An Application of Eye Tracking Methodology in Cartographic Research

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ABSTRACT

Eye Tracking is a valuable tool for studies related to visual search and visual perception. In cartographic research, visual experimentation is considered appropriate in order to investigate the variables of the map that can influence the map reading tasks. In the present paper, we demonstrate how the eye tracking technology may contribute to cartographic research by presenting an experiment on the selectivity of the visual variable of shape. Specifically, we examine how map readers are reacting with point symbols that are characterized by the topological property of having a hole as basic shape characteristic. The Viewpoint Eye Tracker® by Arrington Research is used for the recording of the eye movements. The detection of the center of vision is accomplished by locating the center of the pupil. Furthermore, an algorithm is developed in order to control the accuracy and the precision of the recording data. The analysis of fixations, saccadic movements and scan paths is significant for the map reading tasks during the process of visual searching. Eye Tracking seems to be very robust in cartographic research, as it represents the visualization of map reader's cognitive process.

Keywords

eye tracking, pupil location method, map reading, visual search

INTRODUCTION

Eye Tracking methodology is providing an enriched way to examine processes related to visual search and visual perception. The fundamental metrics of the methodology provides the opportunity to represent the results of the subject's cognitive process, which occurs during the observation of a stimulus. In cartographic research, cognitive processes take place during the map reading tasks. Furthermore, the map elements and the elements of the cartographic background constitute the main objects of the cartographic symbolism and can be considered as the basic stimuli of this procedure. In cartographic symbolization, there are some features, such as color, orientation, motion and size which are detected immediately by the visual system prior to attention (Wolfe 1998, 2000, Wolfe and Horowitz 2004, Michaelidou et al. 2005). Cartographers are focusing on the properties which are rapidly and accurately detected by the visual system in order to facilitate the detection of target symbols during the map reading tasks (Michaelidou et al. 2005). In the present paper, we investigate the reaction of the map readers in point symbols which are located on a simple cartographic background. Specifically, these point symbols are characterized by the topological property of having a hole as basic shape characteristic for which there is evidence that is an immediately detected feature (Chen 1982, Pomerantz 2003). An experiment, using eye movements analysis, is designed and the results are presented below.

EXPERIMENTAL DESIGN

Subjects are asked to search on a computer monitor for a target point symbol with a unique topological property feature being that of having a hole among compact point distractors on a simple cartographic background. The cases where targets are located in the center, the middle and the periphery of the base map are examined. Also, we investigate the case of target-absent trial. Totally, 16 different maps are designed. During the process of visual searching, the eye movements are recorded, using pupil location method, in order to examine the representation of subject's cognitive process. Eight subjects are used for the analysis and each subject is tested individually.

EYE TRACKING LAB SETUP

The Viewpoint Eye Tracker® by Arrington Research is installed at the Laboratory of Cartography of National Technical University of Athens (NTUA). The operation of this system is based on the use of devices that are able to record the gaze on a visual scene by analyzing eye images. The basic components of the Eye Tracker are the recording device (hardware) and the processing tools (software). The system is embedded in a computer machine, which has an additional card for graphics. This fact contributes to the support of two display monitors; the first one for the system's operator (primary monitor, 17-inch diagonal, resolution 1280x1024) and the second for the stimuli projection (secondary monitor, 19-inch diagonal, resolution 1280x1024). The recording device in the central processing unit

(CPU) consists of a board connected to the motherboard and externally of a system attached to the optical system of the observer. The system of attachment supports the existence of a camera and an infrared Light-Emitting Diode (LED) for each eye. The system's geometry is integrated by a mechanism that stabilizes the position of the observer's optical system. The distance between the observer and the secondary monitor is 55.50 cm (21.85 inch). A third camera on the system attached to the observer's head provides the opportunity to extend the stimuli monitor to physical surface.

The function of the system is accomplished by a set of sequential operations. The infrared LED, which is located under the observer's eye, illuminates the eyeball while its image is being captured by the camera placed next to the infrared LED. The illumination contributes to the discrimination between the regions of the pupil and the iris. Furthermore, the application of predefined threshold allows the capturing of corneal reflection. The center of the pupil and the position of corneal reflection are detected by using segmentation algorithms. For each observer, the system creates a transformation that associates every movement of central vision to the relative movement on the stimuli. The generation of this function occurs through a process of auto-calibration.

The Eye Tracker uses three different methods in order to detect the visual center; Pupil Location Method, Glint Location Method and Pupil-Glint Vector. The process of auto-calibration is applied by the observation of fixed point targets that are represented as squares on the stimuli monitor. This process has several variables (e.g. total number of fixed targets, time of target's representation) which are modified by the purpose of the experimental design. Furthermore, the Eye Tracker supports the creation of special Regions Of Interest (ROIs) and the recording of the range of observer's pupil. Additionally, the system is able to compute the ratio of the tangent pupil, the eye torsion. Each Tracker's record is accompanied by a variable of its quality. The sampling frequency can be selected by the operator between two available choices (30Hz and 60Hz). The visual range is ±44 degrees of the visual arc horizontally and ±20 degrees in the vertical dimension. The Eye Tracker's accuracy lies between 0.25-1.00 degrees of the visual arc, when the recording resolution is 0.15 degrees of the visual arc.

Moreover, we have developed an algorithm in order to control the accuracy and the precision of the recording data. The algorithm is executed before and after each procedure of experimentation. Its function depends on the estimation of statistical measures related to the spatial distribution of the records.

RESULTS

The analysis of fixations, saccadic movements and scan paths reveals the followings:

- In most cases, the process of visual search starts from the place where the target symbol is located in the previous stimulus scene. In all other cases, the place where the target is located in the previous scene is included in the scan path.
- Scan path is more complicated and it covers a larger area when target is located in the periphery of the map, while it is simpler in the middle or in the center.
- Fixations correspond to places of the base map where point symbols are located.
- The process of visual search through target and distractors is depicted as the part of saccadic movements in the scan path.
- Scan path is more complicated in the case where target is absent from the stimulus scene.
- In the case of target-absent trials, eye movement analysis does not reveal a special pattern of searching.
- The verification of target's detection is independent of the location that it is indicated.

CONCLUSIONS

In the present paper, we demonstrate how the eye tracking technology may contribute to cartographic research by presenting a cartographic experiment. The results are significant for the study of the map reading process, during the visual search of target symbols on cartographic background. Target symbols are characterized by the unique topological property feature of having a hole, and the process of searching takes place among compact distractors. Eye movements analysis enriches the traditional methods of measuring the visual search through the accuracy and the reaction time on a stimulus. Eye tracking seems to be a valuable tool for experimentation on scientific fields related to cognitive processes.

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