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What path and how fast? The effect of flight time and path on user spatial understanding in map tour animations

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GI Science scholars have identified map tours as an important visualization type for communicating spatial information: map tours are animations where the virtual camera moves through space and are common on the web, mobile devices and television. Understanding how to enhance their effectiveness is timely because of recent, growing interest in virtual reality and animated map presentation tools such as Esri Story Maps^{TM} and Google Earth^{TM} tours. Despite this popularity, little empirical evidence exists about how people learn from map tours and how they should best be designed to improve effectiveness. This research is aimed at answering that need. An empirical study is described, which was designed to understand how virtual camera speed, path and dynamic tilting within a map tour influence subjects' ability to develop survey knowledge. The results of the experiment show that: paths encompassing overviews of the landscape improve the viewer's ability to build up survey knowledge; that tilting appears to have a much weaker effect; and that combining fast speed and a difficult path within a map tour increases the viewer's cognitive load.

Esri story map^{TM}; Google Earth^{TM} tour; empirical study; survey knowledge; zoom and pan.

Introduction

'Map tour' is the term used in this paper to describe widely available map or virtual globe animations where the virtual camera moves through space in order to deliver a narrative (Lobben, 2003; Diabase et al., 1992), they are largely passive with the user simply watching the animation. National Geographic has used them on the web to enhance spatially rich stories, they have found that map tours encourage most users to engage for longer with content when compared to a comparable interactive map resource (Yarnall, 2016, 18.40 minutes).

There has been a rapid growth of map tours in current GIScience so that they now form the outputs of many geospatial visualizations such as Bogdos and Manolakos (2013); Matsuoka, Vu and Yamazaki (2005); and Treinish and Rothfusz (1997). In the more mainstream media, the realism that map tours can bring in representing spatial data, and the way that a general audience can understand them, means that they are a commonly used format on the web and TV. Examples include: illustrating landscapes with dramatic topography such as the Grand Canyon (NASA, NPS, USGS, 2007); the daily BBC weather forecast (BBC, 2015); in museums (Priestnall and Cowton, 2009); and as short animations on mobile devices such as flyover mode in Apple™ Maps, a service that illustrates tourist destinations in realistic 3-D. Many technical developments are responsible for this widespread use; especially software that appeared during the period 1990 to 2010, which made map tour creation straightforward. Example software platforms were: virtual globes, such as Google Earth™ or NASA World Wind™; and GIS with 3-D capabilities such as Esri 3-D Analyst™ and ArcScene™.

***Figure 1 about here

Map tours have advantages when meeting specific cartographic communication needs; two are considered especially powerful. The first type is 'realism' map tours: to engender a sense of immersion and realism in a study area with significant relief, the base map imagery should be as realistic as possible. Harrower and Sheesley (2005) investigated these realistic map tours (left column, Figure 1). This map tour type can be engaging and may contribute towards generating some sort of affective response, which enhances the impact of the visualization and its effectiveness (Bishop et al., 2013). Turning to the second type: 'symbolized' map tours are where the standard techniques of cartographic classification, generalization and symbolization have been applied (right column, Figure 1). There is empirical evidence that in a symbolized map tour using a vertical camera field of view (FOV), acquisition of survey knowledge is improved, such as the location of a landmark within a street map (Midtbø and Nordvik, 2007). These two types of map tour are similar to the distinction identified by MacEachren and Kraak (1997), who classify the purposes of low interactivity 'presentation' output as being either: realistic and designed to produce an affective response or symbolized and designed to support cognitive processing.

Turning to consider virtual reality (VR), all the map tour examples discussed so far are designed for desktop or mobile devices, however, the development of VR hardware promises to offer a more immersive experience. This includes functionality such as a 180 degree FOV and headsets that detect and render the direction of view. Recently there has been a paradigm shift in the use of VR with the introduction of powerful, affordable systems such as Google Cardboard™ (Powell, Powell, Brown, Cook, & Uddin, 2016). VR content with similarities to map tours is appearing; an example is a 360 video of an abseiling trip into a glacier with a controllable FOV (Digital Explorer, 2016). VR for geovisualization has been a topic of interest to scholars since the 1990s (e.g. Bodum, 2005; DiBiase et al., 1992; Fisher and Unwin, 2003) but the power of the technology during this previous period to produce an immersive experience (referring to the technical experience, not the emotional response) is low compared with the affordable systems appearing today. It is considered too early in the current resurgence of VR to discuss the technologies concerned more fully but it is important to note that VR could become a widely used format for map tours.

Despite the extensive use of map tours outlined in the previous paragraphs of this paper, there has been a lack of empirical research investigating their effectiveness. There are many research questions to be answered such as: what 3-D spline should the virtual camera follow to help the user learn the spatial relationships of the landscape below? How fast can the camera move and not reduce the viewer's ability to become disoriented? A review of the strengths and weaknesses of map tours has been attempted by Harrower and Sheesley (2005) and for animated maps in general by Harrower (2007). The main aim of this paper is not to update this work but to identify key characteristics of map tours and investigate them empirically. The specific hypotheses tested refer to 'survey knowledge' which broadly equates to spatial knowledge and is unpacked in a later section of the paper. They are as follows:

(1) *Overview hypothesis*: Subjects viewing a map tour that includes a FOV encompassing the entire study area will build better survey knowledge than one with no such overview.

(2) *Tilt hypothesis*: Survey knowledge is easier to acquire when viewing a map tour where the camera does not change tilt angle during the tour.

(3) *Time hypothesis:* Subjects viewing a fast map tour gain less survey knowledge than those watching a slow one.

The rest of the paper begins with an exploration of the previous research relevant to map tours before a conceptual framework for the experiment is described including a preliminary typology of map tours. In the methods section a human subject experiment using Google Earth™ is described to test the three hypotheses. This is followed by a results section, which relates the ability to gain survey knowledge to the map tour conditions. Finally the paper ends with discussion and conclusions.

Previous work

Previous user experiments on map tours have investigated the use of navigational aids in realistic landscape map tours (Harrower and Sheesley, 2007) and the advantages of a map tour over a non-animated alternative (Midtbø and Nordvik, 2007). Harrower and

Sheesley (2007) found that various navigational aids (a map grid; a graphic rendering of the spline on screen; and an azimuth indicator) all assisted users remaining oriented during a map tour while landmark labels increased disorientation. Midtbø and Nordvik (2007) investigated a simple 'zoom-in' map tour, comparing it to a more stepped, non-animated alternative. They found that it was easier for subjects to follow landmarks in the animated version.

One map tour characteristic investigated in this paper is virtual camera speed. Bederson and Boltman (1999) advocate an animation speed of one second for map tour type animations in an information space, such as virtual camera motions around a family tree graphic based on pilot studies for their main study. This translates to twice the speed of the fastest speed condition in the current experiment. However, the links between this work and the current experiment are not strong since Bederson and Bolman dealt with a spatially abstract environment rather than a map or landscape. A map or landscape is much more visually detailed than an information space with a greater data density and also because that data has not been symbolized.

Another characteristic studied in this paper is the 3-D path spline (hereafter, spline) that the virtual camera follows. Ahmed and Eades (2005) advocate a spline with camera angles that ensure that the path origin and path terminus are in view at all times but do not perform user testing. A similar spline is suggested by Priestnall and Cowton (2009), they propose keeping 'visual anchors' in view during virtual camera motion to help with spatial orientation. A series of HCI (Human Computer Interaction) studies have been completed on defining the best spline in a map tour, for example: Furnas and Bederson (1995); and Van Wijk and Nuij (2003). Both studies propose an optimal spline between different viewpoints as one that zooms out to an overview of the study area. However, they both fail to investigate this assertion beyond informal user testing. In contrast, Wu, Zhang, and Zhang (2009) did use a formal test to compare map tours with other way-finding aids but their findings are also limited in use; their testing did not compare different map tour conditions.

Map tours are a format defined by low user interaction with the 3-D environment (Harrower and Sheesley, 2005; Roth, 2013, p61), which is due to the limited controls available: users can only play, pause and rewind the animation. This would appear to be a problem with the format as lack of interaction can cause passivity which can impede users acquiring survey knowledge (Parush, Ahuvia and Erev 2007). However, the six possible degrees of freedom in a 3-D environment can create difficulties for users (Hughes and Lewis 2002; Chittaro and Burigat 2004), which can lead to the users becoming lost and disoriented (Darken and Sibert 1996a). The low interactivity of map tours can therefore be a solution to this issue by removing some freedom of movement. It is believed that this characteristic goes some way to explain the effectiveness of National Geographic's map tours (Yarnall, 2016, 18.40 minutes).

The 'limited capacity assumption' (Baddeley, 1999), is relevant to the discussion of the map tour in the experiment. It assumes that there is a limited amount of information that can be absorbed by users' auditory or visual systems. Since the experiment does not include audio, the assumption applies only to the visual system. The hypotheses propose that certain characteristics of map tours make gaining survey knowledge more difficult, for example: tilting the FOV or a fast virtual camera motion. The limited capacity assumption suggests that such characteristics add together to decrease the subjects' overall ability to acquire survey knowledge.

Conceptual framework and experimental design

A conceptual framework for the experiment is necessary in order to justify the experimental design. An important consideration is the type of map tour, the split between symbolized and realistic map tours has already been discussed and deserves unpacking: the degree of realistic rendering in a map tour, versus a more symbolized cartographic environment, is a key characteristic (MacEachren et al. 1999; Harrower and Sheesley 2005). Both studies argue that, as with traditional cartography, realism in a map tour may be cognitively inefficient if the purpose of the map tour is to convey spatial information. MacEachren et al. go on to make the point that if a user is viewing a near realistic rendering they may feel immersed in the landscape and experience a sense of place. Harrower and Sheesley (2005) argue that in a realistic map tour the viewer may become both visually saturated and unsure of where to look due to a lack of hierarchy and symbolization. They also note that map tours (up to 2005) tended towards realism despite the well-accepted values of symbolism, hierarchy and other cartographic advantages possible in a symbolized map environment.

The second dimension is a scale between oblique views over a 2.5-D landscape and vertical camera views over a 2-D landscape. Harrower and Sheesley (2007) experiment on the former type, Midtbø and Norvik (2007) on the latter. The term '2.5-D' is used in the sense that the user is not taken below the ground surface or into an enclosed area such as a cave or room.

The experimental map tours had important characteristics that can be used to classify them: The base map was aerial photography; two of the three path conditions use a vertical camera angle; and the third path condition used an oblique camera angle. This classifies it mainly as 'realistic with vertical camera' (bottom left, Figure 1) with some testing of the 'realistic with oblique camera' (top left, Figure 1). Choosing realistic imagery was based on two main reasons: firstly, there are a wealth of examples of this type of map tour (examples include: Bogdos and Manolakos, 2013; Harrower and Sheesley, 2007; Matsuoka, Vu and Yamazaki, 2005; NPS, 2007; Priestnall and Cowton, 2009). Secondly, it was thought that the realistic imagery would be more cognitively demanding for the subjects, which would increase the likelihood of the experiment producing significant results. The bias towards testing vertical camera views rather than the oblique ones follows the suggestion by Treves and Bailey (2012) that the virtual camera in map tours should not use an oblique angle unless there is a compelling reason to do so.

Having justified the types of map tour used in the experiment the discussion can turn to consider the characteristics of the experiment. In this paper a map tour is defined as a narrative made up of a virtual camera moving through three-dimensional space over an underlying 2 or 2.5-D landscape. This is in line with previous human subject experiments on map tours (Harrower and Sheesley, 2007; Midtbø and Nordvik, 2007; Wu, Zhang and Zhang, 2009). Map tours can be based in a 'spatially abstract' environment (MacEachren et al. 1999) such as around a family tree graphic, where the environment space does not correspond to real space. Consideration of this type of map tour animations is beyond the scope of this paper.

The conceptual framework has cognitive aspects, which are defined by previous studies of map knowledge acquisition. The discussion now turns to consider how these can inform us of how it is gained within a map tour. Arguably, the most influential discussion is Siegel and White (1975) who proposed the landmark/route/survey knowledge framework. In this model, users encountering a novel environment such as an unfamiliar city firstly gain knowledge of landmark locations. They then learn routes in the environment between landmarks, this knowledge allows them to navigate adequately but they find it difficult to accurately predict directions of landmarks from within the environment. To achieve this they must gain the final type of spatial understanding: 'survey knowledge' which is the mental equivalent of being able to query a spatial map.

This model was extended by Thorndyke and Hayes-Roth (1982) who showed that if a user studies a map of an environment, (s)he can gain survey knowledge directly without gaining landmark and route knowledge first. This leads to an underpinning hypothesis of this paper: that the multiple fields of view visible in a map tour means it has more in common with the process of studying a map than the normal human spatial knowledge gained from walking around an environment. It follows that users directly gain survey knowledge in a map tour without needing to gain route knowledge. However, there are several ways studying a map could be significantly different, for example: the subjects' view in a map tour is constrained to the FOV of the virtual camera, which mostly is restricted to a subsection of the study area whereas in a map, the whole study area can be viewed.

Studies on users in 2.5-D environments have revealed how important it is, in terms of developing survey knowledge, to retain a sense of orientation and to have a network of clear landmarks within the FOV. When users are given a map with one orientation, and asked to solve a problem in a 2.5-D environment, they do much better when their orientation in the environment is aligned with the map (Levine et al. 1984; Richardson, Montello, and Hegarty, 1999). This is a possible confounding effect on the current study, so in the experiment north was consistently maintained as being towards the top of the screen. Having clear landmarks, or environmental augmentations such as grid overlays, also assists users performing unconstrained searches in 2.5-D environments (Darken and Sibert, 1996a; Darken and Sibert, 1996b; Steck and Mallot, 2000) and also in map tours (Harrower and Sheesley, 2007). In the current experiment the environment was a rural network of fields, roads and buildings providing a visual basis for building a cognitive network of landmarks. Grids or other cartographic annotations to assist the natural landmarks were not used. This design aimed to produce a moderate cognitive load: the reasoning was that if grids were added, the task would be too easy and the experimental variation would be small. On the other hand, if landmarks were too difficult to locate then the experiment would have run the risk of measuring subjects' abilities to search for landmarks rather than effects due to variation of map tour design.

It is important to critically identify the choice of virtual camera motion in the experiment and explain virtual camera characteristics. As with a number of studies (Ahmed and Eades, 2005; Van Wijk and Nuij, 2003; Wu et al., 2009) the experimental spline consisted of a simple path between two low altitude points with camera azimuth and declination angles chosen to represent significant fields of view including a high point with a wide FOV. The camera was kept vertically downwards except in the tilted experimental condition. This vertical camera orientation is the approach taken by Van Van Wijk and Nuij (2003) and Midtbø and Nordvik (2007) whereas Ahmed and Eades (2005) suggest a dynamically changing camera angle in their consideration of camera paths. Given that neither the effect of speed nor spline in map tours have previously been tested experimentally, the simple, fixed, vertical camera orientation was chosen as a good initial approach. Further camera path descriptions and justifications are made in the methods section.

Methods

Written descriptions of the dynamic camera motions in this section are necessarily complex, so the reader is encouraged to view video recordings illustrating the explanations (Treves, 2016). Within this section and beyond, 'spline' is used to describe the 3-D path spline through space; 'path' includes the spline but also refers to the camera orientation and acceleration of the camera along the spline.

Firstly, all subjects were read a script describing the experiment and shown a map tour to illustrate the procedure. The spline of the virtual camera through the basic experimental map tour is illustrated in Figure 2.

***Figure 2 here

The experimental sequence was as follows:

(1) A screen recorder was turned on.

(2) The map tour started at position 1 with markers A and B visible. The virtual camera paused for 0.5 seconds.

(3) Flew to position 2 in two seconds.

(4) Flew to position 3 in two seconds and then paused for 0.5 seconds.

(5) Markers A and B were removed from the FOV and the camera was teleported to position 4. This location was offset from the centre of the 2-D path joining A and B to deter subjects using that information to position markers. The subject then clicked on screen to mark where they believed A and B were in the landscape.

(6) The virtual camera was teleported to a new site and the test restarted at step 2.

(7) When 18 tests per subject were complete, the screen recorder was turned off and the subject was asked a series of open questions.

To estimate their survey knowledge, the distance between the subject's guesses and the true position of the markers in meters was calculated for both markers.

The virtual sites used in the experiment were all located in County Longford, Ireland. Figure 3 illustrates how the markers A and B appeared on screen in the experiment as labelled circles filled yellow and purple respectively.

***Figure 3 here

County Longford was chosen as the landscape is similar to rural UK and would therefore be a familiar type of landscape to students at a university in the UK but with a low chance of them being familiar with the specific area. The study area has subdued topography so the landscape can be considered 2-D. Marker locations were chosen within each site that met the following criteria:

- Distant from strong landmarks (such as large road junctions) and not coincident with line intersections such as the junctions of hedges.
- The distance A to B varied within the range 691 to 1053m to prevent distance being used to predict marker location by subjects
- The azimuth between A and B varied between sites

To test the overview and tilting hypotheses three separate flight path conditions were produced: low, high and tilted paths illustrated by Figure 4.

***Figure 4 here

In the low path (top of Figure 4) the camera altitude remains low and both markers A and B are out of view at point [2] whilst speed of movement across the terrain remains constant. In the high path (middle of Figure 4) both A and B markers are visible at intermediate point 2 and the markers persist within the FOV (A on the ascendant segment, B on the descendant). In addition, the camera speed is not constant; it 'eases out', with a deceleration as it approaches point [2] achieved using the bounce feature of Google Earth™ tours (Google, 2016). This increases the time the camera spends close to the vertex of the map tour. The tilted path (bottom left and right Figure 4) is the same as the high path except the camera is offset and tilted from the vertical at points [1] and [3]. The view target is the same as with the high path: the marker is in the centre of the screen. However, the 2-D path route (the spline projected onto the ground surface) is offset at the origin and terminus of the map tour (bottom left section of Figure 4). A key characteristic of this path is that the camera is panning, zooming and tilting through the map tour, in the other path conditions the camera is only panning and zooming. Key characteristics of the three flight path conditions are summarized in Table 1.

***Table 1 here

There were three time conditions used in the experiment: 2s, 4s and 6s. They refer to the flight time between positions [1] and [2] (Figure 4) and also between [2] and [3]. Three staff members from the school of Geography and Environment at Southampton University were shown sample map tours at different speeds and asked which they preferred. All three selected the 4s flight time which was then set as the middle of the three speed conditions.

Within the experiment, the three flight path conditions (low, high and tilted) were combined with flight time conditions (2s, 4s and 6s) to produce nine possible types of map tour. Each subject viewed the nine types of map tour twice, viewing eighteen separate map tour locations. In order to correct for unwanted learning effects and other confounding factors, the experimental conditions and sites were mixed and randomized.

The map tours were delivered by using Google Earth^{TM} tours on a 1440 x 900 screen. To process the results, recorded clicks were converted into latitude and longitude pairs by reading off the figures at the bottom of the screen via the screen recorder.

There were 31 user subjects who were undergraduate and postgraduate students aged 18 to 24 who were studying spatially literate subjects at Southampton University (engineering, geography, environmental science and geology). They were made up of 14 males and 17 females and were each given a ten-pound book token for taking the test. Within the test, the recording software malfunctioned for two user subjects so their data was not included. Also, there were nine occasions where data for one of the sites had to be rejected because of operational problems.

For the statistical analysis a within subjects (or repeated measures) ANOVA was used as all subjects participated in all experimental conditions. Greenhouse-Geisser corrected degrees of freedom were used in ANOVA when Mauchly's test indicated that the assumption of sphericity had been violated and an alpha level of $\alpha=0.05$ was used. Pairwise comparisons were Bonferroni corrected. Paired t-tests were also used to compare differences within groups and only p values, $p< 0.01$, were regarded as statistically significant.

Results

First the effect of the flight path conditions (hereafter, path) in locating markers A and B was tested, without considering the time conditions (Table 2). We found that there was a significant effect of path in locating marker A and marker B.

*** Table 2 here

***Table 3 here

We also investigated the main effect of path, time and the interaction of path by time in the accuracy of locating markers A and B (Table 3: path by time for marker A). A significant main effect of path, time, and path by time in locating marker A was found, indicating that the effect of time differs by path when locating marker A. With respect to marker B, a significant main effect of the path in the accuracy of locating marker B was found but there was not any significant effect of the time and path by time.

***Table 4 here

To further explore the interaction between path and time, the effect of path on locating each of markers A and B was investigated separately for each of the 2s, 4s and 6s time conditions (Table 4). With respect to marker A, the path condition had a significant effect in all time conditions. A significant effect was found between: low and high; and between low and tilted path conditions in all time conditions (i.e. 2s, 4s and 6s). With respect to marker B, the path had a significant effect only in the 4s and in the 6s time conditions.

Figure 5 shows the effect sizes (average distance from the maker) and 95% confidence intervals. Time in the low path condition has a large effect with the 2s condition clearly under performing the 4s and 6s conditions, the corresponding *t*-tests of: low combined with 2s time (low with 2s) versus low with 4s; and low with 2s versus low with 6s are significant. They also have an effect direction which the time hypothesis predicts.

***Figure 5 here

It is interesting to note that the Low_2s condition for marker A is the most difficult combination of conditions/markers and produces the largest subject estimate error in Figure 5.

Discussion

The experiment was designed to test the effect of virtual camera path and speed on the survey knowledge. Subjects gained this knowledge by relating markers A and B to a network of landmarks visible in the map tours that took place in Google Earth^{TM}. The experiment was designed to dissuade subjects from using other techniques to complete the experimental task.

The subjects of the experiment were from spatially literate subjects at a British University. They are therefore arguably more skilled at interpreting map like representations such as the landscape used in the experiment than the average map viewer. Further research could usefully be performed on groups of less spatially literate subjects to confirm the findings apply to common users of the Map Tour examples quoted in the introduction.

The results show that there was greater evidence for both time and path effects for marker A than for marker B. The most likely explanation of this effect is that marker B was in the camera FOV just before the teleport move to the high point at the end of the map tour. Remembering the position of B in the landscape was arguably less cognitively demanding for the subject than positioning marker A in the landscape, as this marker had been out of sight for between 2.5 and 6.5 seconds prior to the teleport move.

The overview hypothesis stated that if a FOV occurrs within the map tour where both markers were in view at the same time (referred to hereafter as 'apex'), this would aid subjects to build survey knowledge. The effect of path was significant overall and there was a significant difference between pairwise comparisons of high (apex) and low path (no apex) for both markers A and B. Therefore we can consider the overview hypothesis to be proven.

The tilt hypothesis stated that if the camera is tilted dynamically out of the vertical during a map tour then subjects would find it more difficult to build survey knowledge. The results show mixed evidence, the tilt hypothesis is therefore considered not proven but there is indicative evidence that makes it worthy of further investigation.

The proof of the overview but not the tilt hypotheses suggests that a key characteristic of a map tour is the inclusion of the apex. This is because the major difference between the high and low paths was the inclusion of the apex view, whilst both high and tilted paths include an apex view. Harrower and Sheesley (2005) propose that including a dynamic, 2-D, overview map alongside the main map tour view, would help solve the problems of disorientation in map tours. It would seem that supplying an apex view in a map tour improves users' ability to build up survey knowledge in a similar way. However, including an inset, overview map produces a problem: namely split attention where the user needs to look at two different places at the same time (Harrower and Sheesley 2005). The apex view avoids the split attention issue but the relevant view appears on screen for a limited time only and therefore suffers from disappearance issues (Harrower, 2003).

The time hypothesis predicted that subjects find it more difficult to build up survey knowledge if map tours are faster. For marker A, time was found to be significant after adjusting for path. For marker B, time was not significant with or without adjusting for path, which is thought to be due to the subjects not finding positioning this marker cognitive demanding enough to produce significant results. When the two-way paired *t*-tests for speed are considered for the low path, there is good evidence for the time hypothesis. Considering all these points, there is evidence supporting the time hypothesis but it has not been proven in this experiment.

The combination of the most cognitively demanding speed and path conditions (Low_2s) is significantly worse than the other combinations of time and low path (Figure 5). Comparing other results in this figure (e.g. High_2s vs High_6s) reveals no other clear pattern when errors are taken into account. This is thought to be because the other combinations of conditions produced less cognitively demanding tasks for the subjects. This is clear evidence that the limited capacity assumption (Baddeley, 1999), operated in the experiment and that difficult paths and fast flight speeds combine to produce map tours that are cognitively difficult to understand.

Conclusions

The central motivation of this study was to produce empirical evidence that could be translated into best practices in *how* to design map tours to assist users' understanding of a landscape.

The overview hypothesis was clearly proved suggesting a design best practice: map tours should use high rather than low paths to improve users' survey knowledge. The tilt hypothesis was not proven but the results are still worthy of consideration, they suggest that users can deal with complex paths within a map tour with little effect on their acquisition of survey knowledge.

In the experiment, combining cognitively difficult conditions (short time and difficult paths) had a significant negative effect on subjects' understanding. This is proof of the suggestion by Harrower (2003) that a reduction in animation speed (which, in the case of the current study, equates to virtual camera speed) can be used to reduce cognitive load in a map tour and can be considered a second best practice produced by this study.

Tilting the FOV is useful in helping users understand topography (Wood, 2002) but causes occlusion problems (Harrower and Sheesley, 2005). In this experiment tilting was tested over a 2-D landscape, it would be valuable to test it over 2.5-D landscapes with significant topography as this type of situation is where a tilted FOV is of most use.

Map tours are common place, they are used as research outputs on TV and the web. Further study of them is justified by this fact alone, however, empirical evidence from National Geographic is that map tours encourage users to engage with content (Yarnall, 2016, 18.40 minutes). This is further reason for empirical investigation of map tours and and other related map narrative formats.

Further work is planned to build on the simple classification of map tours by producing a thorough review of map tours in order to produce a proper typology of the genre.

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Figures

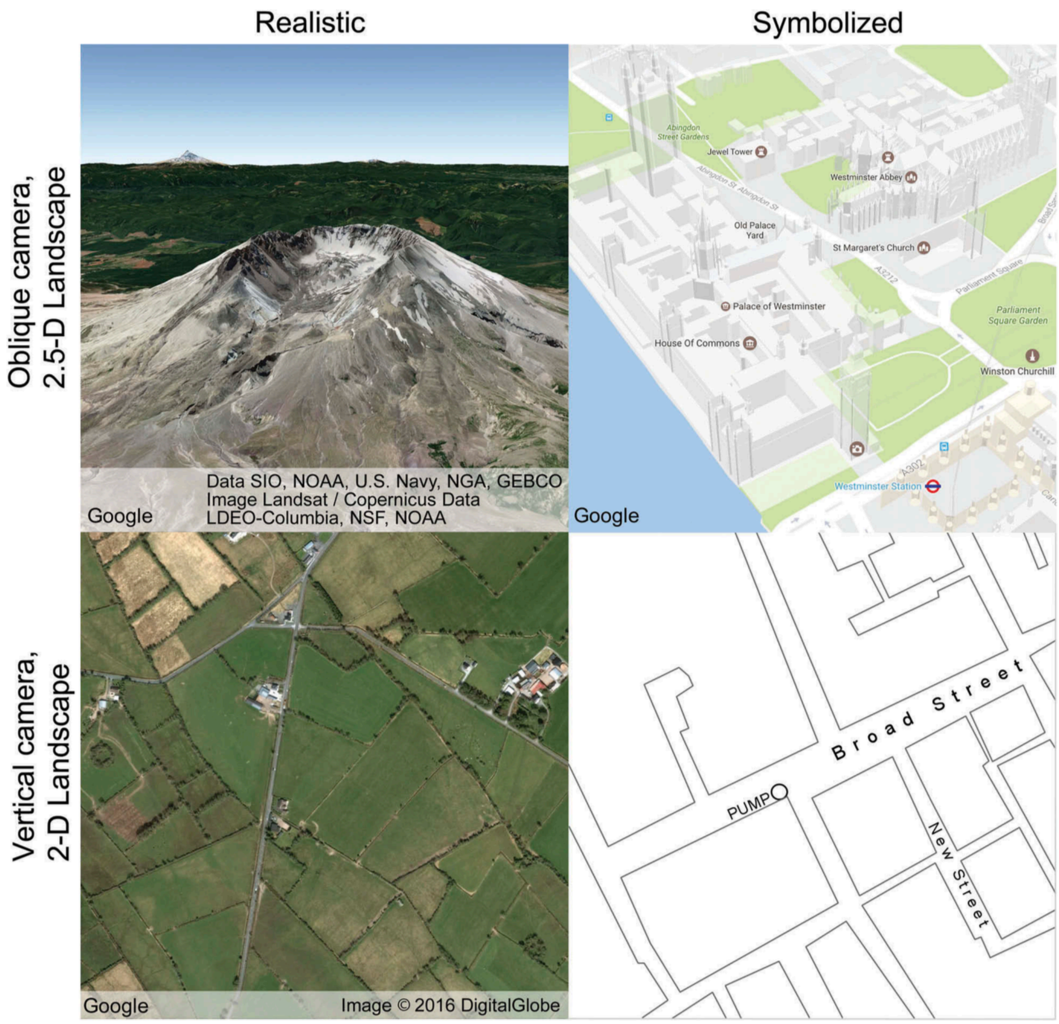

Figure 1: Screen shots that illustrate sample views from four map tour types. Top left: The distinctive horse shoe crater of Mt St Helens in Google Earth. Top right: Big Ben, London, Google Maps. Bottom left: rural Ireland within the experiment study area, Google Earth. Bottom right, a street map in nineteenth century London.

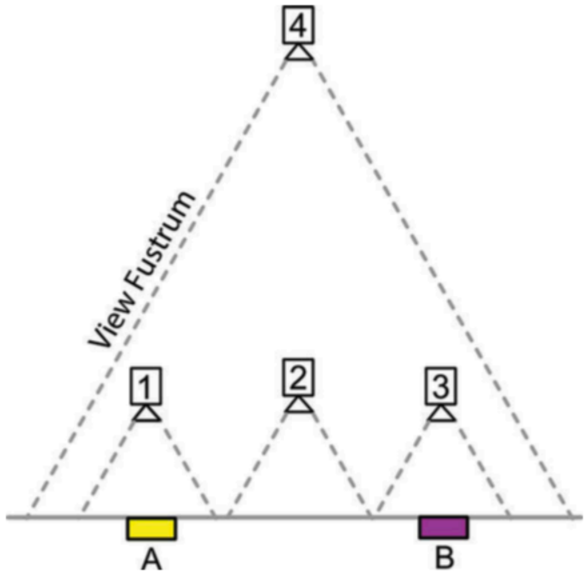

Figure 2: Cartoon in elevation view illustrating the basic route of the map tour in the experiment and the virtual camera view fustrums at key points.

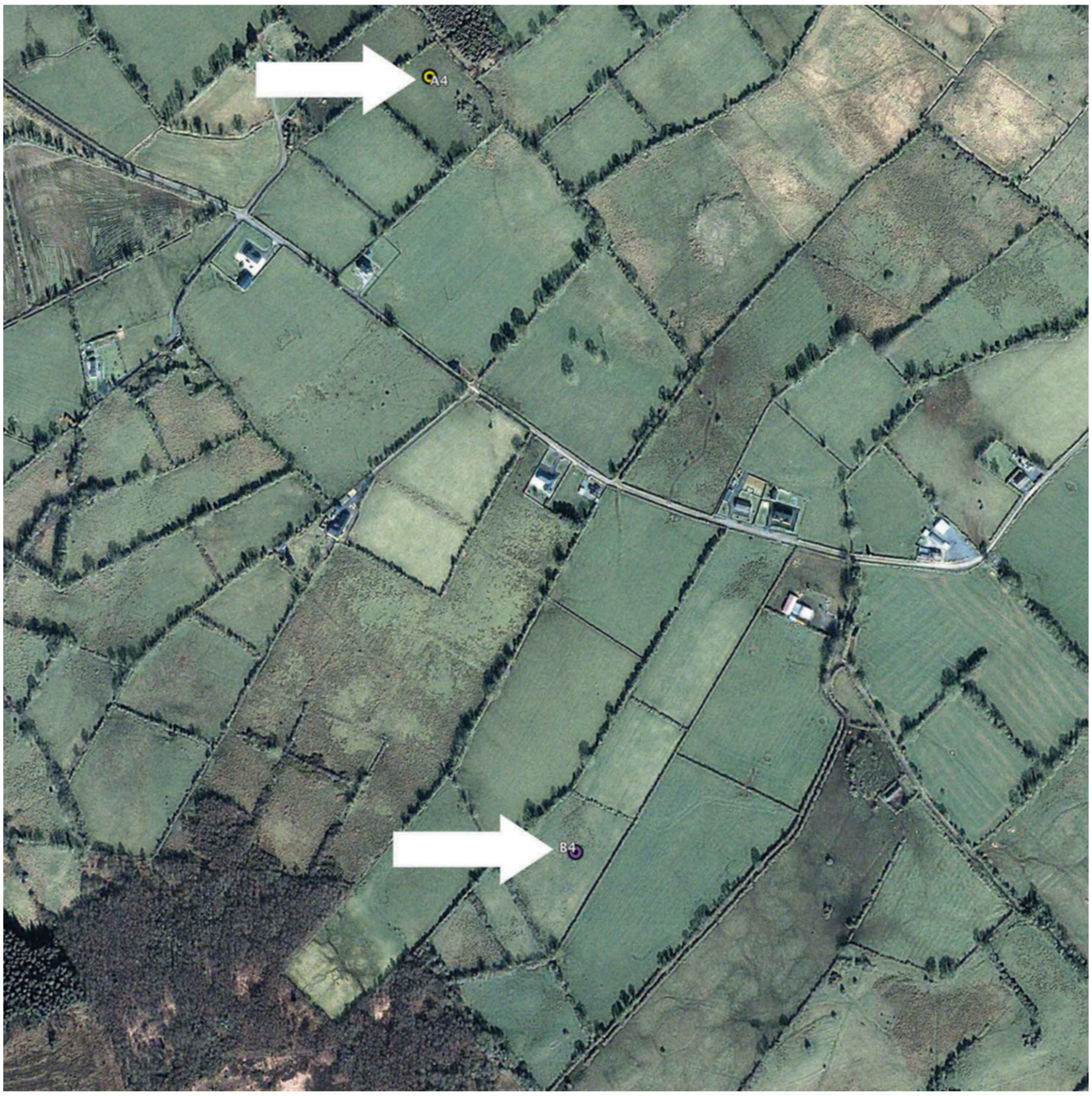

Figure 3: Screen shot of one of the sites from the final FOV of the experimental sequence. Note the white arrows show the markers locations, the arrows were not visible in the experiment.

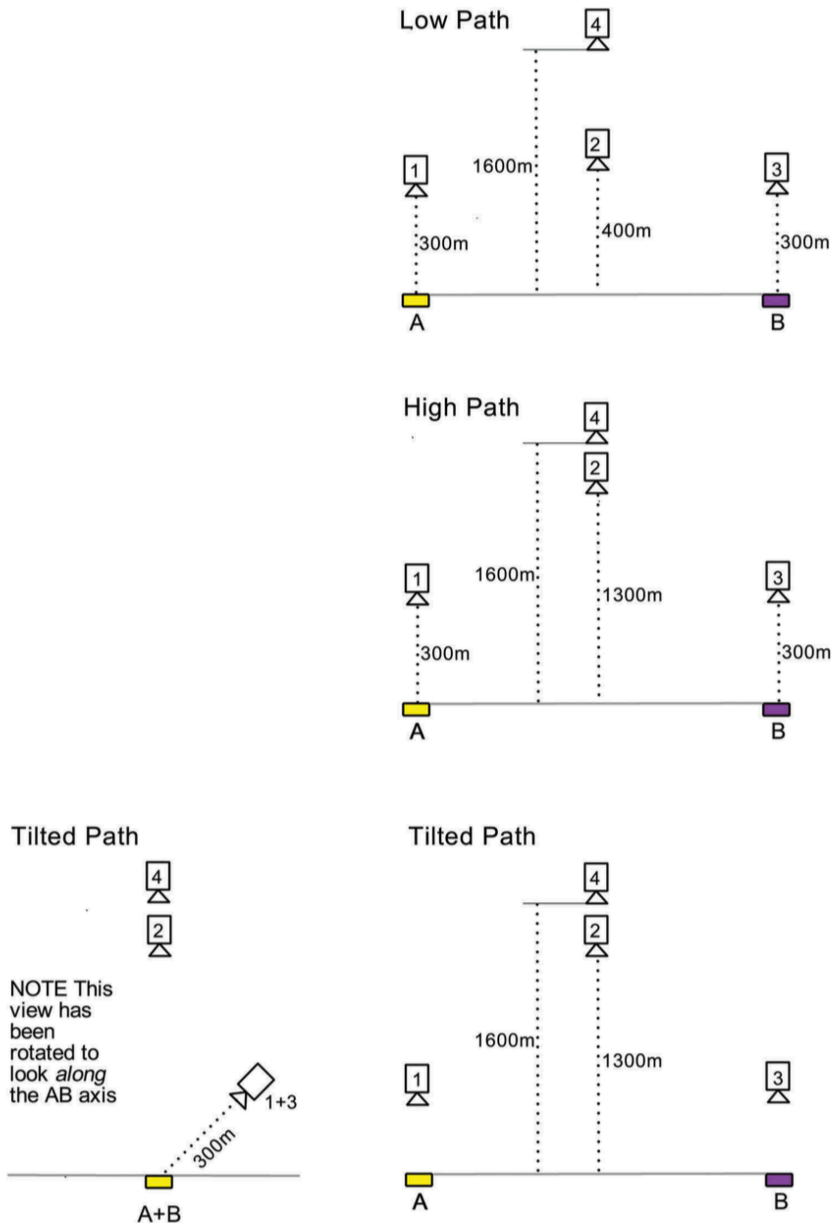

Figure 4: Elevation view of the three different map tour path conditions: high, low and tilted. Distances as marked and not to scale.

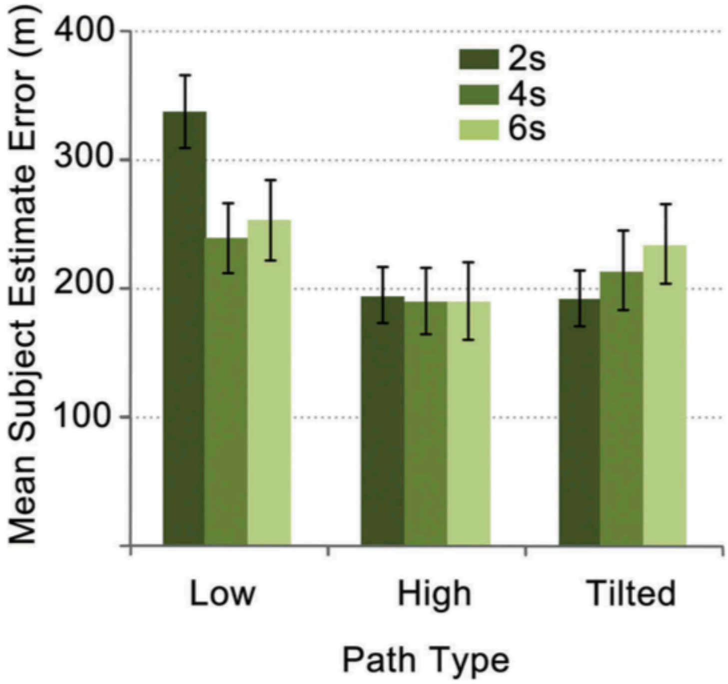

Figure 5: Graphs of mean subject estimate errors under different path conditions. 95% confidence levels are shown as 'I' bars.