Do we need legends? An eye tracking study

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Summary

Within large engineering consultancies, multidisciplinary projects are common, incorporating large volumes of varied and volatile high dimensionality data, often geospatial in nature. Eye tracking is a method used to assess how individuals make decisions using data. Harnessing this technology allows identification of key map and data components used and gives the ability to improve decision making tools within multidisciplinary projects.

KEYWORDS: Eye-tracking, Decision Making, Multidisciplinary, Geovisualisation, Usability

1. Introduction

Within large engineering projects, data of all types is disseminated from a variety of sources to different teams, organisations and stakeholders. One of the key areas of spatial data utilisation within such projects in the UK are Environmental Impact Assessments (EIAs). In order to be submitted to the relevant authorities for approval, data has to be sourced, collected, analysed and then presented in a format that can be annotated, assessed, and subject to decision-making. The EIA process allows for the creation of an Environmental Statement, through a collaborative approach across multiple disciplines (Saarikoski, 2000).

GIS (Geographical Information Systems) is at the core of the process for completing an EIA, as it can be used to encapsulate and present all types of physical, biological, environmental, ecological, geological, and relevant social economic information (Gharehbaghi and Scott-Young, 2018). In recent years, advances in online GIS interfaces have led to increasing use of web mapping portals as the main source for interacting with spatial data during creation and application of an EIA. Within engineering consultancies, web maps are used at all stages of EIA development and are common in a variety of projects, including transportation, critical infrastructure, and environmental policy. However, little is known about how users interact, interpret and collaborate with these online maps. Understanding how different users interact and process the information they deal with on a daily basis will help improve the methods of presentation, and give an indication of what the user relies on to make decisions using spatial data. In turn, this will provide more relevant data needs and help streamline decision making interfaces in the future.

Eye tracking allows measurements of where, what, and the order that, information is being interacted with during a defined task (Carter and Luke, 2020). The 'eye mind link' (Just and Carpenter, 1980; Rayner, 2009; Rayner and Reingold, 2015) connects the gaze of the viewer with particular points and zones of the graphical stimulus, making eye tracking a usable and reliable tool when interested in the distribution of visual attention. Historically, eye tracking has been applied in a variety of different studies, ranging from advertising, street level navigation and map design, and it has been shown to be of value to understand how participants use maps to complete specific tasks (Ooms *et al.*, 2012; Dong *et al.*, 2018; Krassanakis and Cybulski, 2019; Popelka, Vondrakova and Hujnakova, 2019; Keskin *et al.*, 2020). Commonly such studies are comparative, examining two distinct groups (e.g.,

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geographer/non-geographer or expert/novice) to test how each group use and interpret stimuli differently.

2. Study Design

The aim of the study is to understand how participants from a major engineering consultancy use map elements to make decisions, and if these change based on the individual's background (including education, job grade, working team, and use of geospatial data). One key aspect of map usage is how participants use and interpret the legend supplied with a map, this study therefore focuses on the use of the legend. Little is known about how such individuals rely on the legend, and if this is task dependant. Investigating the number of fixations obtained in the legend compared to the map can allow an understanding into how the individual relies on the legend throughout different tasks to make decisions. Examining legend usage will indicate the different levels of interaction, demonstrating that individuals will have different requirements, even when completing the same task.

2.1 Stimuli

Online maps were created using ESRI StoryMaps and presented through an ArcGIS Survey123 interface, which allowed for interactive documenting of user interaction. Although data was collected for three scenarios, this paper will focus on Scenario A. Each scenario represents a different synthetic decision-making situation in which the participant was tasked to complete. Scenario A presents a flood risk assessment exercise. Four maps were presented to each participant (Table 1) with each map adding data to the context map (Map 1). Each individual was asked to rank four areas on the map from least likely to most likely to flood; the complexity of the data increased with each new map. Participants were able to click, zoom and pan, but were unable to turn layers on and off. Participants were, however, able to switch between maps to compare the data if they so wished. Although interactive, the stimuli created were not overly complex and were designed not to overwhelm the participants' cognitive load.

Table 1 – Maps used as in Scenario A, the maps used in can be accessed here (via hyperlink)

Map	Information
Map 1	A context map showing the area of interest and four proposed sites for development
Map 2a	Simulated 1 in 100 year flood extent
Map 2b	Simulated 1 in 1000 year flood data extent
Map 2c	Band of uncertainty for 1 in 1000 year flood data simulation

2.2 Apparatus

The Tobii X2-30, a fixed eye tracker, was used in this study alongside the processing and data collection program Tobii Pro Lab. The system records at 30 Hz (how many times per second the position of the eyes is registered by the eye tracker) and allows for timestamp, eye position, gaze point, pupil diameter and validity code (indicates the confidence level that the eye has been correctly identified) to be measured. The stimuli were presented on a laptop with a screen size of 13 inches and resolution of 1920 x 1080. Importantly, the study was not conducted in a controlled lab environment, but in the participants' usual working environment, meaning the distractions of everyday office life were present; which differs from 'typical' eye tracking studies like those mentioned in Section 1. Which allows this study to mimic the actual situation individuals make decisions in.

2.3 Participants

The participants at the time of the study were employed by an engineering consultancy and worked on a variety of multidisciplinary engineering projects, including being involved in the production of EIAs.

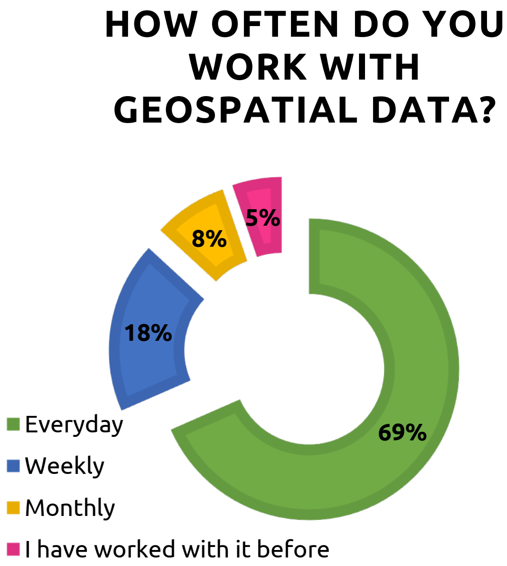

Figure 1 – Participant response to how often they work with geospatial data

A majority of participants were not selected: instead, they opted into the study through an online form. The volunteer participants had a variety of experience, ages, qualifications, disciplines and knowledge (Figure 1). They were also based at different offices locations across the UK and working on a variety of projects. Each participant was uniquely and anonymously identified throughout the study and completed a consent form which allowed for their data and information to be used. Alongside this, they completed a personal profile which were used to help segment the participants during data analysis. The personal profile included information on their age, profession, qualification, job grade and experience of use of geospatial data for decision making. It total 35 participants took part in the formal assessment, in which 31 usable recordings were obtained for Scenario A.

2.4 Recordings

Fixations are one of the primary methods for understanding how a user is interpreting and interacting with data, showing where a user looks and for how long. Eye tracking collects fixations and saccades (the movement of the eye between fixations) from the participant, overlaid on the stimuli (the map). Fixation lengths tend to vary from about 100-600 milliseconds, during which the brain will process visual information which is received from the eyes. Most of the information acquired from a visualisation is attained during fixations (Borys and Plechawska-Wójcik, 2017). Eye tracking metrics, questionnaire responses, map interactivity and screen recordings were collected during this study. Metrics collected include fixation frequency, count and length; mouse clicks and navigation are also recorded. Previously a pilot study (6 male and 7 female) was undertaken to find possible design flaws and assess task length.

3. Preliminary Results

For the preliminary analysis participants were divided into two distinct groups; geo and non-geo. Geo were the participants who stated they worked in the geospatial team, whereas non-geo was a collective of all other participants. The main metric of focus was fixation count, therefore, we will look at how the percentage of overall fixations spent on the map compared to the legend. Using Areas of Interest (AOI) the eye tracking recording was segmented into the map and legend. Furthermore, the recording was segmented temporally to allow for the different tasks given to the user as part of the scenario to be identified (A.1, A.2a, A.2b and A.2c as shown on Table 1).

Figure 2 shows there is a variation in legend use through the different tasks the participant undertook. From interpreting this data, the legend was used the most in the first task (A.1), the map was new to them and they needed to fully understand the contents in order to make the decision. As the tasks progress (A.2a and A.2b) and less new information is added, the use of the legend decreases. However, when introduced to the final map and task (A.2c) the use of the legend increases, likely due to the use of a synthetic uncertainty layer which participants were less familiar with. The confidence interval for the population of the mean was much higher for the non-geo group across all scenarios. For the first task (A.1) the confidence interval for legend % usage almost doubled to 13.80% for non-geo compared to 7.82% for geo, the smallest difference of 2.74% occurs in the second task (A.2a). It is also worth noting that in every task at least one participant did not use the legend at all (although not the same participant each time). When checking back on recordings these were not errors, but an active choice by the participants which is interesting as it is an expectation that the legend will be used at some point.

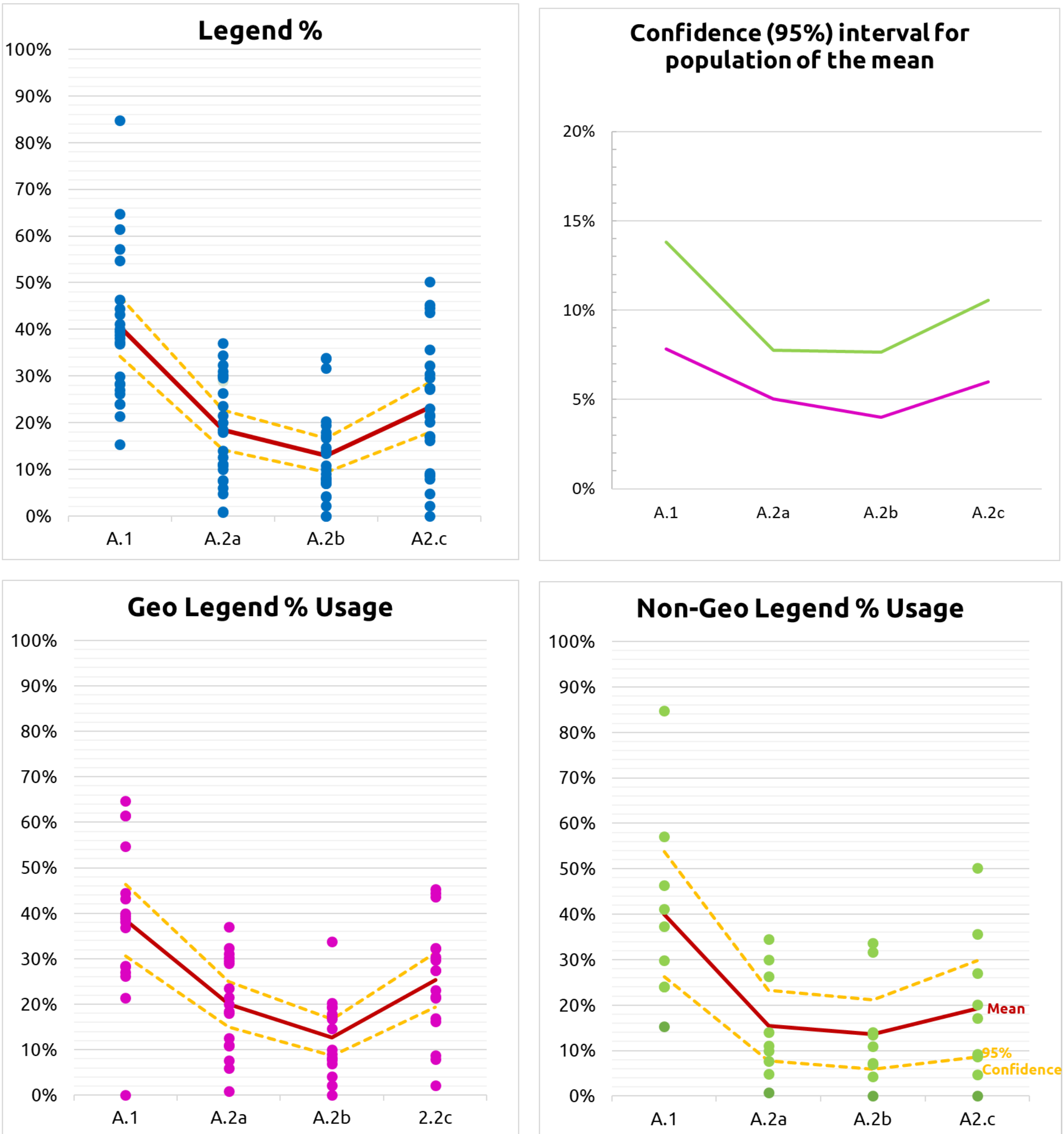

Figure 2 – Percentage of fixations on legend AOI results

Showing (top-left) the percentage of fixations on the map legend for each of the tasks in scenario A, (top-right) 95% confidence interval for both groups, (bottom-left) the legend usage for geospatial professionals, (bottom-right) the legend usage for non-geospatial professionals

Based on the results discussed in Section 3 it is clear that eye tracking is useful to demonstrate differences between user groups in how they use legends on online maps to help them make decisions. Interestingly, when comparing the legend usage between two defined groups (geo/non-geo) there was not a significant difference in the way in which the legend was relied upon in the tasks. However, the confidence interval for the population of the mean was much higher for the non-geo group, this could be expected as the group had more variance in terms of individuals' background and experience with spatial data compared to the geo group.

Better grouping methods are required in order to have a more solid understanding of differences in interpretation across the participants, rather than basing the groups just off job type. We have a good sample size (31), which enables modifications in how we choose to divide the participants. The next steps for this work is to look to define two groups as experts/novices (relative to the task undertaken), based solely on their metrics; such as fixation length. Previous studies show that experts/novices have a significant difference in average fixation length (Dogusoy-Taylan and Cagiltay, 2014; Ooms, Maeyer and Fack, 2014; Keskin *et al.*, 2020) and it will be interesting to apply in reverse. This will give an indication into the participants' decision making beyond legend usage; giving the ability to improve decision making tools within multidisciplinary projects.

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