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CORRELATING THE DEGREE OF OBSERVER'S PREOCCUPATION AND THE OBSERVATION TIME: VISUAL TASKS WITH OBER2 EYETRACKER

Abstract: This paper describes a set of visual tasks performed with a goal to find a correlation between observer's preoccupation and the observation time. Several aspects of objects differentiation were investigated: shape complexity, colour, uniqueness and size. Four visual tasks were performed by 10 volunteers. The eyeball position was captured with use of the OBER 2 eyetracker based on the infrared beam reflection measurements. Finally the recorded eyeball traces were subject of statistical processing. Interesting findings are the high attractiveness of complicated shapes and no influence of object's size on the observation time. Another result is an unexpected high inter-observers variation of attention difference in each visual task. The results play a key role in our research on perceptual model of biomedical signals and images. The other applications may be found in the area of visual information usability, ergonomics or perception-like control of automated visual systems.

1. INTRODUCTION

Since the introduction of automatic visual systems they were expected to follow the human manner of perception. Unfortunately, up to now few systems fulfil this assumption. Recently, the expected improvement of such systems is based on the investigation how the scene is scrutinized by a human expert. The application of such knowledge is not limited only to automatic feature extraction (e.g. recognition and counting of vehicles in a traffic control system), but also gives a new concept of the data density distribution in medical signals and images. Another interesting approach closes a feedback to the human again and uses the eye traces of an expert to optimise teaching the image interpretation to the medical students.

The current work is a part of wider investigation, oriented towards development of background for a new class of compression methods for biological signals and images. The application of variable sampling frequency [1] has been found the most natural way of expressing the non-uniform distribution of diagnostic data in the signal. The local throughput of a resulting data stream may be controlled by appropriate perceptual parameters representing the expert's interpretation skills. In general, our investigation of medical data distribution bases on the analysis of the physician's level of interest, expressed by the intensification of attention focusing on the particular parts of the signal.

This paper concerns the study and experiments on how far the observation time correlates with the amount of perceived information. The temporal distribution of medical information on a signal plot (e. g. ECG chart) or image would be estimated by the time the expert’s eyeball spends on

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it. Unfortunately, the common belief that the amount of information gathered visually is proportional to the observation time needed several corrections. Because the eyeball position is not only depending on perception, before applying it as an instrument for the focus attention localisation several factors have to be considered [2, 3, 4]:

- rapid eye movements during seeking new target
- unknown role of dominant eye in perception
- accuracy of eyeball position during focussing
- dynamic properties of the eyeball
- neurological conditions of visual information flow

All such neighbouring activities can hardly be identified and assessed, therefore our approach aimed at correlating the degree of observer's preoccupation and the observation time with use of visual tasks [5]. These tasks are prepared in order to differentiate presented objects by complexity, colour and size and investigate how they attract the observer's attention.

2. EXPERIMENTS

The equipment used for recording of the eyeball movements was the OBER2 device, consisting of special goggles, 12-bit A/D converter, processor and a memory buffer. The whole instrument is connected to a PC-class computer. The light emitting diodes located in the goggles generate pulses in the infrared band, and the detectors located on the opposite side capture the beam reflections from the eyeball surface [6, 7]. For the experiments described here the eyeball position sampling frequency was set to 1000 Hz.

In principle, the displayed scene is the unique input to the visual system of a human under test. Although all the background inputs (sounds, touch) cannot be eliminated, it is necessary to reduce particularly these influencing the oculomotoric system. Before attempting to perform the visual task, the person under test always calibrates the system sensitivity by a glance at a steady white rectangular contour (4 pixels in width - see fig. 1).

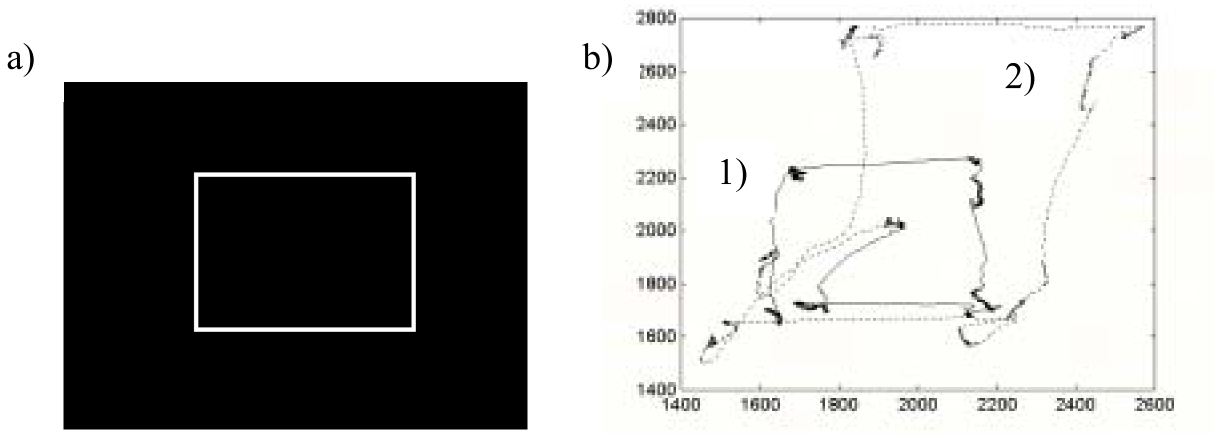

Fig. 1 a) Calibration contour and b) eyeball traces: 1) -well-calibrated, 2) ill-calibrated

Since the determination of the total task execution time was one of the investigated parameters, we needed an unambiguous detection of start and finish moments. At the start of each presentation a dot was displayed in the middle of the screen, on which the sight should have been focused. After a short time the dot was replaced by the actual chart and from that moment the registration started. The observer started scanning the chart after a short delay (idle time). All observers were instructed to direct the sight below the monitor screen with the chart after finishing the task. In this way, the observer finished the task consciously when no longer interested in the displayed scene. The total task execution time has been calculated as difference between the end time and the idle time, both of them detected manually in the eyeball signal (fig. 2) [4].

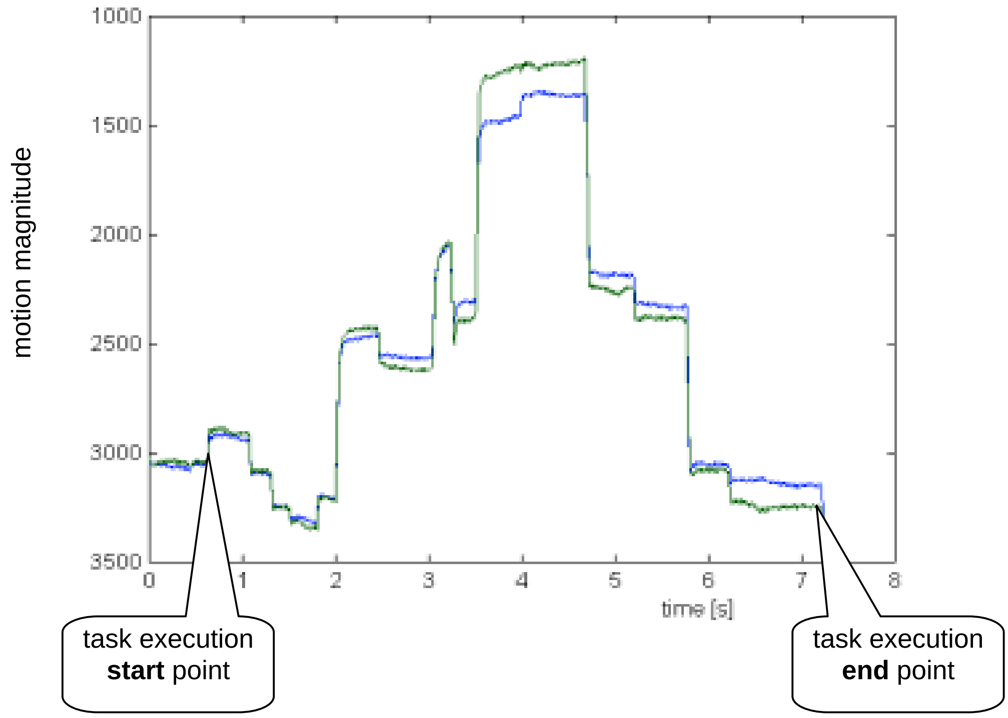

Fig. 2 Estimation of task execution time from the eyeball positioning signal

Ten volunteers (all male aged 22 to 23) took part in the experiments. They were untrained and had never performed such visual tasks before. Each participant performed in random order four different visual tasks described hereafter. The maximum task execution time was limited to 8 s by the length of available data buffer and the subsequent tasks were separated by a relaxation time of 10 s in average.

Four different visual tasks used in the experiment were programmed to investigate various aspects of scene observation and their influence to object's differentiation:

- task 1 - the role of shape complexity (fig. 3a)
- task 2 - the role of shape colour (fig. 3b)
- task 3 - the role of shape uniqueness (fig. 3c)
- task 4 - the role of shape size (fig. 3d)

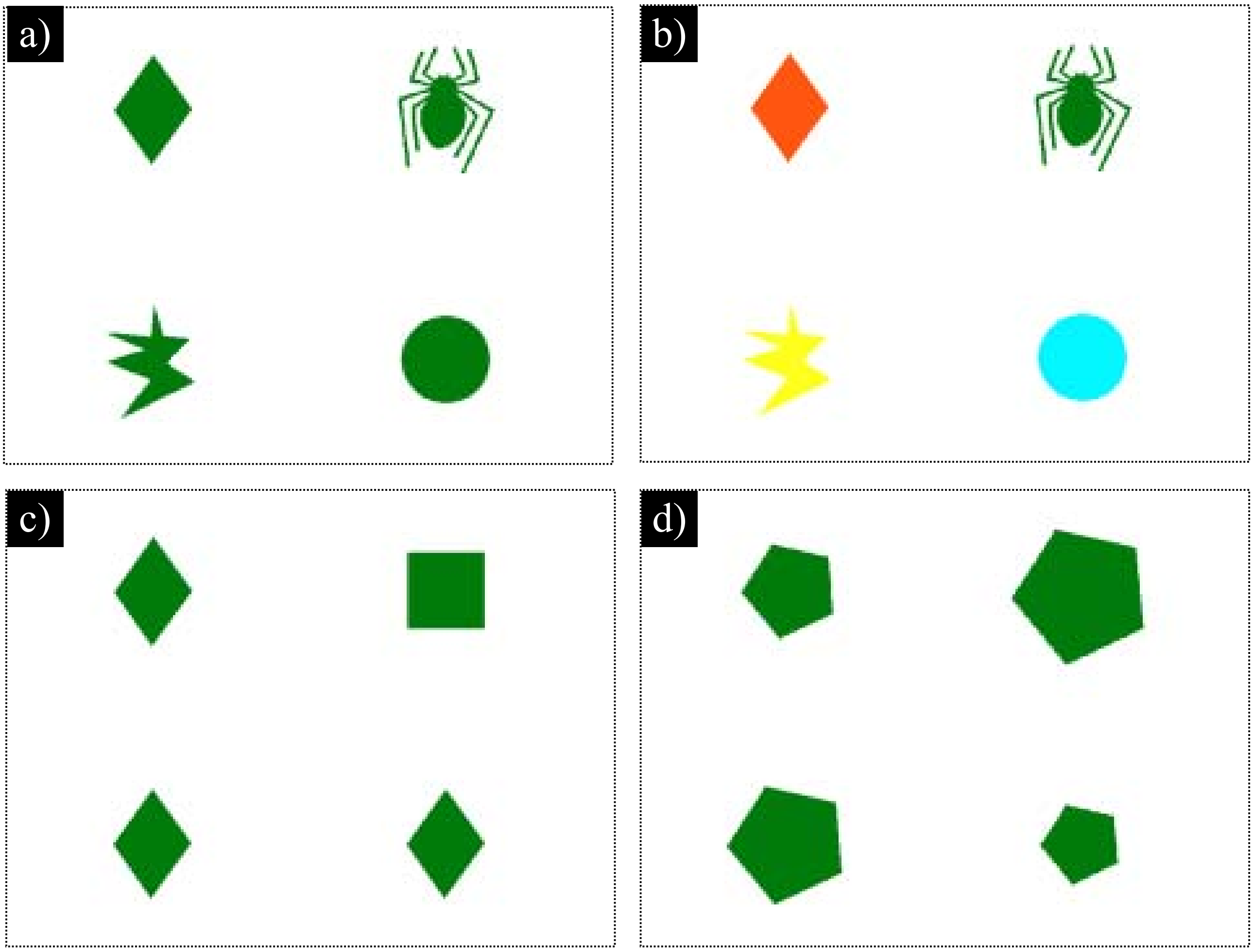

Fig. 3 Scenes displayed in visual tasks (original background is black) a) task one, the role of shape complexity, b) task two, the role of shape colour, c) task three, the role of shape uniqueness, d) task four, the role of shape size.

The eyeball position signal, acquired with use of the OBER 2 device consists of four parallel data streams representing vertical and horizontal co-ordinates of right and left eyes. The signal processing starts by normalisation of data with use of the calibration record. Both eye trajectories were analysed simultaneously with respect to the displayed scene. Each object was assigned a surrounding of a given diameter slightly exceeding its size in order to eliminate the uncertainty caused by eye positioning inaccuracy. The fact that the eye position co-ordinates fall within this surrounding was interpreted as the observer was looking at the object. Since each sample of eyeball positioning signal represents a precise amount of time (1 ms), the estimate of total time that the eye spends on a given object may be calculated by counting the samples of specified co-ordinates. The samples were counted if the co-ordinates of at least one eye fall in a given region (fig.4).

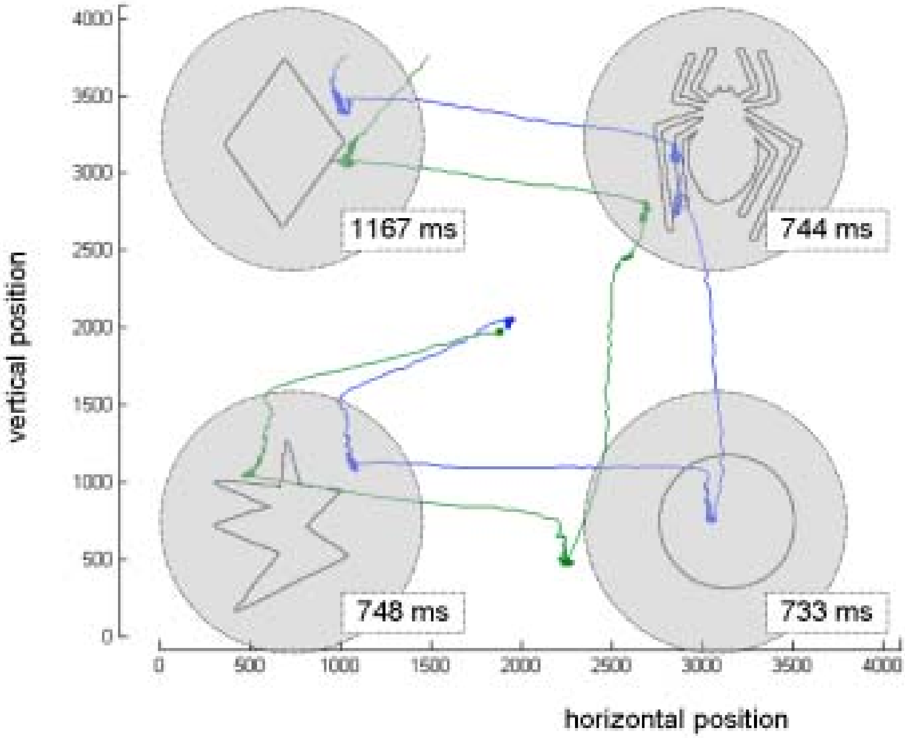

Fig. 4 Illustration of computation method for the focus attention time on particular objects. This example display traces of left (blue) and right (green) eyes during the visual task 1 for the observer 1. Grey background distinguishes object surroundings.

3. RESULTS AND DISCUSSION

Main result of the performed visual task series is the proof of the dependence of observation time on the object's complexity, and thus indirectly on the amount of information it provides. As shown in the fig. 5a this dependence is stronger or weaker from one observer to another and thus it is very difficult to express it in a quantitative way. The colour has been found of secondary importance to the general attractiveness of the shape (fig. 5b), but it is worth to point out that vivid colours (red and cyan) increased the average observer's focus attention time on the respective objects (diamond and circle).

The uniqueness significantly increases the focus attention time in majority of cases. This is also an important finding in aspect of following the expert's eyeball by an automatic recognition system. Spotting a new object among many identical ones requires the additional information to be captured from the scene. This explains the very fast perception of unusual details in medical images by the expert. This relationship justifies the high misleading role of ECG signal distortions, even if they fall in the area of low signal importance.

Finally, the focus attention time shows positive or negative correlation with the object size. For a group of 4 observers larger shapes are easier perceived and identified and this group devoted more attention to smaller objects. Other 3 observers prefer to focus longer on larger objects preferring to capture the details from them and only take a glance at the remaining small ones.

All these results are summarised in the table 1.

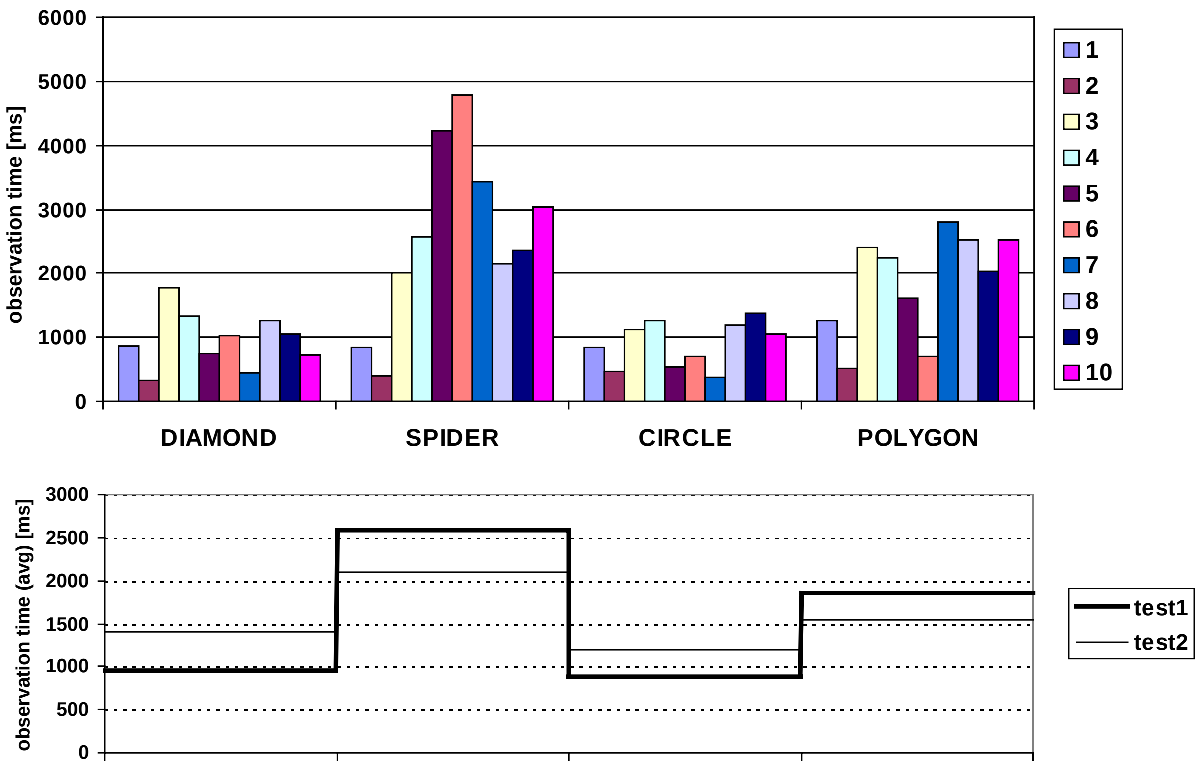

Fig. 5 a) Focus attention time for visual task one. Although the inter-observers differences are significant, the average focus attention time correlates well with object's complexity; b) comparing the average focus attention time for monochrome (visual task one - thick trace) and colour objects (visual task two - thin trace).

Table 1. Summary of the dependence of focus attention time for all visual tasks

task (number and aspect)	**observer** 1	2	3	4	5	6	7	8	9	10
1. the shape is complicated	+	0	+	+	+	+	+	+	+	+
2. influence of the colour	0	+	0	+	0	0	0	+	+	+
3. detection of uniqueness	-	-	+	0	+	+	+	+	+	+
4. the object's area	-	-	+	0	+	-	-	0	+	0

legend:

the sign "+" means respectively (by task number):

1. longest focus attention time on the most complex object,
2. colour change resulted in change of focus attention time (+ or 0),
3. longest focus attention time on the unique object,
4. longest focus attention time on the biggest object,

the sign "–" means "on the contrary",

the sign "0" means no significant correlation was found.

High inter-observers variation of attention difference in each visual task is probably the most problematic finding of our experiments, since it restrains the quantitative assessment of object difficulty based on observation time. Figure 6 displays results of all visual tasks for two extreme observers. Observer 1 seems to have a "cool sight" not influenced by the content of the scene, while observer 5 is probably involved in precise fulfilling the given task and differentiates perceived objects much more than observer 1. This variation is probably caused by individual psycho-physiological predisposition and its origin will be subject for further investigations.

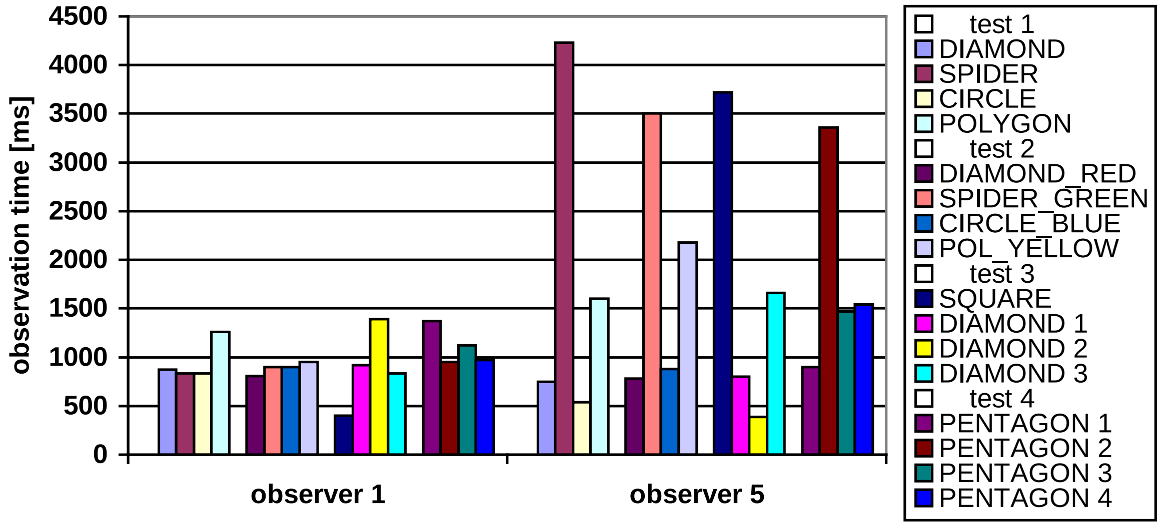

Fig. 6 Focus attention time for all visual tasks acquired from observer 1 ("cool sight") and the observer 5 that was probably more involved in precise fulfilling the given task.

The last set of complementary results concerns the idle time and their variation in particular visual tasks and in the set of observers (tab. 2)

Table 2. The idle time [ms] and its variability

observer	visual task number				average time	st. deviation
	1	2	3	4		
1	358	301	266	398	330,75	58,72
2	290	190	171	177	207,00	55,90
3	186	330	170	152	209,50	81,52
4	308	343	360	299	327,50	28,80
5	587	298	583	343	452,75	153,82
6	314	534	588	289	431,25	151,78
7	168	242	166	298	218,50	63,71
8	514	235	275	456	370,00	135,87
9	228	231	365	306	282,50	65,78
10	283	280	551	346	365,00	127,68
average time	323,6	298,4	349,5	306,4		
st. deviation	134,25	95,65	170,83	91,10		

The results represent the attractiveness of visual tasks as a whole scene. Accordingly to the common belief, the scene containing objects of various size (visual task 4) and those with objects of different colour (visual task 2) are more stimulating that results in lower idle time than for other monochrome scenes with objects of similar size (visual tasks 1 and 3).

Analysis of average idle time reveals also "lazy" observers, but the tested population is to small to make general conclusions. In particular it is interesting whether the idle time is correlated with object differentiation degree. In our study the observer 1 that shows minimum differentiation of focus attention time has an average value of idle time (330,75 ms) while the observer 5 with maximum differentiation of focus attention time has the highest value of idle time (452,75 ms).

4. CONCLUSIONS

This work proves the positive correlation of observation time and the amount of information gathered visually, although the quantitative assessment can not be derived from the observation time at this stage of research. The future investigation should concern the order in that objects are focussed in the scene and should give an explanation of returns of focus attention to the objects that have already been glanced. In our opinion, the future algorithm should process the whole trace and continuously identify what the observer is doing. In particular the comparison of scanpaths from two observers may be interesting and useful for detection their skills or preferences.

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BIBLIOGRAPHY

[1] AUGUSTYNIAK P., WRZEŚNIOWSKI A., ECG recorder sampling at the variable rate. Proc. 6th Int. Conf. SYMBIOSIS, Szczyrk, Poland, pp. 128-135, 2001.

[2] AUGUSTYNIAK P., MIKRUT Z., Task-Dependent Parameters of Attention Measured by Two Eyetrackers. JMIT, Vol. 2, pp. BP57-BP65, 2001.

[3] LAAR P., HESKES T., GIELEN S., Task-dependent learning of attention. Neural Networks, Vol. 10, No. 6, 1997.

[4] MIKRUT Z., AUGUSTYNIAK P., Estimation of execution time for tasks of objects counting and localisation using the OBER2 device. Proc. 12th Nordic-Baltic Conference on Biomedical Engineering and Medical Physics, Reykjavik, 2002. pp. 144-145

[5] WOLFE J. M., Visual search. In: H. Pashler (ed.) Attention. University College London Press, London UK, 1996

[6] OBER J., HAJDA J., LOSKA J., JAMICKI M., Application of eye movement measuring system OBER2 to medicine and technology. Proc. of SPIE, Infrared technology and applications, Orlando, USA, vol. 3061, part 1, pp. 327-333, 1997.

[7] OBER J., LOSKA J., Function of eye movement measurement system OBER2. Proc. Conf. on Medical Informatics and Technologies, MIT 2000, Ustroń-Jaszowiec, pp. BP111 – BP115, 2000 (in Polish).