The Relationship between Color vision and Arousal Level

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Citation

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Abstract

Human arousal level could be influenced by color through visual and non-visual pathway. The purpose of the researches was to focus the relationship between the color and arousal level on subjective reception and objective visual perceptual comparison performance. In the first study, the subjective reception of color was tested during the process from sober to sleep using questionnaires . 344 questionnaires were taken back. The results showed that there were distinct color reception in different arousal levels. The results were consistent with that of the previous physiology research.In the second study, we evaluated the influence of the different color background of non-attention areas on the objective performance of cognitive test which were sensitive to arousal level. 80 participants carried out visual cognitive task using microcomputer screen. Analysis showed that the results of the cognitive performance were significant difference in different color background of non-attention areas. The similar color sequence in which every color represented a arousal level were gained in the subjective test and the objective visual cognitive tests.

INTRODUCTION

Since Trichromatic Theory by Young in 1809 and Helmhotz in 1860, the research on system of color vision has become gradually deep and gained universal recognition and continuous validation. Color vision of human is realized through three kinds of basic photoreceptor in various kinds of cone cells(Maxwell, 1860). Research on cone pigment absorbing spectrum has been conducted for nearly one century(Smith & Pokorny, 1972), during which many theories were adopted, such as psychophysical color matching(Rushton, 1972), reflection densitometry(Neitz, M., 1991), electroretinography (Schnapf, J. L.,1987), single-cell action spectra(Brown & Wald, 1964) and the most directly, microspectrophotometry (Dartnall, 1983), as well as the research on different optical bleach deviations absorbing spectrum of each group of cultured cells of each cone pigment apoprotein expressed by transfecting corresponding DNA clone(Nathans, et al.,1986;1989). The mean values for the wavelength of maximal absorption are 426 nm for the blue pigment, 530 nm for the green pigment, and 552 nm and 557 nm for two polymorphic variants of the red pigment(Shannath & Jeremy 1992).

With the imaging function and physiological anatomy structure of color vision becoming increasingly definite, the discovery of non-visual effect of color arouses the attention in scientific world again. It may date back earlier to the research on the influence of ray with long wave and short wave on babies by Barnet et al. in 1968. After 1991, more researches Horne JA, 1991 Morita T, 1996 Noguchi H 1999 on non-visual effect of color appeared, including awakening level, automatic nervous system (including Heart-rate variability, blood pressure, body temperature and sleeping structure), and etc., and discovered ray of shortwave length had obvious impact on biological rhythm, i.e. blue shift effect. Thapan, Arendt, Skene et al (2001) and Brainard et al 2001 all conducted relevant research, and argued about the ways through which light ray effects on biological rhythm or arousal, and put forward that photic stimulation accommodates with melatonin and cone cell system is not the main sensor system. Berson(2003) and Menaker (2003) mentioned the hypothesis of two pathways in the process of vision receiving light signals and transmitting to brain. There are two main neural pathways when considering the photic signal currency originating in the retina and traveling to the brain: one is the pathway responsible for image-forming visual function via the intergeniculate leaflets (IGL) connected to the visual cortex, and the other is the pathway responsible for circadian regulation to the pineal body via the suprachiasmatic nuclei (SCN), which carries non-visual information including that from the third photopigment in the retina.

All these researches indicate that color light could have something to do with arousal level of human. But the result above is different from the classic description of color vision system. Classic color vision system makes us tend to divide color into cold color and warm color, and red with long wavelength belongs to warm color and blue with short wavelength belongs to cold color, while both cold color and warm color bring about different physiological feelings of human, namely cold color makes people quiet and warm color makes people excited. This kind of feeling about color is just contradictive with the conclusion from the division of color light in the research above, and the explanation of this result is still unclear. However, it can be said that these researches on color and physiological rhythm are based on color light to some extent, and in psychology, the research on color light as a stimulating object being “environment/ background” factor gradually started.

The research on the background of color is first conducted in application filed, such as environment in room and factory. Knez(1995)made a research on the influence of indoor rays on sensation and perception. The effect of indoor lighting on cognitive performance via mood were investigated in two experiments. Experiment varied two lighting parameters in a factorial, between-subject design: two illuminance levels (dim; 300 lx vs bright; 1500 lx) by two colour temperatures (‘warm' white; 3000K vs ‘cool' white; 4000K) at high CR1 (Colour Rendering Index; 95). In experiment 2 the parameters of lighting were identical to the first experiment, except for the low CR1 (CRI; 55). Results in experiment showed that a color temperature which induced the least negative mood enhanced the performance in the long-term memory and problem-solving tasks.

Stone, Nancy J. et al (1998,2003) did research on the influence of color environment in working place on the emotion, satisfaction degree and performance of completing relevant tasks as well as the research on the influence of cold color (blue) and warm color (red) on work efficiency in simulative sales activity in long distance. Work efficiency was influenced by the color of environment. When one were working on a task with lower requirement, it took more time in blue background than in red environment and the efficiency was lower, unless he took a rest or was shown a landscape. When one was working on a task with higher requirement, the efficiency was low in red environment, unless he had a break or was presented with a landscape.

The research above was established on typical division of warm color and cold color, and elicits relevant conclusion. But due to the limits of experimental research, the color in research was monotonous, and could not elicit the relationship between work efficiency and the wavelength of different color.

With the development of visual technology, more and more information and tasks are operated through screen. Research on the background color of screen is thus valued.

Wachtler et al.(2001) studied the non-regional interaction of color perception: the non-linear processing course resulted by color signal in distance. The interaction of color space took place in hundred of milliseconds when background color changes, and had little relationship with inducing filed. Ling & Van Schaik (2002) did research on the influence of text and background color of web pages on visual search of web pages. Wang & Chen(2003) studied the influence of color foreground and background on reading tasks and believed the foreground of color has larger influence on reading.

All these researches hinted that color background had influence on cognition, emotion and work efficiency. But due to the orientation of research, it was inevitable to give priority to color comparison, while the sheer influence of color background was not sufficiently explained. What's more, the research on the overall situation of color in spectrum series was not enough, with more focus on individual colors.

Nowhere in our living environment is not surrounded by color light. In our research, there were two aims. 1) In daily life, how did people value the influence of color on arousal level and whether it could have formed particular subjective feeling 2)If color, fused into background, was not taken as the main attention of vision, namely, it did not enter the brain through attention, what effect it would have on arousal level and work efficiency and whether blue shift effect (with shortening of wavelength, namely, moving towards blue spectrum, it will result higher arousal level and better work efficiency) also existed. While the purpose of this research was to put forward the relationship between color and arousal level, and by means of the experiment of color background and visual tasks presenting simultaneously and acting separately, to observe the influence of color on people's sober degree and cognition.

RESEARCH 1 THE RELATIONSHIP BETWEEN COLOR AND SUBJECTIVE AROUSAL LEVEL

METHOD

PARTICIPANTS

410 Chinese youths, average age: 21.45±4.00. 310 men and 100 women color vision was normal, no disease in visual system, normal eyesight, no disease in psyche and nerve recently. The average educational level was above high school.

RESEARCH MATERIALS

Half-open questionnaire on color vision and subjective arousal level was used.

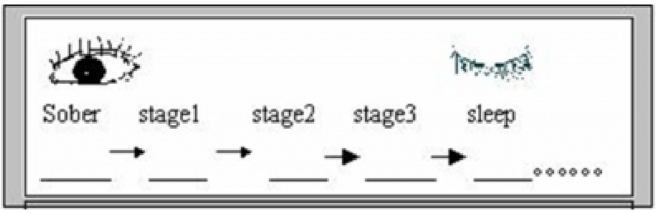
EXPERIMENT PROCESS

Experiment was performanced in a quiet room with normal sunlight, and it was always kept quiet during the process. Color spectrum ribbon was given, and it was required to observe color ribbon. Achromatic color includes white, grey and black; chromatic color includes red, orange, yellow, green, cyan, blue and purple.

During the process of experiment, first tried to relax, and closed the eyes for rest, to feel the process from being sober to sleepy, and then according to the process, choose a color most adapted to the subjective feeling in each stage of consciousness referring to color ribbon, and describe the process as figure 1 shows.

Figure 1

Figure1 The process from sober to sleep state



RESULT

Data collected: 344 questionnaires from 410 questionnaires were collected and processed. Some names of color with vague meaning were integrated and deleted. The result was following: (Table1)

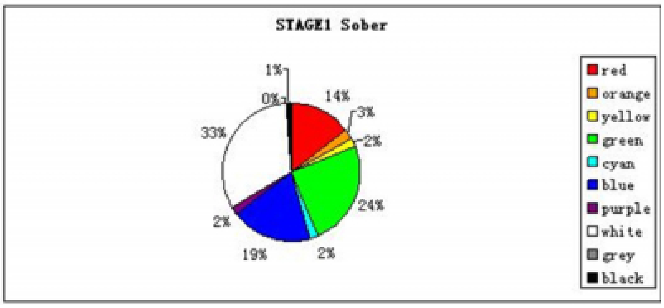
Figure 2

Table1 The numbers of the colors in different subjective arousal level

	red	orange	yellow	green	cyan	blue	purple	white	grey	black
Stage1 sober	50	9	7	85	7	67	1	112	1	3
Stage2 tiredness	18	19	65	12	30	25	16	25	90	11
Stage3 drowsy	13	34	32	12	18	30	39	20	78	28
Stage4 sleepy	13	22	18	13	16	26	30	16	112	44
Stage5 sleeping	6	10	7	9	6	17	13	18	7	230

Figure 3

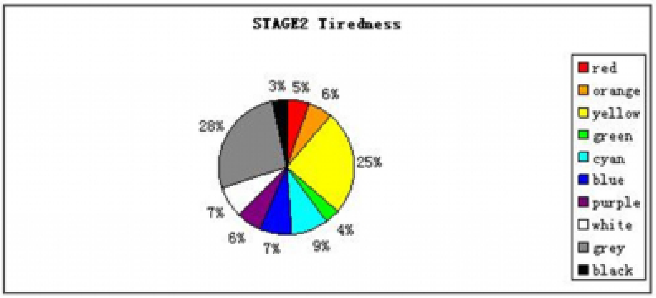
Figure2: the color proportion in completely sober state



In completely sober state, main colors were red, green, blue and white, and the order of proportion is white, green, blue and red. (As shown in figure 1) Achromaticity takes up 34%, with white covering 33%.

Figure 4

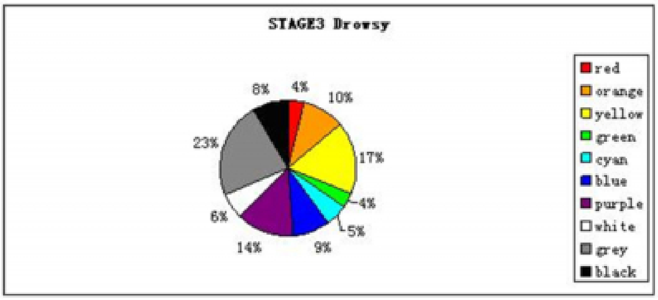
Figure3: the color proportion in state 2.



In the description of "tiredness", neutral color takes up 38%, giving priority to grey, while yellow and cyan are the main chromatic colors in multicolor series.

Figure 5

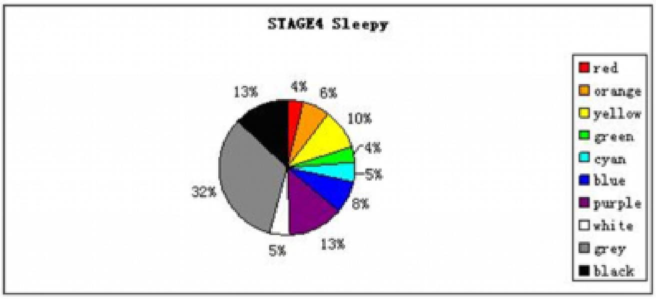
Figure4: the color proportion in state 3.



In drowsy state, neutral color takes up 37%, and yellow, purple and orange take larger proportion in multicolor series.

Figure 6

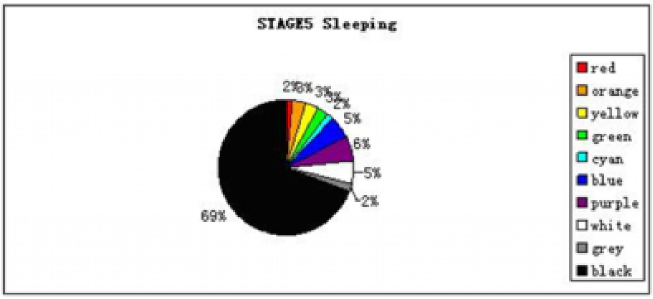
Figure5: the color proportion in state4.



In sleepy state, it can be seen that neutral components take up 50% while purple and yellow take a larger proportion in multicolor components.

Figure 7

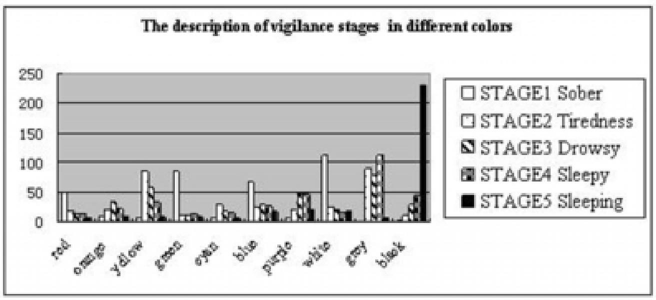
Figure6: the color proportion in sleeping state.



In description of sleeping state, it can be seen that neutral color takes up 76% giving priority to black, while cold color, i.e. blue and purple take a larger proportion in multicolor series, but both lower than 10%.

Figure 8

Figure 7: the description of arousal level in different colors



From the perspective of different color itself, white, green, blue and red were the most chosen colors in describing sober state, and become less with the increasing degree of sleepy state. Yellow and cyan are the most in describing tired state, and then become less in describing other states. Orange and purple present a form of inverted "v", most in sleepy state. Grey was less in two extreme points as sober state and sleeping state, and more in tired, drowsy and sleepy state, with the most in sleepy state. Black presented a trend of ascending, and reaches the highest in description of sleeping state.

DISCUSSION

THE BRIGHTNESS OF RAYS COULD HAVE CLOSE RELATION WITH AROUSAL LEVEL

Biological rhythm has important influence on arousal level. More researches demonstrated that biological rhythm was closely related to intensity/brightness of rays of environment. No matter homochromatic light or polychromatic light, the brighter rays tended to reduce drowsy degree, and could more strongly control the secretion of melatonin and enhance activity of autonomic nerve. Through the result above, we could see that in each process from being sober to sleeping, neutral colors (white, grey and black) occupied larger proportion, namely, 34% 38% 37% 50% 76% respectively. With the proportion becoming increasingly large, and meanwhile, it could be seen that white took the largest proportion in describing sober state, with the proportion of 33%, while grey occupied larger proportion in middle stages, and black increased with the reduction of arousal level, reaching 69% in sleeping state. Neutral color itself was component of brightness/luminance, thus it could be concluded that the brightness of color also had large effect on subjective arousal level, identical to the results of physiological experiment.

COLOR LIGHT WITH DIFFERENT WAVELENGTHS HAD DIFFERENT INFLUENCE ON AROUSAL LEVEL.

SUBJECTIVE COLOR DESCRIPTION IN STATE1: "SOBER"

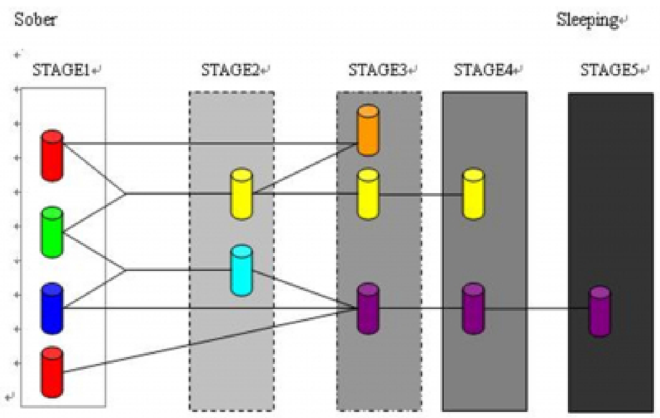
Trichromatic Theory by Young in 1809 and Helmhotz in 1860 suggested that retina was made up of three cone cells which were sensitive to red, green and blue respectively, with the proportion of 32: 16: 1, each cone cell would primarily be stimulated by one basic color, while showing a reaction to other colors to certain extent. The cognition on colors was all brought about by different degree of excitement of the three cone cells, and the existence of the three cone cells has already been confirmed by anatomy and electrophysiology. The three cone cells are light adapted cells, and among people with normal vision, the activities of cone cells take the lead in bright vision in sober state. We surprisingly find out that subjective description was so similar with physiological conclusion. In sober state, subjective feelings were mainly on colors of white, red, blue and green, and white was a mixture of light color, manifesting high luminance, while the feelings on red, blue and green were corresponding to photoreceptor cells of cones. The objects of research were from different educational backgrounds and large scope of age, it was impossible for them to possess common and similar cognition on physiological knowledge. Color is always discussed in philosophy about whether it is a subjective feeling or an objective existence, while in this research, it was found out that subjectivity and objectivity were identical to some extent, and it may be said that in color research, subjective phenomenon and objective practice have something interrelated, and can refer to each other.

SUBJECTIVE COLOR CHANGES IN DIFFERENT AROUSAL LEVELS

Without considering neutral colors, from sober state to sleeping state, we saw that colors were changing in this way: (green, blue and red)—(yellow and cyan)—(yellow, purple and orange)—(purple and yellow)—(blue and purple). In sleeping stage, the function to describe color disappears, so if this stage was omitted, we can get such a simplified process(figure8):

Figure 9

Figure8 the hypothetic ray fitting of Subjective color changes in different arousal levels



In this diagram, we made hypothetic ray fitting. Color vision was the distinguishing function of cone cells of retina on different colors. In bright place, the color vision of macula central fovea of retina and macula part was most sensitive. This is in compliance with the distribution of cone cells in retina, the cone cells are less when they are further from macula, and the sensitivity of color vision is lower. Based on Trichromatic Theory, red cone cells are possibly more in quantity, the rays into vision are experiencing a process from clarity to gradual vague fusion, and our assumption was that with the reduction of arousal level, red and green, blue and green of tricolor fuse first, and form yellow and cyan; with the increase of drowsiness, yellow and cyan fuse with redundant red signal and form orange and purple, and the colors gradually disappear with the increase of drowsiness. While the brightness of color changes from high to low degree, which was from white, grey to black.

In 1878, Hering put forward Antagonism Theory and contended that retina has three pairs of antagonistic cone cells, namely, red-green pair, yellow-blue pair and black-white pair. When certain kind of cell is stimulated by some color, it can cause certain excitement, and its antagonistic colors will be prohibited. The activity of three pairs of antagonistic cone cells results in color perception. But the two theories are both limited in the range of cone cells, and cannot completely account for the theory of color vision. In 1982, Hunt(1982) established a model for phase theory of color vision and believed that the process of color vision follows not only trichromatic theory but also antagonism theory, which accounted for the function of the second and third neuron of retina in color vision and pushed color vision theory into a new stage. However, retina-cortex theory by Land in 1950s now has aroused people's attention. He put forward that visual pigment of light sensitive cells on retina absorbs energy of lights and produces signal outside cells which is transformed into sense of brightness. The process from absorbing energy to producing sense of brightness happens in certain stage or the whole signal transfer process of visual path from retina to cortex, and three different brightness values of three different stages of illuminance (long wave, medium wave and shortwave) are the basic stimulants of color vision, and thus has formed the theory of color vision of four stages. The theory of color vision is a complicated problem, and is still in research so far, but clinical practice proved that when brain is ill, it will result in complete loss of color vision or color blindness in individual colors. How color vision forms many colors finally in brain through visual system cannot be clearly explained all the time. This research made analysis of the perceiving process from visual (sober) state to non-visual (sleeping) state of rays, and may provide some clue to the formation of color vision.

From the result above, we haven't seen the clear blue shift of arousal level, but we have preliminarily recognized the relationship between subjective color and arousal level. For further discussion, we performed the second psychological cognition experiment to see whether there is objective evidence to prove the relationship between subjective color and arousal level.

RESEARCH 2 THE OBJECTIVE RESEARCH ON THE INFLUENCE OF COLOR ON AROUSAL LEVEL

METHOD

PARTICIPANTS

Participants were 80 graduate students from local universities who were recruited through an advertisement. Those participants were consisted of 60 males and 20 females between 19 to 30 years of age(M=24.7years) who were prescreened by a physician and classified as fit to participate if they met the following criteria: they (a)were healthy;(b)were normal color vision; and (c)had no allergies or hematological, cardiovascular, neurological, psychiatric, or other optic disorders. All participants were fully informed about the purposes of the study and the procedures to be employed.

RESEARCH MATERIALS

This experiment was operated with microcomputer screen. Computer configuration: Lenove Intel® Pentium/256M / 40G / ATI 9600SE 128M /15'LCD Card: Inter(R)82845G Graphics Controller, resolution: 800*600, deep color 32 bits refresh rate: 85 HZ constant luminance.

Because color light was brought into the previous other experiments as background stimulant, several problems might exist: 1 measurement could not be taken at the same time, while the method that the research adopted is to assess the change of cognition after the physiological changes caused by color light, and little research is done on the influence of color background on the simultaneity or immediateness; 2 color light might produce color rendering effect on testing field, and color light has changed the physical property of task.. But if testing content is directly presented by different colors, the pureness of experiment result could also be influenced as a result of the interaction between testing content and colors. In this research, we chose to present color background and testing content simultaneously, and separate testing field from color background. The testing field was grey, the stimulant was black, and stimulant was always kept in the center of visual field to reduce the disturbance of color deviation from color background. In the situation of color background and cognition task taking on simultaneously, we examined the work efficiency under different color backgrounds through comparison, so as to discuss different arousal levels resulted by different color backgrounds.

Background colors for research: ten colors, namely, white, grey, black, red, orange, yellow, green, cyan, blue and purple were background colors in microcomputer. RGB values were white 255 255 255 grey 128 128 128 black 0 0 0 red 255 0 0 orange 255 165 0 yellow 255 255 0 green 0 128 0 cyan 0 255 255 blue 0 0 255 purple 238 130 238 respectively. The experiment interface contains a stimulant-reactive platform, whose background color is 20% grey, and the overall horizontal angle of view is 9 0, vertical angle of view is 50 and the line segment was black, which conformed to the best central vision of visual scope. The luminance of screen was kept constant, and it was guaranteed that the object on attention locates in the central vision during separate processing course, and was less directly influenced by color background and thus to reduce the interference of color deviation.

Visual perceptual comparison (2min) was a sensitive index in psychology(Baranski,et al., 2002; Leonard et al.,1998) which was applied in assessing arousal level and it lasted a little short, and it could not cause tiredness. This cognition task had 4 different degrees of difficultness and further analysis on whether task with different difficult degree was influenced differently was made.

The comparison task required the relative judgment of line length. Each trial began with the presentation of an instruction (“LONGER”or”SHORTER”), which was display appeared the consisted of two horizontal lines, divided by one short line. The stimulues remained on the screen until the participant responded. The participants' task was to determine which of the two lines was longer or shorter. Four levels of judgment difficulty were randomly presented to the participants; the difficulty was defined a priori on the basis of the ratio of the longer to the shorter line: 1.03, 1.05, 1.07, 1.09. All lines appeared black on a 20% grey background .Participants were encouraged to respond as quickly and as accurately as possible. Response time and response accuracy were recorded on each trial.

RESEARCH PROCESS

Participants entered the lab one day before the formal experiment so as to be familiar with experimental environment and know about the content and items of experiment, as well as make practice to remove practice effect. In the formal experiment, it was required that participants should keep the distance of 60-65 cm form the computer screen, and their eyes were kept horizontal with the center of screen. The experiment started when they were prepared. Under different color backgrounds, the experiment was made for 10 times, and the order of experimental color backgrounds was random in order to remove sequencing effect. There should be at least 1-minute break for each two experiments under different color backgrounds to remove visual tiredness and color after image.

STATISTICS

Microsoft Office Excel of Microsoft Office 2003 was adopted to process data SPSS 11.0 were adopted for statistics analysis. Statistics method was one-way ANOVE.

RESULT

1. Visual perceptual comparison under different color backgrounds and comparison on accuracy in time unite. There were significant differences in statistics of the performances in the different color background (F= 1.944,p=.043). Post Hoc Tests were done. The results only shown that there were significant differences in White background and others color background except the cyan and yellow. (Table2)

Figure 10

Table2 The comparisons of White background with other colors background

Color(I)	Color(J)	M D (I-J)	SE	Sig.	95% CI	
white	Grey*	.05916	.01881	.002	.0222	.0961
	Black*	.06305	.01881	.001	.0261	.1000
	Red*	.03823	.01881	.042	.0013	.0752
	Orange*	.05746	.01881	.002	.0205	.0944
	Yellow	.03444	.01881	.067	-.0025	.0714
	Green*	.04964	.01881	.008	.0127	.0866
	Cyan	.03117	.01881	.098	-.0058	.0681
	Blue*	.04239	.01881	.025	.0055	.0793
	Purple*	.05269	.01881	.005	.0158	.0896

* The mean difference is significant at the .05 level.

The homogeneous subsets in Visual perceptual comparison under different colors background. Means for groups in homogeneous subsets are displayed.(Table 3)

Figure 11

Table3 The homogeneous subsets of performance means

	color	N	Subset for alpha = .05	
			1	2
Student-Newman-Keuls(a)	Black	80	.6426	
	Grey	80	.6465	
	Orange	80	.6482	
	Purple	80	.6529	.6529
	Green	80	.6560	.6560
	Blue	80	.6632	.6632
	Red	80	.6674	.6674
	Yellow	80	.6712	.6712
	Cyan	80	.6745	.6745
	White	80		.7056
	Sig.		.750	.077

2. Under the different degrees of difficulty, the influence of different color backgrounds on line segment visual perceptual experiment. (Table 4)

Table 4 The comparison of performance records in the different line ratio

The research has discovered that visual perceptual task with medium difficulty was more largely influenced by color background.

DISCUSSION

The research on human body under color background can date back to the record of ancient oriental nations applying color light in treatment Cocilovo A. 1999 and later, the influence of color light on human body is more studied by physiology, focusing on the influence of color light on physiological rhythm and other physiological indexes, among which some psychological index and method are utilized for assessment since it involves the measurement of arousal level. Until the appearance of visual screen, the research on color background has gained further development.

We pay attention to research on colors, and many researches at present all show that background color exerts influence on distinguishability and appearance of target stimulant. For example, Breitmeyer & Breier (1994) studied the influence of different color backgrounds of screen on the reaction time of light spot stimulation with gradually changing diameter and discovered that the reaction of light stimulation with small diameter in red background is faster than that in blue and green background. When the diameter of stimulation gradually enlarges, the reaction under blue and green backgrounds will become faster, and this result is believed to influence the activities of magnocellular-channel through dispersion rays with different wavelengths. Michimata et al. (1999) proved different color backgrounds had different influences on the overall processing course of low spatial frequency stimulation and green and red backgrounds exert influence on processing, but the influence in green background is dissymmetrical, while the influence is symmetrical in red background. Murata, Miyoshi & Fujii (2000) did research on the influence of background color of multiwindow and size on the cognitive function, and discussed the influence of peripheral window size, color as well as size and color of task region under the background of multiwindow on visual interference. The conclusion showed the displaying mode of multiwindow has little inference to vision; the size of peripheral and central window has decisive influence on visual interference, while the influence of color background of peripheral window on visual interference is not obvious, but the background color of task region seemingly has influenced the accuracy of calculation, and this influence depends on conners' preference of color. The influence above not only exists in perceptual layer, but also influences cognitive layer.

However, there is no definite conclusion about the function of color background. Rosenholz(2004) advanced that dissymmetry of research on color may root in the relationship between stimulation and background. The experiment researched on color stimulation hypothetically under different color backgrounds, and color backgrounds would result in dissymmetry of visual research. Neutral color and red background react to target stimulation, and in neutral background, reaction time will short with the increase of hue and saturation, while dissymmetrical reaction happens in red background. The result has proved that background color has large influence on the reaction to visual target stimulation. With retrospect to these researches, we discovered that the existence of color background could be more significant in the influence it exerts through color deviation and contrast, while in conditions of small color deviation, whether color, as implicated information but not central visual stimulation of visual task, could really influence the accomplishment of visual task ,while non-color vision effect of color background can be validated is what this paper intends to prove.

INFLUENCE OF DIFFERENT COLOR BACKGROUNDS ON VISUAL TASKS

Visual perceptual comparison of line segment is considered a classic cognition examination, which was used in cognitive assessment of arousal level in the course of sleep deprivation for many times in past literature and has good sensitivity (Joseph et al., 2002; Leonard C,1998). Meanwhile, this task contained 4 different levels of difficulty, thus it avoided “ceiling” effect or “floor” effect that could happen in the process of experiment. In this experiment, we saw that under different color backgrounds, there was remarkable difference between line segment visual perception experiments $F=1.944$ $P<0.05$. Therefore, this research suggested that under different color backgrounds, with other conditions kept the same, the color background which was not taken as attention object had influence on foreground content. The past researches all suggested that the influence of color light on biological rhythm and automatic nervous activities was not mainly through cone cells, and recent research by Munch et al 2006 showed that conners were shown blue (460 nm), green (550 nm) and black (0 lux) with the same density after sleep, to examine the EGG change, and the result showed that SWA of blue light reduced in the first stage, and increased in the third stage, and REM obviously shortens. The influence of color/color light on physiology (including biological rhythm, sleeping structure, heart rate, core temperature, etc.) was not examined through cone cell system, and this experiment put forward that the influence of certain color light on psychological activities in non-attentive conditions possibly depends or less depends on the activities of cone cells. Thus it proved that color, not as attention object but as background, had influence on psychological cognition, which is inconsistent to the result of experiment with computer screen made by Murata, A. and Miyoshi, T (2000) and suggested that color influences operation ability not only through central vision but also through peripheral vision, which supported the research on non-visual psychological effect by Knez (2001) .

Through comparison of color backgrounds, we discovered that there was no difference between white, cyan and yellow, but they were distinctly different from other colors, and no remarkable difference was observed between these colors. This result could have something to do with numbers of samples and the presenting time of color background, and the difference between different color backgrounds within 2 minutes could be not sufficient.

We made analysis on the sensitivity of influence of line segment visual perceptual comparison test with different degrees of difficulty on color backgrounds. In the 4 tasks from easy one to difficult one, not every task was influenced by color background. We discovered that task with medium difficulty, or close to easiness, was more largely influenced by color background in visual perception of short time. As for the influence of color on psychological control ability in this research, color background was not taken as attention target stimulant, but it could be sensed by vision at the same time with task being observed. Another possible reason for this research result could be the influence of subjective comfort of colors on tasks.

THE INFLUENCE OF COLOR ON WORK EFFICIENCY AND THE DEGREE OF FITTING OF SUBJECTIVE COLOR DESCRIPTION

We thought the most conspicuous result was that through the comparison of experiment achievements of line segment visual perception, the order of achievement was in this sequence from high to low: white, cyan, yellow, red, blue, green, purple, orange, grey and black. With retrospect to the result of color description of subjective arousal level in research 1, the colors occupying main proportion from sober state to sleeping state were: white, green, blue and red—grey, yellow and cyan—grey, yellow, purple and orange—grey, black and purple—black. In this sequence, we discovered that red, blue and green which described sober state did not rank the top, while cyan and yellow which were corresponding to tiredness moved forward, and the order of purple, orange, grey and black were generally identical to the order in subjective feeling. As for the inversion of colors of soberness and tiredness, we believed that though tricolor was most likely to cause attention and arousal subjectively, it could not improve psychological perception, while under mild background of cyan and yellow, the work efficiency was improved. This result still did not show the blue shift effect of color light on work efficiency, but it could further improve our research since it was largely identical to the result of subjective description. Whether this sequence was contingent or an actual result, and whether this sequence could change if influenced by different conditions, such as content, time and method of experiment, and how physiological index changeed during the experiment process will be further studied.

CONCLUSION

5.1 In subjective and objective conditions, different colors have different influence on arousal level.

5.2 Different color backgrounds, as non-attentive stimulants, exert influence on visual perception.

5.3 Meanwhile we get a conclusion about work efficiency, which is on visual perception tasks, the background of white, cyan and yellow may improve work efficiency, or on the work mainly related to vision, the working environment of white, cyan and yellow is beneficial for improving perception of workers.

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