Cartography MSc

An Empirical Evaluation of 2D and Interactive 3D Terrain Visualisations for Cycling Maps

MSc Thesis Defence

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PRESENTATION OUTLINE

1| Introduction

What problems stimulated the research?

- How can we best **show the hills** on a cycling route?
- Which visualisations of terrain are **most usable** for a cyclist?
- Which visualisations are more usable for cycle route-planning – **2D or 3D**?

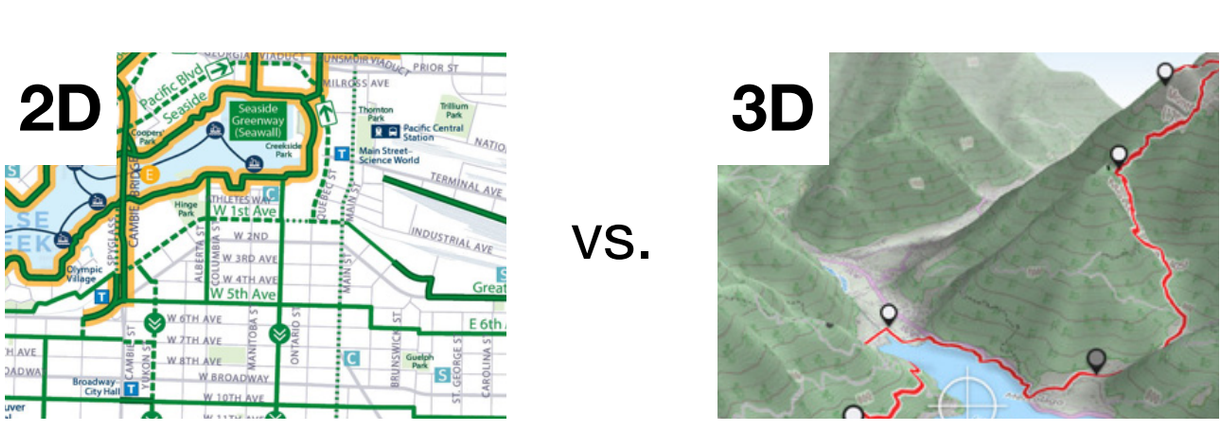
Broad Aim

To assess the relative usability of 2D and 3D elevation visualisations for cycle route planners

1| Introduction

Justification – why do we care?

- Growth in the **ubiquity** of 3D and interactive cartographies, but do they offer any real benefits?
- Research into 3D cartography usability has drawn **differing conclusions**, and suffers from **methodological flaws**.



- For cyclists, **terrain is important**. Better communication of terrain should mean better cycling maps.
- There is a need for **better design guidelines** for cycling maps.

2| Context and Background

What other work has been done in this field?

Cycling Map Research

- Maps to make cyclists 'happy' (Dickinson, 2012), and 'universal' maps to meet the needs of all users (Wessel & Widener, 2015).

- Most relevant research – Brügger et al (2016):
  - Study of the usability of 2D terrain depictions for cycle planners.
  - Results showed that arrow symbolisation was most efficient & effective for determining height, and colour for determining slope.
  - User preference = elevation profile.
  - BUT! Methodological flaws (potential learning effects) & a-typical visualisations...

THIS THESIS: Expand on Brügger's research by looking at 3D visualisations, while addressing that study's flaws.

2| Context and Background

What other work has been done in this field?

2D vs. 3D carto research

- A larger body of research has focussed on the usability of 2D and 3D cartographies in general.
- But, it has issues...
  - Results can't necessarily be applied to cycling maps/route planners.
  - Some research has suggested 3D is more usable than 2D, other research the opposite.
  - Focusses mainly on 3D terrain models.
  - Majority use static rather than interactive 3D depictions.

So, the need for further research into 2D and 3D terrain visualisations for cycling maps is still there!

3| Specific Research Questions

What are we trying to find out?

Broad Aim

To assess the relative usability of 2D and 3D elevation visualisations for cycle route planners.

Research Questions

1. Is there a significant difference in the **relative efficiency** of 2D and 3D elevation visualisations for cycle route-planners?

2. Is there a significant difference in the **relative effectiveness** of 2D and 3D elevation visualisations for cycle route-planners?

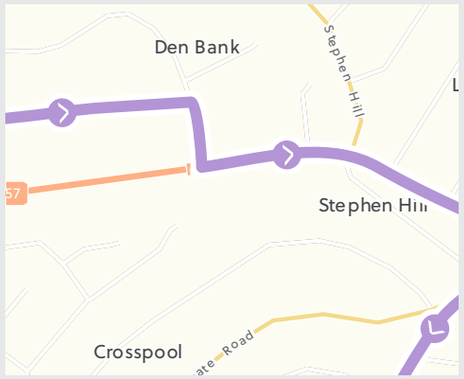
3. Do users **prefer** 2D or 3D elevation depictions when performing cycle route-planning tasks?

Efficiency + Effectiveness + User Preference = Usability (ISO 9241-11)

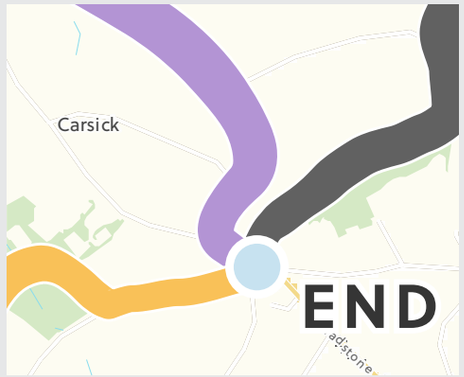
4| Methodology

- Conducted an **empirical user-study** (repeated measures, 36 participants), under controlled experimental conditions.
- Tested **six different visualisation types**:

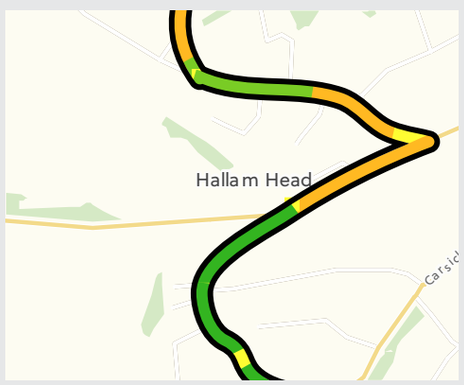
2D



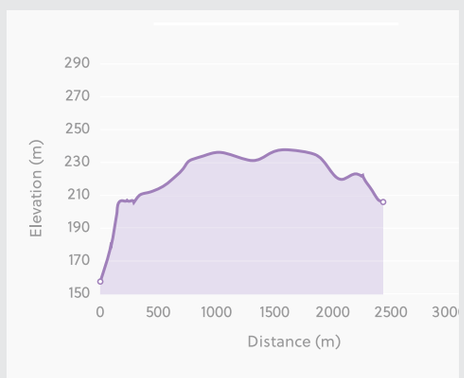
Arrow



Line-Width

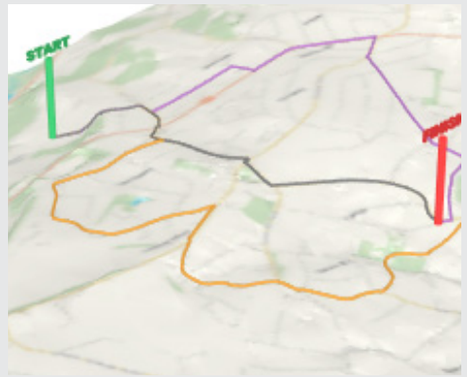


Colour



Elevation Profile

3D



Terrain

Elevation Profile

4| Methodology

- For each visualisation type, users were asked to find:

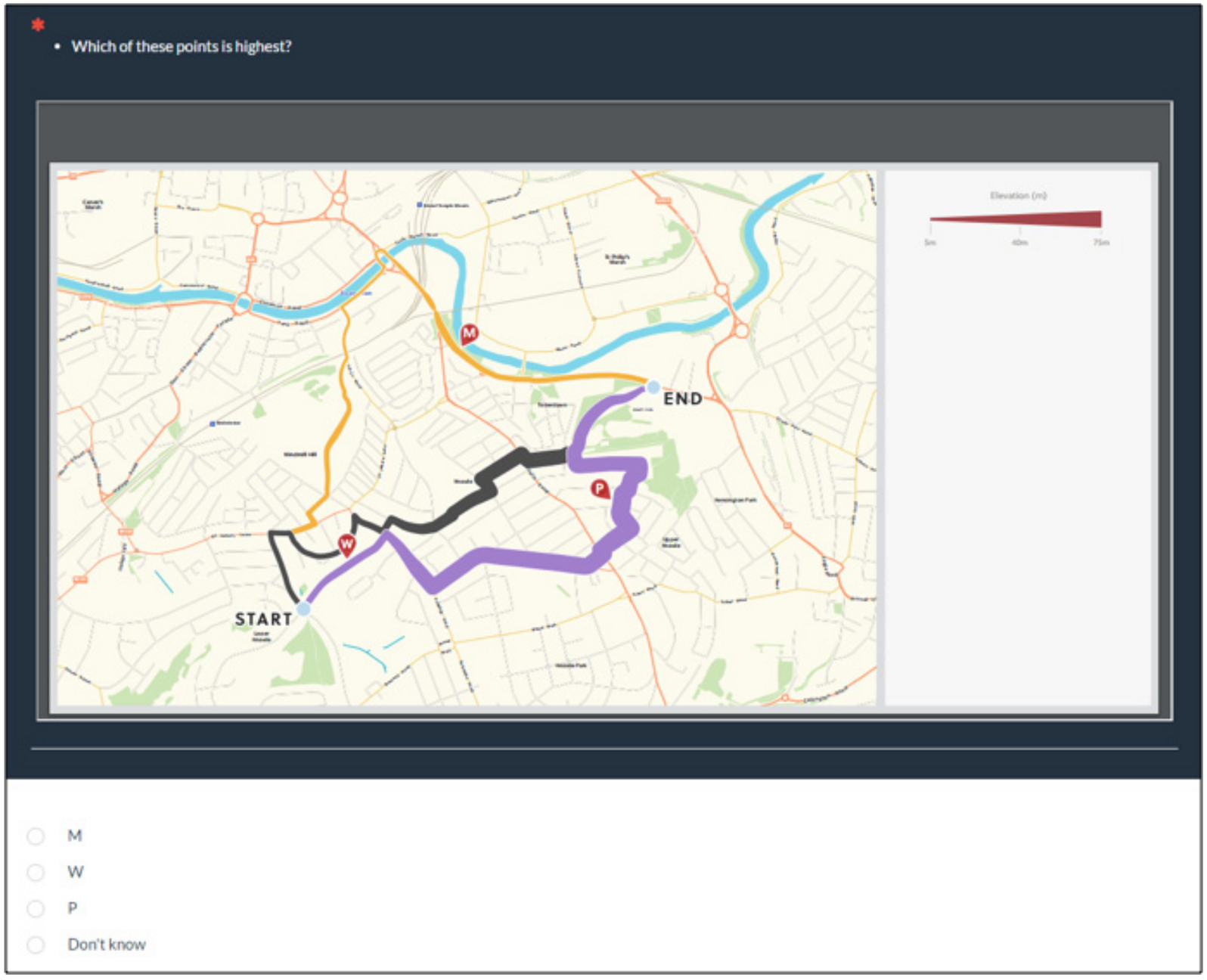
  1. The highest of three points.
  2. The steepest of three slopes.
  3. Which of three routes contained the highest total amount of climbing?

- Used a web-hosted survey (based on LimeSurvey open source software), allowing:

  1. Automated recording of responses (to calculate effectiveness).
  2. Automated recording of response times (to calculate efficiency).
  3. Submission of user feedback (to determine user preference).

- Visualisation and statistical analysis of results data then identified significant differences between visualisation types, for each of the three usability criteria.

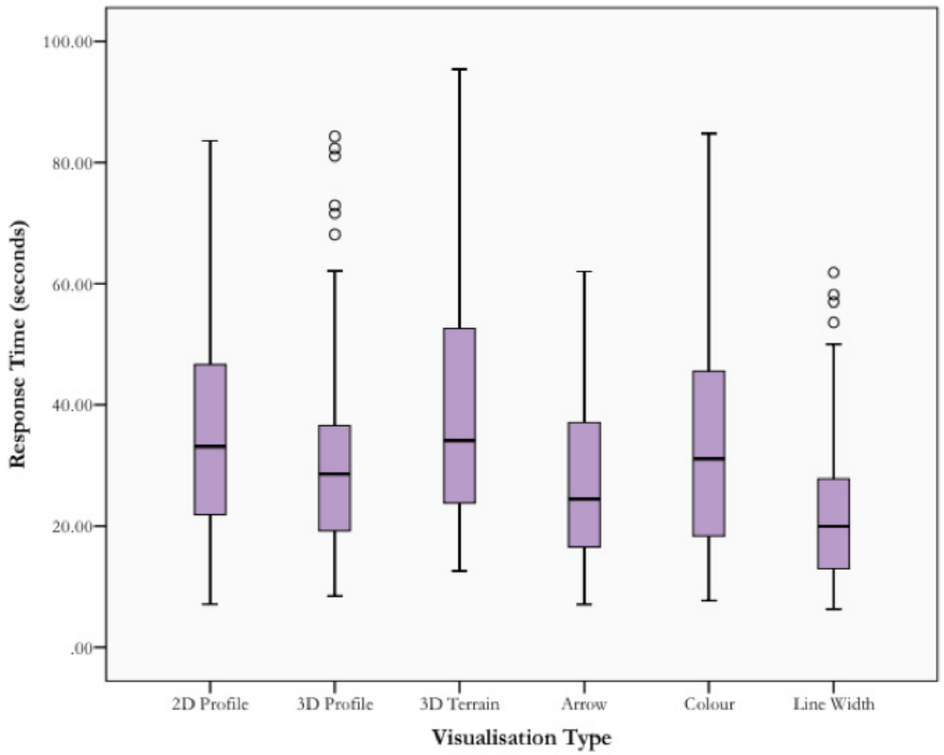
4| Methodology



Example user-study question (height detection).

5| Results

Efficiency



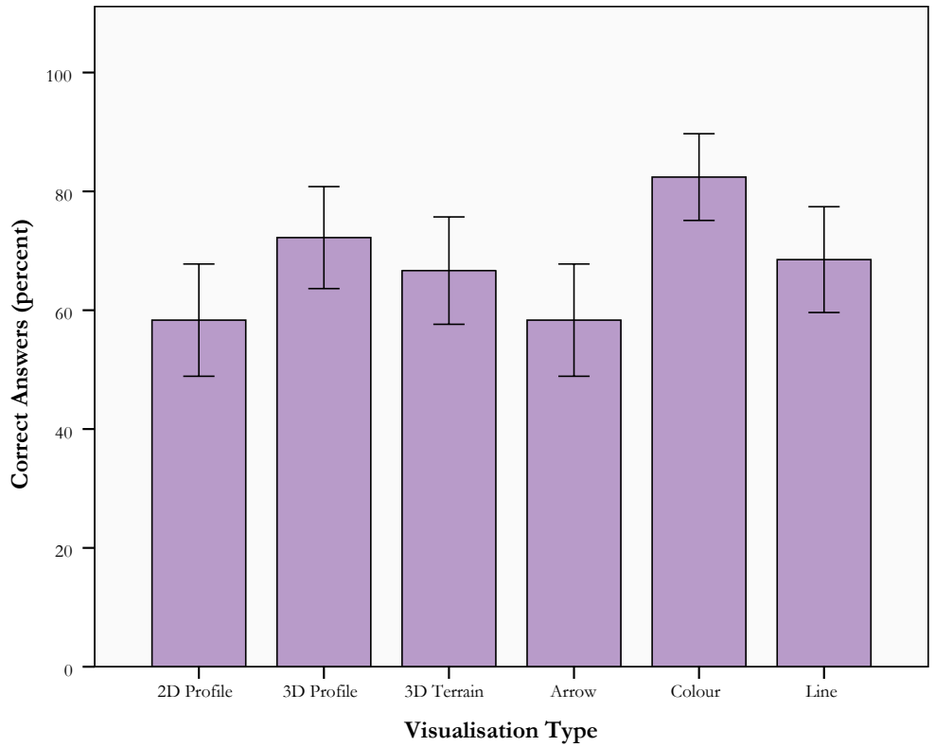
Box-whisker plots showing response time differences for each visualisation (for all question types).

Measured using user response time

- Relative efficiency dependent upon route-planning task (height/slope/climb detection).
- Line-width was most efficient for the majority of tasks.
- For slope tasks, arrow and colour visualisations were significantly more efficient than all others.
- 3D terrain model = consistently inefficient.
- No single dimensionality (i.e. 2D or 3D) was consistently more efficient than the other.

5| Results

Effectiveness



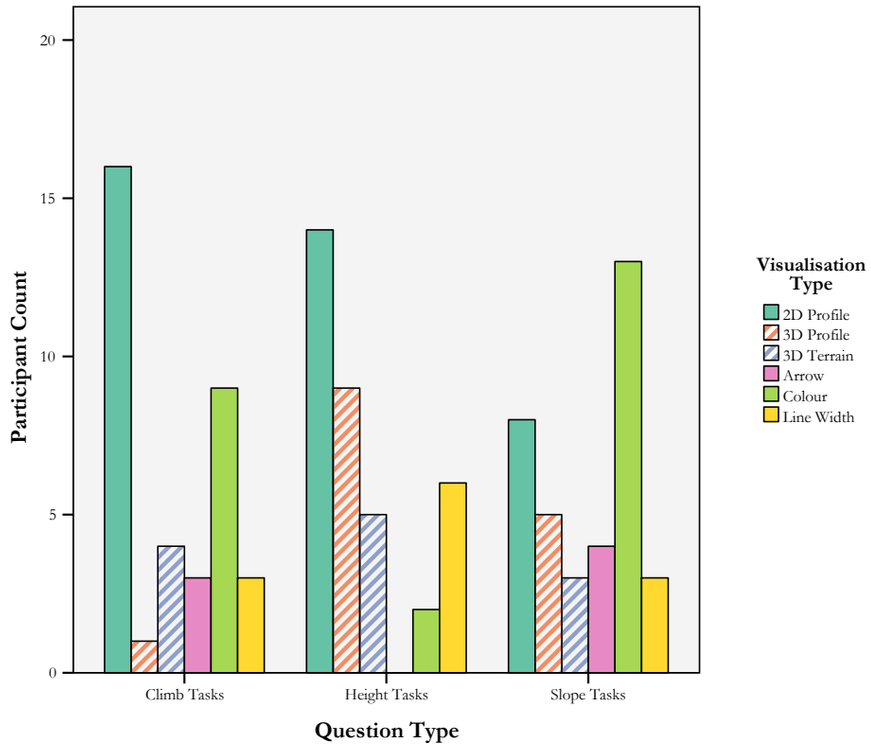
Differences in the percentage of correct answers between different visualisations (using data pooled from all question types)

Measured using the proportion of correct answers

- Relative effectiveness also dependent on task (height/ slope/climb detection).
- No single dimensionality (i.e. 2D or 3D) was consistently more effective than the other.
- The lower the cognitive load demanded by the visualisation, the more effective it appeared to be.
- e.g. point matching or judging line angles = high cognitive load = ineffective

5| Results

User Preference



The variation in user preference for different route-planning tasks.

Solid fill – 2D

Line fill – 3D

- Visualisation preference depended on the task at hand.
- However, the majority of users preferred 2D visualisations, for all tasks.
- The 2D profile was especially popular.
- Dislike of 3D visualisations mainly stemmed (according to majority of user comments) from the need for interaction.

6 Conclusions

What can we conclude from these results?

1. The diversity of different 2D and 3D visualisation types, means we cannot state that one dimensionality is ‘more usable’ or ‘better’ than the other.

2. The usability of each visualisation type is inherently tied to the problem it is being used to solve.

3. The greatest impact on usability appears not to be visualisation dimensionality, but the cognitive load placed upon the user.

4. 3D visualisations which presented targeted, abstracted versions of reality appear more useful than those which simply attempt to imitate reality.

7| Limitations & Future Research

Limitations		Future Research
Inconsistent data visualisation: slope/elevation/both.	→	Only compare like for like, e.g. 2D profile with 3D profile
Participants were all highly educated, and mostly skilled in Cartography.	→	Include a wider range of participants & use a study design that allows testing of educational influence.
Lack of eye tracking (due to interactivity) = hard to explain usability differences.	→	Develop/apply eye-tracking techniques that can be used with interactive systems.
Artificial test environment - indoors, quiet, constant lighting.	→	Repeat the study in an outdoor setting using mobile devices.

Thankyou!

Any questions?