Assessing Aerial Imagery Interpretation of High School Students with Eye -Movement Analysis

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Abstract

The successful development of spatial thinking and map interpretation skills are critical components not only of geography education but any discipline that uses maps as a visualization tool to enhance student understanding. This research presents results from twenty-seven high school students who participated in a series of planned map exercises using Google Earth. While participants viewed an aerial image, eye-movement data such as gaze paths, eye fixation locations, and additional eye-movement data were collected and analyzed. This study uses eye-movement analysis to understand how web-based geospatial technologies can be applied and designed for geographic education research. Eye-movement data provided insight in determining how students solved location tasks and utilized boundaries in aerial images. The results suggest that students do not use boundaries to orient themselves in web-based aerial imagery; they learn locations not by spatial representation, but instead through reading labels; and, perhaps most importantly that students are not able to intuitively interpret aerial images and need to be explicitly taught these skills.

Keywords: Spatial Learning, Aerial Imagery Interpretation, Eye-Movement Analysis, Geovisualization, Geographic Education

Introduction

There is a well-established body of literature that currently seeks to address the integration and application of geoinformation technologies, especially Geographic Information Systems (GIS) in K-12 classrooms (Meyer et al. 1999; Kerski 2003; Pedersen et al. 2005). Major obstacles associated with the implementation of GIS-based lessons, such as training time requirements, available technology, high costs, lack of appropriate curriculum, and additional educational priorities (Bednarz and Audet 1999; Baker 2005), have led many educators to consider the integration of web-based mapping products in K-12 education as an appropriate alternative (Patterson 2007). However, it is still unclear how these digital mapping products impact student learning.

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Web-based mapping applications such as Google Earth provide students with a realistic depiction of the Earth through the use of aerial imagery. Google Earth has become a powerful classroom application due to its ability to engage students through the use of detailed visual images (Patterson 2007). Teachers can create fly-bys, three-dimensional tours of physical terrain, and other features thereby supplementing classroom lessons with realistic images. Students can view their communities, and even find their own homes, which provide a sense of relevancy to their learning. While the application may be successful at motivating students to learn, the use of Google Earth to improve students' spatial learning is largely untested.

The advent of web-based mapping applications such as Google Earth provides new methods for map instruction but the application's impact on student learning needs further empirical investigation (Taylor 2000). The need to assess the effectiveness of web-based media to teach mapping skills and the enhanced use of geovisualization tools in the classroom are important aspects of the international research agenda developed by Slocum et al. (2001). The integration of geoinformation technologies into the classroom should be accompanied by a pedagogical perspective (Deadman et al. 2000; Gatrell 2004) and the development of explicit and well-defined curriculum for the K-12 system which is currently lacking (Baker 2005). The appropriate utilization of technology will enhance the teaching and learning of geographic skills and concepts (Nellis 1994; Podell et al. 1994; Pederson et al. 2005). The goal of this research is to provide empirical evidence using eye-tracking analysis methods to support effective geovisualization methods and geoinformation technologies in an educational environment. While many methods are available for testing the usefulness and usability of teaching media (Maguire 2001), the research described in this publication was conducted using an eye-movement tracking device to investigate how students interpret Google Earth-based aerial imagery. The results of the research reported here will (1) introduce eye-movement analysis into the field of geographic education and (2) determine how effectively high school students locate features on Google Earth-based aerial imagery.

Context

Effective cartographic communication is efficient if it immediately provides map content for reading and interpretation (Dent 1972). Maps have historically been two-dimensional abstract representations of geospatial objects and phenomena. Today, web-based mapping services, i.e. Google Earth, provide three-dimensional geospatial representations. Two and three-dimensional interactive geovisualization is gaining popularity as a method of exploring and disseminating geospatial information (Fisher et al. 1993). The three-dimensional depth perception of aerial imagery, photorealistic representation, and view transformations such as rotating, scaling, translating and zooming, allow the map user to interactively change his/her viewing position, and review geospatial information from different perspectives (Kraak 1993). Guidelines for assessing effective three-dimensional web-based map communication and design have not been established yet (Jenny et al. 2008).

Eye-movement analysis in cartography

An empirical approach to map design and map communication involving eye-movement analysis commenced in the 1970s and 1980s (Antes et al. 1985; Montello 2002); however, the studies did not specifically address the implications for spatial learning and the development of best practices in geographic education. These eye-movement studies investigated the relationships between map reading and map design (Dobson 1977; Castner and Eastman 1984; Antes et al. 1985; Castner and Eastman 1985; Brodersen et al. 2001). Castner and Eastman (1984) reasoned that eye-movement recordings would allow a better understanding of map reading and interpretation during human visual/cognitive processing. Such insight would be particularly important to geographic educators to improve map comprehension. This insight also needs to be tested to confirm its applicability to web-based mapping platforms.

Historically, eye-movement analysis has been conducted in psychology and specialized fields of textual and graphical communication such as art and advertising (Montello 2002). Eye-movement studies involving aerial photographs, artwork, geometric designs, and newspaper advertisements were conducted as early as the 1930s (Steinke 1987). Currently, eye-movement analysis is applied in fields such as cognitive psychology, cartography, marketing, advertising, radiology, aviation, etc. (Antes et al. 1985; Steinke 1987). Several studies have demonstrated the value of using eye-movement measurements to investigate individuals' visual scan and search patterns on maps and others images (Dobson 1979; De Lucio et al. 1996; Rajashekar et al. 2004; Nguyen et al. 2005; Fabrikant et al. 2008). Additionally, a recent call for research in GIScience includes the positive opportunities the method has for providing insights in the field of cognitive research in GIScience (Montello, 2009).

Castner and Eastman (1984) classify eye-movement studies into two generic tasks: spontaneous map viewing, and task-specific map reading and interpretation. Spontaneous viewing, also referred to as free examination, involves participants viewing an image without any instructions and recording their eye-movement patterns. Human spontaneous viewing is influenced by expectations and previous experiences and is guided by the properties of an image, which include: color, isolation, contrast, complexity, novelty, proximity, and similarity (Castner and Eastman 1984). For task-specific viewing, participants are given instructions before or during map viewing. The same properties that impact spontaneous viewing also play a role in task-specific map viewing; however cognitive factors have a greater influence on eye-movement when participants are given specific tasks (Castner and Eastman 1984).

Castner and Eastman (1985) also discuss the role of perceived map complexity—defined by Eastman (1977) as the reader’s subjective assessment of a map display’s visual complexity-and its impact on eye-movements. Their study with sixty undergraduate students concluded that when participants described the map as complex, more fragmented eye-movement patterns emerged, indicating a higher cognitive processing load (Castner and Eastman

1985). Findings in these early eye-movement studies indicate that the map design and the arrangement of features and boundaries seem to impact how map readers view, store, and interpret map information. In this study, we use eye-tracking methods to determine the impact of the representation of boundaries in web-based aerial images on high school students' ability to interpret aerial imagery.

Spatial thinking

Successful map interpretation requires spatial thinking which involves cognitive processes used to perceive, process, and remember information related to spatial concepts. Spatial thinking is comprised of three elements a) the concept of space and its properties such as dimension, connectivity, and proximity; b) tools of representation which may be static maps, dynamic maps, or other means of displaying spatial data; and c) processes of reasoning including critical and higher order thinking (Committee on the Support for Thinking Spatially 2006). There are several types of cognitive mapping skills involved in navigation (Lobben 2004), including: landmark recognition, route and survey knowledge, environmental mapping, object rotation, map/environment interaction, and path integration. The research presented in this article is primarily concerned with the map interaction and students' ability to recognize landmarks in the aerial imagery represented in Google Earth.

Montello and Golledge (1999) suggest that students' inability to locate themselves within a map is often due to a poor understanding of scale and how the concept translates from the real world to a map. Students use typical user interfaces—tools such as pan, zoom, identify, and select—in web-based Geographic Information Systems (Milson and Earle 2007). In virtual representations such as Google Earth, the user is constantly and rapidly adjusting the scale through the use of zooming tools. Students may become confused in these virtual depictions because the representative fraction of scale is mostly undefined (Longley et al. 2005). Instead of a representative fraction, the metaphor of eye height above the Earth's surface is often used in many web-mapping environments including Google Earth. The eye height, or "flight elevation" at which the image is viewed, is not easily transferred to meaningful scale information for the students. Recognizable spatial patterns might be altered as aerial imagery is automatically exchanged during zooming, and landmarks might become more or less prominent due to changes in the level of detail.

Humans may navigate or describe locations in relative terms (topological relationships) related to familiar landmarks (Montello and Golledge 1999). This is due to the geometric process used to determine location through triangulation, which requires that the bearings to two landmarks, or the distance to one landmark be known (Aretz 1991). Humans often triangulate between objects intuitively. Research has shown that humans learn landmarks first and then relate those landmarks to routes, and eventually develop survey knowledge (Siegel and White 1975). Map users may use other objects in a map, such as roads and borders, to create a frame of reference used for navigational purposes. Without an "interpretive framework" such as borders or a street grid/network, research has indicated that it is more difficult for humans to develop a cognitive map (Kulhavy et al. 1982; Rossano and Morrison 1996). Rossano and Morrison (1996) describe that borders or other types of "interpretive frameworks" are used as spatial references by map users. A map user's attention will initially focus on prominent map features which are then used to create a cognitive map. Research has also shown that such a cognitive map will differ depending on the map scale viewed (Rossano and Hodgson 1994). The cognitive process of using an interpretive framework is very similar to the "edge effect" described by Verdi and Kulhavy (2002). The edge effect describes the process in which study participants remember features around the edge of a map more often than those in the interior of the map; except when the features are near interior borders. Mackworth and Morandi (1967) and Gratzer and McDowell (1971) note that participants' attention focused on edges and linear boundaries, based on their studies of pictures and landscape photographs, respectively. However, Dobson (1977) completed a study using paper maps with and without state boundaries and found no distinction between participants who viewed the two representations. The studies above were an attempt to understand how viewers interpret maps and develop their cognitive maps. The "edge effect" phenomenon was observed in interpreting traditional maps. During the use of web-based aerial imagery, the edges and outer boundaries of the map are constantly changing due to the ability of the user to zoom in and out. Therefore, the types of boundaries that produce an "edge effect" in a web-based aerial image and whether this "edge effect" can be observed when students use these web applications are the focus of this research.

Research questions

During our study, we are building on these previous studies to investigate whether or not the "edge effect" phenomenon is still observed when utilizing the digital aerial imagery in Google Earth instead of traditional paper maps. Therefore the research focused on the following research questions and hypotheses:

- First, the study examines the assumption when using eye-tracking methods that those students who have lower eye fixation counts have the ability to correctly identify objects in an aerial image. The researchers therefore asked, "Is there a correlation between students' eye-movements and their ability to correctly interpret an aerial image?" Hypothesis A: Students who correctly locate objects will have a lower eye fixation count than those students who do not locate the objects.
- Second, the study examines the presence of an "edge effect" in

web-based aerial imagery. The researchers therefore asked, "Do students use geopolitical boundaries as a point of reference when using a web-based aerial image?" Hypothesis B: High school students use edges and internal boundaries to orientate themselves in aerial imagery.

Study population and setting

Twenty-seven high school students voluntarily participated in ten-minute individual sessions that consisted of eye calibration, aerial imagery interpretation, and a short post-test. Four student datasets were eliminated from the analysis due to data recording and calibration errors. The participants were six males and seventeen females attending a summer geography program for underrepresented high school students with an average age of fifteen years. While attending the program, students were invited to voluntarily participate in the study. All of the students took part in an hour-long introductory training about the basic functions of Google Earth. Therefore each participant had basic knowledge of the Google Earth user interface and aerial imagery before participating in the study.

Method

The Tobii X120 Eye Tracker and Tobii Studio Analysis Software were used to determine:

- eye fixation – the position of where the eyes focus on an object. The radius of this position is 35 pixels by default.
- eye fixation locations – a spot where the subject focused for at least 100 milliseconds.
- eye fixation counts – the number of locations for which students' gazes were fixated for at least 100 milliseconds.
- eye fixation durations – the cumulative duration a student's gaze was fixated on a location, which had a minimum time of 100 milliseconds.
- eye gaze paths – records the route or the direction the eyes used when searching the image, by connecting the eye fixations through an animation called a "bee swarm."

Eye fixations were recorded to determine the focus of the participants' eyes on the aerial image's content. The eye fixation count of each participant was used to test for a correlation between the total number of fixations on the map's elements and the search efficiency of each participant using the non-parametric Mann-Whitney U statistical test. The eye fixation data was used to create gaze plots for each participant that show each fixation point as a circle, the size of which depends on the duration of the fixation. Density maps were created using the fixation data to indicate where the highest fixation concentrations for all participants were located. Finally, the eye gaze path of the participants was recorded using the bee swarm function, which is an animated representation of the eye gaze path which allowed the researchers to identify common scan and search patterns.

All of this data were collected using a sixty centimeter high-resolution monitor (1920 by 1200 pixels) positioned seventy-six centimeters from the participants' eyes. Each participant sat on a classroom chair and placed their chin on a chin rest to stabilize their head allowing for a manual eye calibration of each subject and maintaining that individualized calibration throughout the session.

Limitations

The major limitation of this student research lies in the fact that the participants in the study were students attending a university summer program, and that limited both the diversity and the sample size of the population studied. Because of this, the statistical methods applied (Mann-Whitney U Test) provided limited analysis results. The study, while small raises some important questions as well as possibilities for future research in the field.

Procedure

Each participant was shown a full-screen aerial image extracted from Google Earth with a viewing distance (eye altitude) of fourteen kilometers (Figure 1). The image represented the metropolitan area of El Paso, Texas. This region was chosen because while all of the students attended Texas high schools, none of them were from West Texas. Another reason the researchers chose El Paso was because the image of El Paso in Google Earth does not have "false edges" that students may confuse with boundaries. These "false boundary lines" result when the aerial images of neighboring quadrants are taken at different times or have different resolutions creating a noticeable edge between the two images. El Paso is also adjacent to both a natural international border (United States-Mexico), and a geometric state border (Texas-New Mexico) that would allow an investigation of the true "edge effect".

Participants viewed the aerial image of the El Paso region with the international boundary layer drawn and major landmarks and natural features labeled using default Google Earth labels. Each participant was given forty-five seconds to spontaneously view the image before Google Earth opened at an aerial view distance (eye altitude) of seventy-seven kilometers containing the area of El Paso, Texas and the United States–Mexico border. However, this second image was not directly centered on El Paso, but was instead panned so El Paso was located north west of the center of the image. Participants were asked to locate El Paso, Texas, and use the mouse to zoom into the region – matching the initial aerial image extent. Next, participants were shown a series of four aerial images with the initial eye altitude of fourteen kilometers, but without the descriptive labels. For each image, the user was asked to find a specific

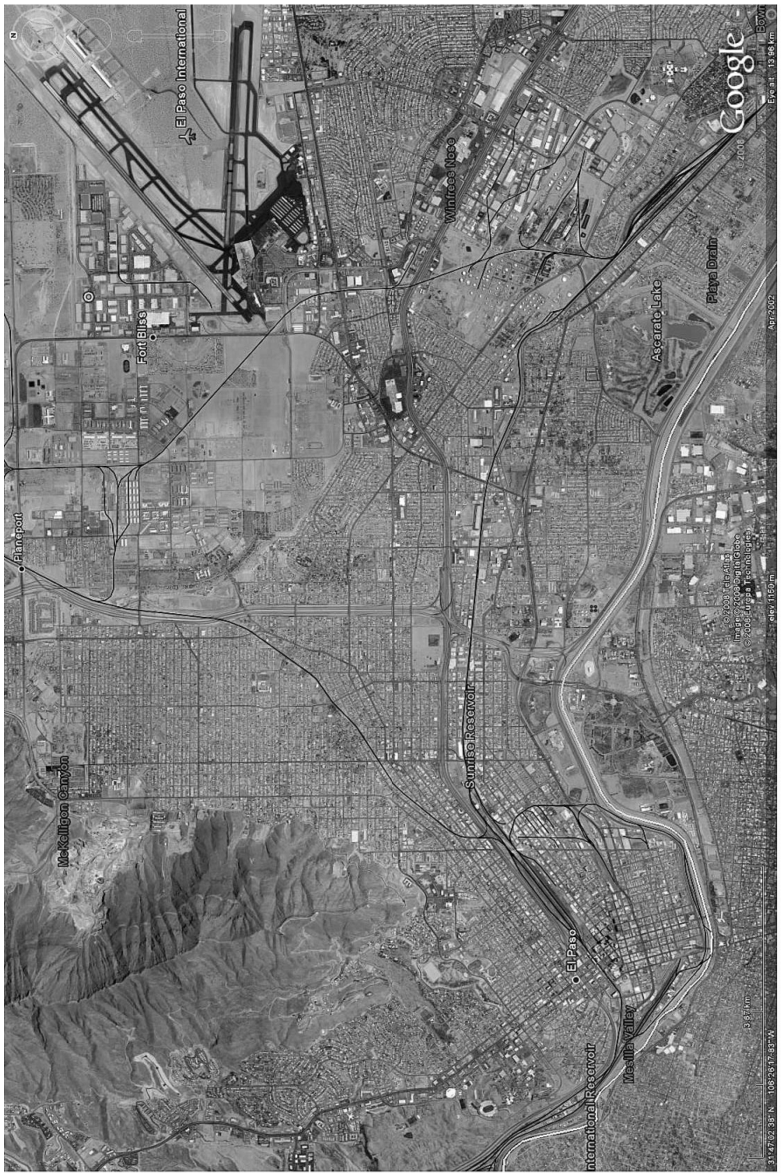

Figure 1: Aerial image of El Paso, Texas

feature: the El Paso International Airport, Ascarate Lake, Franklin Mountains, and the University of Texas at El Paso football stadium. Separate images were used for each localizing task for individual analysis of all four tasks. The features selected for the study were chosen to include two physical features with organic shapes, and two anthropogenic features with geometric shapes: one of each type labeled and one not. To verify that participants had located the feature of interest, they were asked to point to it on the screen.

As a follow up to the eye movement recording session, students went into a different room to participate in a ten minute timed post-test. The post-test included ten questions and required the students to elaborate on aspects of their eye-movement recording session and generate a cognitive sketch map of the El Paso region.

Data analysis

To understand if students' eye-movements correlate with their ability to correctly interpret aerial images, eye fixation counts between students that could and could not locate the assigned landmarks were examined. The eye fixation counts for all four landmarks were examined in this study. El Paso International Airport and Ascarate Lake were labeled in the initial aerial image while Franklin Mountains and the University of Texas at El Paso football stadium were unlabeled. Franklin Mountains were considered a simple location task, since the mountain range represented a large feature in the aerial image and twenty-two (96%) of the students were able to correctly identify this feature even though it was not labeled in the initial image. The airport was correctly identified by 18 students (78%). Fourteen students (61%) determined the location of the lake, while only four students (17%) found the football stadium.

To determine if the eye fixation count was larger in the student population that was unable to identify the assigned landmarks than the students that recognized the landmarks, the non-parametric Mann-Whitney U Test was applied. A larger fixation count suggests a higher degree of difficulty in locating a feature. The Mann-Whitney U Test was chosen even though it is not as powerful at the T-test because of the small sample size and the lack of the normal population needed to run those statistics.

Except for the one participant that did not identify Franklin Mountains, the other three location tasks have eye fixation counts greater than 50% for unsuccessful search tasks compared to successful location tasks (Table 1). The non-parametric Mann-Whitney U Test results show significant differences between successful/unsuccessful search tasks for the El Paso International Airport ($P = .021$) and the Ascarate Lake ($P = .006$). No significant differences were found between successful/unsuccessful search tasks for Franklin Mountains ($P = .291$) and the University of Texas at El Paso football stadium ($P = .542$). The results suggest that if a student correctly remembered a previously labeled object he/she would use less eye fixations than a student that did not. The results show no significant difference in eye fixation counts for locations that were not

Feature to be located	Could locate object n	Could locate object Ave. number of fixations	Could not locate object n	Could not locate object Ave. number of fixations	Mann – Whitney U	P (.025)
El Paso International Airport	18	37.28	5	56	14	0.021
Ascarate Lake	14	18.86	9	34	19.50	0.006
Franklin Mountains	22	18.27	1*	8*	4	0.291
UTEP Football Stadium	4	20.25	19	30.74	30.50	0.542

* Information reported is total data for the one person who could not locate the mountains.

Table 1: Number of students who could and could not locate the object along with average fixation count P (.025) value from the non-parametric Mann-Whitney statistical test.

labeled in the initial aerial image, indicating that the aerial image interpretation task for unlabeled features is more difficult than labeled features for the students even when they are successful. Overall, data analysis results support the hypothesis that students who correctly locate landmarks have a lower eye-fixation count than those students who did not locate the landmarks.

The second aspect of the research was designed to understand if students use edges and internal boundaries to orient themselves in the aerial images. Eye-movements were tracked while students were asked to zoom into El Paso using Google Earth. Out of the 23 students only four participants (15%) were able to complete this task. In order to determine why these students were successful, and what elements of the map they used to orient themselves, only the gaze plots of the four successful students were used for data analysis (Figure 2).

El Paso is situated in a distinctive bend of the borders between Texas, New Mexico, and Mexico. The eye fixation counts were taken before they began to zoom in. The eye fixation counts (2, 3, 6 and 14 fixations per participant), suggest that participants used the international airport as a landmark but did not use the international border, to zoom into El Paso. Of the four students who successfully zoomed into El Paso, two never looked at the international border while the other two had two eye-fixations each on the border (1.016 to 2.015 milliseconds). When comparing the four gaze plots, it is evident that all

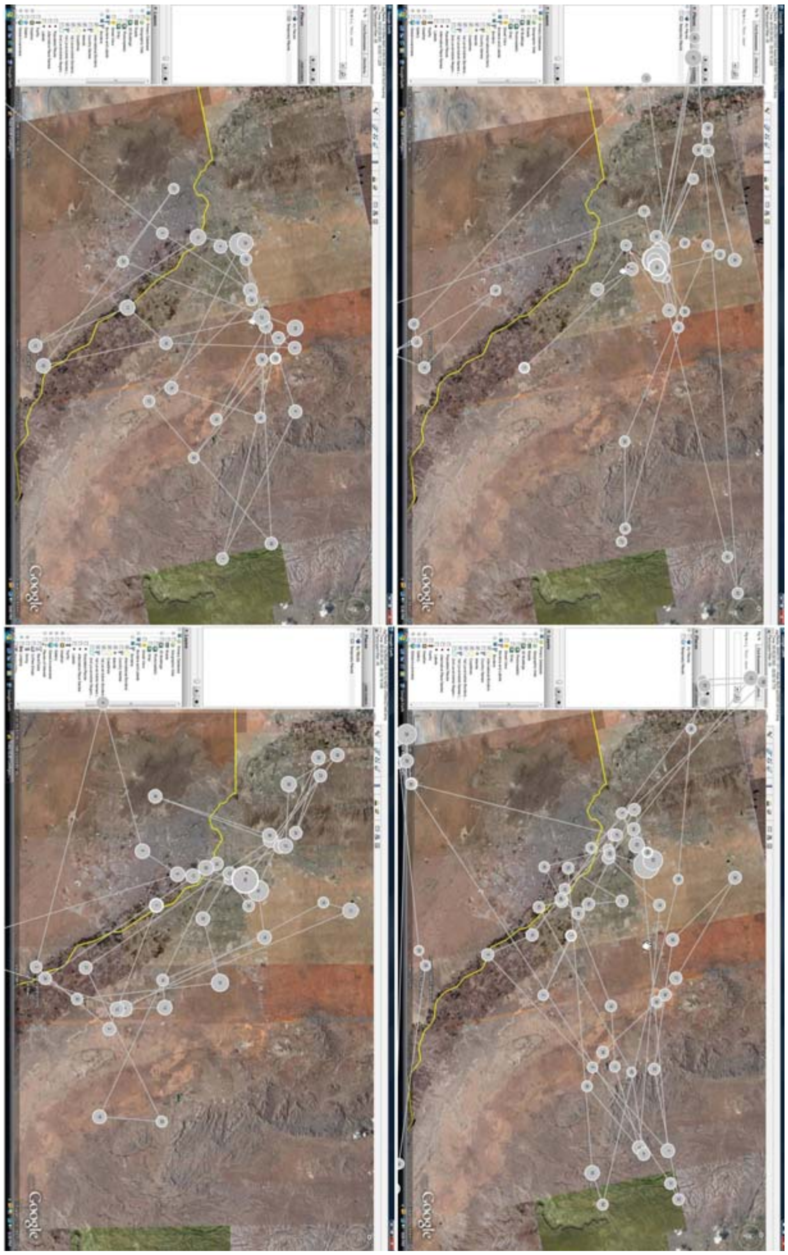

Figure 2: Gaze plots for students who successfully zoomed into El Paso.

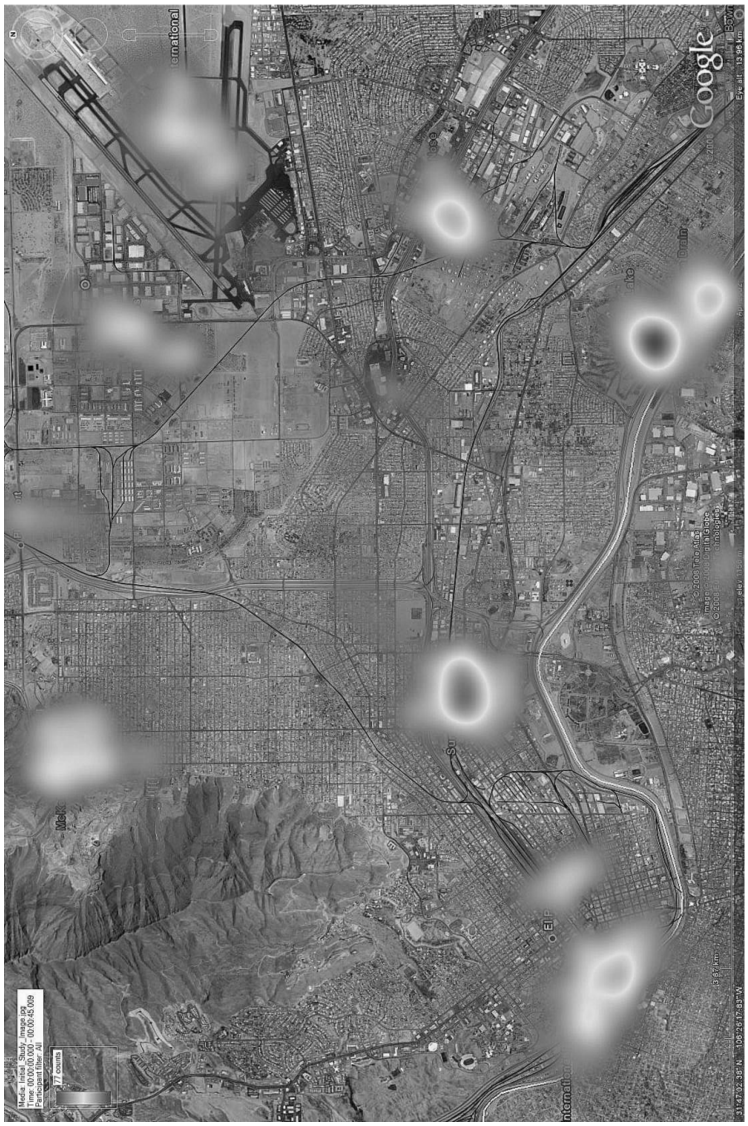

Figure 3: Participants' eye fixations.

four of the students used the international airport as a landmark to guide them when zooming into El Paso, and two of the four students appeared to also use the Franklin Mountains as a landmark. This suggests that when using aerial imagery, students do not use boundaries to orient themselves but instead use easily distinguishable landmarks.

Not only did the students not use the border as a landmark the student generated sketch maps and the post-test questions show that students did not interpret the yellow line as being a border. Only thirteen students (54%) drew the international border on their sketch map. Based on the corresponding question in the post-test, student interpretation of the yellow line was overall incorrect. Google's use of a yellow line for a border may be used for visualization on grayscale image, but it does not follow the map conventions that students are taught. Eleven students (47%) realized that it was a border, state line, or a boundary: only three of which correctly identified that it was the US/Mexico border. The majority of the students (54%) incorrectly interpreted the meaning of the border: one answered it was the Rio Grande River; two others described it as a running body of water or river. While this border is a natural border following the river, that is not what the line represents. Five wrote it was a highway or road, one thought it was a railroad, four said they were not sure what the yellow line was, and three did not remember seeing a yellow line.

Overall, the majority of students seemingly paid more attention to landmark labels, as illustrated in the density map of all of the participants' eye fixations (Figure 3). During the post-test when asked the question, "what did you spend more time looking at, the text or symbols?" students consciously realized that they spend more time reading the text than studying the image and legend symbols. Twenty-two students replied that they spent more time reading the text while only three students said they looked at the symbols more. One student did not recall seeing any text or symbols, and one did not answer the question. From the drawings it was difficult to discern whether students were drawing what they observed, or the features about which they were asked. This finding suggests either that task-specific viewing may have a greater impact on student learning than spontaneous viewing, or that interpretation of the image is difficult, and the students rely on the labels to assist in the task.

Results

This study offers an application of eye-movement analysis in the field of geographic education research. The results of this study focused mostly on eye fixation counts. Analyzing the eye gaze plots provided the researchers with preliminary insights and will aid better understanding of human spatial learning and reasoning with geovisualization, i.e. aerial images, cartographic representations, etc. The insight gained is explained in the following discussion.

The eye gaze plots explain why participants had a difficult time locating the football stadium on the aerial image. The fixation clusters indicate an extensive amount of searching in different areas of the aerial image. During the location task for Ascarate Lake, students exhibited extensive search patterns and many of them incorrectly selected the lake as the football stadium. The reflected green color of the water might have led many participants to the assumption that the green color would represent the green grass of a football stadium: a finding that indicates the need to educate students about aerial image reflectance patterns.

Similar eye-movement patterns were found when participants were asked to find Ascarate Lake. The gaze plots and eye fixation counts indicate that long search times occurred when students were locating the lake. The eye fixation locations clearly identify the lake as a fixation cluster, but additional clusters were identified around other features, suggesting uncertainty in differentiating the water body from other land uses.

The “bee swarm” representation animates the eye gaze paths of all participants allowing the direct visual comparison of eye-movement patterns. In this study the bee swarm patterns indicate a common strategy for searching and scanning: most of the first eye-fixations were on the landmark labels. This finding can also be seen in both the eye fixation density map and some participant remarks during the post-test which stated that they were looking for labels during the four landmark locations tasks. The bee swarm representation also indicates that many participants selected the last landmark identified as a reference point for the subsequent location task. The bee swarm analysis also reveals that students paid little attention to the table of contents, north arrow, and other essential map elements. This could explain the difficulty students had in correctly interpreting the image.

Implications

Patterson (2007) suggests that Google Earth could be used effectively to teach the second National Geography Standard (Geography Education Standards Project 1994) regarding the creation of cognitive maps as a means of organizing information about people, places, and environments by having students consider their perceptions of the world. The development of map and aerial image interpretation skills is an essential aspect of geographic education, and the increasing public accessibility of aerial imagery through web-based mapping applications will change how humans will search, select, and analyze spatial information and make spatial decisions in the future. Open source web-based mapping applications will also strongly influence teaching strategies. This study set out to investigate how eye-movement analysis might facilitate learning about how high school students interpret web-based aerial imagery by examining students’ eye fixations in relationship to correct interpretation and their use of boundaries in orientation.

The findings conclude that the fixation count for students correctly identifying objects is lower than those that could not locate the objects. The fixation location of the counts were concentrated around the labels or the features in the image. Therefore, educators need to be aware of the emphasis students place on reading the labels in the image instead of true interpretation of the imagery. This impacts not only the knowledge students take from a map during spontaneous viewing, but their ability to read imagery that is not labeled as well as transferring those skills to other images. Students are not able to intuitively interpret aerial images and need to be explicitly taught these skills.

The initial research results suggest that students do not use boundaries to orient themselves in web-based aerial imagery. Students seem to remember landmark locations not by image interpretation, but instead by which objects are labeled. This finding has great implications for web-based aerial imagery and map design, since current research results do not clearly indicate whether web-based mapping (i.e. Google Earth) is appropriate for teaching spatial skills in educational settings. It is imperative that follow-up research be conducted, because researchers and educators need to understand how aerial imagery-based spatial learning differs from map-based spatial learning. Educators especially need to be aware of which geography skills are taught and which spatial content is actually learned from these representations, e.g. label-based learning versus landmark-based learning. Future research could investigate how boundaries might aid spatial learning, how colors are interpreted, and how descriptive labels are used by high school students during web-based aerial imagery interpretation.

Applying eye movement analysis to understand how high school students might interpret Google Earth-based aerial imagery introduces a new method into the field of geographic education research. The results presented here showcase that eye-movement analysis might hold the key to a better understanding of spatial learning and spatial reasoning. Future research should continue to investigate spatial learning using eye-movement analysis as part of a mixed method approach to develop a theoretical framework that includes eye movement analysis in geographic education research. It is through such research that educators will develop pedagogical strategies such as the fact that students are unable to intuitively discern what the colors represent in an aerial image, or the differences between physical features such as lakes and urban structures such as a stadium indicating that these skills need to be taught in the classroom. This information also needs to be shared with other fields that use web-based aerial images in their classrooms. Improving the knowledge of how students learn using various geoinformational technologies can improve the geographic education they are receiving in the public schools.

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