Evaluating the Effectiveness of 2D vs. 3D Trailhead Maps

A Map User Study Conducted at Zion National Park, United States

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Abstract

This paper discusses the findings of a comparative user study conducted in Zion National Park, Utah, in September 2006, which tested conventional (2D) and perspective (3D) trail maps in an outdoor setting. The study aimed to answer questions about the effectiveness of both map types for communicating cartographic information, whether hikers are attracted to one map type over the other, and the map preferences of hikers at Zion National Park. The findings revealed that 2D and 3D maps have different strengths and weaknesses for communicating trail information to park visitors. The decision about which map type to use should be made on a case-by-case basis, depending on the steepness of the terrain through which the trail passes, and the hiking experience and demographic characteristics of typical users of the trail.

1. Introduction

Many inexperienced map users have trouble reading 2D topographic maps that typically depict landscape features with contour lines, shaded relief, and height points. To help these users, which comprise a large segment of the general population, cartographers have increasingly turned to 3D perspective maps, which allow users to more easily visualize three-dimensional landscapes. Applications such as Google Earth and the Atlas of Switzerland indicate the growing popularity of 3D maps in recent years. However, as useful as 3D maps are, they are not without problems: compared to 2D maps, they are more time-consuming and expensive to produce; scale diminishes from the front to the back of the map, making distances difficult to judge; and high mountains can obscure adjacent lowland areas and slopes facing away from the reader, depriving the reader of critical information.

Little research presently exists on the effectiveness of 3D maps in general, and less information is available about their effectiveness for hiking, the focus of this study. Most research on the topic relies on surveys of expert users (Häberling, 2003; Petrovič and Mašera, 2006) or students. Small sample sizes and testing conducted in controlled indoor settings are the norm. The research presented here, in contrast, evaluates 2D and 3D maps by gathering data from a large sample of actual hikers at Zion National Park, Utah. The study investigated the trailhead maps that hikers see before setting off on a hike.

The idea for the study originated at International Cartographic Association (ICA), Commission on Mountain Cartography (CMC) workshop at Vall de Núria, Spain in 2004. At that meeting, US National Park Service (NPS) cartographer, Tom Patterson, questioned whether the 3D maps increasingly used by the NPS for trailhead exhibits were worth the extra time and expense to produce—about twice the cost of 2D maps. Patterson presented an outline for a proposed study to investigate the effectiveness of 3D trailhead maps compared to 2D maps. David Schobesberger, then a graduate student at the Institute of Geography and Regional Research, University of Vienna, teamed up with Patterson and expanded and refined the study for his M.A. degree research. Schobesberger was the principal investigator for the study, which took place in September 2006 at Zion National Park.

2. Definition of 2D maps and 3D maps

This article uses the terms 2D maps or conventional maps for maps that depict the surface of Earth from a theoretical vantage point of directly overhead, in an orthogonal projection. Two-dimensional maps have relatively equal scale in the x and y dimensions. From topographic sheets to atlas plates to road maps, the vast majority of maps available today are of the 2D variety.

By comparison, 3D or perspective maps, often called birds-eye views or panoramas, depict the terrain with faux three-dimensionality and contain perspective that diminishes the scale of distant (background) areas. Häberling (2005) defines a 3D map as a "computer-generated perspective view of a three-dimensional geo-data model with cartographic content." German-language cartographic literature usually refers to 3D maps not as maps, but rather as map-related representations (Hake, 2002). Three-dimensional maps are suitable for display on printed brochures, computer monitors, outdoor exhibit panels, and a variety of other two-

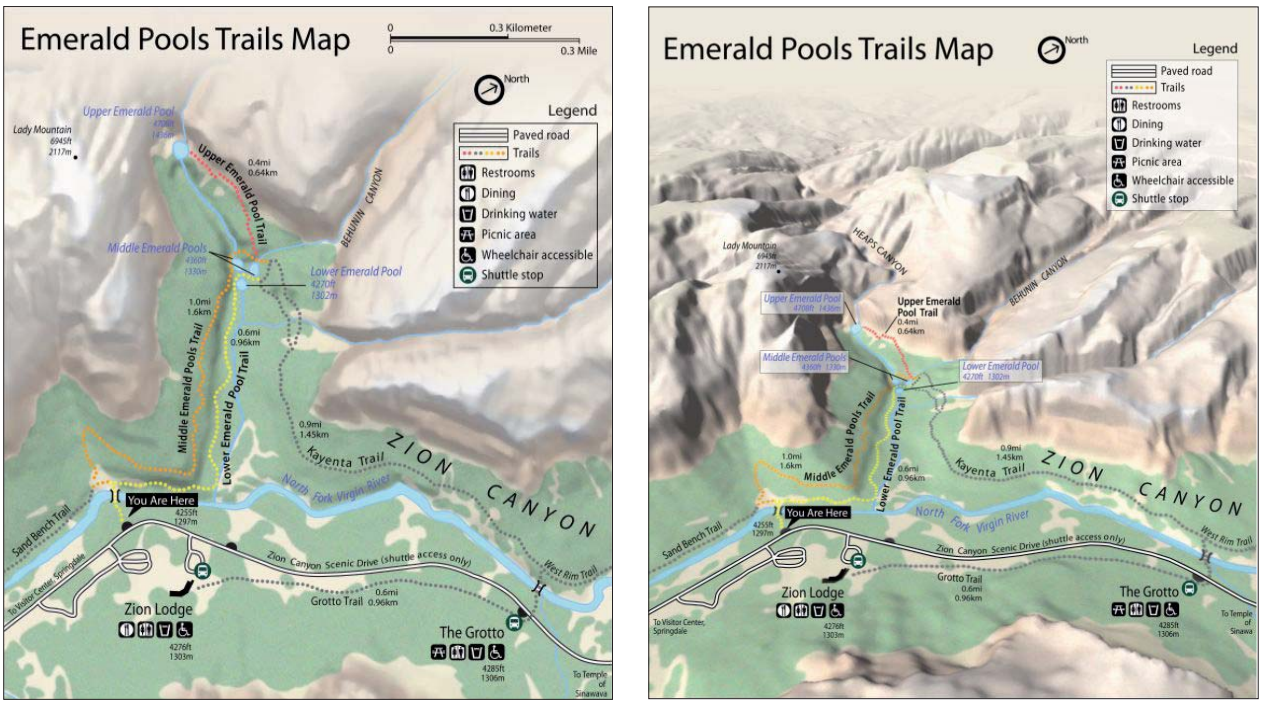

Fig. 1: The 2D map (left) and 3D map (right) of the Emerald Pools trails used for comparative testing.

dimensional media surfaces. Fig. 1 shows the 2D and 3D maps used for comparative evaluation for one of two trails studied at Zion National Park.

The following summarizes the assumed advantages and disadvantages of 3D maps.

Advantages of 3D maps:

- They appeal to readers, especially in informal situations such as when on holiday. For example, the eye-catching 3D maps often used in ski resort advertisements.
- The virtual camera position and viewing direction are customizable.
- Readers can easily visualize and understand elevation differences and topographic features.
- Overlaying thematic or photo-realistic information is possible.

Disadvantages of 3D maps:

- Scale varies from front to back within a scene.
- High topographic features can obscure information in the background.
- Printing of vector lines on 3D terrain is difficult.
- 3D map production requires more time than for 2D maps.
- 3D maps are more expensive to make than 2D maps.
- Successful production depends on a high-quality digital elevation model, which is not always available.
- Specialized software is needed for production.
- Standardized techniques for 3D map production are not familiar to many cartographers.

3. Research goals and study design

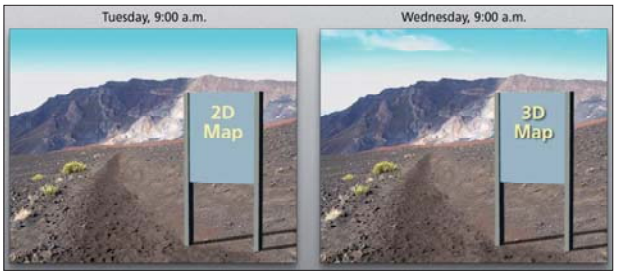

Fig. 2: 2D and 3D trailhead maps with equivalent content and design were displayed for testing on alternating days and under similar conditions. Source: Patterson, 2004.

The goals of the study were to find out the differences in communication efficiency between 2D and 3D maps, which type of map attracted the attention of more people and motivated them to go hiking, and the type of map preferred by park visitors.

The study used two methods for collecting data. Trailhead monitoring: involved mounting either 2D or 3D maps at the trailhead exhibits on alternating days, and monitoring the exhibits from far enough away so as not influence the park visitors' behavior and interaction with the map. The principal investigator noted hiker characteristics and the time that they spent interacting with the maps.

Questionnaires: the principal investigator conducted hiker interviews at midway point along the studied trails, noting the respondents' answers on standardized forms. The questionnaire had four parts:

1) Background information – Collected data included age, gender, whether hiking with a group or solo, hiking experience, native language, and whether they are left or right handed. The respondents were also asked if they had hiked the trail before or were carrying maps or any devices for orientation, to control for bias.

2) Trailhead map interaction – Respondents estimated their time spent reading the trailhead map, rated the map for graphic design and legibility, and rated how well the map on display matched the actual landscape seen from the trail.

3) Cartographic communication – Relying on mental maps formed at the trailhead, respondents were asked to recall basic geographic information presented on the maps.

4) Orientation and direct preferences – Respondents indicated as best they could their present position on a copy of the map that they saw at the trailhead exhibit. The principal investigator afterwards measured the difference between their estimated position and their actual position. For the last task a copy of both map types was handed to the respondents and they were asked to compare both and tell their preferences.

Fig. 2 demonstrates the testing methodology of using alternating 2D and 3D trailhead maps. A more detailed description of study methodology including the full questionnaires is available in the final report submitted to the NPS (Schobesberger, 2007).

4. Zion National Park study site

The research took place from September 4 to 21, 2006, at Zion National Park, Utah. With more than 390 parks in the NPS system to choose from, selecting the appropriate park and trails to study was a difficult decision. Zion National Park offered many advantages as an ideal study venue.

Topography was a top consideration. At Zion the dramatic landscape was conducive to making 3D maps with unambiguous three-dimensionality, a necessity for comparative testing with flat 2D maps. Zion is a park renowned for its hiking trails, and it offered two suitable trails for testing, one easy and the other moderately strenuous. Both trails attracted ample numbers of hikers needed for the study, but they were not overcrowded. In addition, the trailhead exhibits at these trails were well situated for unobtrusive monitoring of hikers as they read the maps. The park with its shuttle bus system, very supportive park staff and the consistent good weather in September was also ideal concerning logistical issues.

5. Characteristics of study population

A total of 208 people were asked to participate in the questionnaire. Twenty people refused to take the survey resulting in a final response rate of about 90%. By comparison, a wilderness experience study conducted in the remote backcountry of Zion National Park in 2002 had a response rate of 80%.

Of the 185 valid questionnaires, 100 were collected on the easy trail popular with less experienced hikers, and 85 on the strenuous trail that attracted more experienced hikers. Male respondents outnumbered females on both trails 61% to 39%. The study excluded children under the age of 15. Because the study occurred in mid September when school was in session, it includes relatively few young people (15-25 years). Most questionnaire respondents were between the ages of 26 and 60.

During the trailhead monitoring sessions that took place at the easier of the two trails, a total of 827 people walked within close range of the trailhead exhibit. Of these, 46% were females, 43% were males, and 11% were children (gender not noted). Most of the hikers traveled in pairs (49%), followed by an assortment of groups (27%) and families (17%).

6. Study findings

The principal investigator analyzed the gathered data with SPSS statistics software. The large sample sizes collected during the study yielded many correlations significant at the 1% level of certainty, determined with the chi-square test. The following is a brief description of the main findings.

6.1. Map preference

Questionnaire respondents looked at a 2D and 3D map of the trail they were on and indicated which they preferred. Counting all respondents on both trails, a clear preference did not emerge: 48% declared that the 3D map was their favorite and 47% favored the 2D map.

However, the questionnaire revealed significant correlations based on gender, age, handedness, English as native language, and whether a respondent had looked at the trailhead map before going on the hike. Three-dimensional maps were clearly preferred by the 26-40 age group. The other age groups had more balanced preferences, leaning slightly toward the 2D maps.

Females preferred 3D maps (52%) over 2D maps (44%). With males the preference was the opposite: 50% preferred 2D maps, whereas 46% preferred 3D maps. Considering the preponderance of male respondents (113) to females (72), the overall preference with equal gender rates should tend stronger for 3D maps. Respondents who were not native English speakers preferred 3D maps (52%) over 2D maps (42%).

A small but significant correlation exists between handedness (left-handed vs. right-handed people) and map preference. For the left-handed respondents, 45% prefer 3D maps, 40% prefer 2D maps and 15% were undecided.

An unexpected correlation exists between map type preference and whether respondents looked at the trailhead map before setting off on their hike (Fig. 3). Respondents, who passed the trailhead without looking at the map, preferred 2D maps (55%) over 3D maps (41%). Those who looked

at the map preferred 3D maps (53%) over 2D maps (43%). The reasons for this correlation are not known. The fact that visitors who actually read trailhead maps prefer the 3D versions, suggests the need for more 3D maps.

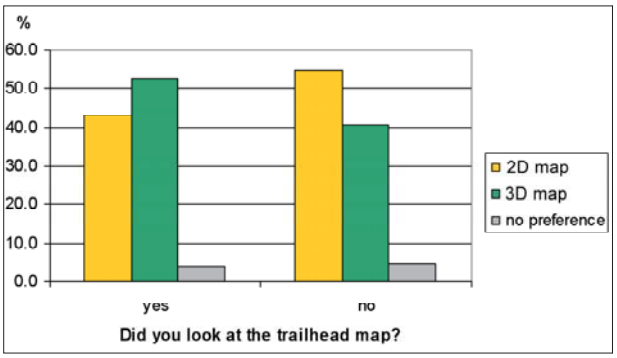

Fig. 3: Map type preference based on whether a respondent looked at the trailhead map.

6.2. Cartographic communication

The questionnaire investigated whether 2D maps or 3D maps better communicate relevant trail information to hikers, based on the mental maps they formed at the trailhead. To statistically analyze these data, the principal investigator converted the answers given by respondents to a point system. Of 20.75 possible points that a respondent could tally, the average was 6.14 points for 3D maps and 5.79 points for 2D maps. However, the correlation was not significant at the 5 percent level.

Looking at the distribution of points for different communication tasks reveals only small variations. 3D maps are slightly better for communicating distances, a general overview of topography, and environment, whereas 2D maps are slightly better for communicating names.

Conclusion: Both map types are equally well suited for communicating spatial information. The decision on which map type to place at a trailhead, is not a matter of communication efficiency, but of other criteria such as user preferences, age, or the gender of prospective readers.

6.3. Positioning accuracy

The questionnaire ended by asking respondents to mark their present location on the trail on a paper print of the same map type that they observed at the trailhead. There were significant differences in positioning accuracy between the 2D and 3D maps.

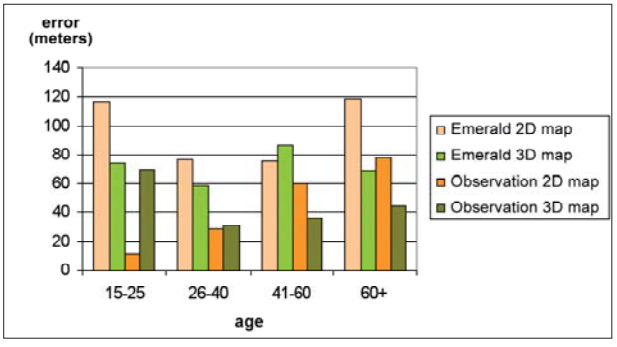

Fig. 4: Average position error normalized by trail length by age groups.

In general, hikers identified their positions more accurately with the 3D maps than with the 2D maps. Fig. 4 shows the average position error by trail, map type, and age group. Nearly all groups show a smaller positioning error with the 3D maps. This is especially true for older people (over the age of 60) and females. Paradoxically, despite this advantage, when asked which map type they prefer, respondents over the age of 60 strongly indicated 2D maps.

6.4. Map attraction

This part of the user study investigated which map type was more successful at attracting and holding the attention of hikers as they passed within viewing distance of a trailhead exhibit.

Monitoring at the trailhead revealed that when the 3D map was on display, 50 percent of hikers viewed the map and 50 percent passed by without looking at it. When the 2D map was on display, 45% looked at the trailhead exhibit and 55% did not. Although the 3D map was more successful at attracting the attention of hikers, the fact that 50 percent of hikers did not look at it is not an encouraging statistic.

6.5. Summary of key findings

- 3D maps enable hikers to more accurately identify their position on the landscape compared to 2D maps, especially for older people (over 60 years of age) and women.
- Hikers who looked at the trailhead exhibits prefer 3D maps (53%) over 2D maps (43%). Those who did not look at the trailhead exhibit prefer 2D maps.
- Older respondents, men, and native English speakers generally prefer 2D maps.
- Younger respondents, women, and non-native English speakers generally prefer 3D maps. Left-handed individuals prefer 3D maps.
- Less experienced hikers on the Emerald Pools trails rated the 2D map easier to read. More experienced hikers on the Observation Point Trail rated the 3D map easier to read.
- 3D maps were rated as more accurate by experienced hikers on the Observation Point Trail than by inexperienced hikers on the Emerald Pools Trail.
- Respondents on both trails generally agreed that 3D maps depict reality better.
- The two map types revealed slightly differing strengths for cartographic communication. Readers of 3D maps had a better understanding of distances, topography, and environment. Readers of 2D maps could better recall place names.

- 3D maps attract more trailhead readers than do 2D maps.

- At the trailhead, 3D maps are on average viewed for a few seconds longer than 2D maps.

For more information please refer to the final report for the NPS (www.nps.gov/hfc/carto/zion_map_study.pdf).

7. Outlook

Although the study revealed interesting correlations about map users and the effectiveness of 2D and 3D trailhead maps at a national park in the US, the findings are not necessarily valid internationally. The existence of large differences in map preferences between native English speakers and those who are not, suggest that a similar user study conducted elsewhere in the world would yield different results. A need exists for comparative evaluation of 2D and 3D trail maps in other countries, along with testing for different communication goals and map content besides trail information.

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