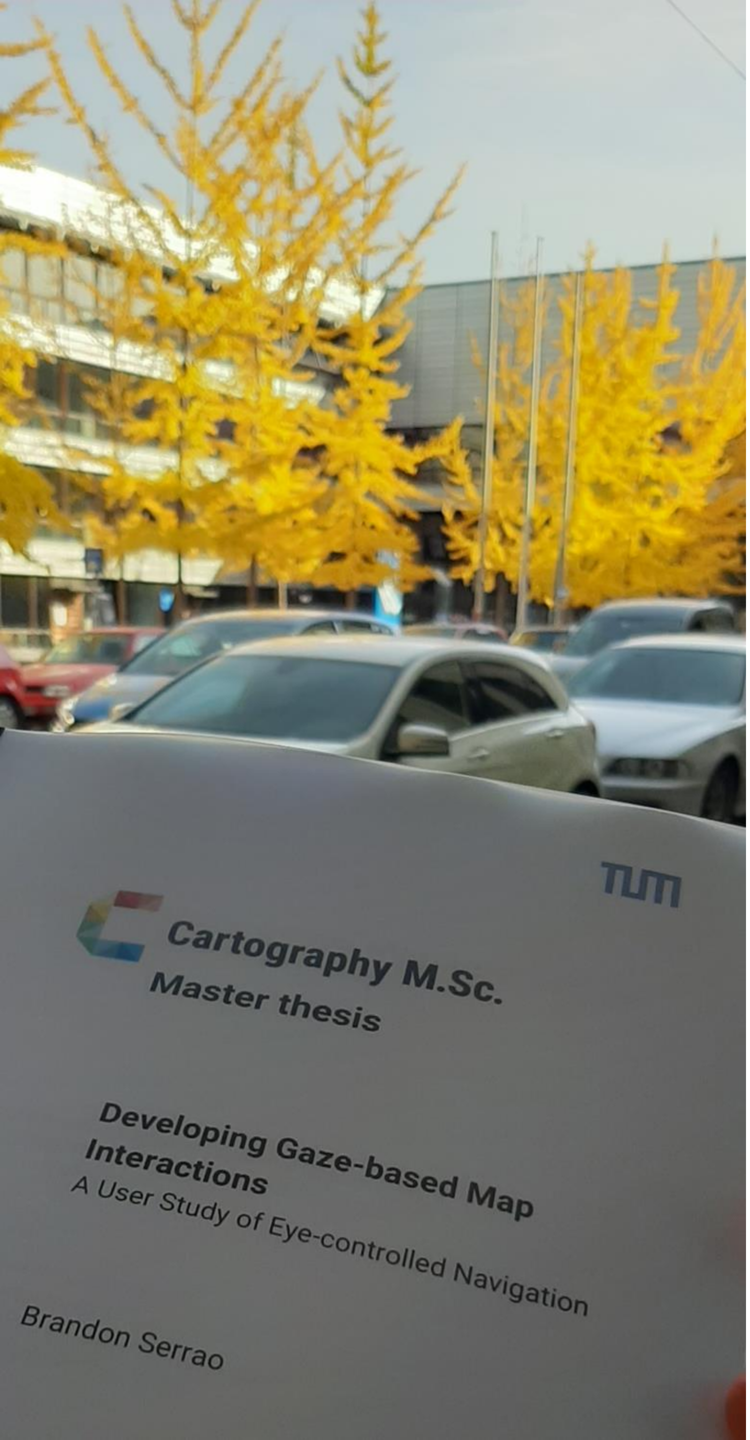
Cartography M.Sc.

Developing Gaze-based Map Interactions

A User Study of Eye-Controlled Navigation

Brandon Serrao

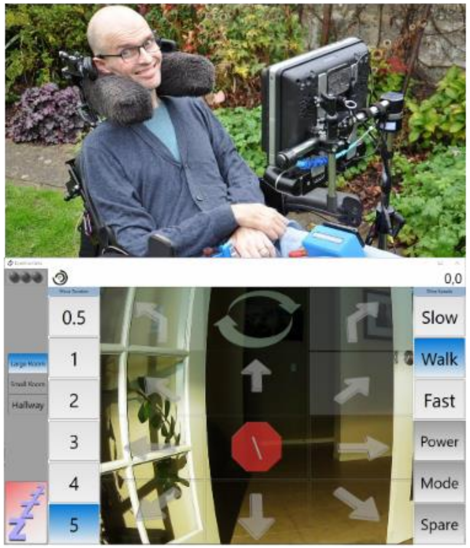
29th October 2019



Outline

- Introduction and Motivation
- Research Objective and Questions
- Concept and Interfaces Developed
- The User Testing
- Results and Takeaways
- Conclusion

Eye-tracking as Control Mode



Eyedrivomatic (eyedrivomatic.org)

- Eye-typing
- Text-to-Speech
- Gaze-buttons and gaze-aware interfaces
- Mobility control (wheelchairs)

The EyeGaze Edge (eyegaze.com)

EyeMine (specialeffect.org.uk/eyemine)

Eye-tracking as Control Mode

Figure 1. Basic idea: Gaze-supported interaction in combination with a handheld touchscreen and a distant display.

(Stellmach & Dachstellt, 2012)

Investigating Gaze-supported Multimodal Pan and Zoom

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Remote pan-and-zoom control for the exploration of large information spaces is of interest for various application areas, such as browsing through medical data in sterile environments or investigating geographic information systems on a distant display. In this context, considering a user's visual attention for pan-and-zoom operations could be of interest. In this paper, we investigate the potential of gaze-supported panning in combination with different zooming modalities: (1) a mouse scroll wheel, (2) tilting a handheld device, and (3) touch gestures on a smartphone. Thereby, it is possible to zoom in at a location a user currently looks at (i.e., gaze-directed pivot zoom). These techniques have been tested with Google Earth by ten participants in a user study. While participants were fastest with the already familiar mouse-only base condition, the user feedback indicates a particularly high potential of the gaze-supported pivot zooming in combination with a scroll wheel or touch gesture.

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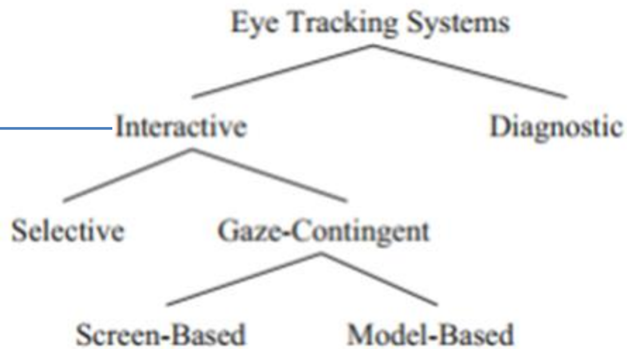
(Stellmach and Dachselt, 2011)

(Klamka et al. 2015)

Eye-tracking – Cartographic



(Duchowski, 2017)

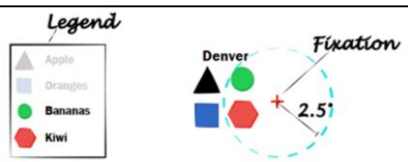


Figure 7: Fixed adaptive legend FA: The legend highlights symbols that have been looked at.

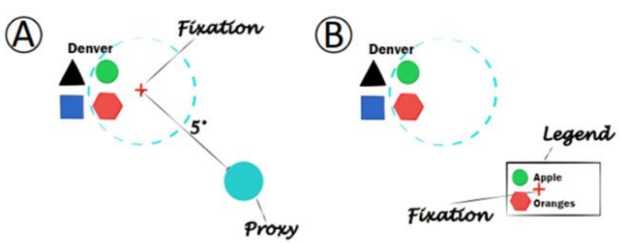
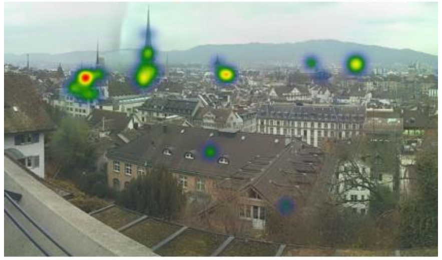
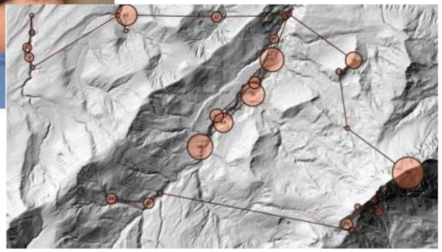


Figure 8: Dynamic adaptive legend (DA): Ⓐ The legend proxy is located at bottom right, at 5° from fixation. Ⓑ User looks at the proxy which immediately unfolds the legend showing the reduced content.

(Goebel et al. 2018)



(Kiefer et al. 2017)



(Kiefer et al. 2017)

Research Objective:

Find suitable ways to facilitate map interaction directly using eye-control.

Research Questions:

1. What pairing of map interaction and eye-control method would produce a usable eye-based map interface?
2. Can its implemented gaze control/awareness provide beneficial map interactions?

(Goebel et al. 2018)

Conceptual Model

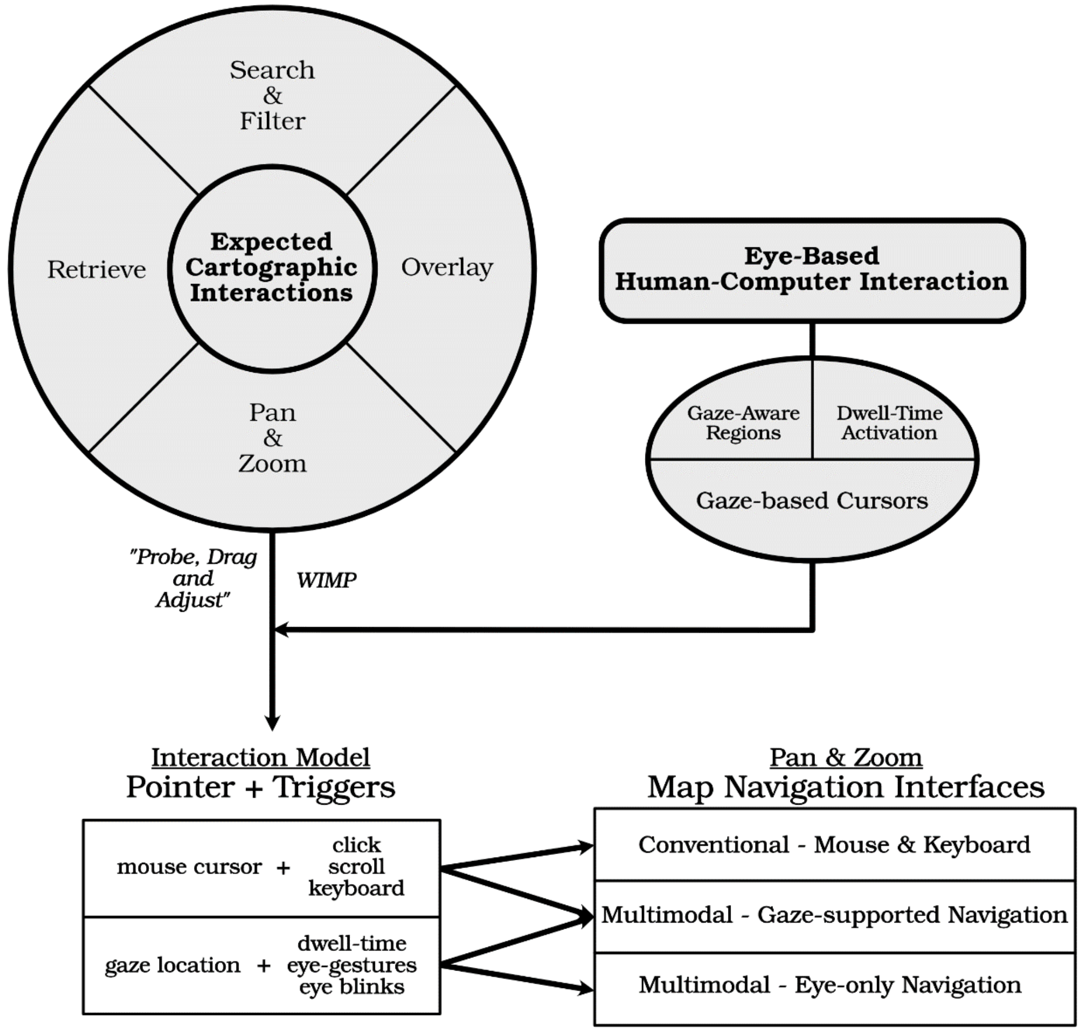
- Map interaction chosen for implementation - _Navigation (Pan & Zoom)_
- Common interaction model identified: _Pointers and Trigger(s)_
- Assembled into three interface concepts:

#1 – _Conventional Desktop Interface_

#2 – _Gaze-supported Interface_ _(gaze-pointer, hardware triggers)_

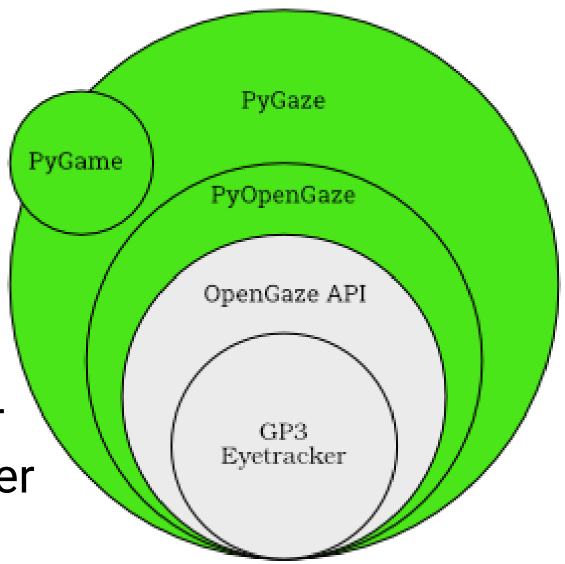
#3 – _Eye-Only Interface (gaze-pointer, eye behaviour triggers)_

- For Comparison via User Testing

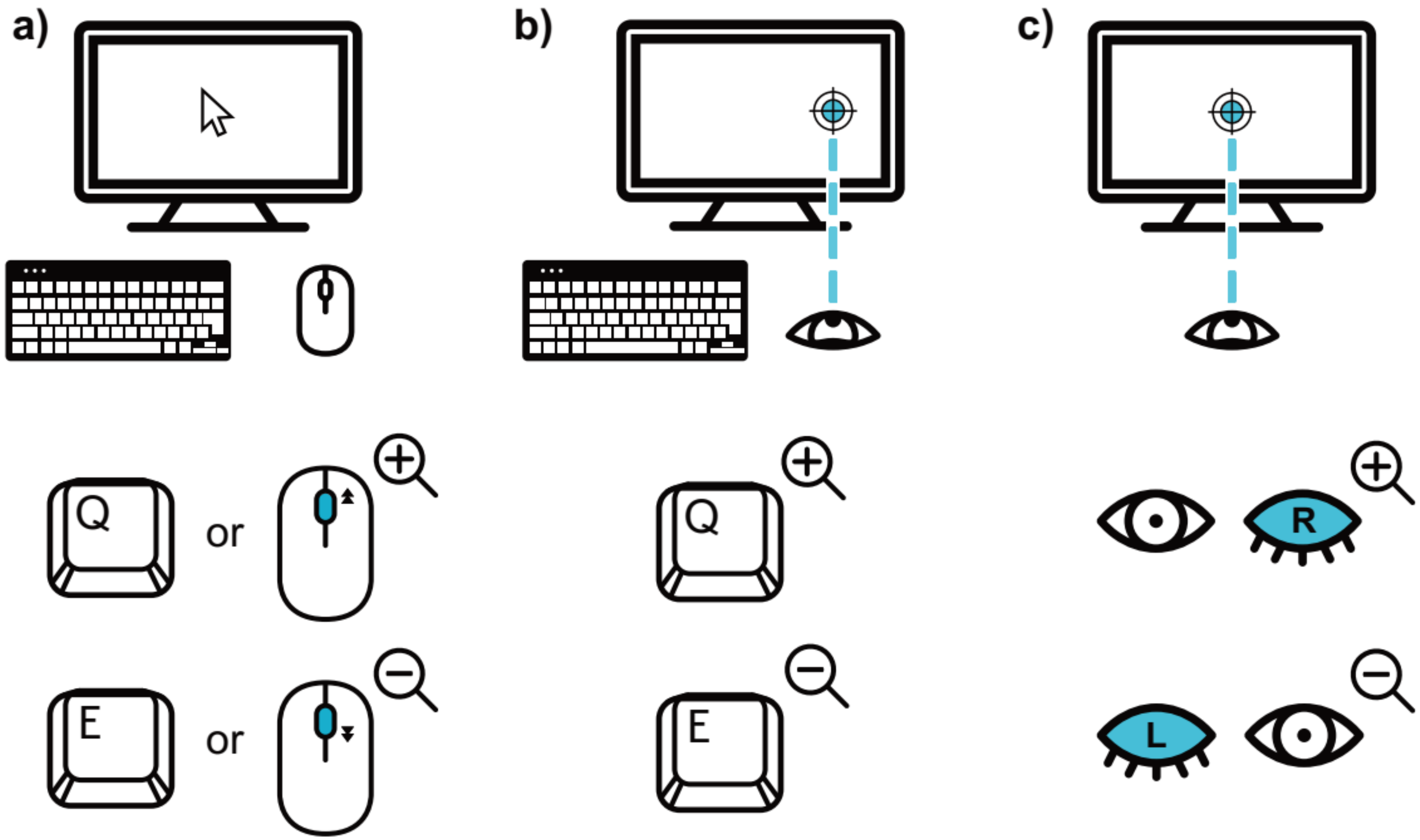


Implementation - Programming

- Python, using *PyGaze* and *PyGame* modules
- *PyGaze* – Python wrapper to the *Gazepoint API*, and provides built-in calibration and eye-tracking functionality
- Uses *PyGame* for interactivity, allows for extending *PyGaze's* functionality
- ! Quirks in behaviour of the GP3 Eyetracker



Implementation - Zooming

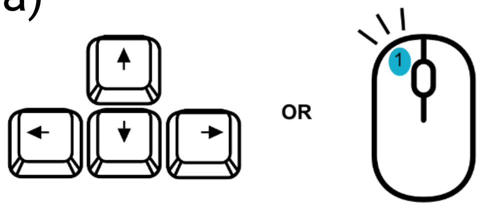


The zoom interactions of the developed Interfaces: a) Conventional Mouse & Keyboard Interface, using the mouse scrollwheel for zooming or a pair of keyboard keys, b) Gaze-supported Interface, pressing the keyboard to zoom based on the viewer's gaze location, c) Eyes-Only Interface, where closing an individual eye would zoom based on the other eye's gaze location.

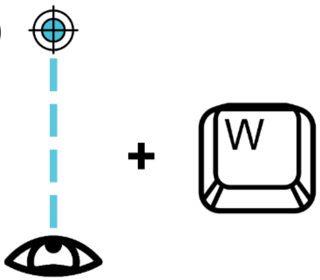
Implementation – Panning

- Panning

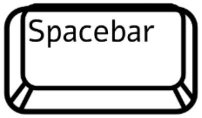
a)

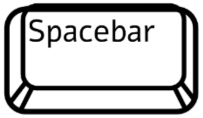


b)



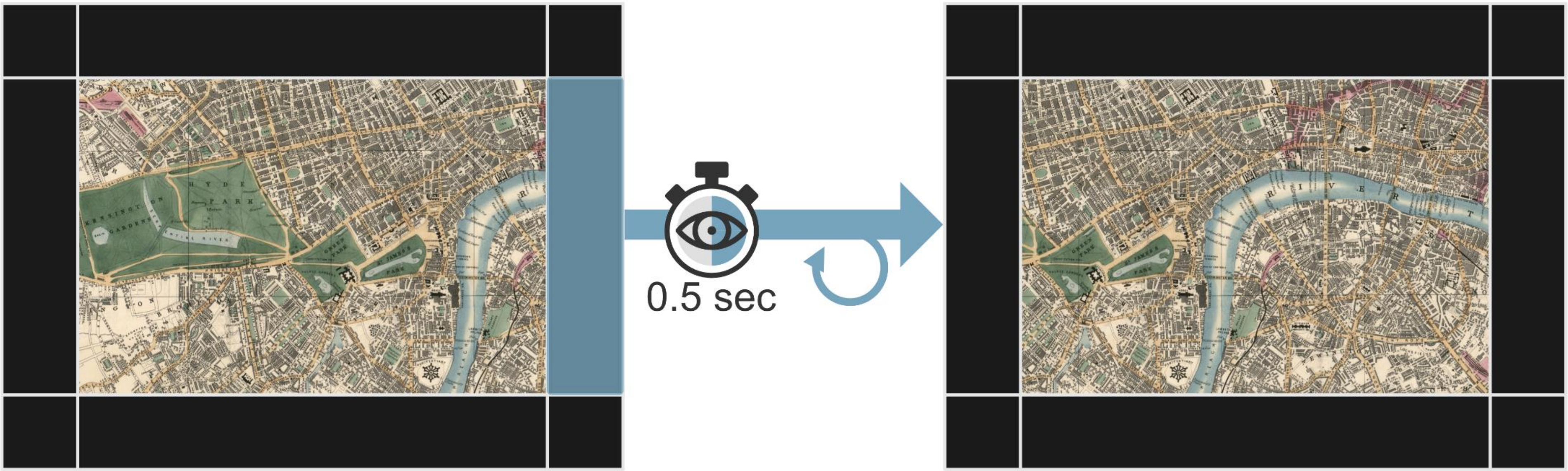
- Recentering



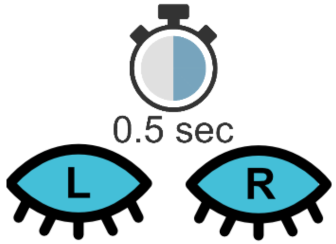


Implementation - Panning

c) Panning



- Recentering



Setup and User Testing

User Test

User tests consisted of three parts:

- 1. Briefing and Background Questionnaire
  - *Demographics, Map Use Familiarity, Glasses Wearing*
- 2. Interface Testing (in order 1, 2, 3)
  - *a) User Tasks (randomized Trial Order)*
  - *b) Usability/UX Questionnaires*
- 3. Post-Study Questionnaire and Debriefing
  - *Interfaces and Interaction Preference/Ranking*

User Profiles

- 16 participants (1:1 male-female)
- 50% wore glasses during testing
- Highly map literate
  - as expected – participants from TUM Chair of Cartography, its students and alumni
  - 14 of 16 use maps regularly and had made maps for use

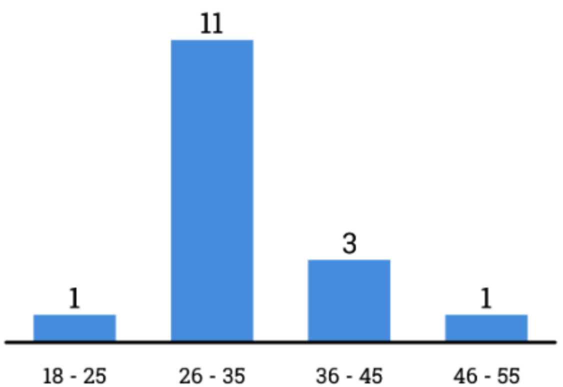


Figure 18: Number of Participants in each Age Range


WHITBREAD'S NEW PLAN OF LONDON
DRAWN FROM AUTHENTIC SURVEYS
REGENTS PARK
HYDE PARK
KENSINGTON GARDENS
VICTORIA PARK
RIVER THAMES
LONDON DOCK
KENSALL GREEN
KILBURN
WALHAM GREEN
PARSONS GREEN
BATTERSEA
EARLS COURT
BROMPTON
NEW CROSS
DEN MARK HILL
DALSTON
PUBLISHED BY J. WHITBREAD, MAPSELLER, 142 OXFORD STREET.

HIGH STREET OR UPR SHADWELL
ST GEORGES STREET
PENNINGTON STREET
LONDON DOCK
EAST LONDON DOCK
BASIN
OLD GRAVEL LANE
NEW GRAVEL LANE
BROAD STR
ANCHOR STR
FARMERS
SHAKSPEARE
SPRINGS
FOXS LANE
MARKET
LEADINGS
LOWER SHADWELL
WAPPING WALL
2 MILES FR
Shadwell Dk. Sta.
Eastern Entrance to London Dock
Bull Head Dk.
New Crane Sta.
Hanover Sta.
THE POOL
TUNNEL
Pier
Execution Dock
Wapping N.Sta.
Wapping O.Sta.
Union Sta.
East La. Sta.
•1 MILE FROM L.B.
E
S
HERMITAGE ST.
WAPPING
CINNAMON
LOVE LA.
GREEN
ROTHERHITHE
ROTHERHITHE STREET
CLARENCE STREET
SWAN LANE
ADAM STREET
ALBION STREET
CHURCH S.
ELEPHANT LA.
PRINCESS
WALL
PARADISE STR.
PARADISE ROW
MILL POND
CHERRY GARDNS
MARYGOLD ST.
SALISBURY STR.
ROPE WALK
WEST ST.
QUEEN
KINGS
UPPER CLARENCE STR.
KINGS ROAD
GRAND
OUTER DO
NEPTUN
R
H

User Tasks

- Three sets of tasks (called '*Trials*')
- Randomized order for each user
- Tasks modelled to encourage use of panning and zooming in varied ways

(1) Trial #1

(a) "Find the *stamp* on the *border* of the map, and tell me the date inside."

(b) "Find the *park* containing the '*Serpentine River*'."

(c) "There is a *railway* to the north of *Victoria Park* – what *red area* is it connected to?"

(2) Trial #2

(a) "Please find the '*South Eastern Railway*'."

(b) "That Railway ends at a *red* terminal area – what is the closest *bridge*?"

(c) "Please name the hills next to *Regents Park*."

(3) Trial #3

(a) "What *church* is within the *red outlined area* of the city?"

(b) "Please find the '*Abbey*' between the *Thames River* and *St.James* Park."

(c) "Please find the tunnel that crosses the Thames River."

Task Model

- *"Find a feature apparent from an overview of map, but requires close inspection to successfully complete"*
    - encouraging the user to use zooming interactions to inspect items of interest
- *"Find small-scale information, at a location far from the last task's end, in the neighbourhood of a larger-scale feature"*
    - deliberately forcing reorientation of the user, requiring combinations of pan and zoom interactions
    - localized search requiring both user visual attention and control near simultaneously or in quick succession
- *"Follow an extended/linear feature to a described target/destination"*
    - exercising smooth or continuous control of panning function over larger amounts of geographic space

Task Performance

- Mouse and Keyboard was fastest on average
- Gaze-interface times slower and larger variance
- Some users achieved similar or better times using gaze interaction
- All users successfully completed all tasks

Minimum Times		Trial 1	Trial 2	Trial 3
Interface	#1	34	20	69
	#2	52	38	23
	#3	125	35	73

Figure 21: Minimum Recorded Trial Completion Times (in seconds)

Average Time Difference to Baseline				
Interface	Trial #	Task 1	Task 2	Task 3
#2 - Gaze-Supported Navigation	1	25	18	35
	2	18	8	25
	3	15	-11	-20
#3 - Eyes-Only Navigation	1	28	6	125
	2	91	84	52
	3	15	13	11

Figure 21: Average Completion Times (in seconds) - Per Task Comparison to Mouse & Keyboard Interface

Problems Impacting the Eyes-Only Interface

Inability to Wink

Some users covered the respective eyes with their hand

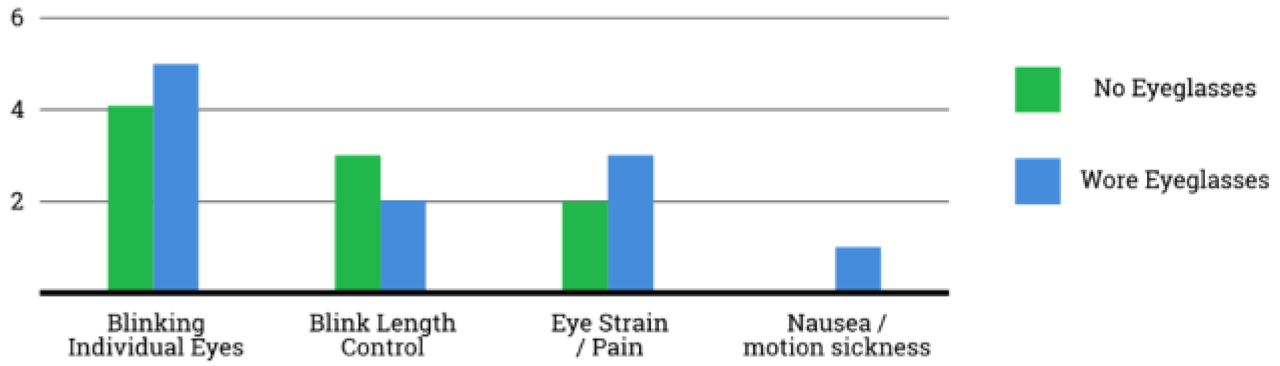
Unexplained Swapping of Eye Functions

Users adapted and persisted using the interface

Head motion & Users viewing monitors up close

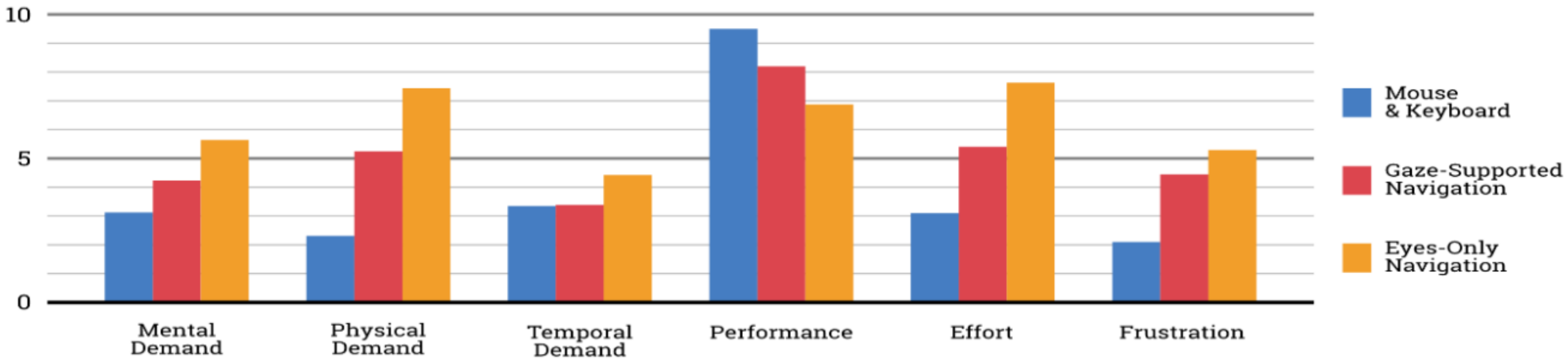
Returning to sat back, resting state allowed eye-tracker to regain eye- lock

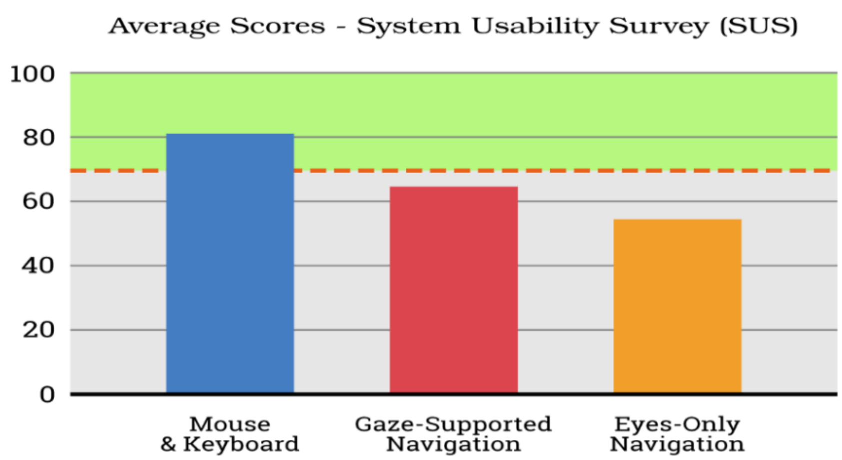
User Problems and Behaviours



- Winking was difficult for a majority (9 of 16)
- Poor eye-tracker calibration without discernable reason with some users
- Users shifting out of eye-tracker view
  - No indicator of eye-lock present in the interfaces
- Head motion in desired direction of target/panning
  - Coupled with frustration at non-responsiveness/failure to trigger gaze-based interactions

User Assessment – Task Load and Usability

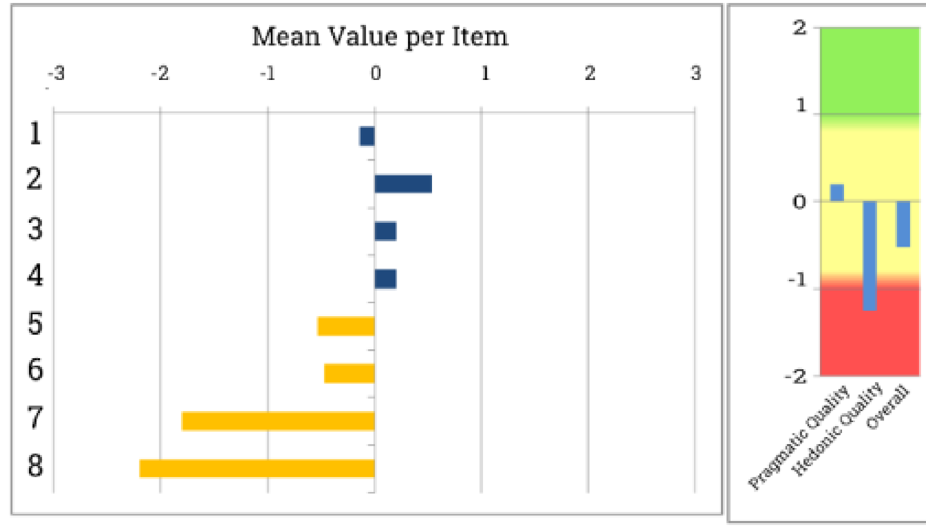




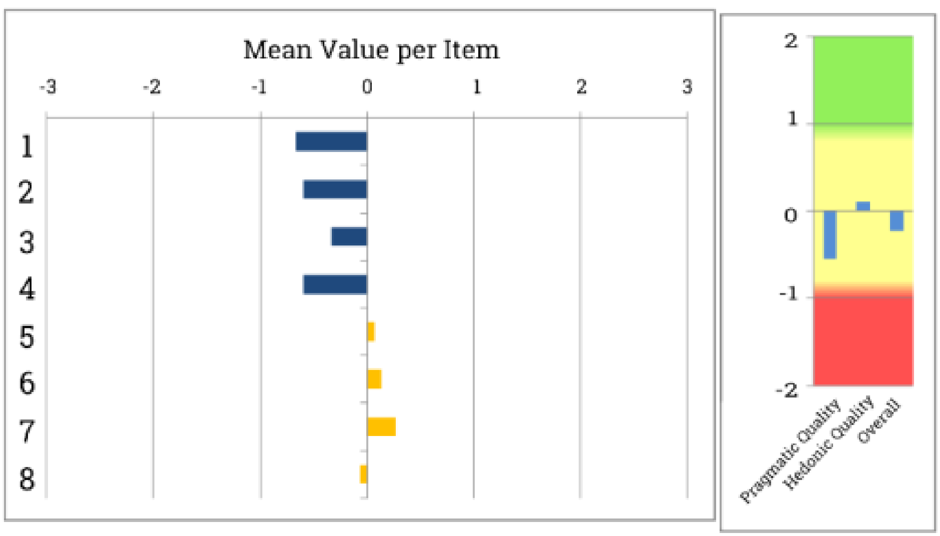
User Experience Questionnaire (UEQ-S) Items and their Related Scales

Scale	Item #	Negative	Positive
Pragmatic Quality	1	obstructive	supportive
	2	complicated	easy
	3	inefficient	efficient
	4	confusing	clear
Hedonic Quality	5	boring	exciting
	6	not interesting	interesting
	7	conventional	inventive
	8	usual	leading edge

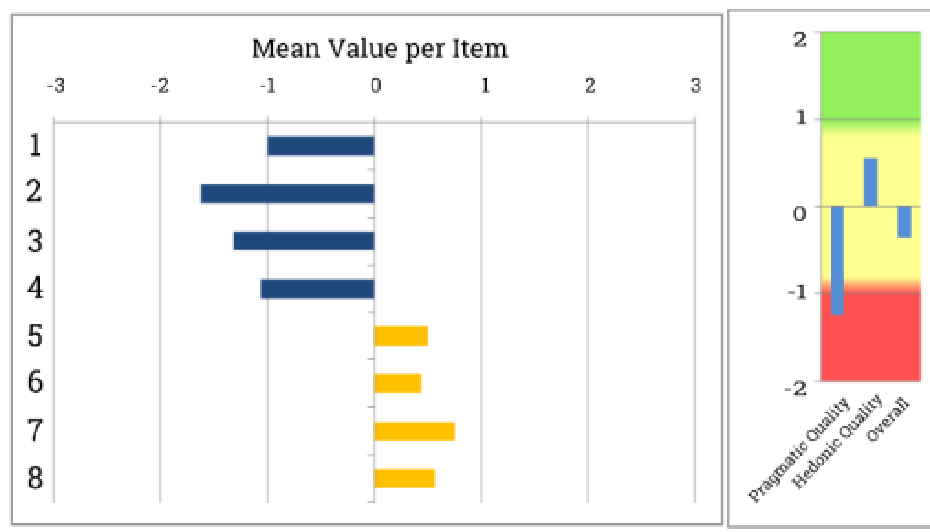
Interface #1
Mouse and Keyboard



Interface #2
Gaze-Supported Navigation



Interface #3
Eyes-Only Navigation



Users’ Ranked Preferences

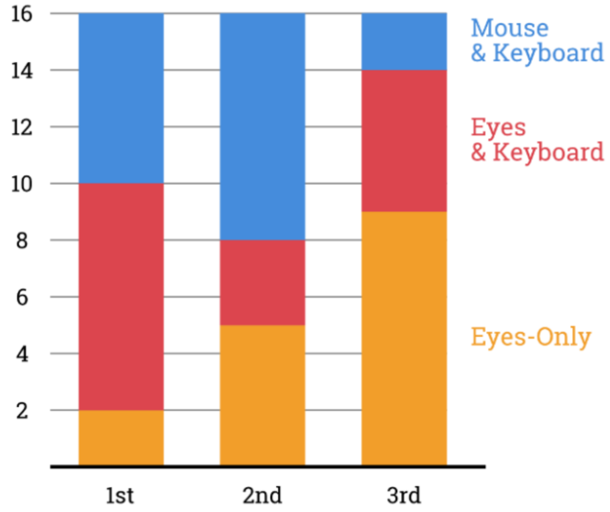


Figure 25: User Ranking of Interface By Preference

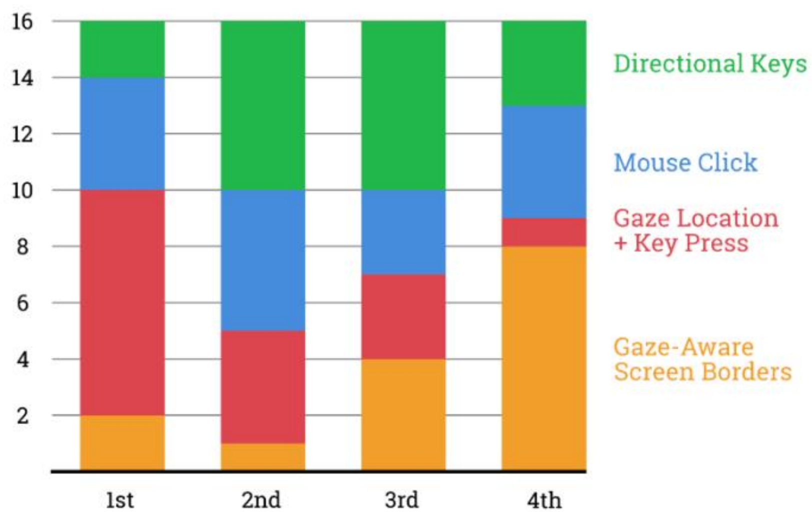


Figure 27: User Ranking of Panning Interactivity

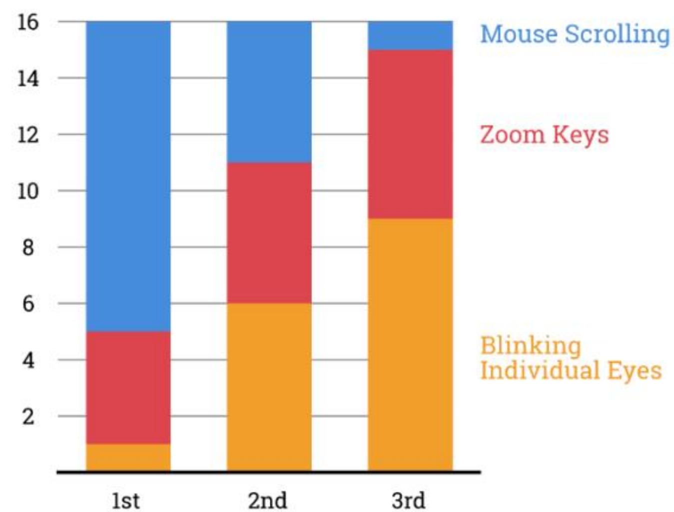


Figure 27: User Ranking of Zooming Interactions

Takeaways

- Gaze-interfaces more stimulating to users
  - Practicality hindered by instability and user capabilities
- Strong preference for Gaze-directed panning
  - Likely skewed due to lack of mouse drag panning
- The strong preference for Eyes & Keyboard interface
  - Corroborates previous research on well received gaze-pivot zooming
  - Shows potential for adoption and successful use

Research Questions

1. What pairing of map interaction and eye-control method would produce a usable eye-based map interface?
   - Based on the interaction model identified, an interface for map Panning and Zooming using gaze-based pointers and triggers

2. Can its implemented gaze control/awareness provide beneficial map interactions?
   - It successfully facilitated the map navigation for all users
   - Some users' performance and preferences indicate gaze-interfaces allow for similar efficiency to the baseline mouse and keyboard
   - Gaze-supported navigation (interface #2) specifically can has a marginally worse load and usability than mouse; Both gaze-interfaces offer more user stimulation
   - Interface stability, users' physical capabilities, and the interplay of glasses and lighting are challenges for such an interface.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