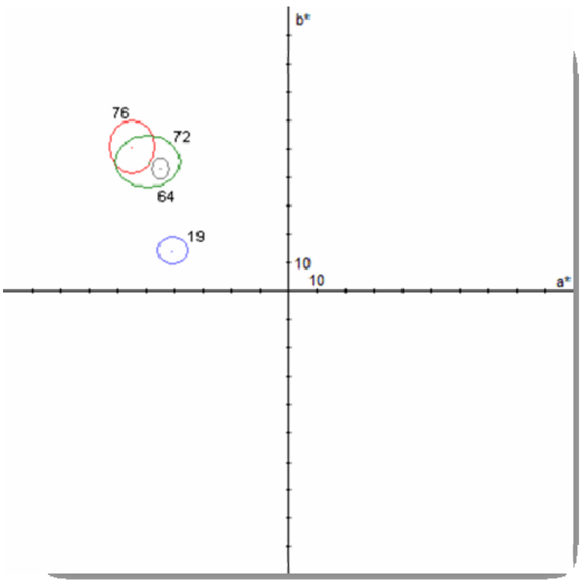

Fig. 6. The result of memory color of grass,
average elementary school children (red) $L^*=76$
intellectually disabled children (green) $L^*=72$,
game addict university students (blue) $L^*=19$,
university students who play with VR games rarely or never (grey) $L^*=64$

Figure 7. Sample of the memory color of grass,
upper row: Average elementary school children, intellectually disabled children
lower row: game addict university students, university students who play with VR games rarely or never

The results of Caucasian face skin are different too. The memory color of game addict students is more grey.

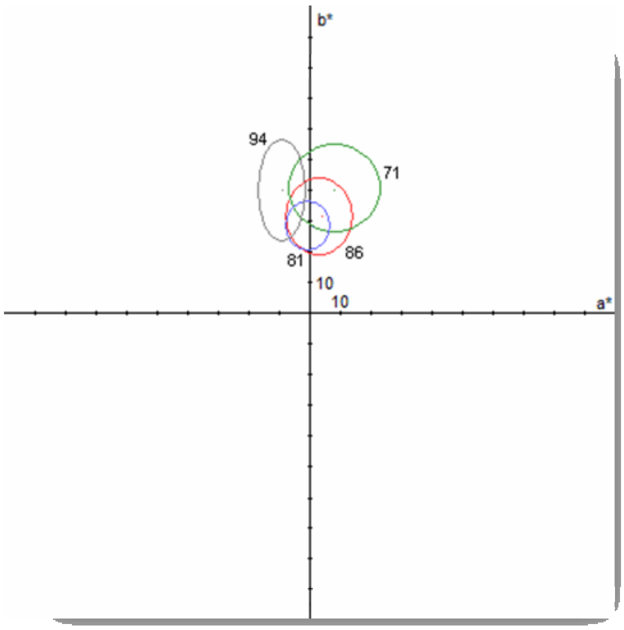

Figure 8. The result of memory Caucasian face skin,
average elementary school children (red) *L*=86*
intellectually disabled children (green) *L*=71*
game addict university students (blue) *L*=81*
university students who play with VR games rarely or never (grey) *L*=94*

Fig. 9. Sample of the memory color of Caucasian face skin,
upper row: Average elementary school children, intellectually disabled children
lower row: game addict university students, university students who play with VR games rarely or never

5 SUMMARY

Answering the questions in the introduction:

Are influenced the memory color of virtual game addict people by VR games' color, or not? Yes, there was difference between the game addict observers and the other 3 groups.

If a child has some intellectual disability or learning problems has he/she other memory colors as the average children, or not? We found difference only in the Caucasian face skin color.

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