EYE TRACKING AND AUTONOMIC NERVOUS SYSTEM REACTIVITY DURING PERCEPTION OF VISUAL ENVIRONMENTS OF DIFFERENT COMFORT

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Abstract

Participants included 50 individuals of age20.5. Oculo-motor reactions and sympathetic skin response (SSR) have been monitored during perception of visual stimuli of different comfort. The research is unique in that sympathetic skin response registration is realized at the same time with eye tracking, giving thus an opportunity of analyzing cognitive visual-motor activity while viewing images and related physiological parameters, which reflect the autonomic nervous system (ANS) functional status.

Activation of the ergotropic brain system has been found during uncomfortable stimuli perception that is to provide vegetative mobilizationof organizm. When comfort visual stimuli were presented to participants the trophotropic brain system was activated, indicating relaxing influence of the stimuli.

An eye tracking analysis revealed an increase of dynamic and static parameters during uncomfortable images perception. This increase characterizes high tension of visual functional system.

A correlational analysis has revealed diverse and significant relations between eye tracking and SSR measures in comfort stimuli perception. This relies upon consensual functioning of the ANS and oculo-motor system, providing optimal mode of visual analyzer.

Keywords: Eye tracking, visual perception, autonomic nervous system, visual environment of different comfort, sympathetic skin response

Introduction

The visual system plays an enormous role in perception of the environment, surrounding us. Due to vision capacity a human being receives from 80% to 90% information about outward things. Eye movements are the necessary and important part in complete work of visual system. The eye is the most active sensory organ, it never stops working but moves constantly relative to head posture (Hubel 1990). When we look at any objects our eyes move continuously for images cannot be detected by fully immobile retina (Adam 1983, Irie et al. 2002, Filimonov 2003, Schraa-Tam et al. 2008).

Objects viewing is always accompanied with saccades (characterized by dynamic oculo-motor parameters) they are jumbled up with fixations (characterized by static oculo-motor parameters). In order to differentiate symbols we stare at things for a while. Duration of such ocular fixations depends on stimulus complexity as well as on individual distinctions.

There is no perception at the very moment of saccade and consequently image viewing appears to be a set of successive fixations. During fixation individual processes visual information, this action is connected with thinking. Longer fixation time is usually associated with hard and more intensive cognitive process. Just and Carpenter (1980) conceived an idea of the Strong Eye-Mind Hypothesis and they assert that there is a distinct lack of time delay between what has been fixed and what has been processed. The study made by Filin (2002, 2006) show that the more difficult activity causes the larger intervals between both voluntary and involuntary saccades. At the time of saccade visual perception is blocked by reflectory way. In biological terms this reflex is explained by the fact that its activity leads to the attention switch for a new object appeared in the visual field (Filin 2002, 2006-a). Thus, oculo-motor activity is an essential component in mental processes, related to obtaining, transformation and use of visual information, and state and activity of human being as well (Barabanschikov, Milad 1994).

The whole visual environment can be figuratively divided into two parts: natural and artificial. The natural one corresponds with physiological norms of vision, as nature “has sculptured” the human eye for its own purposes. The artificial environment is quite the different. “Aggressiveness” of modern visual human impact is determined by its fundamental difference from the natural one. Depending on comfort level, influence on organism and visual system homogeneous, aggressive and comfortable visual environments can be distinguished (Filin 2006-a-b).

Homogeneous visual environment has no visible elements or their number is reduced dramatically. In nature, such an environment is represented by the illimitable snowy spaces of the Arctic and the Antarctic regions (Filin 2006-a-b). Nowadays many homogeneous visible fields, created of bare gable facades are appearing in urban environment. Besides, often there is asphalt covering in front of buildings, which is also an example of homogeneous environment. Architectural use of large size windows seems to be an equal adversity. Building face and asphalt covering are empty visual field. Having appeared in such a zone, one is surrounded by homogeneous fields with no opportunity for an eye to stare at something since elements for fixation are missing. Amplitude of eye movements increases by 3 – 5 times (saccadic automatism switches to a search mode), visual mechanisms cannot work adequately. All this leads to evident psychological discomfort (Rappoport 1990, Filin 1990).

Aggressive visual environment is created by surface appearance of contemporary city architecture in most cases. It is common for all high-rise buildings with plenty of windows. Looking at such a surface is rather unpleasant thing as it is difficult to piece images obtained by left and right eyes together. Hence adequate work of binocular eye apparatus is impossible. Eyes cannot catch on a concrete window, minimize the amplitude of saccades, fix an image and the brain is overloaded with the same information (Filin 2006-a-b). The number of aggressive fields is multiplied by wide use of tile for walls, diverse grids, corrugated aluminum sheeting and flagstoned pavements (Filin 2002).

Comfortable visual environment is distinct in presence of curves having different widths and contrasts, acute angles (especially on the top part of visible field) forming shapes, variable color grade, condensation and rarefaction of elements and their remoteness. For sure nature in all its diversity - forests, mountains, rivers, seas etc. - can be referred to comfortable visual environment. Nature has so large variety of elements that eye may switch from one to another for hours. Moreover, all vision mechanisms function in an optimal mode in comfortable visual environment (Filin 2006-a).

Since visual perception as any other function requires participation of others systems to a significant extent activated and coordinated by the ANS it is evidently that different tension of the ANS might be observed during different visual environments influence. It is well known that the ANS is rather plastic and may easy change its functional parameters at the first presentation of any significant sensory stimulus (Gorbunov, Nechaev 1990). Changes of the ANS activity during different functional states – emotional reactions, stress, tension etc. – could be measured via SSR value (Aldersons 1985, Chroni et al. 2006, Dementienko 2010). Sensory fibers extending from receptors affected by irritant signals serve as afferent paths of the ANS. During visual perception such a role is played by fibers of the visual tract. Impulses from receptors reach thalamus, visual cortex and ultimately arrive at limbic cortex and hypothalamus, which execute excitatory or inhibitory sympathetic effect on sweat glands. Changes in body perspiration give information about the extent of the ANS activity and appears as SSR deviation (positive or negative) (Krauklis, Aldersons 1982, Dawson, Shell, Filion 1990, Kostin, Golikov 2010).

Considering the information above, it would be interesting to investigate human oculo-motor reactions peculiarities and the ANS reactivity during perception of stimuli of different comfort.

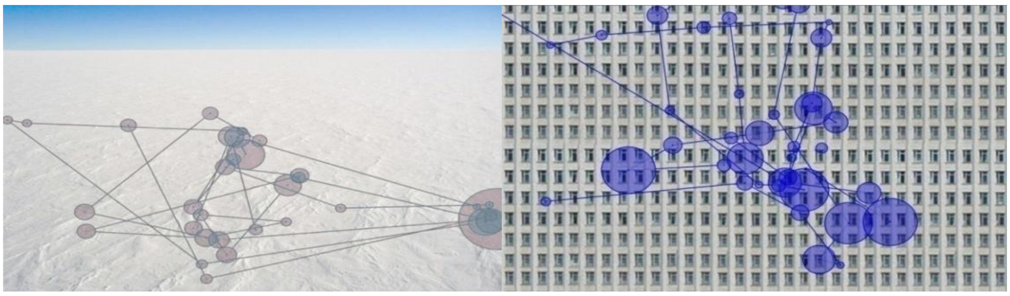
I.

The experiment was held in a quiet room with minimized distractions. Fifty subjects (mean age 20.5 years, 25 females, and 25 males) participated in the study. They had normal vision. All gave their written informed consent prior to the start of the study.The experiment was conducted in accordance with the ethical standards, represented in Declaration of Helsinki and European Community directives (8/609 EC).

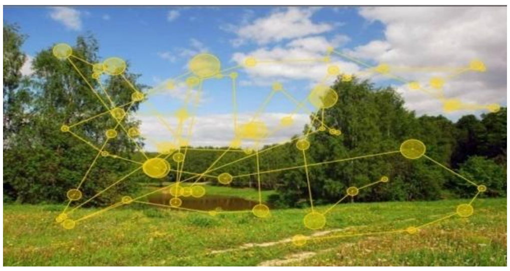
Oculo-motor reactions were recorded via eye tracking system iView X™ RED produced by German company SMI (HSSMI). The system is intended for high-speed registration of eye movements within infrared band. Remote eye tracking device (RED) was used for completely noncontacting measurments of eye movements and compensating head motions at once. In parallel sympathetic skin response was monitored by use of VNS-spectrum apparatus ("Neurosoft"). Electrodes were attached to the mid-palm of left hand.

Four visual stimuli (images) of different comfort were presented one by one at computer screen for 20 seconds for each one. The four variants of stimuli were selected according to the Filin's classification 2006: homogenious visual environment (HVE), comfortable visual environment (CVE), aggressive visual environment (AVE), emotive visual environment (EVE) (Fig.1).

a b



c



a - homogeneous visual environment;

b – aggressive visual environment;

c – comfortable visual environment.

Fig.1. Eye movements and fixations during perception of environments of different comfort.

The last one was chosen to emotionalize the participants the image was like those ones pictured on packets of cigarettes for health warning, it was not included in the article for ethical reasons. The presented images were supposed to model daily life environment. SSR curves and eye tracking data were measured at every stage of the experiment. The obtained SSR curves were processed via VNS-spectrum Copyright program and SMI BeGaze (BeGaze 3.0. User's guide 2011) program analyzed eye tracking recordings. Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) for Windows 20.0. Distribution observations was determined by using Kolmogorov-Smirnov test. As the explored data had not corresponded to Gaussian distribution model we used nonparametric tests. Significant differences between stimulus procedures in the same subjects were performed using Wilcoxon test. Statistical significance was set at $p<0.05$. The participants were not divided into gender groups since there was no significant difference between males and females performance. In order to find out connections between different parameters of eye tracking and SSR during perception visual environments with diverse comfort Spearman rank correlation coefficient was calculated. In further discussion significant correlation coefficient $r \geq 0{,}3$ will be taken into account (Nasledov 2007).

Data obtained during the study and statistically analyzed are represented in Table 1. A1 and A2 parameters reflect activity levels of trophotropic and ergotrophic centers relatively (Krauklis, Aldersons 1982). The largest amplitude parameters (A1, A2) of SSR curve were found during emotive stimulus presentation – 0.19 мV (0.01-0.78) and 0.43 мV (0.05-1.20). A1 measurement was significantly higher (0.19 мV, $p<0.05$) during emotive stimulus viewing compared to others stimuli (Fig. 1-a). Furthermore, significantly higher A1 measurement in homogeneous image presentation (0.12 мV) was observed in contrast to the comfortable one (0.04 мV).

Table 1. SSR and eye tracking measures during presentation of stimuli of different comfort
(Me; 25%; 75%)

Measures	Experiments			
	HVE	AVE	CVE	EVE
LP, s	1.34 (0.91-3.05)	1.14 (0.92-2.73)	1.55 (0.99-3.34)	1.31 (0.96-1.71)
A1, mV	0.12 (0.01-0.34)	0.08 (0.02-0.31)	0.04 (0.01-0.22)	0.19 (0.01-0.78)
S1, s	0.84 (0.33-1.55)	1.05 (0.50-1.51)	1.15 (0.50-2.36)	0.99 (0.52-1.97)
A2, mV	0.39 (0.05-1.17)	0.23 (0.06-0.65)	0.07 (0.01-0.33)	0.43 (0.05-1.20)
S2, s	5.76 (2.89-7.62)	5.53 (2.78-8.57)	5.00 (1.85-8.95)	5.57 (3.52-7.83)
Number of fixations	5.00 (3.00-6.00)	5.00 (3.75-6.00)	5.00 (4.00-7.00)	6.00 (5.00-7.00)
Durationof fixations, ms	1535.0 (1356.1-1690.9)	1577.8 (1332.7-1880.9)	1522.6 (1406.4-1702.2)	1496.3 (1242.1-1695.4)
Number of saccades	4.00 (3.00-6.25)	5.00 (3.00-7.00)	6.00 (3.00-7.00)	6.00 (4.75-8.00)
Duration of saccades, ms	49.50 (42.15-60.80)	45.65 (39.22-53.30)	46.20 (39.22-52.60)	44.55 (39.40-51.30)
Amplitude of saccades, degree	6.15 (3.82-10.22)	4.25 (2.85-5.97)	3.75 (2.95-5.60)	3.80 (2.87-5.77)

HVE - homogeneous visual environment; CVE – comfortable visual environment; AVE – aggressive visual environment; EVE – emotive visual environment; LP - latency; A1- amplitude of the first phase; A2 - amplitude of the second phase; S1 – duration of the first phase; S2 – duration of the second phase.

A2 measurement was significantly lower (0.07 мV, $p<0.05$) at the time of the comfort stimulus viewing than during others stimuli presentations (Fig.2-b). Again, it was found that

A2 during the emotive stimulus presentation (0.43 мV, p<0.05) was significantly higher compared to A2 in aggressive image presentation (0.23 мV, p<0.05).

Significant increase of SSR amplitude during emotive stimulus perception confirms an active role of the sympathetic nervous system in uncomfortable image perception. The wave height in this case depends on strength of emotion but unrelated to whether it is positive or negative, i. e. its valence. Consequently, this might indicate comfort visual environment as the most neutral in the study.

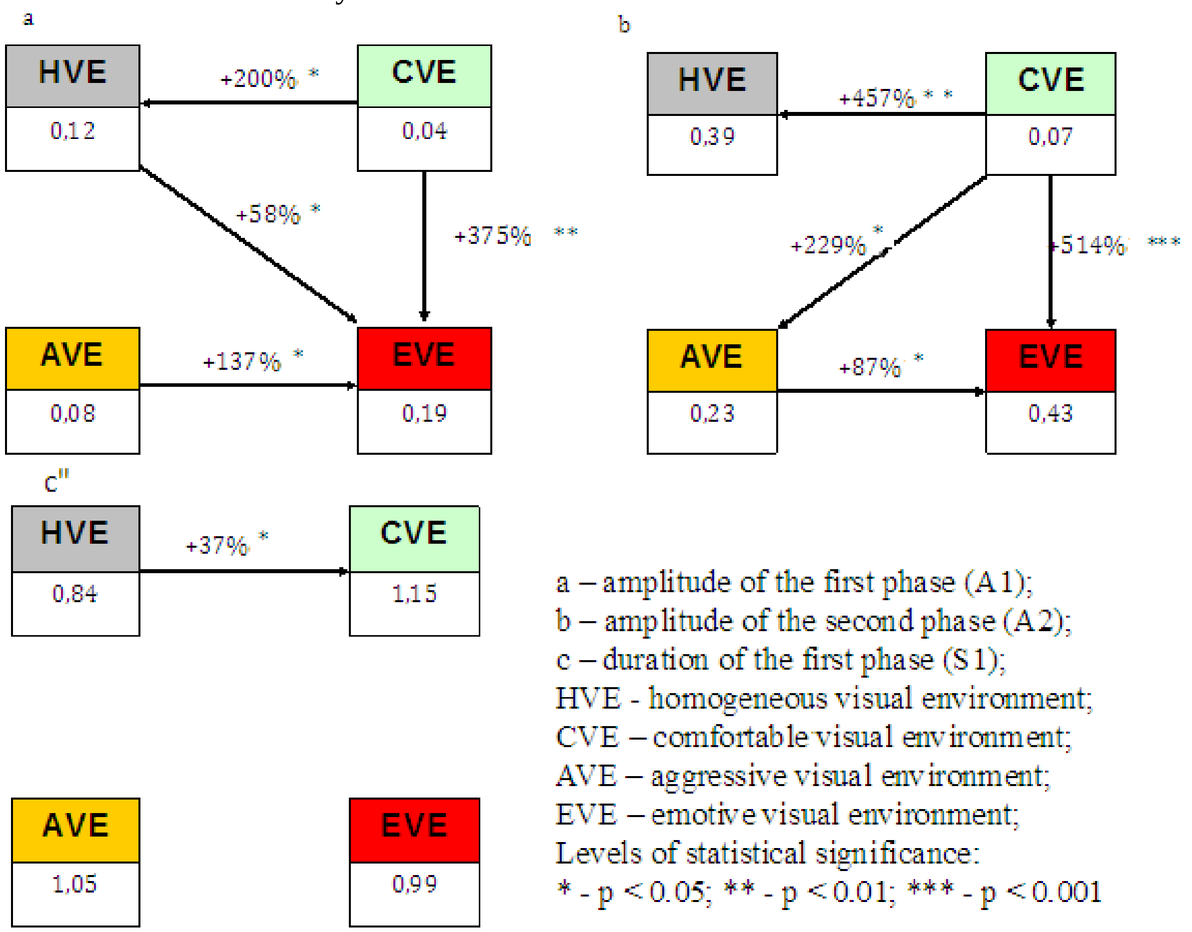


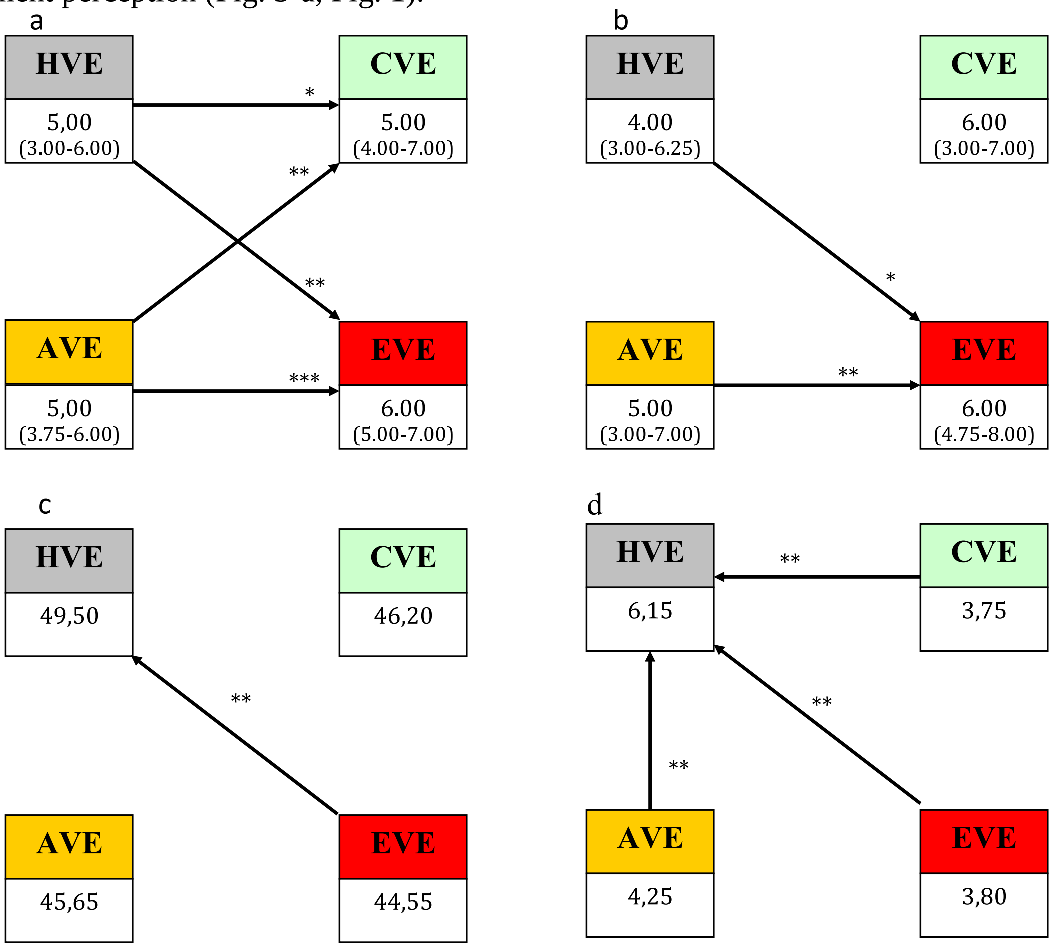
Fig.2. Significant differences between SSR parameters (A1, A2, S1) during perception of environments of different comforts.

Statistical analysis of SSR wave length revealed that duration of the first phase (S1) significantly increased (Fig. 2-c) in comfortable visual environment perception (1.15 s, p<0.05) compared to the homogeneous one (0.84 s, p<0.05). There is a temporary delay in hypothalamic structures that postpones activation of nerve centers. The delay activates trophotropic centers, the parasympathetic nervous system (vagotonia),and probably provides an optimal mode of visual perception.

No differences in SSR latencies, duration of the second phase (S2), time of fixations were found, independently from presented stimuli (Table 1).

Statistical analysis on number of fixations and saccades during different visual stimuli perception yielded significant differences (p<0.05). Most of the fixations and saccades was observed in emotive stimulus perception (Table 1, Fig. 3-a-b) since this environment influences negative emotions and gaze is not fixed upon its elements for long. It should be noted that long-term maximum mode of saccades and fixations first causes discomfort, then leads to disturbance in mechanism of saccadic automatism (Filin 2002).

We also found significant increase in saccades number during comfortable visual environment perception (Fig. 3-a, Fig. 1).



a – number of visual fixations; b – number of saccades; c – average duration of saccades; d – average amplitude of saccades; HVE - homogeneous visual environment; CVE – comfortable visual environment; AVE – aggressive visual environment; EVE – emotive visual environment; Levels of statistical significance: * - p< 0.05; ** - p < 0.01; *** - p < 0.001.

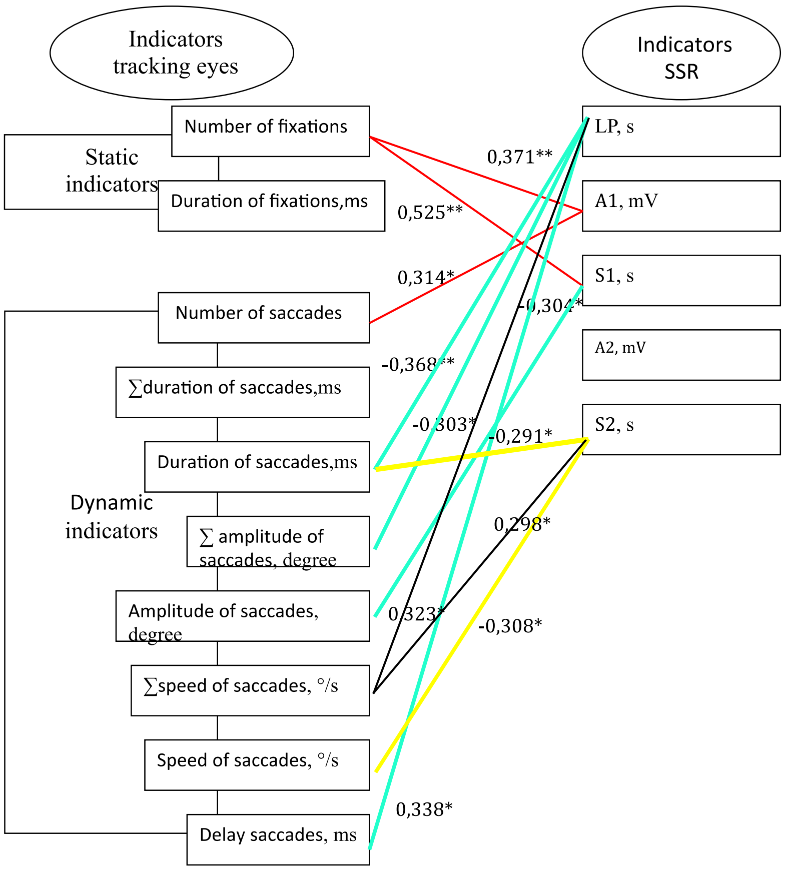
Fig.3. Significant differences between eye tracking parameters during perception of environments of different comforts.

Comfortable and emotive environments are marked by complexity of presented stimuli, plenty of diverse elements for possible eye fixation, that results in increase of given parameter as well.

Average duration and saccade amplitude were significantly less (Fig. 3-c-d) in situation of emotive visual environment perception that also gives evidence of avoiding unpleasant visual stimuli perception. Average amplitude of saccades was significantly higher during homogeneous environment perception (6.15 deg, $p<0.01$) compared to others environments (Fig. 3-d, 1-a), it is connected with the lack of elements for gaze fixation within homogeneous environment. Therefore, saccadic automatism switches to a search mode and mean amplitude increases. For aggressive environment perception a similar tendency was observed (Fig. 1-a-b).

On the basis of correlational analysis of explored parameters and statistical interaction peculiarities between eye tracking and SSR measurements we can conclude that there are differing mechanisms realizing visual perception of environments of different comfort.

Thus, in situation of emotive image perception dominance of direct correlations between SSR first phase and eye tracking values was found (Fig.4). This suggests that an image causing strong negative emotions is associated with intensive thinking tension since just at such moments of gaze fixations visual stimulus is being processed and requires additional activation of the ANS (sympatheticotonia).



SSR – sympathetic skin response; LP - latent period; A1- amplitude of the first phase; A2 - amplitude of the second phase; S1 – duration of the first phase; S2 – duration of the second phase. - homogeneous visual environment; – comfortable visual environment; – aggressive visual environment; - emotional visual environment;
Levels of statistical significance: * - p < 0.05; ** - p < 0.01; *** - p < 0.001.

Fig.4. Correlations between eye tracking and SSR parameters during perception of visual stimuli of different comfort.

Connections between SSR parameters and dynamic measures of eye tracking have been reported to be highly variable during comfortable environment perception. It can be assumed that in the act of this information perception it is an efficient functional system forming that provides optimal mode of visual processing.

A decrease of significant correlations between eye tracking and SSR parameters was observed in perception of aggressive and homogeneous environments. In both situations gaze is kept within the frame of homogeneous visible field (Fig.1). Consequently, after a regular saccade the brain does not receive enough information, namely, an action (saccade) has no confirmation of the action. As a result, insufficiency of sensory signal reduces strength and connections diversity between sensory apparatus and the ANS, which normally function seamlessly (Filin 2006-a-b). Long-term perception of homogeneous and aggressive visual environments leads to securing given misbalance, saccadic automatism disturbance, rapid fatigue and psychological discomfort.

In respect with the matter above, it is necessary to refuse creation homogeneous and aggressive visual environment. Nonetheless, every year cities increase in size moving human beings away from nature that is why competent organization of city visual environment is highly desirable (Filin 2006-a-b). In the practice of town-planning along with park areas preservation there are examples of wall painting (Fig.5), which allows to get rid of homogeneous and aggressive environments.

Fig.5. Examples of wall painting.

Conclusion

To conclude, we have found that there was an increase of SSR amplitude during the uncomfortable images perception that reflects the ergotropic brain system activation providing vegetative mobilization. Given that sympatheticotonia is explained by stress response to the presented stimuli. Long term influence such conditions may cause a chronic stress.

Under the comfort visual stimuli a decrease of SSR amplitude was observed. It is an indication of the trophotropic brain system activation. Vagotonia is determined by relaxing effect of the presented stimulus.

Perception of the images causing negative emotions is determined by increase of dynamic and static parameters that on the one hand connected with greater variety of elements on the other hand is related to avoidance of viewing unpleasant visual stimuli.

A correlative analysis has shown forming of the more diverse and significant correlations between eye tracking values and SSR parameters during the comfortable image perception that is explained by the ANS and oculo-motor system consensual functioning providing optimal visual perception.

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