AN ALTERNATIVE WAYFINDING MAP DESIGN FOR
MAP ILLITERATE TOURISTS

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Table of Contents

Acknowledgements ..........................................................................................................i
List of Figures .................................................................................................................. ix
List of Tables .................................................................................................................. xv
List of Abbreviations ..................................................................................................... xvi
Abstract ......................................................................................................................... 18
Samenvatting ................................................................................................................ 20

Chapter 1 - Introduction ................................................................................................. 22
  1.1 Background Information and Context ........................................................................... 22
  1.2 Problem Statement ....................................................................................................... 26
  1.3 Aim, Objectives, and Research Questions ................................................................. 27
  1.4 Rationale ....................................................................................................................... 28
  1.5 Outline of the Thesis ..................................................................................................... 29
  Summary ............................................................................................................................. 30

Chapter 2 - Map Literacy ................................................................................................ 31
  2.1 Map Literacy Defined ................................................................................................... 31
  2.2 Literacy .......................................................................................................................... 32
    2.2.1 Design Literacy ....................................................................................................... 33
    2.2.2 Graphics Literacy .................................................................................................... 34
    2.2.3 Visual Literacy ........................................................................................................ 35
    2.2.4 Spatial Literacy ....................................................................................................... 35
    2.2.5 Map Literacy ........................................................................................................... 37
  2.3 Methods Available to Assess Map Literacy .................................................................. 40
    2.3.1 Santa Barbara Sense of Direction Scale ................................................................. 40
    2.3.2 Functional Map Literacy Test ................................................................................. 42
    2.3.3 Spatial Thinking Ability Test ................................................................................... 43
    2.3.4 Geospatial Thinking Scale ...................................................................................... 44
    2.3.5 Map Literacy Scale ................................................................................................. 44
  2.4 Effectiveness of Tests ................................................................................................... 45
Chapter 3 - Methods for Studying the Wayfinding Behaviours of Map-(Il)literate Users ...

3.1 Review of Methodologies for Evaluating Map Designs .............................................. 49

3.1.1 Methods of Evaluating Map Design ................................................................. 49
3.1.2 General Case ................................................................................................... 50
3.1.3 Pedestrian Map Use ...................................................................................... 53
3.1.4 Indoor You-Are-Here (YAH) Maps ............................................................... 55
3.1.5 Electronic Map Displays .............................................................................. 56
3.1.6 Wayfinding in Virtual Environments ............................................................ 58

3.2 Evaluation of Data Collection and Analysis Techniques ....................................... 59

3.2.1 Applicable Methodologies ........................................................................... 61

3.3 Methodology Development ................................................................................... 63

3.3.1 Collecting Data Using Questionnaires .......................................................... 65
3.3.2 Collecting Data Using Eye-Tracking Equipment ............................................ 65
3.3.3 Collecting Data Using Think-Aloud Protocols .............................................. 66
3.3.4 Justification of Methods Chosen ................................................................... 67

3.4 Selecting a Test Scenario ...................................................................................... 67

3.4.1 Bangkok ....................................................................................................... 69
3.4.2 London ......................................................................................................... 70
3.4.3 Paris ............................................................................................................ 70
3.4.4 Dubai ........................................................................................................... 70
3.4.5 New York City .............................................................................................. 70

3.5 Selecting Appropriate Users .............................................................................. 77

3.6 Selecting Map Platforms .................................................................................... 78

Summary .............................................................................................................. 80

Chapter 4 - Identifying Challenges Map Illiterate Users Experience When Wayfinding in a Small City with an Irregular Road Network ......................................................... 82

4.1 Study Outline .................................................................................................... 82

4.1.1 Route Planning .............................................................................................. 83
4.1.2 Wayfinding .................................................................................................. 87
An Alternative Wayfinding Map Design for Map Illiterate Tourists

4.1.3 Post-Test Interview ................................................................................................ 87
4.2 Study location - Enschede ........................................................................................ 87
4.3 Identifying an App for Testing ................................................................................ 90
4.4 Identifying Participants ............................................................................................ 96
   4.4.1 Map Literacy Assessment ................................................................................... 97
   4.4.2 Recruitment Processes ....................................................................................... 97
   4.4.3 Participant Selection .......................................................................................... 98
   4.4.4 Participant Demographics ................................................................................ 98
4.5 Investigating Challenges Experienced by Map-(il)literate Individuals ................. 99
   4.5.1 Equipment ........................................................................................................ 99
   4.5.2 Eye-Tracking Technologies .............................................................................. 100
   4.5.3 Collecting Verbal Data ...................................................................................... 106
   4.5.4 Computer ......................................................................................................... 106
   4.5.5 Smartphone ..................................................................................................... 107
   4.5.6 Data Analysis Strategy .................................................................................... 107
4.6 Pilot Testing ............................................................................................................. 110
4.7 Route-Planning on a Desktop Computer .................................................................. 118
4.8 Wayfinding ............................................................................................................. 120
4.9 Results and Discussion ........................................................................................... 121
   4.9.1 Map Literacy .................................................................................................... 121
   4.9.2 Route-Planning ............................................................................................... 122
   4.9.3 Wayfinding ..................................................................................................... 126
   4.9.4 Post-Test Interviews ....................................................................................... 137
4.10 Findings ................................................................................................................ 138
4.11 Limitations ............................................................................................................. 139
Summary ..................................................................................................................... 140

Chapter 5 - Identifying Challenges Map-Illiterate Users Experience When Wayfinding in a
Medium City with a Grid-Style Road Network ............................................................... 141
5.1 Study Outline ...................................................................................................... 141
   5.1.1 Route Planning ............................................................................................... 142
   5.1.2 Wayfinding ..................................................................................................... 142
5.1.3 Post-Test Interview ................................................................. 143
5.2 Study Location – Melbourne ................................................... 143
5.3 Selecting a Map for Testing ..................................................... 146
5.4 Selecting a Study Area ............................................................... 148
5.5 Identifying Participants ............................................................ 149
  5.5.1 Map Literacy Assessment ..................................................... 149
  5.5.2 Recruitment Processes ....................................................... 149
  5.5.3 Participant Selection ........................................................... 149
  5.5.4 Participant Demographics .................................................. 150
  5.5.5 Equipment ....................................................................... 150
5.6 Identifying challenges experienced by map-illiterate individuals ..................................................... 151
  5.6.1 Data Analysis Strategy ....................................................... 151
  5.6.2 Limitations in Analysis ..................................................... 152
5.7 Pilot Testing ............................................................................ 154
5.8 Route Planning ....................................................................... 154
5.9 Wayfinding ............................................................................ 155
5.10 Results and Discussion .......................................................... 162
  5.10.1 Map Literacy ................................................................. 162
  5.10.2 Route Planning ............................................................... 163
  5.10.3 Wayfinding ................................................................. 183
  5.10.4 Post-Test Interviews ....................................................... 196
5.11 Findings ................................................................................ 200
5.12 Limitations ........................................................................... 201
Summary .................................................................................... 202

Chapter 6 – Designing a Wayfinding Solution for Map-Illiterate Users .................................. 203
6.1 Potential Solutions to the Problems Identified .................................................. 203
6.2 Design Brief ........................................................................ 219
  6.2.1 Project Overview and Background .................................. 219
  6.2.2 User Overview .............................................................. 220
  6.2.3 Functional Requirements ................................................ 220
6.2.4 Content/data ........................................................................................................ 221
6.3 Proof-of-Concept Smartphone App Development ................................................. 221
6.3.1 Detail is Added at Larger Scales ........................................................................... 223
6.3.2 Important Features are Visually Salient ............................................................... 226
6.3.3 Unnecessary Complexity is Reduced but Necessary Complexity is Retained ...... 226
6.3.4 Symbols that Support Map/Environment Matching are Used ............................ 228
6.3.5 Software and Design Procedure ........................................................................... 232
Summary ........................................................................................................................... 233

Chapter 7 – Designing Maps for Map-Illiterate Users in Urban Locations ............... 234
7.1 Identifying Participants Who are Map-Illiterate ....................................................... 234
7.1.1 Similar Studies ...................................................................................................... 235
7.1.2 Recruitment Process ............................................................................................ 235
7.1.3 Test instrument .................................................................................................... 236
7.1.4 Data Analysis ........................................................................................................ 236
7.1.5 Results and Discussion ......................................................................................... 236
7.2 Testing of the Proof-of-Concept App ........................................................................ 241
7.2.1 Recruitment Process ............................................................................................ 241
7.2.2 Participant Selection ............................................................................................ 241
7.2.3 Participant Demographics .................................................................................... 242
7.2.4 Exercise Development .......................................................................................... 243
7.2.5 Equipment ............................................................................................................ 245
7.2.6 Pilot Testing .......................................................................................................... 245
7.2.7 Wayfinding ........................................................................................................... 245
7.2.8 Data Processing .................................................................................................... 246
7.3 Results ......................................................................................................................... 247
7.3.1 Map Literacy ......................................................................................................... 247
7.3.2 Wayfinding Behaviour Between Routes .............................................................. 249
7.3.3 Wayfinding Behaviour of Successful and Unsuccessful Participants ................. 257
7.3.4 Verbalisations ...................................................................................................... 267
7.3.5 Post-Test Interviews ............................................................................................ 270
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.3.6 Discussion of Findings</td>
<td>275</td>
</tr>
<tr>
<td>7.3.7 Limitations</td>
<td>277</td>
</tr>
<tr>
<td>7.4 Guidelines</td>
<td>278</td>
</tr>
<tr>
<td>7.4.1 Basemap Design</td>
<td>279</td>
</tr>
<tr>
<td>7.4.2 Route Design</td>
<td>279</td>
</tr>
<tr>
<td>Summary</td>
<td>282</td>
</tr>
<tr>
<td>Chapter 8 – Conclusion</td>
<td>283</td>
</tr>
<tr>
<td>8.1 Summary of Main Findings</td>
<td>283</td>
</tr>
<tr>
<td>8.2 Research Questions and Outcomes</td>
<td>286</td>
</tr>
<tr>
<td>8.3 Future Research</td>
<td>289</td>
</tr>
<tr>
<td>8.4 Findings</td>
<td>291</td>
</tr>
<tr>
<td>Summary</td>
<td>292</td>
</tr>
<tr>
<td>References</td>
<td>293</td>
</tr>
</tbody>
</table>
List of Figures

FIGURE 3-1 Procedure for identifying appropriate experimental map reading tasks (Board 1978, p. 4) .... 52
FIGURE 3-2 Procedure for identifying appropriate experimental map-reading tasks, adapted from Board (1978) ................................................................. 64
FIGURE 3-3 Tourist Map of Bangkok (Tourism Authority of Thailand 2017, http://www.tourismthailand.my/ematerials/pdf/bangkok.pdf) ........................................... 72
FIGURE 3-5 Tourist Map of Paris (A’Prim Graphic 2013) .......................................................... 74
FIGURE 4-1 District of Roombeek, North of Enschede City Centre. This map shows the origin of the experiment, G.J. van Heekpark and the destination, Museum TwentseWelle ...................... 85
FIGURE 4-2 Example of a participant’s three routes, drawn in Microsoft Paint ........................................ 86
FIGURE 4-3 Location of Enschede, The Netherlands ........................................................................ 88
FIGURE 4-4 Map of Enschede with inset of the city centre .............................................................. 89
FIGURE 4-5 Google Maps (left), Maps.Me (right) ........................................................................... 91
FIGURE 4-6 Route 66 (left), Scout (right) ..................................................................................... 92
FIGURE 4-7 Collecting fixed eye-tracking data (Tobii Technology AB 2015b) ..................................... 100
FIGURE 4-8 Dark Pupil and Bright Pupil Effect (Tobii Technology AB 2015a) ................................. 101
FIGURE 4-9 Tobii X60 Fixed Eye-Tracker (Tobii Technology AB 2011) ........................................ 103
FIGURE 4-10 Tobii X60 Eye-Tracker Setup (Tobii Technology AB 2010) .......................................... 104
FIGURE 4-11 Tobii Pro Glasses 2 (Tobii Technology AB 2016b) .................................................... 105
FIGURE 4-12 Route-planning behaviour model ............................................................................ 108
FIGURE 4-13 Wayfinding behaviour model ................................................................................ 109
FIGURE 4-14 Exercise facilitator wearing a baseball cap to try to reduce the effect of sunlight on the infrared of the eye-tracking sensors ......................................................... 114
FIGURE 4-15 Tourist Map of Roombeek (Purchased at the Information Shop in Enschede) .............. 115
FIGURE 4-16 Experiment facilitator trying to reduce the effects of sunlight on eye-tracking sensors by using an umbrella (left) or wearing a head scarf beneath a hat (right) .................................... 116
FIGURE 4-17 Solar Geometries on the Winter (2015), Spring, Summer, and Autumn (2016) Solstices in Enschede (University of Oregon 2017) .............................................................. 118
FIGURE 4-18 Maps.Me Screenshot Used for Route Planning Activity in Microsoft Paint ................ 119
FIGURE 4-19 Planned and Actual Route Traversed by Participant 15 (Job Applicant) ...................... 120
FIGURE 4-20 Box plots summarising the distribution of Santa Barbara Sense of Direction Scale Scores (SBSODS) for N = 14 participants equally allocated into Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution ................................................ 122
FIGURE 4-21 Code Use Frequency during Route-Planning Activity ............................................. 123
FIGURE 4-22 Gaze plot from the route-planning exercise (top). P15 heat map from route-planning activity (bottom) ................................................................. 125
Figure 4-23 Box plots summarising the distribution of Confirms landmark scores for N = 14 participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution. ................................................................. 127

Figure 4-24 Box plots summarising the distribution of confusion scores for N = 14 participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution. P1 (Job Applicants) is an outlier. ............................................... 128

Figure 4-25 Box plots summarising the distribution of confusion scores for N = 14 participants equally allocated into the Job Applicants and Tourists groups. P1 (Job Applicants), and P2 (Tourists) are outliers. ........................................................................................................ 129

Figure 4-26 Box plots summarising the distribution of Looks at map scores for N = 14 participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution. ...................................................................................................... 130

Figure 4-27 Box plots summarising the distribution of Looks for landmark scores for N = 14 participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution; P2 (Tourists) is an outlier. ............................................................. 131

Figure 4-28 Box plots summarising the distribution of Stop walking scores for N = 14 participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution; P15 (Job Applicants) and P2 (Tourists) are outliers. ...................... 132

Figure 4-29 Box plots summarising the number of times participants interacted with the map for N = 14 participants, equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution. P1 (Job Applicants) is an outlier. ...................... 133

Figure 4-30 Box plots summarising the number of times participants rotated the map for N = 14 participants, equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution. P1 (Job Applicants) is an outlier. .......................... 134

Figure 4-31 Verbal code frequency during wayfinding activity ................................................................. 135

Figure 4-32 P1’s planned and actual routes .......................................................................................... 136

Figure 4-33 Screenshots of scenes and eye-tracking for P1 .................................................................. 137

Figure 5-1 Participant wearing Tobii Pro Glasses 2 while completing the route-planning exercise (left) and the wayfinding exercise (right) ................................................................................... 142

Figure 5-2 Location of Melbourne, Australia ...................................................................................... 144

Figure 5-3 Map of Inner Melbourne ..................................................................................................... 145

Figure 5-4 City of Melbourne Tourist Map (Destination Melbourne 2016) with study area and enlarged section of map indicated by a red rectangle ................................................................. 147

Figure 5-5 Enlarged section of City of Melbourne Tourist Map (Destination Melbourne 2016) showing origin and destination of route and the addition of footpaths. This figure shows the area delineated by red rectangle on the map in Figure 5-4. .................................................. 148

Figure 5-6 Percentage of gaze samples acquired by Tobii Pro 2 Glasses during the route-planning and wayfinding activities ........................................................................................................ 153

Figure 5-7 P2’s three routes drawn on the enlarged section of City of Melbourne Tourist Map ............ 155

Figure 5-8 P2 the planned route selected (drawn in blue) by P2 to walk from the origin (intersection of Little Bourke Street and Tattersalls Lane) to the destination (Royal Exhibition Building) ............. 156

Figure 5-9 Comparison of P2’s planned (left) and travelled routes (right) ........................................ 158

Figure 5-10 P2’s route walked (left) and route planned (right) ............................................................ 159

Figure 5-11 Locations where P2 attempted to cross Victoria Street .................................................... 160
FIGURE 5-12 LA TROBE STREET CROSSING ................................................................. 161
FIGURE 5-13 TRAM STOP CROSSING ................................................................. 161
FIGURE 5-14 SPRING STREET CROSSING ......................................................... 162
FIGURE 5-15 BOX PLOTS SUMMARISING THE DISTRIBUTION OF SANTA BARBARA SENSE OF DIRECTION SCALE SCORES (SBSODS) FOR N = 9 PARTICIPANTS ALLOCATED INTO JOB APPLICANTS (N=5) AND TOURISTS (N=4) GROUPS. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION. P3 IS AN OUTLIER. 163
FIGURE 5-16 BOX PLOTS SUMMARISING THE DISTRIBUTION OF CALCULATE ROUTE DISTANCE SCORES FOR N = 10 PARTICIPANTS EQUALLY ALLOCATED INTO THE JOB APPLICANTS AND TOURISTS GROUPS. P1 (TOURISTS) IS AN OUTLIER. 164
FIGURE 5-17 BOX PLOTS SUMMARISING THE DISTRIBUTION OF CALCULATE ROUTE TIME SCORES FOR N = 10 PARTICIPANTS EQUALLY ALLOCATED INTO THE JOB APPLICANTS AND TOURISTS GROUPS. P1 (TOURISTS) IS AN OUTLIER. 165
FIGURE 5-18 BOX PLOTS SUMMARISING THE DISTRIBUTION OF CONFIRMS LANDMARK SCORES FOR N = 10 PARTICIPANTS EQUALLY ALLOCATED INTO THE JOB APPLICANTS AND TOURISTS GROUPS. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION; P1 AND P10 (TOURISTS) ARE OUTLIERS. 166
FIGURE 5-19 BOX PLOTS SUMMARISING THE DISTRIBUTION OF CONFUSION SCORES FOR N = 10 PARTICIPANTS EQUALLY ALLOCATED INTO THE JOB APPLICANTS AND TOURISTS GROUPS. P4 AND P8 (JOB APPLICANTS) ARE OUTLIERS. 167
FIGURE 5-20 BOX PLOTS SUMMARISING THE DISTRIBUTION OF CONFIRMS LANDMARK SCORES FOR N = 10 PARTICIPANTS EQUALLY ALLOCATED INTO THE JOB APPLICANTS AND TOURISTS GROUPS. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION; P4 (JOB APPLICANTS) IS AN OUTLIER. 168
FIGURE 5-21 BOX PLOTS SUMMARISING THE DISTRIBUTION OF CONFUSION SCORES FOR N = 10 PARTICIPANTS EQUALLY ALLOCATED INTO THE JOB APPLICANTS AND TOURISTS GROUPS. P3 AND P6 (JOB APPLICANTS) AND P1 (TOURISTS) ARE OUTLIERS. 169
FIGURE 5-22 BOX PLOTS SUMMARISING THE DISTRIBUTION OF MAP ROTATION SCORES FOR N = 10 PARTICIPANTS EQUALLY ALLOCATED INTO THE JOB APPLICANTS AND TOURISTS GROUPS. P10 (TOURISTS) IS AN OUTLIER. 170
FIGURE 5-23 JOB APPLICANTS’ PLANNED (LEFT) AND TRAVELLED ROUTES (RIGHT) ................................................. 171
FIGURE 5-24 TOURISTS’ PLANNED (LEFT) AND TRAVELLED ROUTES (RIGHT) .......................................................... 172
FIGURE 5-25 CODE USE FREQUENCY IN ROUTE PLANNING ACTIVITY ................................................................. 174
FIGURE 5-26 OPTIONS OF WALKING ALONG RATHDWINE STREET (LEFT) OR THROUGH THE CARLTON GARDENS (CENTRE AND RIGHT) TO REACH THE ROYAL EXHIBITION BUILDING ............................................................................. 177
FIGURE 5-27 P5’S PLANNED (LEFT) AND TRAVELLED ROUTE (RIGHT) ................................................................. 178
FIGURE 5-28 P6’S PLANNED (LEFT) AND TRAVELLED ROUTE (RIGHT) ................................................................. 179
FIGURE 5-29 P7’S PLANNED (LEFT) AND TRAVELLED ROUTE (RIGHT) ................................................................. 180
FIGURE 5-30 P8’S PLANNED (LEFT) AND TRAVELLED ROUTE (RIGHT) ................................................................. 181
FIGURE 5-31 P9’S PLANNED (LEFT) AND TRAVELLED ROUTE (RIGHT) ................................................................. 182
FIGURE 5-32 BOX PLOTS SUMMARISING THE DISTRIBUTION OF CONFIRMS LANDMARK SCORES FOR N = 10 PARTICIPANTS EQUALLY ALLOCATED INTO THE JOB APPLICANTS AND TOURISTS GROUPS. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION; P3 (JOB APPLICANTS) IS AN OUTLIER. 184
FIGURE 5-33 BOX PLOTS SUMMARISING THE DISTRIBUTION OF CONFUSION SCORES FOR N = 10 PARTICIPANTS EQUALLY ALLOCATED INTO THE JOB APPLICANTS AND TOURISTS GROUPS. P3 (JOB APPLICANTS), AND P5 AND P10 (TOURISTS) ARE OUTLIERS. 185
FIGURE 5-34 BOX PLOTS SUMMARISING THE DISTRIBUTION OF DEVIATION FROM ROUTE SCORES FOR N = 10 PARTICIPANTS EQUALLY ALLOCATED INTO THE JOB APPLICANTS AND TOURISTS GROUPS. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION. 186
An Alternative Wayfinding Map Design for Map Illiterate Tourists

Figure 5-35 Box plots summarising the distribution of looks at map scores for N = 10 participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution ................................................................. 187

Figure 5-36 Box plots summarising the distribution of looks for landmark scores for N = 10 participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution; P3 (Job Applicants) is an outlier .................................................. 188

Figure 5-37 Box plots summarising the distribution of map rotation scores for N = 10 participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution; P10 (Tourists) is an outlier ........................................................... 189

Figure 5-38 Box plots summarising the distribution of stop walking scores for N = 10 participants equally allocated into the Job Applicants and Tourists groups. P3 (Job Applicants) and P1 (Tourists) are outliers ....................................................................................................... 190

Figure 5-39 Box plots summarising the distribution of self-localisation scores for N = 10 participants equally allocated into the Job Applicants and Tourists groups; P10 (Tourists) is an outlier. .................................................. 191

Figure 5-40 Frequency of verbal codes identified in transcripts from the Job Applicants and Tourists groups during the wayfinding activity ....................................................................................................................................... 192

Figure 5-41 P10’s planned (left) and travelled route (right) .......................................................................................................................... 195

Figure 5-42 Facing north at Spring Street. Cars can keep to the left, and continue along Spring Street, or follow the right lane, which becomes Nicholson Street. When pedestrians cross the road at this intersection, they can only follow the road to the right, which becomes Nicholson Street ................................................................. 196

Figure 5-43 City of Melbourne tourist map, where label placement causes confusion around Spring Street .................................................................................................................................................... 198

Figure 5-44 Examples of inconsistent labelling: Victoria St and Spring St .......................................................................................................................... 199

Figure 6-1 Google Maps labelling on smartphone application (2019); pharmacy label extends over street segment (left); only one main road is labelled (right) .......................................................................................................................... 208

Figure 6-2 Context model for mobile cartography (Reichenbacher 2005, p. 145) .......................................................................................................................... 215

Figure 6-3 Wayfinding app at the four scales clockwise from top-left; 1:18,000, 1:9,000, 1:2,250, 1:4,500 .................................................................................................................................................... 225

Figure 6-4 Photo showing Exhibition Street crossing over Lonsdale Street. The 7-Eleven and Comedy Theatre landmarks are visible on the right side of the image .......................................................................................................................... 226

Figure 6-5 Photo of Lonsdale Street showing lanes divided by a median strip .......................................................................................................................... 227

Figure 6-6 Photo of Lonsdale Street showing lanes divided by car parking .......................................................................................................................... 228

Figure 6-7 Landmark symbols used in the proof-of-concept wayfinding app .......................................................................................................................... 229

Figure 6-8 Visible signage for 2 Lonsdale Street .......................................................................................................................... 231

Figure 6-9 Comedy Theatre landmark icon is selected, and Comedy Theatre image is displayed in top-left corner of the screen (left); no landmarks are selected (right) .......................................................................................................................... 232

Figure 7-1 Percentage of respondents by age .............................................................................................................................................................................................................. 238

Figure 7-2 Percentage of respondents by gender .............................................................................................................................................................................................................. 238

Figure 7-3 Percentage of respondents by country of residence .............................................................................................................................................................................................................. 239

Figure 7-4 Percentage of respondents by highest level of education .............................................................................................................................................................................................................. 239

Figure 7-5 Most common fields of study among respondents .............................................................................................................................................................................................................. 240

Figure 7-6 Respondents by occupation .............................................................................................................................................................................................................. 240

Figure 7-7 View of Comedy Theatre for participants travelling Route AB (left); View of Comedy Theatre for participants travelling Route BA (right) .............................................................................................................................................................................................................. 244
FIGURE 7-8 BOX PLOTS SUMMARISING THE DISTRIBUTION OF SANTA BARBARA SENSE OF DIRECTION SCALE SCORES (SBSODS) FOR N = 14 PARTICIPANTS EQUALLY ALLOCATED INTO AB AND BA ROUTES. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION. P17 IS AN OUTLIER. .................................................. 247

FIGURE 7-9 BOX PLOTS SUMMARISING THE DISTRIBUTION OF SANTA BARBARA SENSE OF DIRECTION SCALE SCORES (SBSODS) FOR N = 14 PARTICIPANTS IN SUCCESSFUL (N=10) AND UNSUCCESSFUL (N=4) GROUPS. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION. ............................................................. 249

FIGURE 7-10 BOX PLOTS SUMMARISING THE DISTRIBUTION OF TIME TO WALK ROUTE SCORES FOR N = 14 PARTICIPANTS EQUALLY ALLOCATED INTO THE AB AND BA ROUTES. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION; P16 (ROUTE AB) AND P13 (ROUTE BA) ARE OUTLIERS. ..................................................... 250

FIGURE 7-11 BOX PLOTS SUMMARISING THE DISTRIBUTION OF NUMBER OF DEVIATIONS FROM ROUTE SCORES FOR N = 14 PARTICIPANTS EQUALLY ALLOCATED INTO AB AND BA ROUTES. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION. ...................................................................................................... 251

FIGURE 7-12 BOX PLOTS SUMMARISING THE DISTRIBUTION OF NUMBER OF VOLUNTARY STOP SCORES FOR N = 14 PARTICIPANTS EQUALLY ALLOCATED INTO AB AND BA ROUTES. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION. P1 (ROUTE AB) IS AN OUTLIER. ........................................................... 252

FIGURE 7-13 BOX PLOTS SUMMARISING THE DISTRIBUTION OF FREQUENCY OF LOOKING AT MAP PER MINUTE, SCORES FOR N = 14 PARTICIPANTS EQUALLY ALLOCATED INTO AB AND BA ROUTES. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION. ...................................................................................................... 253

FIGURE 7-14 BOX PLOTS SUMMARISING THE DISTRIBUTION OF MATCHING LANDMARK SCORES FOR N = 14 PARTICIPANTS EQUALLY ALLOCATED INTO AB AND BA ROUTES. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION. ...................................................................................................... 254

FIGURE 7-15 BOX PLOTS SUMMARISING THE DISTRIBUTION OF THE PROPORTION OF TIME PARTICIPANTS SPENT LOOKING AT THE MAP WHILE WALKING FOR N = 14 PARTICIPANTS EQUALLY ALLOCATED INTO AB AND BA ROUTES. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION. P17 IS AN OUTLIER IN GROUP ROUTE BA. ............................................................. 255

FIGURE 7-16 BOX PLOTS SUMMARISING THE PROPORTION OF TIME SPENT LOOKING AT THE MAP DURING FORCED STOPS FOR N = 14 PARTICIPANTS EQUALLY ALLOCATED INTO AB AND BA ROUTES. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION. P1 IS AN OUTLIER IN GROUP ROUTE AB. ............................................................. 256

FIGURE 7-17 BOX PLOTS SUMMARISING THE NUMBER OF TIMES PARTICIPANTS INTERACTED WITH THE MAP FOR N = 14 PARTICIPANTS EQUALLY ALLOCATED INTO AB AND BA ROUTES. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION. ...................................................................................................... 257

FIGURE 7-18 BOX PLOTS SUMMARISING THE DISTRIBUTION OF TIME TO WALK ROUTE SCORES FOR N = 14 PARTICIPANTS ALLOCATED INTO THE UNSUCCESSFUL (N=4) AND SUCCESSFUL (N=10) GROUPS. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION; P13 (SUCCESSFUL) IS AN OUTLIER. ............................................................. 260

FIGURE 7-19 BOX PLOTS SUMMARISING THE DISTRIBUTION OF NUMBER OF VOLUNTARY STOP SCORES FOR N = 14 PARTICIPANTS ALLOCATED INTO THE UNSUCCESSFUL (N=4) AND SUCCESSFUL (N=10) GROUPS. ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION. P1 AND P9 ARE OUTLIERS IN THE SUCCESSFUL GROUP. ...................................................................................................... 261

FIGURE 7-20 BOX PLOTS SUMMARISING THE DISTRIBUTION OF FREQUENCY OF LOOKING AT MAP PER MINUTE SCORES FOR N = 14 PARTICIPANTS, UNSUCCESSFUL (N=4) AND SUCCESSFUL (N=10). ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION. ...................................................................................................... 262

FIGURE 7-21 BOX PLOTS SUMMARISING THE DISTRIBUTION OF MATCHING LANDMARK SCORES FOR N = 14 PARTICIPANTS, UNSUCCESSFUL (N=4) AND SUCCESSFUL (N=10). ERROR BARS REPRESENT 95% CONFIDENCE INTERVALS OF EACH DISTRIBUTION. ...................................................................................................... 263
Figure 7-22 Box plots summarising the distribution of the proportion of time participants spent looking at the map while walking for N = 14 participants, unsuccessful (n=4) and successful (n=10). Error bars represent 95% confidence intervals of each distribution.

Figure 7-23 Box plots summarising the proportion of time spent looking at the map during forced stops for N = 14 participants, unsuccessful (n=4) successful (n=10). Error bars represent 95% confidence intervals of each distribution.

Figure 7-24 Box plots summarising the number of times participants interacted with the map for N = 14 participants, unsuccessful (n=4) and successful (n=10). Error bars represent 95% confidence intervals of each distribution.

Figure 7-25 Box plots summarising the number of times participants zoomed the map in or out for N = 14 participants, unsuccessful (n=4) and successful (n=10). Error bars represent 95% confidence intervals of each distribution. P4 and P5 are outliers in the successful group.

Figure 7-26 Comparison of verbalisations between the Route AB and Route BA.

Figure 7-27 Comparison of normalised verbalisations between successful and unsuccessful participants.

Figure 7-28 Mean map evaluation scores for Route AB and Route BA.

Figure 7-29 Mean map evaluation scores for successful and unsuccessful groups.

Figure 7-30 Mean evaluation scores of the paper map used in the first Melbourne study (Chapter 5) and the proof-of-concept app used by group Route AB.

Figure 7-31 Box plots summarising the distribution of Santa Barbara Sense of Direction Scale scores (SBSODS) for 16 participants, Route AB (n=7) and paper map (n=9). Error bars represent 95% confidence intervals of each distribution. *Note, despite 10 participants completing the paper map study, only nine participants completed the SBSODS.
List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TABLE 2-1</td>
<td>DEFINITIONS OF VISUAL LITERACY</td>
<td>35</td>
</tr>
<tr>
<td>TABLE 2-2</td>
<td>DEFINITIONS OF SPATIAL LITERACY</td>
<td>36</td>
</tr>
<tr>
<td>TABLE 2-3</td>
<td>OLSON AND CLARKE'S HIERARCHIES OF MAP READING TASKS</td>
<td>39</td>
</tr>
<tr>
<td>TABLE 2-4</td>
<td>COMPARISON OF TESTS APPLICABLE TO MAP LITERACY</td>
<td>46</td>
</tr>
<tr>
<td>TABLE 3-1</td>
<td>EXCLUSION CRITERIA FOR POTENTIAL PARTICIPANTS</td>
<td>78</td>
</tr>
<tr>
<td>TABLE 3-2</td>
<td>COMPARISON OF PAPER MAPS AND DIGITAL MAPS</td>
<td>78</td>
</tr>
<tr>
<td>TABLE 3-3</td>
<td>BENEFITS AND CONSTRAINTS OF MAPS DISPLAYED ON SMARTPHONES, TABLETS, AND DESKTOP COMPUTER</td>
<td>80</td>
</tr>
<tr>
<td>TABLE 4-1</td>
<td>PROFILE OF RESPONDENTS TO THE MAP APP ASSESSMENT SURVEY OF CARTOGRAPHIC EXPERTS</td>
<td>94</td>
</tr>
<tr>
<td>TABLE 4-2</td>
<td>SAMPLE OF SCORING</td>
<td>94</td>
</tr>
<tr>
<td>TABLE 4-3</td>
<td>MEAN SCORES FROM MAP APP ASSESSMENT SURVEY</td>
<td>95</td>
</tr>
<tr>
<td>TABLE 4-4</td>
<td>PARTICIPANT DEMOGRAPHICS USING BERTIN'S REORDERABLE MATRIX METHOD TO DISTRIBUTE THE PARTICIPANTS BETWEEN THE TOURIST AND JOB APPLICANT GROUPS</td>
<td>99</td>
</tr>
<tr>
<td>TABLE 4-5</td>
<td>TOBI X60 FIXED EYE-TRACKER SPECIFICATIONS (TOBI TECHNOLOGY AB 2010)</td>
<td>104</td>
</tr>
<tr>
<td>TABLE 4-6</td>
<td>TOBI PRO GLASSES 2 SPECIFICATIONS (TOBI TECHNOLOGY AB 2018)</td>
<td>105</td>
</tr>
<tr>
<td>TABLE 4-7</td>
<td>EXPECTED MAP-USE ACTIVITIES AND MAP-USE TASKS</td>
<td>107</td>
</tr>
<tr>
<td>TABLE 4-8</td>
<td>ACTIONS FOR ANALYSIS WITH CORRESPONDING CODES</td>
<td>110</td>
</tr>
<tr>
<td>TABLE 4-9</td>
<td>SAMPLE VERBAL STATEMENTS WITH CORRESPONDING CODES</td>
<td>123</td>
</tr>
<tr>
<td>TABLE 4-10</td>
<td>PARTICIPANTS' ESTIMATES OF THEIR PREFERRED ROUTE'S LENGTH VERSUS ITS ACTUAL LENGTH</td>
<td>124</td>
</tr>
<tr>
<td>TABLE 4-11</td>
<td>SUMMARY OF OUTLIERS</td>
<td>134</td>
</tr>
<tr>
<td>TABLE 4-12</td>
<td>SAMPLE OF VERBAL STATEMENTS WITH CORRESPONDING CODES</td>
<td>136</td>
</tr>
<tr>
<td>TABLE 5-1</td>
<td>PARTICIPANT DEMOGRAPHICS SHOWN IN REORDERABLE MATRIX. BY COMPILING THE DEMOGRAPHICS OF EACH PARTICIPANT, IT IS POSSIBLE TO 'REORDER' THEM INTO GROUPS FOR THE EXPERIMENT EXERCISES. NOTE, NULL VALUES HAVE BEEN INCLUDED WHERE PARTICIPANTS DID NOT COMPLETE A QUESTIONNAIRE QUESTION</td>
<td>151</td>
</tr>
<tr>
<td>TABLE 5-2</td>
<td>SAMPLES OF VERBALISED STATEMENTS WITH CORRESPONDING CODES</td>
<td>174</td>
</tr>
<tr>
<td>TABLE 5-3</td>
<td>PARTICIPANTS' ESTIMATED AND ACTUAL DISTANCES OF PLANNED ROUTES AND THE DISTANCES EACH PARTICIPANT WALKED</td>
<td>175</td>
</tr>
<tr>
<td>TABLE 5-4</td>
<td>SAMPLES OF VERBALISED STATEMENTS WITH CORRESPONDING CODES</td>
<td>192</td>
</tr>
<tr>
<td>TABLE 6-1</td>
<td>DESIGN CONCEPTS AS THEY RELATE TO THE KEY FINDINGS</td>
<td>218</td>
</tr>
<tr>
<td>TABLE 6-2</td>
<td>RESULTS OF EMPIRICAL WORK ALONGSIDE CORRESPONDING DESIGN SOLUTIONS</td>
<td>222</td>
</tr>
<tr>
<td>TABLE 7-1</td>
<td>PARTICIPANT DEMOGRAPHICS IN THE TWO STUDY GROUPS</td>
<td>242</td>
</tr>
<tr>
<td>TABLE 7-2</td>
<td>SAMPLES OF VERBALISED STATEMENTS WITH CORRESPONDING CODES</td>
<td>268</td>
</tr>
</tbody>
</table>
List of Abbreviations

ANOVA  Analysis of Variance
AOI    Area of Interest
App    Application
CBD    Central Business District
CTA    Concurrently Thinking Aloud
EOG    Electro-Oculography
FMLT   Functional Map Literacy Test
FOV    Field of View
GIS    Geographic Information System
GNSS   Global Navigation Satellite System
GTS    Geospatial Thinking Scale
ISS    International Space Station
ITC    Faculty of Geo-information and Earth Observation, University of Twente
MLS    Map Literacy Scale
NAAL   National Assessment of Adult Literacy
NCES   National Center for Education Statistics, United States
NCTE   National Council of Teachers of English
POG    Photo-Oculography
RACS   Royal Australasian College of Surgeons
RTA    Retrospectively Thinking Aloud
SBSODS  Santa Barbara Sense of Direction Scale
STAT   Spatial Thinking Ability Test
UNESCO United Nations Educational, Scientific and Cultural Organization
US     United States
UT     University of Twente
VOG    Video-Oculography
WEIRD Western, Educated, Industrialised, Rich and Democratic
YAH You Are Here
2D Two-Dimensional
3D Three-Dimension
Abstract

This thesis investigated the challenges experienced by map illiterate pedestrians when wayfinding in an unfamiliar urban environment. Solutions for the challenges identified were explored, and a proof-of-concept app was developed and tested.

It is not uncommon for people to express their inability to read a map, or even for other people to reveal that someone they know cannot read a map. Given the pervasiveness of this phenomenon, people with poor map reading skills are often left behind when wayfinding solutions are designed. More often, it’s the skills of the user that are said to require improvement, rather than the wayfinding solution. Aside from COVID-19 which led to global travel restrictions, people constantly move about the environment and are often required to travel to unfamiliar locations, such as when visiting a new restaurant, attending a job interview, or travelling as a tourist, to name a few reasons. For those who struggle to read maps, these activities can be complicated by their poor spatial abilities. At best, poor map reading abilities may lead to inconvenience, but at worst, an incorrect decision can be fatal; like when a mother and son were lost for five days in California’s Death Valley during the Summer of 2009 which resulted in the death of the son. Therefore, to address this phenomenon, three studies were completed to first identify the challenges experienced by this user group, and then to test a proof-of-concept solution.

In Study 1, participants completed a route-planning and wayfinding activity using a mobile map application. Participants were assigned and assumed the role of Job Applicant or Tourist. Participants in the Job Applicant group were advised to find their way as quickly as possible between their origin and destination, while those in the Tourist group were advised to take their time and visit other points of interest along the way. This study took place in a small city with a complex road network. The aim was to identify challenges that map users experience when using a mobile map application to find their way.
In Study 2, participants used a paper map to plan their route and then find their way along their route. This study took place in a large city, with a regular road network. The aim was to identify challenges map users experience when using a paper map. Again, participants were separated into Job Applicant and Tourist groups. The findings of these two studies were used to inform the design of a proof-of-concept app which aimed to address the challenges experienced by this user group.

In Study 3, participants used the proof-of-concept app to find their way between the origin and destination. Participants were divided into two groups. One group traversed the route in one direction, while the other group traversed the route in the reverse direction. The findings of this study indicate that by identifying the challenges experienced by map illiterate users, wayfinding solutions can be designed that successfully support these users in an unfamiliar urban location.
Deze dissertatie onderzocht de uitdagingen die voetgangers zonder kaartleesvaardigheden ervaren bij het vinden van de weg in een onbekende stedelijke omgeving. Oplossingen voor de geïdentificeerde uitdagingen werden onderzocht, en een proof-of-concept app werd ontwikkeld en getest.

Het is niet ongewoon dat mensen tijdens het gebruik van kaarten aangeven dat ze niet in staat zijn een kaart te lezen, of dat ze in een gesprek aan anderen toegeven geen kaart te kunnen lezen. Ondanks de wijdverbreidheid van dit fenomeen, worden mensen met een slechte kaartleesvaardigheid vaak vergeten wanneer oplossingen voor route-aanduidingen worden ontworpen.

Als oplossing wordt vaak naar het verbeteren van de vaardigheden van de gebruiker gewezen en niet naar een mogelijk verbetering van route aanduidingen. Afgezien van COVID-19, dat tot wereldwijde reisbeperkingen leidde, verplaatsen mensen zich voortdurend in de omgeving en moeten zij vaak naar onbekende locaties reizen, zoals bij het bezoeken van een nieuw restaurant, het bijwonen van een sollicitatiegesprek of het reizen als toerist, om maar een paar voorbeelden te noemen. Voor mensen die moeite hebben met kaartlezen kunnen deze activiteiten worden bemoeilijkt door hun slechte ruimtelijke vaardigheden. In het beste geval kan een slechte kaartleesvaardigheid leiden tot ongemak, maar in het slechtste geval kan een verkeerde beslissing fataal zijn; zoals toen een moeder en haar zoon in de zomer van 2009 vijf dagen lang verwaaiden in Death Valley in Californië, wat resulteerde in de dood van de zoon. Daarom werden, in het kader van deze studie drie studies uitgevoerd om eerst de uitdagingen van deze gebruikersgroep te identificeren en vervolgens een proof-of-concept oplossing te testen.

In studie 1 voltooiden deelnemers een routeplanning en route vinden activiteit met behulp van een mobiele kaartapplicatie. De deelnemers kregen de rol van sollicitant of toerist toebedeeld. Deelnemers in de sollicitantengroep kregen het advies zo snel mogelijk hun weg te vinden tussen herkomst en bestemming, terwijl deelnemers in de toeristengroep het
advies kregen de tijd te nemen en andere interessante punten onderweg te bezoeken. Deze studie vond plaats in een kleine stad met een complex wegennet. Het doel was na te gaan welke uitdagingen kaartgebruikers ervaren bij het gebruik van een mobiele kaartapplicatie om hun weg te vinden.

In studie 2 gebruikten de deelnemers een papieren kaart om hun route te plannen en vervolgens hun weg langs hun route te vinden. Dit onderzoek vond plaats in een grote stad, met een regelmatig wegennet. Het doel was na te gaan welke problemen kaartgebruikers ervaren bij het gebruik van een papieren kaart. Ook hier werden de deelnemers verdeeld in groepen werkzoekenden en toeristen. De bevindingen van deze twee studies werden gebruikt voor het ontwerp van een proof-of-concept-app die de door deze gebruikersgroep ervaren uitdagingen moest aanpakken.

In studie 3 gebruikten deelnemers de proof-of-concept app om hun weg te vinden tussen herkomst en bestemming. De deelnemers werden verdeeld in twee groepen. De ene groep legde de route in één richting af, terwijl de andere groep de route in omgekeerde richting aflegde. De bevindingen van deze studie geven aan dat op basis van de geïdentificeerde uitdagingen ondervonden door gebruikers met een slechte kaartleesvaardigheden, route aanduidings-oplossingen kunnen worden ontworpen die deze gebruikers succesvol ondersteunen in een onbekende stedelijke omgeving.
Chapter 1 – Introduction

This chapter presents initial background information, the context and the overall problem before providing the aim, objectives and research questions addressed in this research. Following this, the rationale and motivation for this research are discussed. Next, the research methodology used to address the objectives is outlined.

1.1 Background Information and Context

Examples abound of people becoming lost or making wrong decisions because they were unable to correctly interpret the spatial data with which they were presented. At best, these wrong decisions lead to inconvenience and at worst, to serious injury and maybe even death (Lin et al. 2017). For example, since 2015, hundreds of tourists using Google Maps to find their way to the Blue Mountains in New South Wales, Australia have been incorrectly directed to a residential street, approximately 30 kilometres from their goal location, causing inconvenience and frustration to both themselves and local residents (Biggs 2017). Similarly, a Belgian woman entered an address located 38 miles from her home into her satellite navigation system; however, the satellite navigation system directed her to Croatia (Waterfield 2013). The woman was reported missing, and public resources were used to locate her. Tragically, a mother and son became lost in California’s Death Valley for five days during the summer of 2009, resulting in the death of the son (Clark 2011). These examples, whilst extreme, highlight the potential consequences for people who cannot effectively interpret spatial information. What each of these examples has in common, is the reliance on navigation systems by passively following instructions, rather than reading and interacting with the map. This lack of interaction with the map results in a failure in the user to acquire sufficient spatial knowledge of their location, impacting their ability to successfully find their way and avoid undesirable outcomes.

The frequency with which people become lost, despite the huge amount of data available, and the abundance of platforms for displaying such data, is, in the opinion of this
An Alternative Wayfinding Map Design for Map Illiterate Users

researcher, disconcerting. Whilst it may be easy to put the blame on the map user for not learning how to read a map properly, it cannot be expected that the user can in fact read a map.

Evidence indicates that adults, when using a map in the real world, can often become confused and unable to effectively determine orientation or direction (Liben 2006). Other studies show that people differ in their abilities to read maps and move about within the environment (Hegarty, Burte & Boone 2018; Hegarty et al. 2006). Since these differences exist, it cannot be assumed that all people can read and use all maps effectively. In his book *Semiology of Graphics*, Bertin (1983) discussed the ways in which the interpretation of a graphic can vary between people. He attributes these variations in interpretation to “personality, surroundings, period and culture” (p. 2). These variations were also noted in several later studies (Aykin 1989; Delikostidis 2011; Liben 2006; MacEachren 2004; Slocum et al. 2001). There is no known limit to what a person might find to be ambiguous in a particular graphic and therefore, in a particular map. Supporting this theory are results from a study by Albert et al. (2016), which found that “group-specific mistakes are hard to be found among beginner map readers due to the diversity of people within the group. Since they have different strengths and weaknesses in cognitive skills, their mistakes vary” (p. 251). Maps are typically designed so that the graphical logic matches the information logic (Bertin 1983). However, what one person perceives to be logical may not be the same as another. There is therefore, no single way to display data, and hence, no single way to display spatial data (MacEachren 2004). In addition, the features available for inclusion in a map are almost limitless, as are the ways in which they can be depicted (Liben 2006). Therefore, it is important for map makers to appropriately select what should be displayed in a map as well as how it should be displayed.

In his book *How Maps Work*, MacEachren (2004), championed a different perspective of geographic visualisation, arguing that we need to take “multiple perspectives of data rather than trying to find one optimal view” (p. 433). He warned, however, that there are too many possibilities for all to be covered, and that this approach will only be useful if constraints are applied to the analysis of geographic visualisations. Hence, the geographic visualisation – in
this case, a map – must be fit for purpose and fit for the user. Although it is evident that multiple platforms already exist to present spatial data (e.g., paper maps, digital maps, turn-by-turn instructions, satellite navigation, and so on), there is still room for new perspectives and more options for users.

To determine how effective a graphic representation is, Bertin (1983, p. 5) explained that a graphic is only effective when it allows the reader to “evaluate fully the content of the information”. Thus, the reader should be able to explore all aspects of the graphic, answer all questions they may have, and draw meaningful information from it. In applying this idea to maps, this means that maps are only effective when they can provide answers to all (relevant) questions a user might have.

To describe those map users at one extreme end of the spatial ability spectrum, who cannot adequately interpret spatial information, the term “map illiterate” was adopted. This term is borrowed from Clarke (2003) research on map literacy, and is expanded upon in Chapter 2. From a review of the literature, it is apparent that there is little research into the issues that map-illiterate individuals face. There are publications that describe how maps should be designed (Brewer 2005; Delikostidis 2011; Hegarty, Smallman & Stull 2012; Khazravi & Karimipour 2012; MacEachren 2004; Robinson et al. 1995) and also on how designs can be improved (Delikostidis 2011; Hegarty, Smallman & Stull 2012; Khazravi & Karimipour 2012; MacEachren 2004). However, more can be done to identify areas for improvement in design or to identify map-use situations that could be aided by the development of new designs. Improving upon techniques and technologies that already exist is an important endeavour, but it will not remedy the situation when these map designs fail to communicate with certain users.

Montello (2002) provided an overview of cognitive map design research in the twentieth century. In his research, Montello determined that there is no single way in which every map can be read, concluding that, “given the increasing role of computerized geographic information systems in everyday life, especially apparent in systems for navigation and tourism, the need to produce widely and easily comprehensible cartographic displays will
An Alternative Wayfinding Map Design for Map Illiterate Users

only increase” (p. 299). The term “widely” suggests that alternatives are essential if maps are to appeal to and be useful to all who require them.

Individuals who are map illiterate or have poor map-use skills are more likely to experience anxiety when attempting to plan a route and wayfind on their own (Khazravi & Karimipour 2012). When an individual is anxious, they find it much more difficult to concentrate (Robinson et al. 2013). Therefore, in a wayfinding situation, an individual’s likelihood to become lost can increase, since they are not confident in their map reading abilities.

Little literature about map literacy exists, but research in this area is growing (Albert et al. 2016; Clarke 2007; He, Ishikawa & Takemiya 2015; Ishikawa & Nakamura 2012; Kiefer, Giannopoulos & Raubal 2014; Korpi & Ahonen-Rainio 2015; Lloyd 2011). There are many unknowns, such as the prevalence of poor map-use skills, how much of a problem it is (as in how much poor map-use skills detract from people’s lives), and what challenges map illiterate people experience when reading maps. Current wayfinding tools (paper and digital maps, navigation systems) use a generalised approach in their design or method for communicating the necessary information (turn-by-turn instructions), instead of a personalised approach based on the abilities of the individual user (Wakabayashi 2013). To understand all elements of map literacy would require an integration of cognitive (Brügger, Richter & Fabrikant 2019) and neuroscientific research, which is beyond the scope of the work presented in this thesis. However, it is believed that the results of this research will contribute to knowledge about spatial abilities for wayfinding.

This research project is focused on developing an approach and guidelines for designing wayfinding maps that will be effective and efficient for map-illiterate users. Bertin (1983) defined efficiency in this way:

*If, in order to obtain a correct and complete answer to a given question, all other things being equal, one construction requires a shorter period of perception than another construction, we can say that it is more efficient for this question* (p. 9).
This definition explains how one graphic may be more efficient than another based on the amount of time a user needs to engage with it. It does not, however, identify whether a construct is efficient in an absolute sense or not; rather, it determines relative efficiency. Therefore, the term “efficiency” in this research is defined as “functioning or producing effectively and with the least waste of effort” (2009, p. 529).

An effective and efficient map product might be one which would remove almost all cognitive effort from wayfinding activities. It would also facilitate and promote spatial knowledge acquisition, reducing the user’s dependence on the map product.

The range of influences on an individual’s spatial and map reading ability, as discussed above, show that map reading and wayfinding are complex, and there can be a wide range of individual differences in these abilities due to numerous factors. These variations in abilities provide opportunities for new representations of spatial information to be developed so that the needs of different people can be met.

Jonsson (2002) argued that since we can manage to find our way around using just our cognitive maps (which, of an urban area, are never complete), maps do not need to show every feature, only those relevant to the user. In this way, he stated, our cognitive maps are “tailor-made for us, showing only what we need to see” (Jonsson 2002, p. 32). Therefore, taking inspiration from the simplicity of cognitive maps, could it be beneficial to design maps that only show users what is necessary for them to find their way?

1.2 Problem Statement

Due to complexities in geographic layout, differences in language or the general unfamiliarity of a location, map users who are in an unfamiliar environment risk becoming lost (Chang 2013). To alleviate the problem of people getting lost, it is argued that it is necessary to create maps that are useful to the individuals using them – that is, maps that take into account the abilities of their users. Past research has worked to design such maps. For example, focus maps have been proposed by Dupont et al. (2016), Klippel and Richter (2004), Neis and Zipf (2008), van Dijk et al. (2013), and Zipf and Richter (2002), and adaptive
maps have been proposed by Elias, Hampe and Sester (2005), Reichenbacher (2005), Sarjakoski and Sarjakoski (2008), and Zipf (2002). This research is novel in its focus on the map user group of map-illiterate users undertaking wayfinding activities. Current map designs often fail to help this group find their way effectively and efficiently. It seeks to understand the challenges this group faces when reading maps and to produce design guidelines for making wayfinding maps that will support this population.

1.3 Aim, Objectives, and Research Questions

The aim of this research was to develop design guidelines for producing wayfinding maps for map-illiterate users. To achieve this aim, three sub-objectives, and their corresponding research questions were identified.

1. Discover how to identify individuals as map illiterate.
   - Research Question 1: What is map literacy?
   - Research Question 2: What methods already exist to measure map literacy?
   - Research Question 3: How can an individual be identified as map (il)literate?

2. Identify which elements of current map designs map-illiterate individuals find ambiguous.
   - Research Question 4: How can the challenges that map users encounter when using maps for wayfinding be determined?
   - Research Question 5: What wayfinding behaviours do map-illiterate individuals exhibit?
   - Research Question 6: Which map elements are sources of ambiguity for map-illiterate individuals?

3. Provide alternatives to current wayfinding map designs to enable more effective use by map-illiterate individuals.
• **Research Questions 7:** How can wayfinding maps be designed to work with the compromised abilities of map-illiterate individuals?

### 1.4 Rationale

Whilst undertaking my undergraduate degree of Bachelor of Applied Science in Geomatics, I often had to explain what it was I was studying. Throughout these conversations, I was surprised by how many people seemed to have negative attitudes towards maps. Comments such as, “Maps are useless, I can’t use them” or “My friend always gets lost, they have no sense of direction!” were not uncommon. I began researching the differences in spatial abilities between people and found that much of the research indicated that individuals differed widely in their spatial abilities. I began wondering, “What is it about maps that these people find difficult to use?”, and “Why do so many people seem to dislike map reading?” I developed a strong desire to find answers to these questions.

The use of satellite navigation and voice-directed guidance means that people no longer need to consult a paper or digital map, they can just be instructed as to when they need to make their next turn or alerted when they have arrived at their destination. This releases users from having to make wayfinding decisions, such as where to turn, or from having to reconcile what they see in the map with what they see in the environment. Automated navigation systems may allow map users to offload their map-reading skills to digital devices but this makes them ever-more reliant upon the device (Parush, Ahuvia & Erev 2007). This would not be an issue except for the fact that data is not always accurate, and therefore navigation systems do not always provide correct instructions. Moreover, the evidence strongly suggests that spatial knowledge acquisition is weaker when using satellite navigation technologies (Brügger, Richter & Fabrikant 2019; Dickmann 2012; Ishikawa et al. 2008; Parush, Ahuvia & Erev 2007). Put simply, these systems cannot be relied upon as heavily as some users rely on them.
1.5 Outline of the Thesis

I began this thesis by demonstrating some of the possible outcomes for map users when they become lost and providing an overview of variations in spatial abilities (section 1.1). I outlined the overall problem (section 1.2), and posed a research aim, accompanied by a series of research questions (section 1.3). The motivations and rationale for undertaking this research were also explained (section 1.4).

To achieve the first objective and answer the related research questions outlined in section 1.3, a literature review was undertaken to determine what it means to be map illiterate. This literature review explores the meanings of literacy in relation to reading and writing, design, visual information, graphics, spatial information, and maps. These definitions of literacy were used to create an overall definition of map literacy as it relates to this research. To determine the map literacy status of a map user, existing tests for assessing spatial abilities and map-reading skills were reviewed for their applicability to this research. These topics are covered in Chapter 2.

To determine the challenges experienced by map-illiterate users when undertaking route planning and wayfinding activities, suitable empirical case studies needed to be developed (research question 4). To develop these case studies, I analysed the methodological approaches used in similar studies (Koletsis, Chrisman & Cartwright 2014). This analysis provided a foundation on which to develop the empirical research. The contexts in which these case studies should be undertaken are also identified. To obtain the most informative results, the user context should yield the most insights into the behaviours of map-illiterate users when undertaking route planning and wayfinding activities. This is discussed in Chapter 3.

To answer research questions 5 and 6, I recruited participants to undertake route planning and wayfinding case studies (Chapter 4 and Chapter 5). I used several methods to collect comprehensive information about the behaviours, feelings, and actions of participants for analysis.
Using the findings obtained from the experiments outlined in Chapters 4 and 5, I explored design solutions (Research Question 7). I reviewed the literature to determine if any solutions already existed to meet the needs of users as identified from the challenges they faced. A design brief for a proof-of-concept app was created and the proof-of-concept app was developed. This is covered in Chapter 6.

Chapter 7 presents two studies. The first study defined a threshold for map literacy to ensure participants that were recruited to test the proof-of-concept app could be deemed to be map-illiterate. The second study tested the proof-of-concept app with map-illiterate participants. Finally, a set of guidelines for creating wayfinding maps for map-illiterate users to enable them to find their way efficiently and effectively are proposed.

Chapter 8 concludes this thesis, beginning with a summary of the findings, followed by a discussion of the limitations of the research and recommendations for improvement. Finally, further opportunities for research in this field are proposed.

**Summary**

This chapter provided the context of this research, highlighting the need for different representations of geography for different users, in particular, for map-illiterate users. The aim and objectives of this research were provided, followed by a rationale for the study. Finally, an outline of the study and the structure of the thesis are provided.

The next chapter discusses the concept of map literacy and addresses the first objective and related research questions. Specifically, a definition of map literacy is provided and how individuals can be assessed as map (ill)iterate is outlined.
Chapter 2 – Map Literacy

The previous chapter provided an introduction to this research, including the objectives and research questions, the importance of the research and where it fits within the greater realm of cartographic research. This chapter explores map literacy, presenting meanings of literacy related to reading and writing, design, graphics, visual, spatial information, and finally, maps. Using these definitions, I propose a definition of map literacy as it applies to wayfinding. This proposed definition underpins the overall research goal of developing guidelines for making maps for map-illiterate users.

Methods for assessing an individual’s map-reading skills or spatial abilities are discussed along with an appraisal of which assessments could be used in this research as a preliminary step in identifying map literacy levels.

2.1 Map Literacy Defined

The skills of individual map users vary (Aykin 1989; Board 1978; Gilmartin & Patton 1984; Hegarty et al. 2006; Keates 1982; MacEachren 2004), and thus no single map can be suitable for all map users. Map-reading skills include detection, discrimination, interpretation, and short and long-term memory capabilities (Board 1978; Gilmartin & Patton 1984; Hegarty et al. 2006). The effectiveness of the map in providing information is determined by how well the map user can decipher and extract the information they require. This does not depend on memory, because the map user can refer to the map at any time to retrieve any information they may have forgotten. Even though maps are evaluated based on how well a map user can use a particular map, not all map users will be able to engage with the same map to the same effect, and differences in people’s abilities must be taken into consideration. This is especially important for people with very limited map reading skills, who seem to really struggle to use a map for its intended purpose. People who cannot read maps and in turn use maps ineffectively have been described as functionally map illiterate (Clarke 2007). To understand map literacy, we first need to understand literacy in the traditional sense of reading and writing.
2.2 Literacy

Literacy can be defined in several ways depending on one’s perspective and purpose. Here, an overview of the general concept of literacy is provided. A challenge faced by those attempting to define literacy is that its definition is ever-changing due to constant changes in technology. These changes in technology directly affect the definition of literacy, since people engage in reading and writing activities in different ways, such as handwriting, typing, reading from books, and reading web pages. For example, someone who did not grow up with computers and the Internet may have been able to read and write reasonably well using paper but may not have learnt to use a computer or the Internet, and therefore could be considered less literate when reading using those media.

To understand the concept of map literacy, a general definition of literacy must first be established. The United Nations Educational, Scientific and Cultural Organization (UNESCO 2004, p. 13) provided the following definition:

*Literacy is the ability to identify, understand, interpret, create, communicate and compute, using printed and written materials associated with varying contexts. Literacy involves a continuum of learning in enabling individuals to achieve their goals, to develop their knowledge and potential, and to participate fully in their community and wider society.*

Similarly, the National Council of Teachers of English (NCTE 2015d, p. 1) argued that to be literate in today’s society, one must be able to:

- Develop proficiency and fluency with the tools of technology;
- Build intentional cross-cultural connections and relationships with others so to pose and solve problems collaboratively and strengthen independent thought;
- Design and share information for global communities to meet a variety of purposes;
- Manage, analyse, and synthesise multiple streams of simultaneous information;
In addition, the Educational Development Center, Inc. referred to literacy as “not only the ability to read and write, but rather in an individual’s capacity to put those skills to work in shaping the course of his or her own life” (EDC 2015h, para. 1).

Two definitions of literacy are provided in a report related to the National Assessment of Adult Literacy (NAAL). The NAAL was an assessment of adult literacy in the United States (US) in 2003 by the National Center for Education Statistics (NCES). Nineteen thousand adults from across the US participated in this assessment (NCES 2016d). The NAAL provided two definitions of literacy, one task-based and the other skills-based. The NAAL’s task-based definition of literacy is that it “is the ability to use printed and written information to function in society, to achieve one’s goals, and to develop one’s knowledge and potential” (para. 3). The skills-based definition states that “successful use of printed material is a product of two classes of skills; word-level reading skills and higher-level literacy skills” (para. 4).

In these definitions, literacy, or what it means to be literate, does not have the traditional meaning of simply being able to read and write. Instead, it relates to the continued improvement of one’s skills using technology and the ability to apply those skills to better oneself and one’s community.

2.2.1 Design Literacy

Design literacy is of interest because this study is focused on how maps should be designed for map-illiterate users. Whilst the definition is somewhat similar to that of UNESCO (2004), there are certain aspects of design that make it different to text-only literacy. In the 1990s researchers reinvestigated what it meant to be literate, and by the 2000s the definition was expanding (Sheridan-Rabideau & Rowsell 2010). From this evolving research, it became evident that “… literacy is not only alphabetic print, but inclusive of multiple modes”
(Sheridan-Rabideau & Rowsell 2010, p. 9). These multiple modes include images, symbols, maps, audio and anything graphic that a user needs to interpret through visual perception to form an understanding. Sheridan-Rabideau and Rowsell (2010, p. 10) further highlighted that to be literate, one needs not only to be textually literate but to be “literate across multiple modes”, because the world now is so technologically rich.

2.2.2 Graphics Literacy

“Graphicity” is a term used to describe literacy in relation to graphics, and was coined in 1965 by Balchin and Coleman (Danos & Norman 2009). Balchin and Coleman (1966, p. 23) defined graphicity as “the intellectual skill necessary for the communication of relationships which cannot be successfully communicated by words or mathematical notation alone”. Later, Wilmot (1999, p. 91) defined graphicity “as a form of communication in that it utilises some form of symbolic language to convey information about spatial relationships”. Whilst initially intended as a definition of the ability to interpret spatial information, it can be extended to any graphic form that conveys information. As a result, graphicity refers to the understanding of graphs, symbols, maps, pictures, drawings, photographs, and so on. To be “graphicate”, one must be able to understand different forms of graphics, gain information from them, and use it.

Numerous researchers (Balchin 1972; Balchin & Coleman 1966; Boardman 1976; Molyneux & Tolley 1987; Wilmot 1999) argued for the need for graphicity to be included in formal education along with literacy, numeracy and articulacy (spoken communication). Graphicity plays a vital role in early childhood development; indeed, children begin learning graphicity before literacy and numeracy (Aldrich & Sheppard 2000). This is evident due to the presence of graphics in pictorial form in children’s books, and the fact that at present, graphicity is learned implicitly (Aldrich & Sheppard 2000).
2.2.3 Visual Literacy

Another term that is applicable to map literacy, albeit a much more generally applicable one, is “visual literacy” (Table 2-1). Because map users use their eyes to read a map and view their surroundings, the notion of visual literacy is relevant and should be considered.

Table 2-1 Definitions of Visual Literacy

<table>
<thead>
<tr>
<th>Author</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>Toledo Museum of Art</td>
<td>Being able to read, comprehend, and write visual language.</td>
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<td>(2017, para. 3)</td>
<td></td>
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<tr>
<td>Merriam-Webster (2017,</td>
<td>The ability to search and understand ideas conveyed through visible actions or images (such as pictures).</td>
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<tr>
<td>para. 1)</td>
<td></td>
</tr>
<tr>
<td>Hortin (1983, p. 99)</td>
<td>The ability to understand (read) and use (write) images and to think and learn in terms of images, i.e., to think visually.</td>
</tr>
<tr>
<td>Ausburn and Ausburn</td>
<td>A group of skills that enable an individual to understand and use visuals for intentionally communicating with others.</td>
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<td>(1978, p. 291)</td>
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</table>

2.2.4 Spatial Literacy

Spatial literacy has been defined by multiple authors, including Blake (2016), Sinton (2012), Kemp (2008), Goodchild (2006) and NRC (2006). Spatial literacy refers to broad spatial abilities, such as recognising and interpreting patterns, understanding scale and spatial resolution, and thinking spatially (Goodchild 2006; NRC 2006), whereas map literacy refers to a person being able to read and use a map. In looking at the definitions of spatial literacy in Table 2-2, it is evident that they vary in their complexity, and not all of them use the term “map”. While spatial literacy may not be a synonym for map literacy, map literacy is a component of spatial literacy.

Comparing Table 2-1 and Table 2-2 enables identification of common words or phrases. The most frequently used terms in these definitions are “solve problems”, “understand” and “communicate”. It is therefore reasonable when creating a definition of map literacy to consider these terms because they are accepted components of spatial literacy.
<table>
<thead>
<tr>
<th>Author</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Blake (2016, para. 5)</td>
<td>People who possess spatial literacy are able to utilise space and understand its properties in order to solve problems, communicate effectively and make rational decisions. Literacy in this mode requires an understanding of when to apply spatial reasoning and the ability to evaluate and use visual information to complete tasks or projects.</td>
</tr>
<tr>
<td>Sinton (2012, para. 2)</td>
<td>Spatial literacy is the competent and confident use of maps, mapping, and spatial thinking to address ideas, situations, and problems within daily life, society and the world around us.</td>
</tr>
<tr>
<td>Kemp (2008, pp. 422-423)</td>
<td>The ability to understand the concept of space; apply processes of reasoning employing appropriate tools to determine spatial relationships between people, places or objects; and visualise or communicate those spatial relationships in various contexts.</td>
</tr>
<tr>
<td>Goodchild (2006, pp. 1-2)</td>
<td>An ability to capture and communicate knowledge in the form of a map, understand and recognise the world as viewed from above, recognise and interpret patterns, know that geography is more than just a list of places on the earth’s surface, see the value of geography as a basis for organising and discovering information, and comprehend such basic concepts as scale and spatial resolution. Together, these amount to what one might term spatial literacy, a set of abilities related to working and reasoning in a spatial world and to making a picture truly worth a thousand words.</td>
</tr>
<tr>
<td>NRC (2006, p. 4)</td>
<td>Spatially literate students who have developed appropriate levels of spatial knowledge and skills in spatial ways of thinking and acting, together with sets of spatial capabilities, have the following characteristics: 1. They have the habit of mind of thinking spatially—they know where, when, how, and why to think spatially. 2. They practice spatial thinking in an informed way—they have a broad and deep knowledge of spatial concepts and spatial representations, a command over spatial reasoning using a variety of spatial ways of thinking and acting, and well-developed spatial capabilities for using supporting tools and technologies. 3. They adopt a critical stance to spatial thinking—they can evaluate the quality of spatial data based on its source and its likely accuracy and reliability; can use spatial data to construct, articulate, and defend a line of reasoning or point of view in solving problems and answering questions; and can evaluate the validity of arguments based on spatial information.</td>
</tr>
</tbody>
</table>
2.2.5 Map Literacy

Clarke (2003, p. 717), defined functional map literacy as “the ability to understand and use maps in daily life, for work and in the community”. To develop this definition, Clarke used the Basic Skills Standards as outlined by the Basic Skills Agency (BSA) to delineate levels of literacy. The BSA (now known as the Learning and Work Institute) was a government-funded organisation in the United Kingdom tasked with assisting people to improve their skills so they could obtain employment (Learning and Work Institute 2017). The BSA identified three levels of literacy: entry level, level 1 and level 2. To be classified in one of the three levels, one’s performance had to reach at least 80% of that level. At entry level, an individual would need to be able to identify the main idea from a simple source. At level 1, an individual would be required to “understand and act on a graphical source up to one page long” (Clarke 2003, p. 715). At level 2, one would be required to “select material from more than one graphical source” (Clarke 2003, p. 715).

An example of one of Clarke’s tasks with increasing levels of complexity is orientating a map. At entry level, an individual would be able to orient a map with north at the top. At level 1, an individual would be able to orient the map so that any direction other than north is at the top and be able to identify which direction was now at the top. At level 2, an individual would be able to orient a map so that it corresponds with their surrounding environment (Clarke 2007).

Clarke used his classification system in conjunction with the three hierarchical levels outlined by Olson (1976, p. 152) to describe map literacy (Table 2-3). Clarke proposed that a person is deemed to be functionally map literate when they are classified at level 1; that is, they can consistently perform at 80% of level 1. Therefore, those at entry level would be considered functionally map illiterate.

This definition and classification may be considered to be somewhat vague and too basic. It is necessary to note that Clarke’s definition of functional map literacy is intended to be applied to those undertaking planning and decision-making. Clarke was interested in
determining planners’ literacy levels so that workshops could be developed to fill gaps in knowledge and improve skills. Upon closer inspection of the tasks included in the three levels of map literacy (entry level, level 1, level 2), it is obvious that the tasks at each level are not of the same complexity. This sort of classification system therefore makes it difficult to compare tasks in level of complexity and therefore to classify an individual as map (il)literate.

Since Clarke’s definition of map literacy is vague and intended for a purpose different to that of route planning and wayfinding, it was necessary to develop a definition for my own research. Definitions of map literacy may differ for different map-reading and map-use purposes, since the tasks one must complete to use the map effectively may differ. In addition to the tasks being different, the geographical questions one may ask oneself when reading a map may also differ between maps designed for different uses. Therefore, researchers need to consider developing their own definition of map literacy if one does not already exist for their particular map type and how it is intended to be used.
Table 2-3 Olson and Clarke’s Hierarchies of Map Reading Tasks

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td><strong>Level 1</strong></td>
<td>Comparing the characteristics of individual symbols.</td>
<td>Getting the main idea from a single or simple symbol (search, locate, identify, and compare). Simple estimation (measure, calculate, assess relative size) of familiar symbols.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Level 1</strong></td>
</tr>
<tr>
<td></td>
<td>Recognising properties of symbol groups on the map as a whole: spatial pattern, likeness to other map patterns, etc.</td>
<td>Recognising properties of symbol groups on the map as a whole, and analysing spatial patterns (more complex recognition, reorganisation, decoding, detection, compare, discriminate, contrast) for more complex estimation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Level 2</strong></td>
</tr>
<tr>
<td></td>
<td>Using the map as a decision-making or content-knowledge-building device through integration of the symbols with other information.</td>
<td>More complex tasks leading to understanding the meaning of spatial phenomena for knowledge enhancement. At this level, inferential reasoning is used from the spatial relationships, patterns and map phenomena of one or more referents or sources. Higher-order mental models are constructed. The user draws on domain-specific knowledge.</td>
</tr>
</tbody>
</table>

The research presented in this thesis focused on the use of maps for pedestrian wayfinding. As Delikostidis (2011, p. 119) outlined, questions one may ask oneself during the process of wayfinding could include:

- Where am I?
- Where is my destination?
- In what direction is my destination from my current location?
- What is the distance between my current location and my destination?
- How long will it take me to walk that distance?
- What is the shortest route?
- What is the safest route?
• How many times will I need to turn along the route?
• Do I want the shortest route, or the easiest route? The route with the least amount of direction changes?

The list above is by no means exhaustive; there are many situations that could result in numerous and varying questions being generated. However, these are common questions one might ask oneself when finding one’s way between locations. Therefore, an appropriate definition needs to take these into account.

It is also necessary to define what is meant by wayfinding. In this research, I adopted Golledge (1999) definition of wayfinding, which states, “wayfinding is the process of determining and following a path or route between an origin and a destination”.

With due consideration to the range of relevant literacy definitions and the tasks involved in pedestrian wayfinding, I defined map literacy as:

\[ \text{the ability to use wayfinding maps to walk from an origin to a destination in an efficient and satisfying way.} \]

2.3 Methods Available to Assess Map Literacy

There are many methods of evaluating an individual’s map literacy skills. In the following section I review different methods that could provide insight into how well a person can use a map for wayfinding. The assessments reviewed were selected based on their relevance for evaluating map literacy in accordance with the aims of this research. After evaluating these methods, I selected one to assist in the identification of map-illiterate individuals who could be invited to participate in further testing.

2.3.1 Santa Barbara Sense of Direction Scale

The Santa Barbara Sense of Direction Scale (SBSODS) was developed by the Psychology and Geography departments at the University of California Santa Barbara. The aim was to establish a standardised self-reporting scale for environmental spatial skills. The SBSODS
was intended for use in studying “measures of spatial cognition at different scales and based on different types of learning experiences” (Hegarty et al. 2002, pp. 428-429).

Obtaining an SBSODS score involves participants completing a questionnaire to evaluate their own skills. It consists of 15 statements (Appendix A) relating to use of maps, wayfinding strategies and wayfinding preferences, to which the participant is required to indicate the extent of their agreement or disagreement on a Likert scale of 1 to 7. The individual responses are averaged to get an overall score, with higher scores representing better spatial skills.

The SBSODS was used to assess tertiary students’ spatial cognition (Hegarty et al. 2002). To test the effectiveness of the questionnaire in directly assessing an individual’s spatial skills, participants’ responses were compared to their ability to complete several physical tasks: pointing to a landmark that could not be seen from their current location, estimating the distance between two geographical features, pointing to cardinal directions, and pointing to the starting location of a route they traversed while blindfolded. Calculation of direction and distance was done for features in the real environment, features in a virtual environment navigated by computer keys on a screen, features in a video, and features within a mental map. These tests were carried out at four scales: figural, vista, environmental, and gigantic. Figural space is “small in scale relative to the body and is external to the individual. It includes both the flat pictorial space and the space of small manipulable objects” (Hegarty et al. 2002, p. 427), and is the scale of most psychometric tests of spatial ability. Vista space lies between the scale of the body and the scale of environmental space. It is possible to see it in its entirety without having to move through the space (Hegarty et al. 2002, p. 427). Environmental space lies between the scale of vista space and the scale of gigantic space. The individual is situated within environmental space, can move throughout it, and experience it from different viewpoints. Examples of environmental space include buildings, neighbourhoods and cities (Hegarty et al. 2002, pp. 427-428). Gigantic space is larger than environmental space and cannot be understood by moving through it. To understand gigantic space, it must be experienced by using maps. Examples of gigantic space include
states, countries and planets (Hegarty et al. 2002, p. 428). Participants were also given psychometric (pencil and paper) tests.

The results from these physical tasks were compared to participants’ scores calculated from their responses to the SBSODS questionnaire. It was found that the actual environmental abilities of the participants correlated strongly with their SBSODS scores. The correlations between the SBSODS scores and participants’ physical task performances were stronger than with their psychometric test results. These findings indicate that this measure is more useful for assessing one’s ability to perform actions that facilitate finding one’s way within a physical space (environmental scale) such as self-localisation, rather than the ability to complete map-reading tasks that do not involve movement through the environment (figural scale).

2.3.2 Functional Map Literacy Test

To evaluate the map-reading skills of South African professionals who were involved in development planning and subsequent decision-making processes that utilised spatial information, Clarke (2007) designed the Functional Map Literacy Test (FMLT). Clarke realised that many people in important decision-making positions did not possess adequate skills to evaluate spatial information provided in maps and sought to measure those abilities. The FMLT consists of 18 tasks including, identifying a symbol, orienting a map, understanding the scale of map, drawing a route between two locations, measuring the size of a feature, interpreting the relationship between two features on a map and understanding a map projection. The tasks are all completed within the figural space.

The FMLT (Appendix B) was developed to identify which aspects of map-reading individuals needed to improve, enabling the development of a workshop focusing on improving those skills. It quantitatively assesses whether an individual is functionally map (il)literate based on Clarke’s classification system.
The FMLT underwent a validation process that involved a questionnaire being sent to “professionals working in a public-sector environment” (Clarke 2007, p. 187). The prototype FMLT was issued to these professionals, who were asked to indicate the applicability of each of the 18 map-use tasks to the tasks undertaken by professionals involved in development planning and decision-making.

2.3.3 Spatial Thinking Ability Test

Lee and Bednarz (2012) developed a standardised test of spatial thinking abilities known as the Spatial Thinking Ability Test (STAT). This test “integrates geography content knowledge and spatial skills” (Lee & Bednarz 2012, p. 18).

The STAT (Appendix C) consists of 16 questions that seek to “assess individuals’ growth in spatial thinking skills and to help determine the effectiveness of the TGMG [Association of American Geographers’ Teachers’ Guide to Modern Geography] materials in promoting the spatial thinking skills of teachers” (Lee & Bednarz 2012, p. 18). The test was designed for tertiary students but can be used to assess adults of any age. Two STAT questionnaires exist; one can be used for pre-testing and the other for post-testing, so researchers can identify the differences in skill level before and after training.

Instead of a self-report questionnaire, like the SBSODS (section 2.3.1) and MLS (section 2.3.5), the STAT methodology involves researchers asking participants a series of multiple-choice questions related to spatial thinking. The test includes diagrams, and the participants are required to apply their spatial abilities to the diagrams to answer the questions. As with the FMLT (section 2.3.2), the STAT assesses skills in the figural space.

The STAT was administered at four universities, one high school and one junior high school. Results indicated that as students progressed from junior high school to tertiary education, their performance on the test improved. To assess the validity and reliability of the STAT, the researchers analysed the results using principal components analysis and varimax rotation which produced mixed results in relation to STAT’s questions correlating with
components of spatial thinking. Internal consistency was measured using Cronbach’s alpha which found only moderate reliability (Lee & Bednarz 2012).

2.3.4 Geospatial Thinking Scale

Using Downs’s (1994, 2011, 2012) “vision of geography assessments,” Huynh and Sharpe (2013) developed the Geospatial Thinking Scale (GTS) to “measure participant understanding of spatial relations within a geographic context” (Huynh & Sharpe 2013, p. 3). The GTS (Appendix D) consists of 10 questions, each requiring the completion of between 1 and 8 tasks, that require the use of numerous skills such as “drawing a diagram, multiple choice, short answer and matching vocabulary to a diagram” (Huynh & Sharpe 2013, p. 6). The GTS was designed to measure the geospatial thinking abilities at figural space scale of secondary and tertiary students. The scale was tested in participants from three Canadian educational institutions: year nine students, first-year university geography students and third- and fourth-year university students. The researchers used a factor analysis to identify the key dimensions of geospatial thinking from the answers to these 10 questions. To assess the reliability of the scale, researchers used Cronbach’s alpha (Huynh & Sharpe 2013, p. 7) and found the GTS to have acceptable reliability.

2.3.5 Map Literacy Scale

The Map Literacy Scale (MLS) was developed by Koc and Demir (2014) to provide a reliable method for determining the map literacy of individuals. This scale was developed to assess secondary and tertiary students’ map literacy levels. It was intended that the MLS be used to highlight which map skills individuals have and which they need to develop.

The MLS is a questionnaire comprised of four sections: carrying out procedures with maps (calculating distance, area, and slope ratio); reading and interpreting maps (interpreting physical and human properties of a location); sketching maps; and map use (how to use maps in daily life). Using 28 questions (Appendix E), the individual undertaking the assessment rates their skill according to each of the 28 questions using a five-point Likert scale (‘Never’, ‘Rarely’, ‘Sometimes’, ‘Generally’ and ‘Always’).
The 28 questions were developed in consultation with lecturers, geography teachers and experts in the field of testing and evaluation in Turkey. The researchers used a range of multivariate approaches to validate the four-factor structure of the MLS, finding it to be a valid model. However, results from the MLS were not compared to participants’ demonstrated abilities.

2.4 Effectiveness of Tests

The SBSODS and MLS both involve self-report questionnaires. Tests of their reliability and validity confirm that they are effective methods of collecting information pertaining to spatial abilities. Although people often overestimate their own abilities (the overconfidence effect), Hegarty et al. (2002, p. 443) stated that “the correlations observed in this study indicate that people are somewhat truthful and accurate in estimating their environmental spatial abilities”. In the evaluation of the SBSODS, participants also undertook other activities that tested their skills, and the results were consistent with the questionnaire data (section 2.3.1). The STAT, GTS and FMLT require participants to answer spatial questions and to solve spatial problems at a figural scale, where the SBSODS and MLS do not. This has the advantage of non-reliance on the participants’ personal perceptions of their spatial abilities. However, besides the SBSODS, these tests do not take abilities within environmental space into consideration. While all of the tests are completed using pen and paper, or on a computer, the SBSODS is the only test which has demonstrated correlations with spatial abilities within environmental space as is necessary for wayfinding.

A broader problem with these and many other scales and tests is that much research involving human participation is limited to WEIRDs – Western, Educated, Industrialised, Rich and Democratic societies (Henrich, Heine & Norenzayan 2010). Some of the studies described above were conducted on WEIRD participants rather than more heterogenous and therefore globally representative populations.

Table 2-4 provides an overview of the characteristics of each of the tests covered here, highlighting similarities and differences.
From the literature reviewed above, there appears to be no simple way to determine whether someone is definitively map (il)literate. Rather, individuals can be categorised as beginner, intermediate or expert (Albert et al. 2016) or ranked against one another (Hegarty et al. 2002). Whilst tests exist to evaluate one’s spatial ability, including map-use skills, a threshold for map (il)literacy is yet to be established. Clarke (2003) pointed out that such a test needs to be developed to determine the map literacy status of a map user.
The overall aim of this research was to develop design guidelines for producing wayfinding maps for map-illiterate users. Therefore, it was necessary to identify map-illiterate individuals who could take part in map evaluation components of this research.

The existing assessment method most applicable to my research was the SBSODS. The SBSODS is a test used to predict people’s environmental spatial abilities, whereas the other four tests outlined above are used to identify gaps in users’ knowledge for subsequent improvement. Because the SBSODS produces a score on a scale between one and seven, participants’ spatial abilities can be assessed and ranked. Furthermore, the SBSODS is the only test of the tests reviewed that assesses abilities at the environmental scale. It is the environmental scale at which individuals complete wayfinding tasks, therefore this scale more accurately assesses the skills used in such tasks. Whilst the SBSODS relies on a self-report questionnaire, its developers tested the results of the questionnaire against the actual spatial abilities of participants, confirming that it provides results that correlate closely with the tasks completed in real-life wayfinding. The SBSODS is also a quick, and easy assessment to complete, because it does not require participants to perform any map-reading activities.

Despite the testing of the SBSODS being carried out only with tertiary students, it can be employed for use by the general population due to its simple layout and language. Also, the use of the 7-point Likert scale makes responding relatively easy. It is acknowledged that this might not always be the case, but provided respondents have adequate vision, reading and writing abilities, and comprehension of the English language, completion of the survey should not be complicated. No special skills are required to complete this questionnaire.

To develop an SBSODS score threshold for this research, an online version of the SBSODS was made available to participants using Prolific (https://www.prolific.co/), a commercial company that pays participants to complete online research. 385 participants from 19 countries completed the survey. The mean SBSODS score for this population sample was 4.25, with a standard deviation of 1.04, which is similar to the result obtained by Montello and Xiao (2011) who obtained a mean SBSODS score of 4.22 (standard deviation: 1.06) from
respondents from four countries. Ishikawa and Zhou (2020) used the results from the study by Montello and Xiao (2011) to set a threshold of ‘below 4.0’, when recruiting participants with poor spatial abilities. Therefore, an SBSODS score below 4.0 was used to classify participants in the final study to be map illiterate. The detailed results of this study are discussed in section 7.1.

**Summary**

In this chapter, I explored definitions of literacy and proposed a definition of map literacy. Existing tests that can be used to assess an individual’s map-reading skills were also outlined, and their effectiveness evaluated. Finally, a measure to classify map literacy as it applies to this research was proposed.

The next chapter contains a review of the methodologies of similar studies, conducted in order to develop an appropriate methodology for identifying the challenges map-illiterate users experience when wayfinding in an unfamiliar urban environment. This review is followed by a description of the test scenarios and locations.
Chapter 3 - Methods for Studying the Wayfinding Behaviours of Map-(Il)iterate Users

Sections 3.1 and 3.2 are based on papers presented at GeoCart’14 (Koletsis, Chrisman & Cartwright 2016), the Geospatial Science Research 3 Symposium (Koletsis, Chrisman & Cartwright 2014) and ICC2015 (Koletsis et al. 2015)

In the previous chapter I analysed definitions of literacy as they relate to reading and writing, graphics, vision, maps and spatial abilities, which enabled me to develop a definition of map literacy that is relevant for this research. I reviewed tests of map-use abilities, then discussed their applicability to this research.

In Chapter 3, I provide a review of methodologies used in previous studies related to this type of research. Following this, I present the methodological approach to be used in this research.

3.1 Review of Methodologies for Evaluating Map Designs

Before designing the experiments and methods of data collection for this research, I reviewed the literature to identify the methods that have proved useful in similar studies.

3.1.1 Methods of Evaluating Map Design

To obtain data that can be used to develop guidelines for how maps should be designed for map-illiterate individuals, it was important to learn how others have obtained similar types of data. Therefore, I performed a review of the literature to answer the following questions:

1. What kinds of data should be collected?
2. What tools/equipment can be used to collect the required data?
3. How should the data be analysed?
After searching major scientific databases including Scopus, SpringerLink and Web of Science, relevant journal articles and other documents were reviewed to ascertain the methods used. The documents were chosen due to their focus on evaluating a map product. From this review, I identified a variety of methods that could be employed in this research.

The general aspects of map evaluation identified in the reviewed literature were:

- Testing with real people (rather than simulations);
- Method of data collection;
- Method of data analysis; and
- Testing environments.

The map products that I studied in the reviewed literature included pedestrian maps (Crampton 1992; Delikostidis 2011; Ishikawa et al. 2008; Kiefer, Giannopoulos & Raubal 2014), you-are-here (YAH) maps (Klippel, Freksa & Winter 2006; Marquez, Oman & Liu 2004), electronic navigation displays (Hsu, Lin & Chao 2012; Lavie & Oron-Gilad 2013; Yeh & Chandra 2006), and wayfinding in a virtual environment (Darken & Sibert 1996; Huang et al. 2018). The literature review that follows is structured by map type, because not all maps created for the purpose of wayfinding are engaged with in the same way, under the same conditions, or within the same environment.

3.1.2 General Case

In their wide-ranging discussions of mapmaking and map use, Suchan and Brewer (2000) and Board (1978) recommended using a qualitative method of research to develop theories, and testing these theories using a quantitative method. Citing examples, Suchan and Brewer (2000, p. 152) explained that cartographic research can benefit greatly from a qualitative line of enquiry because such research is interested in “real-world predicaments and real-world strategies”, which can be explored “by employing deliberately selected participants” who can provide insights into their cartographic requirements. These insights can be
obtained using questionnaires, interviews, focus groups and/or verbal protocols. Board (1978) suggested that the map-reading tasks used in map use research should be dependent upon the intended use of the map, and that the evaluation must utilise an empirical approach (Figure 3-1). These authors posed many questions that the researcher should answer before conducting experiments to effectively determine the most appropriate map-reading tasks:

- **What type of map?**
- **For whom is the map intended?**
- **Under what conditions will it be used?**
- **What map-reading tasks are the most appropriate for the purpose?**

By answering such questions, the researcher can maximise extraction of meaningful and useful results from the empirical investigation.

Board (1978) recommended deciding on the types of questions to be asked of participants only after establishing the map-reading tasks, and advised that appropriate methods of “scoring” must be implemented upon the completion of data collection. These methods take the form of statistical analysis. Board’s procedure for identifying appropriate experimental map reading tasks is illustrated in Figure 3-1.
Figure 3-1 Procedure for identifying appropriate experimental map reading tasks (Board 1978, p. 4)
3.1.3 Pedestrian Map Use

Kiefer, Giannopoulos and Raubal (2014) investigated matching the map and environment using landmarks during orientation and self-localisation tasks using mobile eye-tracking technology. They began by asking participants to complete the SBSODS (section 2.3.1) to assess their spatial abilities. The investigation was conducted in the city of Zürich, Switzerland. 14 participants, recruited from an inner-city youth hostel, completed the orientation task; they were unfamiliar with Zürich and did not use maps for professional purposes. Using three maps with iconic symbols, the participants decided whether each of the maps was representative of the environment around them. Another 15 participants (non-professional map users, recruited from the same hostel, and unfamiliar with Zürich) were invited to mark their location on a tourist map. To determine the objects on which the participant fixated, the researchers manually corrected for pupil detection errors and parallax shift, and demarcated Areas of Interest (AOIs) in the video captured by the scene camera of the eye-tracking glasses. Then, they computed the distribution of the participants’ visual attention on features on the map and features within the environment.

Delikostidis (2011) identified several problems with pedestrian maps accessed through smartphones, including limitations of content due to screen size and the cognitive complexity of zooming and panning the map while maintaining knowledge of the user’s location. To eliminate these issues, Delikostidis developed a prototype pedestrian navigation system. He recruited participants based on their lack of familiarity with the pre-selected testing locations. Evaluation of the navigation system involved engaging participants in wayfinding and map-reading tasks in two locations that differed in their spatial layout. The participants were video and audio-recorded as they completed the navigation and map-reading tasks using the new navigation system or the Google Maps interface (each individual used only one interface per location). The participants were given cue cards showing scenarios for them to undertake, including navigating between two locations, identifying their own location, reorienting the interface, landmark identification, and searching for nearby transport access points. The researcher asked the participants to think aloud to provide insight into any difficulties they experienced. Once the map-reading
activities were completed, the researcher conducted semi-structured interviews to collect more information about issues that arose during the experiment. This qualitative data was analysed using the research software Atlas.ti (Scientific Software Development 2020). The quantitative data (completion time and average number of stops) was graphed to compare the usability of the prototype system and the Google Maps interface.

Ishikawa et al. (2008) compared a Global Navigation Satellite System (GNSS)-based navigation system, paper map and direct experience to determine which method was the most effective for pedestrian wayfinding. The researchers split participants into three groups, one per format. The participants completed a wayfinding task and determined where their start point was (by pointing in its direction) after they had found their “goal” location. The participants provided feedback relating to the perceived difficulty of the wayfinding task. This study found that the participants using the GNSS-based navigation system took the longest to complete the tasks and were the least able to determine the direction of their starting location.

A similar study conducted by Field, O’Brien and Beale (2011) involved participants (recruited from a geographic information system [GIS] course) finding their way in an unfamiliar environment using either a hand-held GNSS device or a conventional paper map. The participants all began and completed their journey at the same location and visited the same six waypoints. Participants using the paper maps chose their own route, while those using the GNSS device entered the coordinates of the start, end, and waypoints, and followed the instructions provided. Although all participants successfully completed the exercise, those using the GNSS device included less details in their sketch maps than those who used the paper map, indicating they were less likely to acquire spatial knowledge of their route (Field, O’Brien & Beale 2011).

Dickmann (2012) aimed to identify differences in the efficiency of use of a conventional paper map and a navigation system. Participants drew a sketch map of the route they took in conjunction with any features they saw along the way that would be useful for wayfinding. The paper map group was, on average, able to recall more features, and to
more accurately depict the length of the route than the navigation system group. The findings of this research concur with those of Field, O’Brien and Beale (2011).

Crampton (1992) analysed the differences between novice and experienced wayfinders. Participants were asked to look at an orienteering map and decide how they would travel between two specified locations. Then they were required to pretend they were at the actual location the map depicted and use think-aloud techniques to document their journey. Crampton used participants’ verbal statements to create behavioural graphs and morphograms (a graphic depiction of the morphology – hill, valley, ridge, etc.) that participants verbalised while describing their chosen route. The behavioural graphs represented the “structure of the subjects’” (Crampton 1992, p. 50) problem-solving processes, and the morphograms were used to plot the “number of morphological references in the protocol” (Crampton 1992, p. 50). The behavioural graphs and morphograms allowed the identification of the most commonly used and the most effective strategies that participants used when wayfinding.

From these studies, it can be seen that some common techniques exist for assessing map usability or behaviour strategies when wayfinding. Dickmann (2012), Field, O’Brien and Beale (2011), and Ishikawa et al. (2008) all compared the use of paper maps to navigation systems, and conducted their tests in environments unfamiliar to their participants. Delikostidis (2011) also tested participants in an unfamiliar environment, but used only digital maps. Meanwhile, Crampton (1992) used only one paper map, but tested two groups with different skill levels, and did not conduct his test within a real environment. Of the approaches employed in these studies, those that could be considered suitable for my own research were the comparison of wayfinding abilities using a paper and a digital map, and testing users in an unfamiliar environment.

3.1.4 Indoor You-Are-Here (YAH) Maps

Marquez, Oman and Liu (2004) described their design of YAH maps for use on board the International Space Station (ISS). They faced the problem that astronauts were often
An Alternative Wayfinding Map Design for Map Illiterate Users

disoriented and had trouble navigating within the ISS; due to the lack of gravity while on board the ISS, up–down and left–right are constantly changing. The map designers identified key landmarks that astronauts were likely to use to determine their location and added them to the map. The usability of the map was not tested; instead, the designers suggested how it should be tested, including asking participants to describe how they would find their way from their current location to another using the map.

In another study, Klippel, Freksa and Winter (2006) undertook a desktop analysis to evaluate existing YAH maps to establish whether they could effectively support wayfinding inside a building, and thus help users to exit a building efficiently in an emergency. The researchers obtained three YAH maps and assessed them against multiple criteria: completeness, perceptibility, semantic clarity, ambiguity, consistency, placement, correspondence, alignment, architectural cues, and the effectiveness of the YAH symbol. The maps assessed failed to adhere to two established principals of YAH map design. None were aligned with the environment, therefore requiring users to perform a mental rotation of the map; nor did any of the maps contain a YAH symbol to indicate the user’s location and orientation.

The method used in these YAH studies that could be applied to this research is having participants evaluate map designs by describing how they would navigate from one place to another (similar to Marquez, Oman and Liu (2004)’s suggested method, and Crampton (1992) method – section 3.1.3). Klippel, Freksa and Winter (2006)’s method was deemed to be inappropriate for this study, because the experts involved in the assessment of the maps were not members of the target user group.

3.1.5 Electronic Map Displays

When analysing the usability of an electronic map display, Lavie and Oron-Gilad (2013) evaluated participants’ ability to complete navigation tasks effectively. They also assessed users’ perceptions of the map display’s usability in a driving scenario. Users were invited to complete navigational tasks using the electronic navigation display in a simulated and
unfamiliar environment. Several maps were displayed, and the results analysed using Analysis of Variance (ANOVA) (Sprinthall 2012). The researchers stated that simply testing for actual usability or perceived usability on their own is not sufficient, and that both actual and perceived usability need to be tested to fully determine map usability.

Hsu, Lin and Chao (2012) conducted a series of experiments to determine the effects of different maps on driving performance. Their study engaged participants to complete a series of navigation tasks in an unfamiliar and real environment using two-dimensional (2D) and three-dimensional (3D) electronic maps, as well as a paper map. The amounts of time the participants required to complete the tasks and the routes they took were recorded and analysed statistically; the main conclusion was that in unfamiliar areas, drivers perform more efficiently using a 2D electronic map. In a similar study, Rodes and Gugerty (2012) conducted experiments to establish the effects of electronic map display and individual ability differences on users’ navigation performance. In this study, participants used an unmanned aerial vehicle simulator to perform route-following, map reconstruction, and cardinal direction judgement tasks with track-up and north-up maps. The participants were required to follow a predetermined path and answer a series of questions relating to the tasks. After each “mission”, the participants completed the NASA Task Load Index workload measure (Hart 2006) and then sketched a map of the locations of each of the landmarks they came across on their mission. Participants then completed spatial ability tests and questionnaires. The authors applied statistical analyses appropriate to each task in order to determine the effects of map configuration on participants’ abilities to correctly judge cardinal directions, follow a route and reconstruct the map. They found that north-up displays were better for facilitating accurate map reconstructions, while track-up displays led to better performance on a direction-of-turn task and cardinal direction judgement.

After identifying variations in the symbols included on electronic map displays used by aviation pilots, Yeh and Chandra (2006) set out to standardise these symbols in an effort to minimise their ambiguity. The study involved asking experienced pilots to determine the meaning of a series of symbols. The pilots’ responses were used to ascertain which meanings were most commonly associated with particular symbols. From this information,
the researchers began designing a symbol standard intended to be distributed amongst electronic map display producers to ensure all displays use consistent symbology.

These studies used a range of approaches, and I realised that elements of each could be employed in this research. Lavie and Oron-Gilad (2013)’s testing of both actual and perceived usability of a product was of interest since a user’s perception of a product’s usability can affect the amount of satisfaction derived from using the product. Like Dickmann (2012), Field, O’Brien and Beale (2011), and Ishikawa et al. (2008), Hsu, Lin and Chao (2012) compared the usability of two map products by having participants complete wayfinding exercises in an unfamiliar location. This was a suitable approach for my research, since familiarity with a location could decrease a participant’s reliance on the map used for evaluation. Statistical analyses like those used by Lavie and Oron-Gilad (2013), Hsu, Lin and Chao (2012), and Rodes and Gugerty (2012) were also identified as appropriate for this research, because they allow for interrogation of the collected data and for evidence-based choices to be made when designing new maps.

3.1.6 Wayfinding in Virtual Environments

Darken and Sibert (1996) analysed the wayfinding strategies that people use in large-scale virtual worlds. Five virtual environments with four different environmental cues were tested by 10 participants. Participants completed several wayfinding tasks whilst speaking their thoughts aloud with video and audio data being captured. The routes that the participants took to complete the tasks were also recorded and analysed. By combining behavioural video recordings and verbal protocols from audio recordings, the researchers collected data about the actions and thinking of the participants while they completed the tasks. The approach for this research was a combination of qualitative and quantitative data collection, with analysis of the latter using ANOVA to determine what influence each of the four environmental cues had on participants’ wayfinding strategies.

Huang et al. (2018) assessed an approach for generating wayfinding designs based on different scenarios. These designs were provided as virtual environments with strategically placed signage. To evaluate the wayfinding experience for a given environmental layout,
100 agent-based simulations were performed; the researchers calculated the number of agents that made their way from the source to the destination. Refinements to signage placement were then performed to assess whether more, fewer, or differently placed signs were equally effective. The optimal solution was the one that allowed successful wayfinding without redundant signage.

Like many of the other studies mentioned earlier, Darken and Sibert (1996) took empirical measurements of participant behaviour, but their study differed in taking place in a virtual environment. Huang et al. (2018), on the other hand, used agent-based simulations in lieu of participants conducting wayfinding activities. I saw the potential of virtual environments and agent-based simulations for use in my own research. The advantage of conducting experiments in virtual environments is that the environment can be controlled so that familiarity with a location can be eliminated, and the conditions remain the same for each participant. On the other hand, such environments have less ecological validity and may not generate enough relevant information for use in a natural setting. Agent-based simulation eliminates the need to engage participants and allows a large population to be studied. However, agent-based simulations were judged to be highly unlikely to be representative of map-illiterate users, because the behaviours of this target user group were unknown.

3.2 Evaluation of Data Collection and Analysis Techniques

Before I could determine which aspects of the methodologies discussed in 3.1 could be implemented, it was necessary to determine the applicability of the methods to my research.

Marquez, Oman and Liu (2004) used anecdotal evidence to identify the issue of disorientation on board the ISS, and identified specific wayfinding and orientation problems related to this phenomenon. By consulting astronauts who had been on board the ISS and had experienced orientation and wayfinding issues, the researchers collected valuable information about the environment and the causes of the problems, and which elements could provide possible remedies. However, the researchers did not test the YAH map they created; they suggested that to test it, they would ask astronauts to describe how they
would navigate from one point to another using the map. This may not be the most effective way to test the map, since test participants are not immersed in the map-use environment or within a virtual replica of that environment. Describing the route one would take and trying to actually complete the task in the environment are two very different tasks since traversing a route involves locomotion and engages the vestibular system (Ishikawa & Zhou 2020), while describing a route does not. When one is physically present within an environment, external features may cause confusion or distraction. Such features do not exist when one is not physically present within the environment but rather is in a laboratory and imagining the environment. Thus, to determine the true usability of the YAH map, experiments would need to be conducted within the actual or replicated environment. So, whilst the creation of the map was sound, its proposed evaluation was not.

The studies conducted by Lavie and Oron-Gilad (2013), Delikostidis (2011), Darken and Sibert (1996) and Crampton (1992) are very similar in that they engaged participants in their experiments. These authors asked participants to complete a series of wayfinding activities, as well as to verbalise what they were doing and thinking and how they felt about the activities as they undertook these tasks. This allowed the researchers to identify both the participants’ behaviours and their abilities. Further to this, Lavie and Oron-Gilad (2013) and Darken and Sibert (1996) used statistical analysis of quantitative data to identify where participants experienced difficulties. Crampton (1992) used behaviour graphs to identify and contrast the frequency of behaviours (for example, route choice) visually, and morphograms to compare the various morphological features (hill, valley, spur) to which the participants referred. This method permitted him to determine which protocols and which morphological features were used most effectively for wayfinding. Another similarity between these three studies is that all of them collected qualitative data that could be analysed using both qualitative and quantitative methods.

Kiefer, Giannopoulos and Raubal (2014) and Delikostidis (2011) used mobile eye-tracking equipment to further investigate the behaviours of their test subjects, enabling them to evaluate differences in gaze patterns between successful and unsuccessful participants.
However, Delikostidis (2011) had to abandon his eye-tracking research due to technical complications.

Several authors (Crampton 1992; Darken & Sibert 1996; Huang et al. 2018; Lavie & Oron-Gilad 2013) employed virtual or simulated testing environments. Such environments allow for greater control of geographic elements than real-world settings, and can be purpose built, allowing for the creation of an unfamiliar environment.

Dickmann (2012) and Field, O'Brien and Beale (2011) approaches were similar in that they tested participants’ abilities to recall spatial elements, such as identifying the direction of their starting position once they had reached their destination, or by sketching a map of the route they had travelled. Dickmann (2012) calculated Pearson’s correlation coefficient to determine the similarity of spatial objects drawn in participants’ sketch maps with their real-world characteristics, and conducted a t-test to determine the statistical significance of differences between the mean numbers of spatial objects drawn between the map group and the navigation system group. Likewise, Field, O'Brien and Beale (2011) used means and standard deviations to highlight differences between the GNSS-user and map-user groups’ performances.

### 3.2.1 Applicable Methodologies

Of the data collection and analysis techniques reviewed above, the following were adopted for this research project:

- Participants completing map-reading tasks in conjunction with think-aloud protocols (Crampton 1992; Lavie & Oron-Gilad 2013);
- Participants completing map-reading tasks in conjunction with questionnaires (Delikostidis 2011; Dickmann 2012; Field, O'Brien & Beale 2011; Ishikawa et al. 2008);
- Participants completing map-reading tasks while having their eye movements recorded (Kiefer, Giannopoulos & Raubal 2014)
• Participants completing map-reading tasks in real-world environments 
  (Crampton 1992; Darken & Sibert 1996; Delikostidis 2011; Field, O’Brien & Beale 
  Rodes & Gugerty 2012); and 
• Statistical analysis (Crampton 1992; Dickmann 2012; Hsu, Lin & Chao 2012; 
  Ishikawa et al. 2008; Lavie & Oron-Gilad 2013; Rodes & Gugerty 2012).

To correctly identify the challenges that map-illiterate users experience when using maps to 
find their way, it is necessary that research participants are representative of this user 
group. Therefore, I needed to study people with poor spatial abilities, rather than simulated 
participants (Darken & Sibert 1996). Similarly, conducting the experiments in a real-world 
environment provides more realistic data than does a virtual environment. Participants 
immersed in the physical 3D world move about in that environment as they would when 
wayfinding under typical circumstances. Hence, describing a route one might take in future 
(Crampton 1992; Marquez, Oman & Liu 2004) may not provide sufficient information about 
the challenges that map-illiterate users experience in practice.

Based on this review of research techniques, I developed an evaluation procedure that 
could be used to identify challenges experienced by map-illiterate individuals and then to 
evaluate the alternative map design created for these users:

• Source appropriate unfamiliar environments for experiments; 
• Identify suitable maps of those environments for use in testing; 
• Identify map-illiterate participants using the SBSODS (section 2.5) and invite 
  them to participate in experiments; 
• Conduct wayfinding activities with participants using eye-tracking technologies 
  and think-aloud protocols (Suchan & Brewer 2000); 
• Analyse the resulting data using qualitative and quantitative methods; and 
• Reflect, refine, and undertake iterative experiments, if necessary.
This review of methodological approaches to assess wayfinding behaviours and systems was used to develop procedures for assessing the challenges experienced by map-illiterate users when wayfinding. Undertaking this review provided insights into which techniques were likely to produce useful information.

### 3.3 Methodology Development

Since my research focused on the map-use and wayfinding behaviours exhibited by map-illiterate users, I needed to collect data from such users. I did so using an observational mixed methods approach, involving questionnaires, verbal protocols and eye-tracking; collecting data in this way allowed for a rich picture to be developed and for triangulation among data sources. In particular, qualitative data can be used to explain patterns or trends identified from quantitative analyses (Creswell & Clark 2007). The benefit of a mixed methods approach was that it allowed for the discovery and exploration of nuances of map-use and wayfinding as well as the elements of map design that map-(il)literate users find ambiguous.


Board’s procedure for identifying appropriate map-reading tasks (Board 1978) (section 3.1.2) was used to develop the experiment to identify challenges map-illiterate users experience when travelling between two locations in an unfamiliar urban environment (Figure 3-2). The **bolded** text in Figure 3-2 shows where my approach deviated from Board’s procedures.
Figure 3-2 Procedure for identifying appropriate experimental map-reading tasks, adapted from Board (1978)
3.3.1 Collecting Data Using Questionnaires

An online questionnaire was used to identify potential participants and collect information about their demographic characteristics and map-use experience. It had two sections: background information and the SBSODS (section 2.3.1).

I selected the SBSODS to identify map illiterate participants due to its validity and reliability in determining an individual’s level of environmental spatial ability. As noted in section 2.3.1, Hegarty et al. (2006) performed rigorous testing in developing the SBSODS, and demonstrated that those who scored highly on this scale were able to perform self-localisation when moving through an environment. Therefore, those who receive low scores on this scale would be less likely to be able to perform self-localisation while moving through an environment, and could be considered to be map illiterate.

The demographic characteristics section of the survey required participants to provide information about their age, cultural background, education level and field of education, and their contact details. In addition to this personal information, participants were asked to describe their experience with digital technologies, what methods they used to plan routes, navigate and wayfind, as well as their level of familiarity with the test location.

3.3.2 Collecting Data Using Eye-Tracking Equipment

Eye-tracking captures information relating to a study participant’s gaze behaviour (Tobii Technology AB 2015f). This means where someone looks can be determined, as well as how long they looked at that location, and the path their eyes took to look at a specific feature (Bergstrom & Schall 2014). Eye-tracking research has been applied to many different fields, such as marketing, human factors, human-computer interaction and cartography (Bergstrom & Schall 2014; Steinke 1987).

Eye-tracking enables collection of data from a participant that they themselves cannot convey. Since the eye can move very fast, it is impossible for a user to give a researcher an accurate description of things at which they have looked directly. Eye-tracking information
provides measurements of how long the participant directed their gaze to fixed objects within their field of view. Eye movements can also be the result of a bottom-up process, in which the eyes are reacting to a stimulus rather than being consciously directed to a location where the individual has chosen to look, as is the case in top-down processes. This is relevant because a map may contain elements that are distracting to the map user which could be identified by persistent movements of the eye to particular map features. Eye tracking therefore provides non-invasive insights into our reactions to visual stimuli without conscious thought (Kiefer, Giannopoulos & Raubal 2014). Moreover, Kettunen, Sarjakoski and Sarjakoski (2015) argued that eye tracking is vital in studying the spatial cognition associated with the creation of user-friendly maps since eye tracking can be used to evaluate cognitive load.

3.3.3 Collecting Data Using Think-Aloud Protocols

Think-aloud protocols are a common method of data collection used when trying to understand the behaviours of individuals and groups of people. This type of data collection involves the participant speaking aloud about their experience as they undertake a task (concurrently thinking aloud – CTA) or describing the experience after undertaking a task (retrospectively thinking aloud – RTA). By having participants verbalise their thoughts, it is possible to gain insight into their thought processes, and therefore understand why they might have exhibited certain behaviours.

Kuusela and Pallab (2000) found that CTA provided more insight into decision-making processes than did RTA, whereas RTA provided more insight into the final choices made. Therefore, the choice to use CTA or RTA depends on the data the researcher requires. In my research it was more appropriate to use the CTA approach where the individual speaks aloud whilst completing tasks. This is because CTA provides insight into the cognitive processes as they are happening, and therefore it allows issues to be identified as the user encounters them.
3.3.4 Justification of Methods Chosen

Questionnaires are useful for collecting initial information about potential or actual participants, some of which may be associated with the phenomenon of interest and therefore confounders that can be controlled for in statistical analysis. In addition, questionnaires enable potential participants to be screened for their suitability for the research project (Bloomberg & Volpe 2016). In my research, the background information section of the questionnaire was used to identify people who were familiar with the test location and therefore ineligible to participate, since familiarity with the location would have diminished their need to use the map.

Eye tracking glasses (section 4.5.2) were used to collect eye movements and think-aloud data. Eye-tracking allows for the collection of data about where people are looking in an unobtrusive way, and I theorised that it would provide insights into how map-illiterate users view maps while wayfinding that could not be harvested in any other way.

In some instances, it may be useful to know why an individual is looking at a particular feature for a prolonged amount of time. Perhaps they find the feature difficult to understand, or maybe they are looking at it because it is pleasant. In this situation, a think-aloud protocol can be useful to differentiate between these two explanations. Thinking aloud allows users to express their thoughts and feelings while completing the task.

The combination of these methods provided a rich picture of participants’ behaviours while undertaking the map-reading tasks.

3.4 Selecting a Test Scenario

To observe the challenges map-illiterate users experience when using maps for planning routes and wayfinding, a map-use scenario had to first be established.
An Alternative Wayfinding Map Design for Map Illiterate Users

To do this, map-use tasks must be identified. According to Delikostidis (2011, p. 103) the questions one might ask oneself when undertaking route-planning and wayfinding activities include:

- Where am I?
- What is around me?
- Where am I heading to?
- Where is the destination?
- How far is the destination?
- In which direction is the destination?
- Which route is the most convenient to get to the destination?
- Am I on the correct route?
- Am I heading in the correct direction?
- Is this the correct destination?

To make it more likely that participants ask themselves these questions, and to increase their reliance on the maps, the experiments must take place in locations unfamiliar to the study participants.

One common scenario in which people might need to wayfind is when they are in an unfamiliar location as a tourist. Tourists often spend a lot of time exploring their environments. Other scenarios present time constraints that may affect a map user’s ability to use a map for the purpose of route-planning and wayfinding, such as a job applicant on their way to an interview. To try to produce more generalisable findings about the map-reading behaviour of map-illiterate users, I studied both scenarios: a tourist with plenty of time, and a job applicant on their way to an interview. Therefore, the maps selected for this study had to be suitable for both purposes.

Whilst working and therefore attending job interviews happens almost everywhere, tourist areas can have distinctive geographic characteristics. Therefore, popular tourist destinations
were examined to see what kinds of geographic characteristics they contained. This allowed
the selection of study locations reflective of the spatial structure of popular tourist
locations.

I used the MasterCard Global Destination Cities Index 2016, developed by Hendrick-Wong
and Choong (2016), to identify cities most visited by tourists. In calculating the top 20
destination cities, MasterCard only includes those visitors who have arrived from an
international location and “who actually stay in the destination city for at least one night”
(Hendrick-Wong & Choong 2016, p. 57). It is acknowledged, however, that some tourists
may stay overnight in these locations (for example, Bangkok and Dubai) before continuing
their journey on to their intended destination.

The top five cities on the MasterCard Global Destination Cities Index 2016 were Bangkok,
London, Paris, Dubai and New York City. Given the diverse locations of these five cities, it
was decided that this was a sufficient number of locations to examine carefully.

Using MasterCard’s list (Hendrick-Wong & Choong 2016) I examined official tourist maps of
each city and described their geographic layouts. Given the high numbers of tourists who
visit these cities each year, they can be considered to reflect some important characteristics
of tourist destinations generally. I describe each city and its geographic characteristics in the
following subsections.

3.4.1 Bangkok

In 2016, Bangkok was the most visited city, with 21.47 million annual visitors. A tourist map
of Bangkok is provided in Figure 3-3, showing the Chao Phraya River, other water networks
throughout the city, and some roads. Points of interest are highlighted, and there is some
degree of hierarchy applied to the road types. This map spans a ground area of
approximately 57,500 km².
3.4.2 London

According to (Hendrick-Wong & Choong 2016), London was the city with the second-largest number of international visitors in 2016. Using the map of London shown in Figure 3-4, its area was calculated to be 1500 km$^2$. Although the road network is very irregular, the map does show a road hierarchy. This map displays a lot more information than does the Bangkok map.

3.4.3 Paris

Paris was the world’s third-most frequently visited city in 2016, with 18.03 million international overnight visitors (Hendrick-Wong & Choong 2016). The tourist area (as indicated by the map extent – Figure 3-5) is spread over approximately 100 km$^2$. The direction of roads vary, although, there is some circularity, particularly to the boulevards, designed by Baron Haussmann (Glancey 2016). Apart from road width, no other elements in the map indicate a hierarchy in the roads.

3.4.4 Dubai

With 15.27 million international overnight visitors, Dubai was the fourth most visited city in the world in 2016 (Hendrick-Wong & Choong 2016). The tourist portion of Dubai, as calculated by the area displayed on the tourist map, is approximately 4000 km$^2$. Figure 3-6 shows that the city of Dubai extends more widely along the coast than it does inland. The major roads also tend to follow the shape of the coastline. Unlike the previous tourist maps listed, the Dubai tourist map is not oriented to the north, but to the south and is designed from a perspective view. This is likely because most of the features of interest for tourists are along the coastline and tourists may use the coastline as a point of reference for wayfinding.

3.4.5 New York City

With 12.75 million international overnight visitors, New York City was the fifth most visited city in 2016 (Hendrick-Wong & Choong 2016). The approximate tourist area, as estimated
using the tourist map below (Figure 3-7), is 800 km². Note that the island of Manhattan is made up of a grid system of roads, whereas other areas featured in the map, The Bronx, Queens and Brooklyn, have more irregular road networks. The tourist map of New York City is oriented north-north-east.
Figure 3-3 Tourist Map of Bangkok (Tourism Authority of Thailand 2017, http://www.tourismthailand.my/ematerials/pdf/Bangkok.pdf)
Chapter 3 – Establishing a Method for Identifying Map Illiterate Users

Figure 3-4 Map of Central London (Transport for London 2017, http://content.tfl.gov.uk/bus-route-maps/central-london-bus-map.pdf)
Figure 3-5 Tourist Map of Paris (a’prim Graphic 2013)
Figure 3-6 Tourist Map of Dubai (Department of Tourism 2017, https://www.visitdubai.com/en/visiting/travel-planning/tools/map-of-dubai)
Figure 3-7 Tourist Map of New York City (NYC & Company 2016, http://www.nycgo.com/-assets/files/pdf/nyc-official-visitors-map-2017.pdf)
As noted earlier, when selecting locations for evaluating maps involving tourists, it is important to execute the tests in locations that tourists visit in large numbers (or that are representative of them). The maps of the five most-visited tourist destinations in 2016 were used to compare their geographic layouts. This review revealed that the configuration of the street networks differed between some locations; whereby one city (New York City) has a regular, grid-like structure while four cities (London, Bangkok, Paris and Dubai) have irregular structures. It is therefore necessary to undertake wayfinding studies in locations with these street network configurations to establish whether map design requirements should differ accordingly. While these cities vary in size, wayfinding itself is experienced at the environmental scale, rather than the figural, vista or gigantic scales, so the scale at which the user experiences the environment does not change between cities. The research locations of Enschede, The Netherlands (irregular structure) and Melbourne, Australia (grid-like structure) met these criteria and were subsequently selected at the locations for the case studies.

3.5 Selecting Appropriate Users

This research was focused on map-illiterate users, so needed participants from this user group. As with similar studies (section 3.1), it was determined that the participants of this study should not be familiar with the study area, to decrease the likelihood that they could depend on their cognitive map and to increase dependence on the map provided. People who had to wear vision-correcting glasses were excluded (identified in the initial questionnaire), because the mobile eye tracker that was available for the study could not accommodate them; however, people who wore contact lenses could participate. Finally, the participants should vary in their other demographic characteristics to make it more likely that the findings of this research could be generalised. Table 3-1 shows the exclusion criteria for potential participants.
Table 3-1 Exclusion criteria for potential participants

<table>
<thead>
<tr>
<th>Under 18 and over 80</th>
</tr>
</thead>
<tbody>
<tr>
<td>English language proficiency below conversational level</td>
</tr>
<tr>
<td>Familiar with study area</td>
</tr>
<tr>
<td>Wears vision-correcting eyeglasses</td>
</tr>
</tbody>
</table>

3.6 Selecting Map Platforms

Field, O’Brien and Beale (2011) and Ishikawa et al. (2008) demonstrated that map users tend to perform more effectively when using paper maps than digital maps. In both studies, those participants engaging in wayfinding using GNSS stopped more frequently and made more mistakes. Nielsen and Budiu (2013) reported that wayfinding with maps on small screens such as those on smartphones increases the cognitive load of using the map. Despite these findings, digital maps are commonly used, and technologies utilised for digital maps have continued to improve.

Table 3-2 lists the benefits and constraints of each type of map. It is easy to see that digital maps have more technological benefits than paper maps and conversely, fewer constraints than paper maps.

Table 3-2 Comparison of Paper Maps and Digital Maps

<table>
<thead>
<tr>
<th>Paper Maps</th>
<th>Digital Maps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit</td>
<td>Constraint</td>
</tr>
<tr>
<td>Can see a wide extent</td>
<td>Fixed scale</td>
</tr>
<tr>
<td>Easy to transport</td>
<td>People are less likely to carry a paper map</td>
</tr>
<tr>
<td>No power source needed</td>
<td>Subject to wear and tear</td>
</tr>
<tr>
<td>Only current at date of publication</td>
<td>Ability to search for a route</td>
</tr>
<tr>
<td>Ability to identify current location</td>
<td>Easily updated</td>
</tr>
<tr>
<td>Updated frequently</td>
<td></td>
</tr>
</tbody>
</table>
Despite digital maps having a greater number of technological benefits, it is useful to evaluate their performance relative to paper maps, because digital maps are a relatively recent innovation. Differences between users and map types may also yield useful information for map designers.

Since digital maps can be displayed on smartphones, tablets, and desktop computers, it was necessary to determine which platform should be selected for the study. Table 3-3 outlines the benefits and constraints of maps displayed on each platform.
Table 3-3 Benefits and Constraints of Maps Displayed on Smartphones, Tablets, and Desktop Computer

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Constraint</th>
<th>Benefit</th>
<th>Constraint</th>
<th>Benefit</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smartphone Map</td>
<td></td>
<td>Tablet Map</td>
<td></td>
<td>Desktop Computer Map</td>
<td></td>
</tr>
<tr>
<td>Easy to transport</td>
<td>Small viewing screen</td>
<td>Larger viewing screen</td>
<td>Battery limitations</td>
<td>Larger viewing screen</td>
<td>Not portable</td>
</tr>
<tr>
<td>Many people already have</td>
<td>Battery limitations</td>
<td>Easy to transport</td>
<td>Glare</td>
<td>Can print maps at different scales</td>
<td>Not instantly accessible in the environment</td>
</tr>
<tr>
<td>smartphones</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GNSS capability</td>
<td>Glare</td>
<td>GNSS capability</td>
<td>Not all tablets have internet connectivity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Given that the platform chosen had to be used for wayfinding in a real-world environment, a desktop computer was not suitable. The main difference between smartphones and tablets is screen size; while the larger screen of the tablet allows for a wider overview of the map to be visible, many people already have smartphones and carry them with them wherever they go (Pew Research 2021b). This makes smartphones the most suitable platform for testing digital maps.

**Summary**

This chapter focused on the methodological approaches to be used in collecting and analysing the data for this research. Sections 3.1 and 3.2 presented reviews of the methodological approaches applied in similar studies, providing a solid foundation on which the methodological approach to this research could be developed. The methodologies used in this research were discussed in section 3.3, and justifications for using them were provided. The selection of questionnaires, eye-tracking, and think-aloud data collection methods allowed for a rich dataset to be obtained. These three forms of data are complementary, allowing for deeper analysis of behaviour and more robust explanations for the findings. The map-use context (section 3.4), participant characteristics (section 3.5), and map platform (section 3.6) were also explained in this chapter.
In the following chapter, the data collection process, and results of the first case study, conducted in Enschede, The Netherlands, are described in detail.
Chapter 4 - Identifying Challenges Map Illiterate Users Experience When Wayfinding in a Small City with an Irregular Road Network

This chapter is an extended version of a published article, An investigation into challenges experienced when route planning, navigating and wayfinding (Koletsis et al. 2017)

In Chapter 3 I reviewed possible methodologies for undertaking this research. The review informed the design of the methodology for this research, as well as the user context in which the testing would take place.

In this chapter, the data collection process for case study one, undertaken in Enschede, The Netherlands, is described along with the equipment used for data collection and analysis. It includes information relating to the questionnaires, for selecting an appropriate smartphone map application (app) for testing, and the selection of participants. This chapter also details the analysis process and results, which are then scrutinised and explained.

4.1 Study Outline

The purpose of this study was to investigate the challenges map-illiterate users experience when using a mobile map application to find their way. The outcomes of this study were intended to inform the design of a wayfinding solution for these individuals (Chapter 7).

To most effectively identify the challenges that map-illiterate individuals experience, and for ecological validity, it was necessary for the case studies to reflect real-world wayfinding processes. Using Board’s (1978) procedure for identifying appropriate map-reading tasks (section 3.1.2), and Delikostidis’ (2011) map-reading questions, a route-planning exercise and a wayfinding exercise were developed.
To determine if time pressure impacts on a map-(il)literate user’s ability to find their way, participants were divided into two groups: Job Applicants and Tourists. Job Applicants were advised that they were on their way to a job interview and should therefore take a direct route to arrive in time for their interview. Tourists were advised that they had plenty of time to look around while travelling between the two locations, so they could take any route they liked. The selection of these groups is supported by Allen (1999) who classified wayfinding tasks according to their purpose. Allen (1999) proposed three wayfinding categories, commute, explore, and quest. Commute refers to wayfinding along a familiar and repetitive route, such as the routes taken to go to school, work and supermarket. Explore refers to wayfinding in unfamiliar locations for the purpose of understanding the environment, such as when tourists visit a new city. Quest refers to the travel from a familiar location to an unfamiliar location, such as from home to a friend’s new house, or to a potential new workplace. The tourist and job applicant group therefore fall within the wayfinding categories of explore and quest, respectively. However, it is noted that tourists may also fall within the quest category, if they have partial familiarity with the location they are visiting.

The study took place in Enschede, The Netherlands (Figure 4-1). In the route-planning activity, participants used a static image (Figure 4-2) of the study location from the Maps.Me mobile mapping application (section 4.3) to plan their route on a desktop computer while speaking their thoughts aloud (section 4.7). Participants’ eye movements were recorded using a fixed eye-tracking system. In the wayfinding activity, participants followed their planned route using Maps.Me on a smartphone, while wearing mobile eye-tracking glasses and speaking their thoughts aloud (section 4.8).

4.1.1 Route Planning

For the route-planning exercise participants had to identify three possible routes between G.J van Heekpark and Museum TwentseWelle (Figure 4-1) and select one they preferred based on their identity as a Job Applicant (Appendix F) or Tourist (Appendix G). This route would be the one they would follow in the wayfinding activity.
A drawback of Maps.Me is that it is not available for Windows or online. To overcome this issue, a JPEG image from a tablet, showing the area with G.J. van Heekpark and Museum TwentseWelle, was used, because the screen size of the desktop computer (24 inches = 61 centimetres) was large enough to fit the entire study area. The computer was connected to the Tobii X60 fixed eye-tracking system, which recorded participants’ eye movements while completing the activity.

The JPEG image was opened in Microsoft Paint, in which the participants drew their three routes (Figure 4-2). Once participants selected their preferred route, the route-planning exercise was complete. The participants’ selected routes were then transferred to the smartphone via a KMZ file created using Google Maps.
Figure 4-1 District of Roombeek, north of Enschede city centre. This map shows the origin of the experiment, G.J. van Heekpark and the destination, Museum TwentseWelle
Figure 4-2 Example of a participant’s three routes, drawn in Microsoft Paint
4.1.2 Wayfinding

Once the smartphone had been loaded with the selected route, the participant was set up with the Tobii Pro Glasses 2 in order to measure their eye movements while walking. The glasses were then calibrated, and the participant was led to the starting point of their route.

The participants first had to find their correct position and orientation on the map, and if required, re-orient themselves to face the direction in which they need to proceed along their route. From this point, the participant made their way to the destination, Museum TwenteWelle, while speaking their thoughts aloud.

4.1.3 Post-Test Interview

Once the participants finished the wayfinding exercise, they completed a post-test questionnaire (Appendix H). This questionnaire allowed the participants to answer questions relating to their satisfaction in executing the tasks while using the Maps.Me app. Obtaining information about their satisfaction provides an understanding of how ‘comfortable’ the map app is to use.

4.2 Study location - Enschede

This case study was undertaken in Enschede, The Netherlands (Figure 4-3). As discussed in section 3.4, it was deemed important that the study locations should include cities with complex topographic layouts and that were small in size (relative to Melbourne, Chapter 5); Enschede conforms to these characteristics.

Enschede is a small city located in the eastern region of the Netherlands. It spans an area of approximately 150 km² and has a population of around 150,000 (CBS 2022). It has a circular or radial layout, featuring ring roads (Figure 4-4). The road network is quite irregular with roads intersecting at various angles. In this way, it has similarities with the geographic layout of Paris.
Chapter 4 – Identifying Challenges Map Illiterate Users Experience When Wayfinding in a Small City with an Irregular Road Network

Location of Enschede, The Netherlands

Figure 4-3 Location of Enschede, The Netherlands
Geographic Layout of Enschede, The Netherlands

Figure 4-4 Map of Enschede with inset of the city centre
4.3 Identifying an App for Testing

To avoid negatively influencing the test outcomes, the map selected for testing should be one that is considered to be well-designed and fit for purpose. To establish which map should be used for testing, four pre-existing digital maps that were available at no cost to users were identified as possible test maps. Purchased apps were not considered, because free apps have significantly more downloads, meaning more users are familiar them. The four maps were selected from a Google search using phrases such as, “which navigation apps are best”, which returned lists and rankings of top apps. Comparing multiple lists showed that preferred free map apps were Google Maps, Maps.Me, Route 66 and Scout (Figure 4-5 and Figure 4-6).
Figure 4-5 Google Maps (left), Maps.Me (right)
Figure 4-6 Route 66 (left), Scout (right)
A questionnaire was developed (Appendix I) to determine which map app would be the most suitable to use in this research. This questionnaire was directed at expert cartographers who had experience in map design – whether designing maps themselves, or teaching map design at a tertiary level. The respondents were asked to rank each of the maps against one another in relation to route planning and wayfinding, in conjunction with:

- Identifying self-location and orientation;
- Colours;
- Differentiation between different features (e.g., buildings, parks, roads and important features);
- Design of point symbols;
- Design of line symbols;
- Appropriateness of typography (placement, font, colour, legibility);
- Data generalisation; and
- Wayfinding and navigation, and route-planning between two locations.

The questionnaire had three parts. The first part related to wayfinding, the second related to route planning, and the third required the respondents to rank the four maps and explain their opinion in terms of the app’s suitability for navigation, wayfinding and route planning.

The Map App Assessment questionnaire was developed using Survey Monkey and a link to it was sent to experts within the professional networks of the research team. The survey was completed anonymously, and the profiles of the respondents are provided in Table 4-1. A sample of scoring is provided in Table 4-2 and scores of each map application are provided in Table 4-3.
Table 4-1 Profile of respondents to the Map App Assessment survey of cartographic experts.

<table>
<thead>
<tr>
<th>Professional Position</th>
<th>Years’ Experience in Cartography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecturer in GIS</td>
<td>5-10</td>
</tr>
<tr>
<td>Senior Lecturer in GIS and Cartography</td>
<td>&gt;21</td>
</tr>
<tr>
<td>Assistant Professor</td>
<td>&gt;21</td>
</tr>
<tr>
<td>Cartographer</td>
<td>&gt;21</td>
</tr>
<tr>
<td>Mapping and Visualisation Engineer/Designer</td>
<td>11-20</td>
</tr>
<tr>
<td>Lead Academic Developer</td>
<td>&gt;21</td>
</tr>
<tr>
<td>Freelance Cartographer/Part-time adjunct university professor</td>
<td>5-10</td>
</tr>
<tr>
<td>Assistant Professor in Cartography</td>
<td>11-20</td>
</tr>
<tr>
<td>Product Engineer in Cartography</td>
<td>11-20</td>
</tr>
<tr>
<td>Senior Cartographic Product Engineer</td>
<td>&gt;21</td>
</tr>
</tbody>
</table>

Of the map apps provided to the experts, Google Maps and Maps.Me received similar average ranks. Due to the high popularity (and therefore, familiarity) of Google Maps among general consumers, and the low probability that many participants had experience with Maps.Me, Maps.Me was selected as the app to be used in testing. This selection was supported by statistics obtained from the Google Play app in December 2018: Google Maps had been downloaded over one billion times, and Maps.Me had been downloaded over fifty million times. Lack of familiarity with the Maps.Me app meant that it would require greater user concentration on map-reading than Google Maps.

The scores of each map reflect the average ranking score. Where, the first choice is given a weight of four, second choice a weight of three, third choice a weight of two and fourth choice a weight of one.

Table 4-2 Sample of Scoring

<table>
<thead>
<tr>
<th></th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Google Maps</td>
<td>2</td>
</tr>
<tr>
<td>Maps.Me</td>
<td>3</td>
</tr>
<tr>
<td>Route 66</td>
<td>1</td>
</tr>
<tr>
<td>Scout</td>
<td>4</td>
</tr>
</tbody>
</table>
An Alternative Wayfinding Map Design for Map Illiterate Users

Table 4-3 Mean scores from Map App Assessment survey

<table>
<thead>
<tr>
<th>Question</th>
<th>Google Maps</th>
<th>Maps.Me</th>
<th>Route 66</th>
<th>Scout</th>
</tr>
</thead>
<tbody>
<tr>
<td>The maps show a large-scale area of Vienna. At this scale, navigating and wayfinding is possible. With this in mind, please rank the maps in order of best to worst, where 1 is best and 4 is worst for the following:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identifying self-location and orientation</td>
<td>2.4</td>
<td>2.5</td>
<td>1.9</td>
<td>3.2</td>
</tr>
<tr>
<td>Colours</td>
<td>2.6</td>
<td>2.7</td>
<td>2.0</td>
<td>2.7</td>
</tr>
<tr>
<td>Differentiation between different features (e.g., buildings, parks, roads and important features, etc.)?</td>
<td>2.3</td>
<td>3.0</td>
<td>2.1</td>
<td>2.6</td>
</tr>
<tr>
<td>Design of point symbols</td>
<td>3.0</td>
<td>3.2</td>
<td>1.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Design of line symbols</td>
<td>2.2</td>
<td>3.4</td>
<td>1.7</td>
<td>2.7</td>
</tr>
<tr>
<td>Appropriateness of typography (placement, font, colour, legibility)</td>
<td>3.0</td>
<td>2.4</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Data generalisation</td>
<td>2.6</td>
<td>2.5</td>
<td>2.0</td>
<td>2.9</td>
</tr>
<tr>
<td>Wayfinding or navigating between St. Stephan’s Cathedral (also known as Domkirche St. Stephan and Stephandom) and St. Peters Church (also known as Katholische Kirche St. Peter, Peterskirche and Sankt Peter)?</td>
<td>3.0</td>
<td>3.0</td>
<td>2.5</td>
<td>1.5</td>
</tr>
<tr>
<td>The maps above show a small-scale area of Vienna. At this scale, route planning is possible. With this in mind, please rank the maps in order of best to worst, where 1 is best and 4 is worst for the following:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Locating origin and destination</td>
<td>2.78</td>
<td>2.0</td>
<td>2.44</td>
<td>2.78</td>
</tr>
<tr>
<td>Colours</td>
<td>3.11</td>
<td>2.56</td>
<td>1.78</td>
<td>2.56</td>
</tr>
<tr>
<td>Differentiation between different features (e.g., buildings, parks, roads and important features, etc.)?</td>
<td>2.33</td>
<td>3.11</td>
<td>2.22</td>
<td>2.33</td>
</tr>
<tr>
<td>Design of point symbols</td>
<td>2.44</td>
<td>2.78</td>
<td>2.89</td>
<td>1.89</td>
</tr>
<tr>
<td>Design of line symbols</td>
<td>3.22</td>
<td>2.22</td>
<td>2.0</td>
<td>2.56</td>
</tr>
<tr>
<td>Appropriateness of typography (placement, font, colour, legibility)</td>
<td>2.78</td>
<td>1.67</td>
<td>2.22</td>
<td>3.33</td>
</tr>
</tbody>
</table>
### Data generalisation

| Determining a route between point St. Stephan's Cathedral (also known as Domkirche St. Stephan and Stephandom) and St. Peters Church (also known as Katholische Kirche St. Peter, Peterskirche and Sankt Peter)? | 3.71 | 2.86 | 1.0 | 2.25 |

Please rank these maps overall in order from best to worst, where 1 is best and 4 is worst, in terms of your preference for their suitability to navigation, wayfinding and route planning in relation to their design.

| Total Score | 47.91 | 45.01 | 34.22 | 42.67 |

### 4.4 Identifying Participants

Recruitment of participants involved potential participants completing a questionnaire (Appendix J), designed in accordance with RMIT’s human ethics research policy (Approval # ASEHAPP 11-16, approved 09/03/2016, Appendix K). Respondents provided information about characteristics of interest, most importantly, their map literacy status, because this research was aimed at map-illiterate people. In addition, they provided information relating to age, gender, education level, nationality, map-reading experience and preferences, and familiarity with the test location. Smartphone experience and experience with using maps on smartphones was also collected. The final set of data collected in the participant recruitment process was information relating to their spatial abilities using the SBSODS (section 2.3.1). Given that the wayfinding component of the research uses a real navigation problem, it was necessary to identify the spatial abilities of the participants prior to completing the route-planning and wayfinding exercises. An individual may have poor spatial ability skills, but this might manifest in the map-reading process or only when they need to move about within the environment, and this may affect the way map products should be designed for map-(il)literate individuals. Overall, establishing participants' background characteristics was important for identifying relationships between the responses provided in the questionnaire and the behaviours exhibited by participants.
4.4.1 Map Literacy Assessment

As noted earlier, the SBSODS has produced reliable predictions (Hegarty et al. 2002) of spatial and map-reading abilities (section 2.3.1), so was used to assess potential participants’ map literacy levels. Whilst the SBSODS cannot be used to establish an absolute level of map (il)literacy, it does allow for the identification of participants with different spatial and map-reading abilities. To understand the range of challenges experienced by map-(il)iterate individuals, participants with a wide range of map literacy skills were required for the case study.

4.4.2 Recruitment Processes

Many researchers recruit participants from their own institutions, for reasons of convenience as well as existing trust in the population that results in a higher participation rate. However, I was working within the ITC at the University of Twente (UT) during this phase of the research, and (naturally) a high proportion of the staff and students were familiar with using maps; few or none would not fall into the map-illiterate category. Hence, I had to find another source of participants.

Within UT, psychology students are required to complete a set number of hours as participants in research studies. Whilst these students have little diversity in terms of their demographic characteristics, being mostly young and well-educated relative to the general population of The Netherlands, they are not likely to have extensive training in geospatial fields, and as a result represented a potential participant pool.

Another pool of potential participants were the academic support staff within UT – those who do not perform any direct educational functions within the university. These individuals are diverse relative to psychology students, ranging widely in age, education, and profession.

In March 2016, I sent an email to both groups of people using UT email lists, inviting them to participate in the study. Attached to the email was a recruitment advertisement (Appendix
L) explaining the nature of the research and the exercises and giving information enabling them to make contact with me should they wish to participate. After I received an email indicating a person’s interest in participating in the study, I replied with a link to the online survey.

4.4.3 Participant Selection

By five weeks after the initial email, 24 people had volunteered to be a part of this study (a response rate of 8%), mostly staff or students from the ITC. Four respondents who wore glasses (but not contact lenses) were excluded from the study, since the eye-tracking glasses cannot be worn in conjunction with vision-correcting eyeglasses.

4.4.4 Participant Demographics

20 participants agreed to carry out the case study activities, and each was allocated an ID from P1 to P20. 14 participants attended and completed a route planning and wayfinding exercise (May – June 2016). The remaining six either had very similar characteristics to other participants or were not available on the scheduled exercise days and times.

The study group consisted of seven men and seven women. Most of the participants were aged between 25 and 44 years, and half were students. Seven participants had a geospatial background, while the remaining seven had other educational backgrounds.

Using Bertin’s reorderable matrix method (Bertin, Berg & Scott 1981), (Table 4-4), participants were divided into two comparable groups: Tourists and Job Applicants. These categories were selected because of the ways in which their wayfinding goals may differ. A tourist is assumed to be less pressured by time, and more likely to adopt an exploratory approach to wayfinding, whereas a job applicant who is travelling to a job interview will be more constrained by time, and more likely to take a more direct route to their destination. Bertin’s reorderable matrix method is a process that is used to understand tabular data (Perin, Fekete & Dragicevic 2018); by rearranging this data, patterns may be revealed. This
method was used to distribute participants evenly across the two groups and reduce bias with respect to any of their major attributes (Mengistu 2015).

Table 4-4 Participant demographics using Bertin’s re-orderable matrix method to distribute the participants between the Tourist and Job Applicant groups.

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Age Bracket</th>
<th>Gender</th>
<th>Country of Origin</th>
<th>Occupation</th>
<th>Highest Completed Education Level</th>
<th>Field of Study</th>
<th>Experience in Study Area</th>
<th>SBSOD Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2</td>
<td>25-34</td>
<td>M, F</td>
<td>Netherlands</td>
<td>Student</td>
<td>Bachelor</td>
<td>Geo-related</td>
<td>2-4 times per month</td>
<td>4.9</td>
</tr>
<tr>
<td>P7</td>
<td>35-44</td>
<td></td>
<td>Outside Netherlands</td>
<td>Non-Student</td>
<td>MSc</td>
<td>Non Geo-related</td>
<td>5-10 times per year</td>
<td>4.0</td>
</tr>
<tr>
<td>P9</td>
<td>45-44</td>
<td></td>
<td></td>
<td></td>
<td>Other</td>
<td>Geo-related</td>
<td>Less than once per year</td>
<td>3.4</td>
</tr>
<tr>
<td>P11</td>
<td>25-34</td>
<td>M</td>
<td></td>
<td></td>
<td>Other</td>
<td>Geo-related</td>
<td>2-4 times per month</td>
<td>4.9</td>
</tr>
<tr>
<td>P13</td>
<td>35-44</td>
<td>F</td>
<td></td>
<td></td>
<td>Other</td>
<td>Non Geo-related</td>
<td>5-10 times per year</td>
<td>4.0</td>
</tr>
<tr>
<td>P14</td>
<td>45-44</td>
<td></td>
<td></td>
<td></td>
<td>Other</td>
<td>Geo-related</td>
<td>Less than once per year</td>
<td>3.4</td>
</tr>
<tr>
<td>P20</td>
<td>25-34</td>
<td>M, F</td>
<td></td>
<td></td>
<td>Other</td>
<td>Non Geo-related</td>
<td>2-4 times per month</td>
<td>4.9</td>
</tr>
<tr>
<td>P1</td>
<td>35-44</td>
<td></td>
<td></td>
<td></td>
<td>Other</td>
<td>Geo-related</td>
<td>5-10 times per year</td>
<td>4.7</td>
</tr>
<tr>
<td>P6</td>
<td>45-44</td>
<td></td>
<td></td>
<td></td>
<td>Other</td>
<td>Non Geo-related</td>
<td>Less than once per year</td>
<td>4.2</td>
</tr>
<tr>
<td>P10</td>
<td>25-34</td>
<td>M</td>
<td></td>
<td></td>
<td>Other</td>
<td>Geo-related</td>
<td>2-4 times per month</td>
<td>3.4</td>
</tr>
<tr>
<td>P12</td>
<td>35-44</td>
<td>F</td>
<td></td>
<td></td>
<td>Other</td>
<td>Non Geo-related</td>
<td>5-10 times per year</td>
<td>4.7</td>
</tr>
<tr>
<td>P15</td>
<td>45-44</td>
<td></td>
<td></td>
<td></td>
<td>Other</td>
<td>Geo-related</td>
<td>Less than once per year</td>
<td>4.8</td>
</tr>
<tr>
<td>P16</td>
<td>25-34</td>
<td>M, F</td>
<td></td>
<td></td>
<td>Other</td>
<td>Non Geo-related</td>
<td>2-4 times per month</td>
<td>4.9</td>
</tr>
<tr>
<td>P17</td>
<td>35-44</td>
<td></td>
<td></td>
<td></td>
<td>Other</td>
<td>Geo-related</td>
<td>5-10 times per year</td>
<td>5.1</td>
</tr>
<tr>
<td>P14</td>
<td>45-44</td>
<td></td>
<td></td>
<td></td>
<td>Other</td>
<td>Non Geo-related</td>
<td>Less than once per year</td>
<td>3.9</td>
</tr>
</tbody>
</table>

4.5 Investigating Challenges Experienced by Map-(il)literate Individuals

4.5.1 Equipment

Four types of equipment were used to collect and/or analyse the data. To collect the route-planning data, a fixed eye-tracking system (Figure 4-7) and desktop computer were used. To collect the wayfinding data, a mobile eye-tracking system (Figure 4-11) and smartphone were used.
4.5.2 Eye-Tracking Technologies

Eye-tracking is an important tool for studying the visual gaze behaviour of individuals (Tobii Technology AB 2015g). Researchers use eye-tracking to evaluate their map products, determining how they are used and gaining insights into the behaviours of users. In doing so, they can identify areas of difficulty or confusion and use this information to improve upon their designs (Andrienko et al. 2012).

Eye-tracking enables collection of quantitative data pertaining to map use by individuals and can provide insight into the cognitive processes of the users (Andrienko et al. 2012; Çöltekin et al. 2009; Ooms et al. 2012). Bergstrom and Schall (2014) suggested that the longer a map user spends looking at a certain part of or feature on a map, the less clear that feature must be to understand, therefore it increases the cognitive load of the map user. However, a user may also spend a long time looking at a map feature because they are deriving information from it or find it particularly interesting (Holmqvist et al. 2011). Since it is unclear why users look at a map feature for a prolonged length of time, it is useful to have the users think aloud, so they can explain their behaviour. As such, eye-tracking data can be used to identify people who have difficulty in reading and interpreting a map. By comparing the scan paths of successful/fast users with unsuccessful/slow users, differences in strategies can be identified, as well as areas of difficulty and confusion (Andrienko et al. 2012).
Numerous eye-tracking measurement techniques exist, including electro-oculography (EOG), scleral contact lens/search coil, photo-oculography (POG) and video-oculography (VOG), and video-based combined pupil and corneal reflection (Duchowski 2017). EOG depends on “electrodes mounted on the skin around the eye that could measure differences in electrical potential in order to detect eye movements” (Poole & Ball 2006, p. 211). The scleral contact lens/search coil technique requires the participant to wear large contact lenses, which have a metal coil around the edge of the lens, over their eyes. As the eye moves, so does the lens and the metal coil, and measurement of this movement enables collection of information about the fluctuations of the electromagnetic field (Poole & Ball 2006). POG and VOG collection techniques are much less invasive than the EOG and scleral contact lens/search coil techniques. POG and VOG use infrared light and a camera to measure the reflection of the infrared light from the participant’s eyes. Infrared light, invisible to the human eye, does not interfere with the participant’s vision (Poole & Ball 2006). Two types of reflection techniques exist: bright pupil effect and dark pupil effect (Figure 4-8). Research has shown that there is a correlation between ethnicity and the most effective type of reflection technique. The bright pupil method is more effective for Caucasians and Hispanics, while the dark pupil method is more effective for Asians (Tobii Technology AB 2015a).
Three types of eye movements are measured when collecting eye-tracking data: fixations, saccades and scanpaths. Fixations refer to when the eye stops and looks at something for a period of time, usually from 50 to 600ms (Tobii Technology AB 2015e). It is during a fixation that information is taken in by the brain. Fixations are important because a long fixation can indicate that a feature is difficult to comprehend, pleasant to look at, or interesting to the user. Saccades are the movements of the eye from one point of interest to another. They are short in duration, about 20 to 40ms (Tobii Technology AB 2015e) and generally speaking, little to no information is absorbed by the brain during saccade eye movements. The final measurement of eye movements that was used is the scanpath, the sequence in which the eyes move while looking at a given stimulus over a given time, made up of fixations and saccades (Tobii Technology AB 2015e; Poole & Ball 2006).

Fixations, saccades and scanpaths can be used to assess how an individual reads the map. For example, the scanpath can be used to determine the sequence in which the individual looked at different features on the map, and fixation duration can be used to determine if an individual found something on the map difficult to interpret. Eye movements can also provide evidence about whether a specific map feature was viewed at all. This information can inform how the design of map elements needs to change to make them more effective.

In the early days of eye-tracking research, the equipment could only be used when the map user was stationary. Nowadays, mobile eye-tracking technologies that allow for research to be undertaken within almost any use context are available. Current mobile eye-tracking technologies see what the user is seeing and identify what the user is focusing on. Built-in microphones (if fitted) can be used to record the user’s voice. Such technology allows the user to move freely and almost as naturally as they would in everyday activities. It allows data to be collected in situations close to real life. While the test is being conducted, the researcher can monitor what the user is looking at by watching a direct video feed of eye movements and the scene video on a tablet computer.
Fixed Eye Tracking

To collect eye-tracking and verbal data during the route-planning activity, the Tobii X60 fixed eye-tracking system (Figure 4-9) was used.

Figure 4-9 Tobii X60 Fixed Eye-Tracker (Tobii Technology AB 2011)

This eye-tracking system was attached to the desktop computer in a usability lab, as demonstrated in Figure 4-10. Attached to this system were a table microphone to record the participants thinking aloud, a small video camera that recorded participants' facial expressions, and a keyboard and mouse. The keyboard strokes and mouse clicks were recorded, but this data was not relevant to the study.
Figure 4-10 Tobii X60 Eye-Tracker Setup (Tobii Technology AB 2010)

Table 4-5 provides the technical specifications of the Tobii X60 device, including the eye-tracking technique used, the sampling rate, calibration procedure, accuracy and precision of the eye tracker, and the range in which the head of the participant can move without loss of their gaze.

Table 4-5 Tobii X60 Fixed Eye-Tracker Specifications (Tobii Technology AB 2010)

<table>
<thead>
<tr>
<th>Eye-tracking technique</th>
<th>Binocular, automatic tracking optimization (optimal selection of dark and bright pupil tracking)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling rate</td>
<td>60Hz</td>
</tr>
<tr>
<td>Calibration procedure</td>
<td>Multi-point</td>
</tr>
<tr>
<td>Accuracy</td>
<td>0.4°</td>
</tr>
<tr>
<td>Precision</td>
<td>0.34°</td>
</tr>
<tr>
<td>Freedom of head movement</td>
<td>Width x height: 50 x 36 cm at 70 cm, operating distance: 40–90 cm</td>
</tr>
</tbody>
</table>

The fixed eye-tracking system uses both dark and bright pupil tracking depending on the participant (Figure 4-8). It automatically determines which eye-tracking technique is the most suitable (Tobii Technology AB 2015a).
Mobile Eye Tracking

The Tobii Pro Glasses 2 (Figure 4-11) were used to collect mobile eye-tracking and think-aloud data during the wayfinding exercise.

![Tobii Pro Glasses 2](image)

Figure 4-11 Tobii Pro Glasses 2 (Tobii Technology AB 2016b)

This equipment and the associated technologies, available at the UT laboratory, were current and state of the art when I performed my research (May – June 2016). Table 4-6 provides the technical specifications of the Tobii Pro Glasses 2, including the type of eye-tracking technique used, the sampling rate, calibration procedure, the field of view of the scene camera and resolution of the scene camera.

<table>
<thead>
<tr>
<th>Eye-tracking technique</th>
<th>Corneal reflection, dark pupil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye-tracking</td>
<td>Binocular</td>
</tr>
<tr>
<td>Sampling rate</td>
<td>50Hz or 100Hz</td>
</tr>
<tr>
<td>Calibration procedure</td>
<td>1 point</td>
</tr>
<tr>
<td>Parallax compensation tool</td>
<td>Automatic</td>
</tr>
<tr>
<td>Scene camera, video resolution</td>
<td>1920 x 1080 at 25 fps</td>
</tr>
<tr>
<td>Scene camera, field of view</td>
<td>90°, 16:9 format</td>
</tr>
<tr>
<td>Scene camera horizontal and vertical FOV</td>
<td>82° horizontal / 52° vertical</td>
</tr>
<tr>
<td>Visual field of view (frame obstruction)</td>
<td>More than 160° horizontally / 70° vertically</td>
</tr>
<tr>
<td>Number of eye-tracking sensors</td>
<td>4 sensors</td>
</tr>
<tr>
<td>Fixed geometry</td>
<td>Yes</td>
</tr>
<tr>
<td>Sensors</td>
<td>Gyroscope and accelerometer</td>
</tr>
</tbody>
</table>
The Tobii Pro Glasses 2 provide a 160° field of view (FOV) of what the user sees. This product allows researchers to see exactly what the user sees in real time through a live video feed, while allowing the user to move freely around the environment (Tobii Technology AB 2016b). These glasses do not use the traditional pupil centre corneal reflection (PCCR) technique; instead, “near-infrared illumination is used to create reflection patterns on the cornea and pupil of the eye of the subject and image sensors are used to capture images of the eyes and reflection patterns” (Tobii Technology AB 2015b, para. 3). Using image-processing algorithms and a 3D physiological model of the eye, the position of the eye and gaze length can then be calculated (Tobii Technology AB 2015g).

To visualise the eye-tracking data, the raw points were processed using Tobii Studio for the fixed eye-tracking data and Tobii Pro Lab software for the mobile eye-tracking data. Using this software, the points were processed into eye movements including “fixations, and overlaid on the stimuli used in the test” (Tobii Technology AB 2015e, para. 2). This technology allows researchers to monitor what the map-user looks at on the map and within the real-world environment. Subsequently, relationships between the information obtained during the map-reading process and the connection of this information to the outside world can be established. This approach allows for much insight to be gained from analysing unconscious human behaviour during route-planning and wayfinding activities.

4.5.3 Collecting Verbal Data

Since it can be unclear why people look at particular features when completing a task, participants were instructed to speak their thoughts aloud while completing the route-planning and wayfinding activities. This verbal data was recorded by the fixed and mobile eye-tracking systems.

4.5.4 Computer

The desktop computer used in the route-planning exercise was a Dell Windows 10 workstation, with standard mouse and keyboard, running Tobii Studio software. The monitor was a 24-inch LCD flat panel display with 1680x1050 screen resolution.
4.5.5 Smartphone

The smartphone used for testing in the wayfinding exercise was a Sony Xperia M4 Aqua with Android operating system. This model was selected because it was adequate for displaying the Maps.Me app and was similar to many other types of commercially available smartphones, therefore being representative of the type of equipment that the general population was accustomed to using at the time of the experiment.

4.5.6 Data Analysis Strategy

The large quantity of data collected required development of a strategy for analysing the data in order to maximise its quality. Part of developing this strategy involved identifying the various actions the participants would perform while undertaking the experiments. These actions can be split into two groups: map-use activities and map-use tasks (Delikostidis 2011). Map-use activities describe the interactions between the map user and the map, and map-use tasks refer to the actions resulting from cognitive processing. Table 4-7 list the actions that participants were expected to perform.

<table>
<thead>
<tr>
<th>Map-Use Activities</th>
<th>Map-Use Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pan</td>
<td>Identify</td>
</tr>
<tr>
<td>Zoom in</td>
<td>Recognise</td>
</tr>
<tr>
<td>Zoom out</td>
<td>Locate</td>
</tr>
<tr>
<td>Change map orientation</td>
<td>Define distance</td>
</tr>
<tr>
<td>Look at map image</td>
<td>Define travel time</td>
</tr>
</tbody>
</table>

Building from Table 4-7, more specific behaviour models relating to the route-planning (Figure 4-12) and wayfinding (Figure 4-13) processes were developed.
Figure 4-12 provides a behaviour model for the route-planning process. This figure shows what behaviours were expected from the participants, and what kind of processes they were expected to use whilst planning their routes. Deviations from this process may indicate difficulties or simply a different method of route planning; either way, it provided a framework within which participant behaviour could be analysed and compared. By identifying the behaviours the participants were expected to exhibit, it is easier to produce protocols for coding. It was important to identify such behaviours so that deviations from those expected were easily identifiable and analysed. With a standard behaviour model, anomalies could be identified quickly and therefore explored during the post-test interview.
Figure 4-13 is a behaviour model that illustrates the behaviours expected to be exhibited in the wayfinding exercise. Unlike the route-planning behaviour model (Figure 4-12), which is a straightforward process, some iterative behaviours were expected in the wayfinding process. For example, when travelling along a route, it is necessary for a map user to frequently update their location on the map, so they may ensure they are still following the correct route. Therefore, three behaviours or actions were expected to be performed several times: checking for surrounding landmarks, updating position on map and confirming self-location along the correct route. Again, the importance and function of such a model is that any unusual behaviour exhibited by a participant is obvious immediately and can be explored in post-test interviews.

Table 4-8 displays the actions which were expected to be performed by the participants, and their corresponding codes. The actions referred to in this table are split into three groups: verbal, map interaction and environmental interaction. When analysing the data, any time a participant performs one of these actions, the corresponding code was assigned. Coding the data in this way reduced and simplified it into meaningful and interpretable...
forms. Commonalities between methods of route-planning and wayfinding could be identified, as well as instances of participants experiencing confusion or difficulties.

Table 4-8 Actions for analysis with corresponding codes. The codes were used to analyse the test participants’ actions, using the Tobii Pro Lab software.

<table>
<thead>
<tr>
<th>Participant Actions</th>
<th>Verbal</th>
<th>Code</th>
<th>Map Interaction</th>
<th>Code</th>
<th>Environmental Interaction</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive comment</td>
<td>P</td>
<td>Looks at map</td>
<td>M</td>
<td>Looks for landmark</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Negative comment</td>
<td>N</td>
<td>Pans map</td>
<td>H</td>
<td>Confirms landmark</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Confusion</td>
<td>C</td>
<td>Zooms in/out</td>
<td>Z</td>
<td>Stops walking</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Street Name</td>
<td>A</td>
<td>Reorients map</td>
<td>O</td>
<td>Deviates from route</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>Landmark</td>
<td>K</td>
<td>Returns to correct route</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardinal direction</td>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

These actions were also expected to provide insight into how easy or difficult it was for the participant to complete the experiment tasks. For example, actions could be analysed quantitatively, which could identify the participant stopping more times than necessary or expressing feelings of confusion on a frequent basis. Alternatively, they may provide a large quantity of positive comments and minimal stop times, indicating an easy and effective wayfinding process.

4.6 Pilot Testing

Pilot testing was necessary to identify problems with the case study exercise’s procedures and mitigate or rectify them before participant engagement and data collection took place. Furthermore, pilot testing allowed me to understand the duration of the exercise so that they could be organised effectively, and participants could be told how long they would be required to spend undertaking the exercises.

The first pilot test was conducted on 18th April 2016, and only involved the wayfinding component of the exercise. During this test, a pilot participant undertook the exercise just
as the true participants would. Any difficulties encountered by the pilot participant, whether with the instructions, the exercise, or the equipment, were identified and addressed. During this pilot test, it was noted that the participants would be required to hold the smartphone at a minimum specific height to ensure the scene camera on the eye-tracking glasses could capture it in the video feed. I realised that without full view of the smartphone, it would be difficult to identify the features of the mapping app at which the participant was looking. The solution in this situation was to demonstrate to future participants how to hold the smartphone correctly.

Another problem identified was long, loose hair on a test candidate. The first pilot participant had long hair that, if blown in the wind, obstructed the view of the scene camera on the eye-tracking glasses. The solution to this, should a participant have long hair, was to ensure that it was tied back so it would not interfere with the video feed.

The final issue identified during the first pilot test related to brightness level and glare on the screen of the smartphone. The brightness level was increased to maximum so that it could be viewed more easily in the video. Despite increasing the brightness, glare still caused problems. Glare meant that the screen of the smartphone was reflecting sunlight into the scene camera of the glasses, and therefore the mapping application on the screen of the smartphone could not be seen clearly in the video feed, which would result in further problems during the analysis process. To mitigate this issue, an anti-glare screen protector was applied to the screen of the smartphone.

During the return walk from Museum TwentseWelle to ITC, it was realised that the post-test interview could be conducted during this time. Conducting the interview on the return walk would save time for both the researcher and the participant. Also, since the exercise had just been completed, it would be clearer in the minds of the participants. To test if it was suitable for the interview to take place on the return walk, a trial was conducted in the second pilot test.
The structure of the questions was identified as an issue in the post-test interview. Initially, they were laid out in the following format:

1. How easy did you find the product to use?
   - Very easy
   - Somewhat easy
   - Neither easy nor difficult
   - Moderately Difficult
   - Very difficult

The pilot participant found answering these questions difficult, so layout of the question was therefore changed to a five-point Likert Scale:

1. On a scale of 1 to 5, with 1 being very easy and 5 being very difficult, how easy did you find the map product to use?

   1 2 3 4 5

This format proved much easier for the pilot participant to comprehend and therefore provide a response.

The second pilot test was conducted on 19th April 2016, with a second pilot participant. In this pilot test, the questionnaire was completed as well as the wayfinding exercise and post-test interview. During this second pilot test, some issues with the layout of the SBSODS section of the questionnaire were identified. Multiple choice had been selected as the answer format in Survey Monkey, and using this method, the spacing of the scale could not be altered. As a result, the numbers 1 to 5 were on one line and numbers 6 and 7 were on a separate line below. This made it difficult for the participant to read, increasing cognitive load. To solve this problem, the question layout was changed from multiple choice to a matrix/rating scale, enabling the answer options to be displayed on a single line.

The other issue with the questionnaire was the number of questions displayed. All questions were displayed on one page, and the pilot participant commented that it was overwhelming to have so many displayed at once. To solve this issue, the SBSODS scale was divided over five pages, resulting in only three questions being displayed at a time.
The wayfinding exercise also highlighted an important problem. At some stages along the route, the eye-tracking glasses could not detect the pilot participant’s eyes. It became apparent that the participant’s eyes could not be detected in direct and strong sunlight; cloud cover, or the shadows of buildings, posed no problem. At this stage, it was not certain that sunlight was the direct cause of the issue, so it was decided that I would perform further testing using the tinted lenses provided with the eye-tracking glasses, and the test candidate would be required to wear a hat (see below).

The issue of poor performance of the glasses in sunlight was tested the following day (20th April 2016). These tests were performed by myself with the help of a research assistant because an independent participant was not necessary. The tinted lenses proved to be more useful in conditions of strong sunlight, with the system detecting the eyes of the subject far more frequently. The exercise facilitators then tried a baseball cap (Figure 4-14) in addition to the tinted lenses, which proved even more effective. The eyes were always able to be detected when the subject used the tinted lenses and wore the hat. Hence, it was decided that the tinted lenses would always be used on the eye-tracking glasses, and particularly in sunny weather, the participants would be required to wear a hat during the wayfinding exercises.
Pilot testing was undertaken again on 2\textsuperscript{nd} May 2016 with a third pilot participant, this time to ensure the exercise facilitators were competent in carrying out the procedures. This pilot involved the route-planning exercise. The first issue identified was that there were too few landmarks displayed on the JPEG map in Microsoft Paint to influence participants to choose three different paths. To eliminate this problem, a tourism booklet for Roombeek (Figure 4-15) was used (Roombeek is a district of Enschede, north of the city centre – see Figure 4-1). This booklet contained detailed information about what could be found in the Roombeek area and included a map showing the locations of the attractions. It was also decided that participants could refer to the map in the booklet when creating and selecting their routes.
Another issue was that the JPEG map did not have sufficient salient features on it for participants to relate the two maps to one another. Therefore, textual information was included at two locations on the JPEG map: a shopping centre and the former location of a fireworks factory, which were identified by symbols on the booklet map. The inclusion of a paper map also provided the opportunity for the researchers to study the behaviour of participants when comparing two different maps of the same area.

The next part of the pilot test involved the wayfinding exercise. The glasses were calibrated beforehand in the laboratory, but after walking to the starting point of route, the glasses required re-calibrating. Unfortunately, despite several attempts, the glasses could not be calibrated. It is suspected that the sunlight was too intense and interfered with the glasses' infrared technology. The day’s testing was abandoned, and the researchers purchased a hat with a larger brim in the hope that it would protect the glasses from interfering sunlight. The following day (3rd May 2016) the wayfinding exercise was conducted again, only to find that the sunlight still affected the calibration of the glasses, despite using a hat with a larger
brim. The glasses were then tested on another person, and in this instance, the glasses were able to be calibrated. It is suspected that the previous participant’s contact lenses prevented the eyes being detected properly (rigorous testing of the effects of contact lenses on the eye-tracking glasses was beyond the scope of this research).

Several different interventions were trialled to reduce the effect of the sun on the eye-tracking glasses, including wearing a scarf around the face beneath the hat (Figure 4-16, right), and carrying an umbrella (Figure 4-16, left), but no single solution worked in all situations. It is also possible that the reflection of light from different ground surfaces had an effect, and if so, a hat or umbrella would obviously not prevent such interference. The decision was made that testing would only take place during overcast conditions to reduce the impact of sunlight on data collection.
Kiefer, Giannopoulos and Raubal (2014) reported similar challenges with sunlight when collecting eye-tracking data outdoors. Using a sombrero-style sun hat, they were able to "partially compensate" (p. 667) for the variations in the light conditions. However, the eye-tracking equipment used in their data collection differed from that used in my project. Therefore, it is possible that sunlight has different effects on different models of eye-tracking glasses, and also on effective mitigation strategies for excessive sunlight.

The *Tobii Pro Glasses 2* product description includes a statement about the use of the glasses in sunlight, as follows:

> We recommend that eye-tracking studies be performed in a controlled and well-lit environment. Sunlight should be avoided since it contains high levels of infrared light which will interfere with the eye tracker system. Sunlight affects eye-tracking performance severely and longer exposure can overheat the eye tracker. The eye tracker is not designed for exposure to (direct) sunlight. Eye-tracking generally does not work in strong direct sunlight. Shielding the eye tracker adequately from the sun may prevent sunlight from interfering with eye-tracking. For better performance, use the supplied tinted lenses if the product is used in an environment with strong sunlight. (2016c, p. 15).

Whilst being aware of this limitation prior to acquiring the glasses, they had been tested outdoors and in bright conditions in January 2016, and worked perfectly. Their perfect performance in January but poor performance in May was intriguing. It may have been because the initial testing occurred in January (winter in the northern hemisphere), but pilot testing occurred in May (spring), the maximum elevation of the sun (zenith angle) is much higher in May than in January. Figure 4-17 shows the zenith angle on the days of the solstices.
On 21 December 2015 (the winter solstice in the northern hemisphere), the sun reached a maximum elevation of approximately 15°, and on 21 June 2016 (summer solstice), the sun reached a maximum of approximately 62°. Using these values, and assuming solar elevation increases at a constant rate between the summer and winter solstices, January has an approximate mean elevation of 21.5° and May has an approximate mean elevation of 52.6°, a difference of 31.1°. Illumination intensity increases as a function of the increase in solar elevation. Likewise, illumination intensity decreases as the solar elevation decreases (Spitschan et al. 2016). Therefore, it is plausible that sun elevation could prevent the glasses working correctly. Further work is required to validate this theory, and if shown to be true the knowledge would be useful for planning future eye-tracking work, but this is beyond the scope of this research.

**4.7 Route-Planning on a Desktop Computer**

A JPEG image of the study area on the Maps.Me app was loaded into a Microsoft Paint file, allowing the participants to draw their three routes (Figure 4-18). Participants were
instructed as to whether they were a tourist who had plenty of time to make their way from G.J. van Heekpark to Museum TwentseWelle and that they may like to see some other points of interest along the way, or as a Job Applicant who needed to make their way as directly as possible to ensure they were on time for a job interview. As discussed in Section 4.6, a paper tourist map (Figure 4-15) was also provided to participants to assist them with choosing three different routes.

During the route-planning exercise, each participant identified three possible routes between G.J. van Heekpark and Museum TwentseWelle in the town of Enschede, the Netherlands (Figure 4-2). The routes were approximately 1.1 km in length. From these three routes, participants selected one, based solely on personal preference. This route would be the one they would travel in the wayfinding exercise.

Once the participants had selected their preferred route, the route-planning exercise was complete. The chosen route was then transferred to the smartphone and the participant was taken to the starting point of that route.
4.8 Wayfinding

In the wayfinding exercise, participants traversed their selected route using the Maps.Me smartphone app whilst wearing the Tobii Glasses Pro 2 and speaking their thoughts aloud. Participants were led to the starting point they had chosen in the route-planning activity. Their first task was to orient themselves, so they were facing the correct direction. Once participants were confident of their orientation they began walking their chosen route. Then, once the participants were confident they had arrived at their destination, they would notify the experiment facilitators and the field test was concluded. Participants’ routes were tracked using a separate smartphone and the Runkeeper app (https://runkeeper.com/) (Figure 4-19) which is a fitness tracking app that allows users to record their movements by capturing GNSS data, therefore it was used to collect GNSS points as the participant traversed their route.

**P15_Routes**

![Figure 4-19 Planned and Actual Route Traversed by Participant 15 (Job Applicant)](image)

Recording the actual route traversed by each participant made it easy to identify differences between the actual and planned routes and to see if any mistakes were made. In Figure 4-19, the blue line indicates the planned route, while the red line indicates the participant’s actual route. In the example shown, the participant made a mistake, turning right at...
Deurningerstraat, but realised the error and turned back. Had the actual route traversed not been recorded in this way, experiment facilitators would have had to remember where errors or changes to the route occurred, and no empirical evidence would exist.

4.9 Results and Discussion

4.9.1 Map Literacy

As discussed, participants were allocated randomly to either the Job Applicants or Tourists group. SBOSD scores for the two groups were examined to determine whether there were differences in environmental spatial ability between them. The Shapiro-Wilk test was first used to check for normality. The SBOSD scores of group Job Applicants ($D(7)= 0.92, p=0.45$) were normally distributed, as were the scores of group Tourists ($D(7)= 0.99, p=0.99$). After testing for normality, SBOSD scores of the two groups were analysed using an independent-samples t-test, which showed that there was no significant difference ($t=-0.60; p=0.36; df= 11.06; MD =-0.24; 95\%CI = -1.11 \text{ to } 0.63$) between the two groups. Box plots (Figure 4-20) show the distribution of SBOSD scores between the two groups. This result suggests that any differences in performance between the two groups are not due to differences in map literacy.
4.9.2 Route-Planning

Figure 4-21 shows the frequency of “events” derived from the verbal protocols (for samples of coded statements, see Table 4-9) of the participants for the two groups (Tourists and Job Applicants). The number of events are similar except for two types of events: Use of landmark and Use of street name. The Tourists group verbalised landmarks and street names twice as often on average as the Job Applicants group. A possible explanation is that members of the Tourists group were more inclined to plan longer routes (Tourist $\mu = 1.53$ km, Job Applicants $\mu = 1.06$ km) because they were not under the same time constraints as the Job Applicants group. Given the longer routes, the Tourists may be likely to make more turns, pass more landmarks and encounter more streets.
During the route-planning activity, participants estimated the distance of their preferred route. The Maps.Me map shown in Microsoft Paint (Figure 4-21) had a scale bar in the bottom right corner. This was the only method available for participants to determine the length of the route. Three participants (P9, P11 and P20) miscalculated the distance by a substantial amount, as can be seen in Table 4-10, highlighted in red.

Table 4-9 Sample verbal statements with corresponding codes

<table>
<thead>
<tr>
<th>Verbal Code</th>
<th>Sample of coded statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculation</td>
<td>“Say I walk five kilometres per hour ummm twenty minutes maybe no like half an hour”</td>
</tr>
<tr>
<td>Confusion</td>
<td>“where is it I don't see you I'm having a hard time finding it museum museum museum I see a street called Museumlaan would it be near this I cannot still find the museum where is it”</td>
</tr>
<tr>
<td>Making a correction</td>
<td>no I will go around the shopping centre</td>
</tr>
<tr>
<td>Cardinal direction</td>
<td>“south west of the museum so the museum should be in the north east yeah Lasonderbleek and south of Stroinksbleek it should be ummm this place”</td>
</tr>
<tr>
<td>Landmark</td>
<td>“At least I can try to find the the monument and it's in the Lasonderbleek the disaster monument”</td>
</tr>
<tr>
<td>Street Name</td>
<td>“So it's number 21 and it's between the Stroinksbleekweg and the Lonnekerspoorlaan”</td>
</tr>
</tbody>
</table>
The correlation between spatial abilities and accuracy of distance estimation was weak in these participants, despite all three reporting using maps at least once per month, meaning they were relatively frequent map users. However, they did specify that when preparing to travel to an unfamiliar location, they would use Google Maps. Google Maps has a function that calculates route distance; these participants may use this feature, and therefore may be unaccustomed to calculating route distances themselves.

Table 4-10 Participants’ estimates of their preferred route’s length versus its actual length.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Group 1 - Tourists</th>
<th>Group 2 – Job Applicants</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2</td>
<td>1</td>
<td>1.2</td>
</tr>
<tr>
<td>P7</td>
<td>1</td>
<td>1.45</td>
</tr>
<tr>
<td>P9</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>P11</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>P13</td>
<td>1.25</td>
<td>0.75</td>
</tr>
<tr>
<td>P14</td>
<td>1.5</td>
<td>1.35</td>
</tr>
<tr>
<td>P16</td>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td>P17</td>
<td>1.1</td>
<td>1.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Distance Estimate (km)</th>
<th>Actual Distance (km)</th>
<th>Discrepancy (km)</th>
<th>SBSODS Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>1</td>
<td>1.29</td>
<td>0.29</td>
</tr>
<tr>
<td>P7</td>
<td>1</td>
<td>1.36</td>
<td>0.36</td>
</tr>
<tr>
<td>P9</td>
<td>3</td>
<td>0.8</td>
<td>-2.20</td>
</tr>
<tr>
<td>P11</td>
<td>3</td>
<td>2.04</td>
<td>-0.96</td>
</tr>
<tr>
<td>P13</td>
<td>1.25</td>
<td>1.1</td>
<td>-0.14</td>
</tr>
<tr>
<td>P14</td>
<td>1.5</td>
<td>2.2</td>
<td>0.7</td>
</tr>
<tr>
<td>P16</td>
<td>1</td>
<td>0.843</td>
<td>-0.157</td>
</tr>
<tr>
<td>P17</td>
<td>1.1</td>
<td>0.802</td>
<td>-0.298</td>
</tr>
</tbody>
</table>

To explain the discrepancies, I examined the verbal protocols and eye movement data of these participants (Figure 4-22). The transcripts showed that none of the three participants mentioned using the scale bar to calculate the length of their route, meaning their calculations could be unfounded and arbitrary. To investigate further, the gaze plots were analysed to see if they had looked at the scale bar on the map. The gaze plot (Figure 4-22, top) shows that P11 looks at a point near the scale bar but not actually at it. P9 did not look at points near the scale bar at all; P20 did look at a point close at the scale bar, but at an early stage in the route-planning exercise. Therefore, the scanpaths confirmed that none of these participants used the scale bar when calculating the lengths of their routes, so their...
calculations of distance must have had another basis, for example, perhaps a guess at the typical length of features (e.g., block length, building size, etc.) they could see in the map.

Figure 4-22 Gaze plot from the route-planning exercise (top). P15 heat map from route-planning activity (bottom)
Participant 15 had difficulty in matching the paper map to the map on the computer. This was evident because the participant looked quite a lot at an area where no route was drawn (Figure 4-22, bottom). From the verbal protocols, the following insights can be provided as to where the confusion arose:

... well I don't know if I am in the correct ... I think I am but ah yeah because there is no name of the street in this near the disaster monument and the maps show different words so but I think I am correct ok I did more or less the first route I thought it was there because of the shape this kind of triangle ah yeah I found here a kind of triangle and here yeah a triangle too so that's why. (P15)

The transcript above shows the participant was using the spatial layout to match between the paper map and the map on the screen, as opposed to landmarks or street names. This participant scored 3.9 on the SBSODS, indicating relatively poor spatial ability compared to the other participants, which could explain the difficulty experienced in matching the maps.

4.9.3 Wayfinding

To identify if map users experience challenges when using a map to find their way under time pressure (Job Applicants) or without time pressure (Tourists) the behaviours of the participants in each group were compared. These behaviours were:

(a) Number of times a landmark was confirmed;
(b) Number of times confusion was expressed;
(c) Number of times participants deviated from the planned route;
(d) Fixations to the map per minute;
(e) Number of times participants looked for a landmark;
(f) Number of times participants voluntarily stopped walking; and
(g) Number of times participants interacted with the map
(h) Number of times the map was rotated
(a) Number of times a landmark was confirmed

A Poisson regression was performed, which found the results to be overdispersed ($\phi = 2.07$). Therefore, a negative binomial regression was completed, which found the difference in number occasions a landmark was confirmed between the two groups was not statistically significant ($b = -0.03; SE = 0.57; 95\% CI = -1.14 to 1.08; p = 0.95$). Box plots (Figure 4-23) show the distribution of Confirm Landmark counts between the two groups.

![Box plots summarising the distribution of Confirms Landmark scores for N = 14 participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution.](image)

(b) Number of times confusion was expressed;

A Poisson regression was performed, which found the results to be overdispersed ($\phi = 2.38$). Therefore, a negative binomial regression was completed, which found the difference in number occasions participants expressed confusion between the two groups was not statistically significant ($b = 0.77; SE = 0.73; 95\% CI = -0.65 to 2.20; p = 0.29$). The box plots (Figure 4-24) show that P1 (Job Applicants) was an outlier, expressing confusion on eight occasions. After removing the outlier, a Poisson regression was repeated, again finding the results to be overdispersed ($\phi = 1.15$). A negative binomial regression was again completed,
which also showed no significant difference between the groups ($b = -0.03; SE = 0.82; 95\% CI = -1.64$ to $1.58; p = 0.97$).

![Box plots summarising the distribution of Confusion scores for N = 14 participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95\% confidence intervals of each distribution. P1 (Job Applicants) is an outlier.](image)

(c) Number of times participants deviated from the planned route;

A Poisson regression was performed, which found the results to be overdispersed ($\phi = 1.18$). Therefore, a negative binomial regression was completed, which found the difference in number occasions participants deviated from their planned route between the two groups was not statistically significant ($b = 1.61; SE = 1.22; 95\% CI = -0.78$ to $4.00; p = 0.19$). The box plots (Figure 4-25) show that P1 (Job Applicants) and P2 (Tourists) were outliers, deviating from their planned routes on three and one occasions, respectively. After removing the outliers, the Tourists group did not have any participants deviate from their route, and participants of the Job Applicant Group only deviated once. Therefore, no further analyses were completed.
(d) Fixations to the map per minute

Using data collected from the scene camera of the eye-tracking glasses, the fixation rate (number of fixations to the map per minute) was calculated. Fixation rate was used rather than the total number of fixations because walking speed differed between participants; therefore, those who spent more time walking the route had more time to look at the map. The differences between fixation rates of the two groups were analysed using an independent-samples t-test (Field 2018). There was no significant difference ($t=-0.95 \ p=0.37; \ df=9.27; \ MD=-0.93; \ 95\%CI=-3.13 \ to \ 1.27$) between the rates at which the groups referred to the map. Box plots (Figure 4-26) show the distribution of Confirm Landmark counts between the two groups.
Figure 4-26 Box plots summarising the distribution of Looks at Map scores for N = 14 participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution.

(e) Number of times participants looked for a landmark

A Poisson regression was performed, which found the results to be overdispersed ($\phi = 3.54$). Therefore, a negative binomial regression was completed, which found the difference in number occasions participants looked for a landmark between the two groups was not statistically significant ($b = -0.14; SE = 0.56; 95\% CI = -1.23 \text{ to } 0.96; p = 0.81$). The box plots (Figure 4-27) show that P2 (Tourists) was an outlier, looking for landmarks on 19 occasions. After removing the outlier, the results were still overdispersed ($\phi = 3.48$). A negative binomial regression was again completed, which also showed no significant difference between the groups ($b = -0.01; SE = 0.58; 95\% CI = -1.16 \text{ to } 1.13; p = 0.98$).
Figure 4-27 Box plots summarising the distribution of Looks for Landmark scores for N = 14 participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution; P2 (Tourists) is an outlier.

(f) Number of times participants voluntarily stopped walking

A Poisson regression was performed, which found the results to be overdispersed ($\phi = 2.05$). Therefore, a negative binomial regression was completed, which found the difference in number occasions participants voluntarily stopped between the two groups was not statistically significant ($b = -0.00; SE = 0.98; 95\% CI = -1.91$ to $1.91; p = 1.00$). The box plots (Figure 4-28) show that P15 (Job Applicants) and P2 (Tourists) were outliers, stopping on two and three occasions, respectively. After removing the outliers, no participants in the Tourists group stopped walking, while only one participant (P1) in the Job Applicants group stopped walking on one occasion.
(g) Number of times participants interacted with the map

When users are required to complete several actions (clicking, panning, zooming) before obtaining the information they seek, the system is said to have a “high interaction cost” (Nielsen & Budiu 2013, p. 80). A high interaction cost can lead to user dissatisfaction.

Interactions with the map application (zoom, pan, rotate) were coded from the scene video captured by the eye-tracking glasses. A Poisson regression (Field 2018) was first run which found the results to be overdispersed ($\phi = 35.34$). Therefore, a negative binomial regression was completed, which found the difference in map-use interactions between the two groups was not statistically significant ($b = 0.03; SE = 0.54; 95\% CI = -1.04\text{ to } 1.09; p = 0.96$).

The box plots (Figure 4-29) show that P1 (Job Applicants) was an outlier, interactive with the map on 128 occasions. After removing the outlier, a Poisson regression was performed, finding the results to still be overdispersed ($\phi = 9.24$). A negative binomial regression was completed, which found the difference in map-use interactions between the two groups was not statistically significant ($b = -0.77; SE = 0.57; 95\% CI = -1.89\text{ to } 0.36; p = 0.18$).
Figure 4-29 Box plots summarising the number of times participants interacted with the map for N = 14 participants, equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution. P1 (Job Applicants) is an outlier.

To determine if any particular map interactions (Table 4-6) were performed significantly more or less between the two groups, the number of times participants interacted with the map were compared according to panning, zooming and rotating. One map interaction was found to differ significantly in frequency between the two groups: rotating the map. A Poisson regression (Field 2018) was performed, finding the counts of rotating the map to be overdispersed ($\phi = 7.48$). Therefore, a negative binomial regression was completed which did not find a significant difference between the two groups ($b = -0.75; SE = 0.61; 95\% CI = -1.94 to 0.44; p = 0.22$). Box plots (Figure 4-30) show that P1 (Job Applicants) was an outlier, rotating the map 15 times. After removing this outlier, a Poisson regression was run, finding the counts were still overdispersed ($\phi = 3.33$). Again, a negative binomial regression was completed, finding a significant difference between the two groups ($b = -2.39; SE = 0.82; 95\% CI = -4.00 to -0.78; p = 0.00$), with the Tourists group rotating the map on more occasions than the Job Applicants group. This could be explained due to the fact that participants in the Tourists group tended to take longer, and less direct routes between the G.J van Heekpark and Museum TwentseWelle.
Chapter 4 – Identifying Challenges Map Illiterate Users Experience When Wayfinding in a Small City with an Irregular Road Network

Figure 4-30 Box plots summarising the number of times participants rotated the map for N = 14 participants, equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution. P1 (Job Applicants) is an outlier.

Table 4-11 shows a summary of the outliers. P1 (Job Applicants) was an outlier for six actions (confusion, deviate from route, map interaction, pan map, zoom map, rotate map). P2 (Tourists) was an outlier for three actions (deviate from route, look for landmark, stopped walking), and P15 (Job Applicants) for one action, stopped walking. P1, P2 and P15 scored 3.4, 4.9 and 3.9 on the SBSODS, respectively. Given the relatively low SBSODS score of P1, it is reasonable for them to be an outlier on six occasions.

Table 4-11 Summary of Outliers

<table>
<thead>
<tr>
<th>Action</th>
<th>Participant Number</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confusion</td>
<td>1</td>
<td>Job Applicants</td>
</tr>
<tr>
<td>Map Interaction</td>
<td>1</td>
<td>Job Applicants</td>
</tr>
<tr>
<td>Pan Map</td>
<td>1</td>
<td>Job Applicants</td>
</tr>
<tr>
<td>Zoom map</td>
<td>1</td>
<td>Job Applicants</td>
</tr>
<tr>
<td>Rotate map</td>
<td>1</td>
<td>Job Applicants</td>
</tr>
<tr>
<td>Deviate from Route</td>
<td>1</td>
<td>Job Applicants</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Tourists</td>
</tr>
<tr>
<td>Look for landmark</td>
<td>2</td>
<td>Tourists</td>
</tr>
<tr>
<td>Stopped Walking</td>
<td>2</td>
<td>Tourists</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Job Applicants</td>
</tr>
</tbody>
</table>
Verbal code frequencies (Figure 4-31) for the groups were similar. The largest difference between groups was with respect to use of landmarks; the Tourist group verbalised landmarks more than the Job Applicant group. This was expected, however, because the average distance walked by Tourist group participants was larger than that of Job Applicant group participants (Table 4-10). Table 4-12 provides samples of coded verbal statements.

Figure 4-31 Verbal Code frequency during wayfinding activity
Table 4-12 Sample of verbal statements with corresponding codes

<table>
<thead>
<tr>
<th>Verbal Code</th>
<th>Sample of coded statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculation</td>
<td>“the destination is sort of yeah two or three minutes away on the right hand side”</td>
</tr>
<tr>
<td>Confusion</td>
<td>“so I wonder is this the green spot that I go to the right directly or where's the next street so it's a bit unclear but I think I'll take this one to the right oh no this is one earlier”</td>
</tr>
<tr>
<td>Making a correction</td>
<td>“I think I have to turn what can I pass here I can't go ok so the map is not hmmm made a mistake I have to turn ok actually have to go right here so that's the one yeah ok”</td>
</tr>
<tr>
<td>Cardinal direction</td>
<td>“Now I’m facing north here so first I will walk through the oval”</td>
</tr>
<tr>
<td>Landmark</td>
<td>“The tennisvereniging is over there so I am I need to go that way”</td>
</tr>
<tr>
<td>Street Name</td>
<td>“ok it says Troelstrastraat on that sign and it corresponds ah with the street name on the map so I'm doing something right”</td>
</tr>
<tr>
<td>Negative comment</td>
<td>“the map has signs of the Roombeek which is the water which I oh here I see the Roombeek the water’s actually quite subtle cos I expected really like a river or something”</td>
</tr>
<tr>
<td>Positive comment</td>
<td>“it’s an easy route so I see the Jumbo on the map and I see it now also in real life which means I'm heading the right direction”</td>
</tr>
</tbody>
</table>

Only one participant (P1) failed to reach the destination. This participant walked past the entrance of the destination and proceeded to a different location several metres further along (Figure 4-32).
The transcript and video data provided additional clues about how P1 navigated. The participant initially saw Museum TwentseWelle from quite a distance away, but instead of using it as a guide, continued to use the map and the route they had originally planned. Whilst nearing the museum, the participant saw a sign with the words “TwentseWelle” written on it, but their attention was focused on the other name on the sign, which belonged to the building opposite (21 Rozendaal). The participant took a path between the two buildings, and upon approaching the museum, missed the entrance. Figure 4-33 shows the participant looking towards the entrance of the museum but not actually seeing the entrance. The participant also zoomed in to the maximum scale on the app and therefore could see little surrounding information on the screen, only partial building shapes and building numbers. This participant also attempted to zoom in further several times. By using the map at such a large scale, the participant missed out on other information that it could have provided, such as labels, other nearby landmarks, and pathways.

4.9.4 Post-Test Interviews

The post-test interview consisted of four open-ended questions:

1. What were the best aspects of the map product?
2. What were the worst aspects of the map product?
3. What did you find confusing about the map product?
4. How could the map product be made easier to use?

From this interview, it was apparent that three participants were not satisfied with the label placement of the street names:

- Name of road only visible when zoomed in closely and in centre of road. (P7)
- No street names or path names. (P17)
- Some of the street names do not appear on the map when zooming in. (P16)

Another common complaint was that there was no indication of the participant’s location and orientation. This was due to the location services being switched off on the smartphone prior to beginning the exercise, to ensure map-reading occurred when the participants had updated their locations.

4.10 Findings

This study confirms that some people still struggle with reading maps for the purpose of wayfinding. Given the small number of participants and their similar academic backgrounds, I could not obtain a great deal of valid information about what the greater population may find challenging when engaging in route-planning and wayfinding activities. However, the results from this experiment do contribute to knowledge about how individuals travel through their environment and the landmarks and map information that are used.

From the data collected, three key findings can be identified:

**Finding 1: Looking at the map frequently caused participants to miss important environmental features that would assist with wayfinding and spatial knowledge acquisition.**

During the field study, it was evident that some people spent considerable time looking at the smartphone map and not using the visual cues around them.
Finding 2: Street names were not located in convenient locations on the map, for example at key decision-making locations.

Streets and roads were only labelled once on long stretches on the smartphone map. As a result, participants had to pan the map to find the street name and then pan back to find their location. This creates room for error, because not only does the map user lose their place on the map, they are required to follow an unnamed section of road for quite a distance before finding the necessary information.

Finding 3: Using house numbers as opposed to larger scale features such as streets and landmarks was a common method used for self-localisation for those having lower spatial abilities.

Two participants (P2 and P13), who scored quite low on the SBSODS (3.0 and 2.6, respectively) in comparison to the other participants, relied rather heavily on the use of building numbers to identify and update their location on the map. It was intriguing that they used such small-scale features to identify their location, and at such a frequent rate.

4.11 Limitations

This research was exploratory in nature, rather than seeking to test hypotheses, so I adopted a usability testing approach. The study group of 14 was deemed acceptable following the recommendation from Nielsen (2012) that five test users is a sufficient number to be able to identify most usability problems, and is also in line with similar studies (Andersen et al. 2012; Kiefer, Straub & Raubal 2012).

From the analysis of the data, it was evident that the study population were too heavily influenced by those who had significant map-reading experience. Also, strong sunlight was difficult to manage initially, but new management strategies were devised to overcome this problem; other researchers who seek to collect similar data with similar equipment should employ those strategies. Finally, the area in which the study was conducted had quite a complex road network; therefore, different findings might be achieved if conducted in a less complex geography. Whilst this is not a limitation, it does provide another reason for more
empirical data to be collected. These limitations were addressed in the second case study – performed in Melbourne, covered in Chapter 5.

Summary

This chapter described the data collection process for each of the three stages: background information and spatial abilities, route planning, and wayfinding. The pilot testing process was also discussed, along with the difficulties encountered and the strategies used to mitigate them. From the pilot study, it was clear that further research into using mobile eye-tracking glasses outdoors needs to be conducted by eye-tracking equipment manufacturers due to interference from sunlight. The results of the exercises were also provided, along with a discussion of the data collected in the route-planning, wayfinding and navigation activities conducted in Enschede, The Netherlands. From the testing, three key findings were identified: (1) among those with lower spatial ability scores, frequency of looking at the map was quite high; (2) street names were not located in convenient locations on the map, for example, at key decision-making locations; and (3) using house numbers as opposed to larger-scale features such as streets and landmarks was a common method of self-location among those with lower spatial abilities. Finally, the limitations of the research were outlined, as was the decision to undertake further empirical testing.

Chapter 5 details the methodological approach and results of the second case study, conducted in Melbourne, Australia in 2017–18 using a paper map.
Chapter 5 - Identifying Challenges Map-Illiterate Users Experience When Wayfinding in a Medium City with a Grid-Style Road Network

In Chapter 4 I discussed my first case study, in which I investigated the challenges experienced by map users when wayfinding in a small city with an irregular road network by asking 14 participants to use a map application on a smartphone to find their way between a park and a museum.

This chapter details my second case study, in which 10 participants were recruited to complete a wayfinding activity using an official tourist paper map of Melbourne, Australia. Information relating to the selection of participants, and the methods used to collect information on how participants planned and executed routes for wayfinding, are provided. The analysis process and results for this case study are also explained in this chapter. A complete record of results is outlined, followed by an examination of the results and what they mean for this research.

5.1 Study Outline

As in the approach I used to develop the route-planning and wayfinding exercise using a digital map application (Chapter 4), the aim here was to develop a scenario that would reflect the behaviours that map users exhibit in the real world when trying to plan and find their way, this time using a paper map. Since digital maps have only been in common use for the last decade or so (Laurence 2020), it was of interest to determine if map-(il)literate users experienced similar difficulties when using a paper map. Again, to see if time pressure affected map-(il)literate users’ abilities to find their way, participants were divided into two groups: Job Applicants (Appendix M) and Tourists (Appendix N).
5.1.1 Route Planning

The route-planning exercise followed the same procedure as that outlined in Section 4.1.1. The only differences were the map used (a paper map of Melbourne instead of a smartphone map of Enschede) and participants wore Tobii Pro Glasses 2 while completing the route-planning activity.

Once participants had drawn their three routes (Figure 5-7), they chose the one they preferred, and drew that on a new copy of the map. The map was then attached to a piece of cardboard to ensure that viewing it through the scene camera of the Tobii Pro Glasses 2 could be optimised which would allow for data to be coded more accurately. Before leaving the eye-tracking laboratory at RMIT, the lenses of the eye-tracking glasses were changed to tinted lenses to limit the effects of sunlight on pupil detection during the wayfinding segment of the experiment (section 4.6).

5.1.2 Wayfinding

Participants were taken to the route origin (intersection of Little Bourke Street and Tattersalls Lane), where the eye-tracking glasses were recalibrated. The researchers began recording with the eye-tracking glasses, and enabled GNSS tracking of the route using the Runkeeper app on a smartphone. The route participants took was recorded to provide an
independent record, and to allow visualisation of any differences between the planned routes and the routes the participants walked (Figure 5-9). This would help to demonstrate if participants lost their way, such as P10 (Figure 5-41) or decided on a new route whilst making their way between the two locations (as P5, P8 and P9 did).

During the wayfinding activity, participants used the paper map with their chosen route to walk and find their way between the intersection of Little Bourke Street and Tattersalls Lane, Melbourne and the Royal Exhibition Building, Carlton (an adjoining suburb). As in the Enschede experiment (Chapter 4), they did this whilst wearing the Tobii Pro Glasses 2 and speaking their thoughts aloud.

5.1.3 Post-Test Interview

As per the procedure in the data collection process in Enschede (section 4.9.3), participants were engaged in a post-test interview upon the completion of the exercise. A similar document was used for the post-test interview as was used in Enschede (Appendix O).

5.2 Study Location – Melbourne

The geographic properties of Melbourne (grid-like road network, medium-sized city) make it an appropriate companion to Enschede (irregular road network, small-sized city) for testing, and the study site conforms to the desired characteristics outlined in section 3.4, where it was established that it would be useful to undertake two case studies, where the locations differ in geographic size and layout of road network.
Melbourne is located in the south-east of Australia (Figure 5-2). Within the overall area (450 km²) depicted in Figure 5-3, there are approximately 1,040,000 residents (Australian Bureau of 2016a).
An Alternative Wayfinding Map Design for Map Illiterate Users

Geographic Layout of Melbourne, Australia

Figure 5-3 Map of Inner Melbourne
Melbourne’s central business district (CBD) has a grid-style road network (Figure 5-3 inset). Looking at Figure 5-3, it is evident that the roads east of the CBD are also arranged in a grid, whereas the roads to the north-west of the CBD are more irregular. Hence, the Melbourne CBD fulfills the second criterion (Enschede fulfilled the first criterion) of a test location, as discussed in section 3.4.

5.3 Selecting a Map for Testing

In the Melbourne case study, a paper map was selected (Figure 5-4) to ascertain whether different challenges were experienced when using a paper map as opposed to a digital map on a smartphone (section 3.6). This map was obtained from an official tourist information kiosk in the Melbourne CBD; it is the official tourist map of Melbourne, produced for the Melbourne City Council. It is acknowledged that introducing a different map design results in less experimental control between the Enschede and Melbourne case studies. However, since this map is the map provided to tourists in the real world, it can lead to a greater understanding of real-world map reading behaviours. Because the paper map provides all information at a single scale, the user does not need to zoom and pan the map to view relevant information. This may lead to a difference in the amount of time the user spends looking at, and interacting with the map, thereby influencing perception of environmental cues.
To improve the ability to resolve what map features were being fixated on by the participant, a subsection of the map that encompassed the study area was extracted for use in the study. The north arrow, scale bar and legend of the map were also transferred across to the enlarged map (A3 size) and scaled accordingly. Figure 5-5 shows the entire map, with a red rectangle depicting the study area of the map, and the extent to which it was cropped.

The last amendment made to the map was the addition of the walking paths through the Carlton Gardens (Figure 5-5). I did this because many people use the paths through the Carlton Gardens to reach the Royal Exhibition Building, the destination for the wayfinding participants. The addition of the walking paths also provided more options for participants when planning their routes.
5.4 Selecting a Study Area

The study area was selected by first choosing a route origin and destination. Finding an unfamiliar location with a grid-like layout or finding participants unfamiliar with the Melbourne CBD was challenging. Therefore, it was decided that the origin of the route should be a location with which participants would be unlikely to have previous experience and which would be difficult to find on the map.

In the Melbourne’s CBD, main streets run parallel to one another in a roughly north–south direction and intersect with another set of parallel streets which run roughly east–west. In between the main streets are smaller parallel streets, and narrow laneways are located irregularly throughout. Little Bourke Street is a street in between two larger streets – Bourke Street and Lonsdale Street – and, as its name implies, Tattersalls Lane is a small laneway. Laneways in Melbourne often look like one another and from personal experience,
it is common for people to be unable to find a shop or restaurant that they had visited previously down one of the many laneways. Selecting Little Bourke Street and Tattersalls Lane meant that there was a high chance that participants would not know exactly where the intersection was prior to planning their route, and therefore they would have to find it on the map.

Selecting the destination was a challenge for similar reasons. Given the grid-like layout of Melbourne, it was decided that the destination should be outside the CBD to combine the different road layouts. The site selected was the Royal Exhibition Building, which is located within Carlton Gardens, opposite the Melbourne Museum (Figure 5-5). This location is a popular place for tourists to visit, and therefore the routes the participants would choose were likely to be representative of routes tourists take.

5.5 Identifying Participants

Recruitment of participants involved potential participants completing a questionnaire designed in accordance with RMIT’s human ethics research policy (Approval # SEHAPP 07-17, approved 09/03/2016, Appendix P).

5.5.1 Map Literacy Assessment

The map literacy assessment used for participant eligibility was the same as that used in the study conducted in Enschede (section 4.4.1).

5.5.2 Recruitment Processes

Participants were recruited using a Recruitment Poster (Appendix Q) which was placed around the RMIT City Campus, as well as from personal and professional networks.

5.5.3 Participant Selection

Participants were selected based on their responses to the Recruitment Survey (Appendix R) which was administered using Qualtrics survey software (Qualtrics 2021).
5.5.4 Participant Demographics

The data was collected over seven months (November 2017 to May 2018). As was the case in Enschede, participants were assigned to one of two study groups: Job Applicants and Tourists. Due to the difficulty in finding potential participants and therefore being able to select from a diverse pool of participants, a convenience sampling methodology was adopted, and experiments were completed one participant at a time as they were recruited. Table 5-1 shows a reorderable matrix (Mengistu 2015), which enables distribution based on the characteristics of each of the participants. A sample of 10 participants could be considered small but is consistent with those used in similar studies (4.11).

5.5.5 Equipment

Mobile Eye Tracking

Because the routes were planned on a paper map, rather than a map on a screen (as was the case in Enschede), the Tobii Pro Glasses 2 (Figure 4-11) were used during the route-planning and wayfinding activities (section 5.1).

Smartphone

A Samsung Galaxy S7 smartphone was used to run the Runkeeper app; it used GNSS tracking to record the participant’s route.
Table 5-1 Participant demographics shown in reorderable matrix. By compiling the demographics of each participant, it is possible to ‘reorder’ them into groups for the experiment exercises. Note, NULL values have been included where participants did not complete a questionnaire question.

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Age Bracket</th>
<th>Gender</th>
<th>Country of Origin</th>
<th>Occupation</th>
<th>Highest Completed Education Level</th>
<th>Field of Study</th>
<th>Experience in Study Area</th>
<th>SBSOD Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18-25</td>
<td>M</td>
<td>Australia</td>
<td>Academia</td>
<td>High School Certificate II</td>
<td>Geo-related</td>
<td>Daily</td>
<td>4.40</td>
</tr>
<tr>
<td>2</td>
<td>25-34</td>
<td>F</td>
<td>Outside of Australia</td>
<td>Non-Academia</td>
<td>Certificate III</td>
<td>Non-Geo-related</td>
<td>2-4 times per week</td>
<td>4.80</td>
</tr>
<tr>
<td>3</td>
<td>35-44</td>
<td>M</td>
<td>Australia</td>
<td>Academia</td>
<td>Bachelor</td>
<td>Geo-related</td>
<td>Once per month</td>
<td>3.67</td>
</tr>
<tr>
<td>4</td>
<td>55-64</td>
<td>F</td>
<td>Outside of Australia</td>
<td>Non-Academia</td>
<td>Masters</td>
<td>Non-Geo-related</td>
<td>2-4 times per month</td>
<td>NULL</td>
</tr>
<tr>
<td>P1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5-10 times per year</td>
<td>2.53</td>
</tr>
<tr>
<td>P2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.40</td>
</tr>
<tr>
<td>P3</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>1.27</td>
</tr>
<tr>
<td>P4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.53</td>
</tr>
<tr>
<td>P5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.80</td>
</tr>
<tr>
<td>P6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.47</td>
</tr>
<tr>
<td>P7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.70</td>
</tr>
<tr>
<td>P8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P9</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P10</td>
<td></td>
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</tr>
</tbody>
</table>

5.6 Identifying challenges experienced by map-illiterate individuals

5.6.1 Data Analysis Strategy

Using the previously defined map-use activities and map-use tasks (Table 4-7), route-planning behaviour model (Figure 4-12), and wayfinding behaviour model (Figure 4-13) (section 4.5.6), I analysed the data using the same method as in the Enschede experiment, except that heat maps and gaze plots were not generated for the route-planning activity. Participants moved the paper map around and brought their eyes closer and further away from the map while completing the route-planning activity. Therefore, the map did not
remain in a stable position and distance from participants, so it was not feasible to create heat maps and gaze plots.

5.6.2 Limitations in Analysis

The analysis of eye-tracking data that features dynamic stimuli is still in its infancy (Amati et al. 2018). Studies that involve dynamic stimuli in the forms of changing viewpoints and locomotion in an outdoor environment are particularly challenging (Amati et al. 2018). This is due to the continually changing lighting conditions that inhibit automatic pupil detection (section 4.6), as well as the lack of a fixed reference system to which to map eye movements. In a study of the visual matching process during self-localisation and orientation in an outdoor environment, Kiefer, Giannopoulos and Raubal (2014) corrected for errors in automatic pupil detection by manually checking and adjusting the pupil detection in each frame of each participant’s video. Pinelo Silva (2011) experienced similar difficulties with automatic pupil detection while collecting eye-tracking data outdoors; his solution to this problem was to manually code the videos. As advised by M Ryan, (Tobii Inc., pers. comm. 2020), Tobii Pro software does not provide the functionality to manually correct pupil detection. Therefore, like Pinelo Silva (2011) the eye-tracking videos were manually coded.

Figure 5-6 shows the percentage of eye movements collected during the route-planning and wayfinding activities for each participant. For the wayfinding activity, the lowest percentage of gaze sample collected was for P10 (27%) and the highest percentage was for P7 (86%), \( M = 55.6, SD = 14.8 \). It should be noted that while the gaze sample collected for P7 was high for the wayfinding activity, very dark clouds were present, and rain interrupted the experiment intermittently (for approximately 20 minutes in total). For the route-planning activity, the highest percentage of gaze samples was obtained for P3 and P6 (98%) and the lowest recorded was for P10 (31%), with the average being 82.1% (SD = 22.4).
The percentage of gaze samples captured can vary due to lighting conditions, long eyelashes, ptosis (drooping eyelids), visual impairment and eye colour (Tobii Technology AB 2018). Figure 5-6 shows that during the route-planning activity, lighting conditions could be controlled, participants were stationary and only looking at the map, this enabled a greater percentage of gaze samples to be collected.

Tobii Pro Lab software allows users to manually map eye movements to a snapshot (a still image). For my study, this meant it was possible to manually map a participant’s fixation onto the maps used during the route-planning and wayfinding scenarios. Despite having the ability to manually map eye movements to an AOI (the paper map), the generally low gaze capture rate and inconsistent number of gaze samples collected for each participant means any conclusions based on AOIs and heatmaps could be unreliable, because so many eye movements were not recorded.
5.7 Pilot Testing

An initial pilot test was conducted to ensure the data collection procedure would be effective. The method of data collection was similar to that used for the Enschede case study, but the map platform was a paper map instead of a map app on a smartphone.

There was intermittent cloud during this pilot test, making the conditions almost ideal for data collection. Nonetheless, at times it was difficult to calibrate or detect the participant’s eyes. As discovered during the study completed in Enschede, wearing a hat did not improve the quality of data collection markedly, and therefore this was not implemented in this study either.

Another challenge experienced was that during periods where large amounts of noise was present (traffic, members of the public talking), distortion could be heard through the microphone. Moreover, the voices of the participants could often not be heard clearly over the background noise, which made transcribing participants’ spoken thoughts difficult.

5.8 Route Planning

As in the previous case study (Chapter 4) participants were assigned an identity of Job Applicant or Tourist. Participants in the Job Applicants group were instructed to find the most direct way between the two locations, while the participants in the Tourist group were instructed that they had plenty of time to walk past other features of interest along the way. Participants planned three routes on an enlarged section of the City of Melbourne tourist map (Figure 5-7). Participants used red, blue and purple markers to draw their routes on the paper map. They then chose their preferred route, in conjunction with their group identity as a Job Applicant or Tourist (section 4.7). They then copied their chosen route on to a new copy of the City of Melbourne tourist map for use in the field, which was then attached to a piece of cardboard to assist in identifying actions participants performed (e.g., look at map, look for landmark) while walking their route.
5.9 Wayfinding

During the wayfinding exercise, participants used their selected route, drawn on the paper map, to find their way from the intersection of Little Bourke Street and Tattersalls Lane to the Royal Exhibition Building (marked on the map shown in Figure 5-8). Participants were only instructed to find their way and advise the researchers when they were satisfied that they had reached the destination. While travelling between the two locations, participants wore Tobii Pro Glasses 2 and spoke their thoughts aloud. Participants were advised to begin once the eye-tracking glasses were set to record, and the Runkeeper app had begun tracking the location. The Runkeeper app was used on a smartphone carried by the experiment facilitators while they followed along behind the participant.
Figure 5-8 P2 The planned route selected (drawn in blue) by P2 to walk from the origin (intersection of Little Bourke Street and Tattersalls Lane) to the destination (Royal Exhibition Building)
Figure 5-9 (top) shows the route P2 walked to get from the origin to the destination. There is a slight deviation from the planned route where the participant turns left to cross the road to reach the gardens. This was probably due to the simplified depiction of this intersection on the paper map, and the fact that it does not show where pedestrians can cross the road. In the planned route (Figure 5-9 – bottom), the participant indicates turning approximately 85° when crossing the road, but Figure 5-10 (left) shows that the intersection is more complex than that displayed on the City of Melbourne tourist map. This is due to the scale at which the City of Melbourne tourist map has been drawn and the amount of generalisation that has been applied to the road network. In fact, the City of Melbourne tourist map indicates that La Trobe, Spring and Victoria Streets converge at one intersection (Figure 5-10, right), whereas Figure 5-10 (left) shows that La Trobe Street intersects with Victoria Street prior to the Spring Street intersection.
Chapter 5 – Identifying Challenges Map Illiterate Users Experience When Wayfinding in a Medium City with a Grid-Style Road Network

Comparison of P2's Planned and Travelled Routes

Figure 5-9 Comparison of P2’s Planned (left) and Travelled Routes (right)
Chapter 5 – Identifying Challenges Map Illiterate Users Experience When Wayfinding in a Medium City with a Grid-Style Road Network

Figure 5-10 P2's route walked (left) and route planned (right)

Directly comparing the two routes reveals why there are differences between the route planned and the route walked, and allows for anomalies to be visually demonstrated. This comparison may also account for differences in distance and time estimations.

P2 attempted to cross Victoria Street at three locations (Figure 5-11). The first attempt was made at the intersection of La Trobe and Victoria Streets, which is where P2 had indicated they would cross according to their map, but crossing was only allowed from one side of La Trobe Street to the other (Figure 5-12). The second attempt was made at another pedestrian crossing, but this crossing would only allow pedestrians to cross into the middle of Victoria Street to access a tram stop (Figure 5-13). The third and successful attempt was made at the pedestrian crossing at Victoria and Spring Streets, where P2 could cross from the southern side of Victoria Street to the northern side (Figure 5-14).
Chapter 5 – Identifying Challenges Map Illiterate Users Experience When Wayfinding in a Medium City with a Grid-Style Road Network

Crossings attempted by P2

Figure 5-11 Locations where P2 attempted to cross Victoria Street
Chapter 5 – Identifying Challenges Map Illiterate Users Experience When Wayfinding in a Medium City with a Grid-Style Road Network

Figure 5-12 La Trobe Street crossing

Figure 5-13 Tram Stop crossing
5.10 Results and Discussion

5.10.1 Map Literacy

As discussed, participants were allocated randomly to either the Job Applicants or Tourists group. SBOSDS scores for the two groups were examined to determine whether there were differences in map literacy skills between them. The Shapiro-Wilk test was first used to check for normality. The SBOSDS scores of group Job Applicants ($D(5)= 0.94, p= 0.66$) were normally distributed, as were the scores of group Tourists ($D(4)= 0.95, p= 0.71$). After testing for normality, SBOSDS scores of the two groups were analysed using an independent-samples t-test, which showed that there was no significant difference ($t= -0.11; p= 0.92; df= 6.74; MD= -0.10; 95%CI= -2.16 to 1.97$) between the two groups. Box plots (Figure 5-15) show the distribution of SBOSDS scores between the two groups. P3’s SBOSDS score (1.27) is an outlier in the Job Applicants group. The t-test was repeated after removing this outlier, again revealing no significant difference between the mean SBOSDS scores of the two groups ($t= 0.79; p= 0.46$). This result suggests that any differences in performance between the two groups are not due to differences in map literacy.
5.10.2 Route Planning

To identify if map users experience challenges when using a map to plan a direct route (Job Applicants) or an indirect route (Tourists) the behaviours of the participants in each group were compared. These behaviours were:

(a) Number of times route distance was calculated;
(b) Number of times route duration was calculated;
(c) Number of times a landmark was confirmed;
(d) Number of times confusion was expressed;
(e) Number of fixations to the scale bar;
(f) Number of times participants searched for a landmark on the map; and
(g) Number of times the map was rotated

(a) Number of times route distance was calculated;

A Poisson regression was performed, which found the difference in number of times the route distance was calculated between the two groups was not statistically significant.
An Alternative Wayfinding Map Design for Map Illiterate Users

(b = 0.69; SE = 0.69; 95% CI = -0.66 to 2.07; p = 0.31). The box plots (Figure 5-16) show that P1 (Tourists) was an outlier, calculating route distance on four occasions. After removing the outlier, Poisson regression was again completed, which also showed no difference between the groups (b = -0.22; SE = 0.63; 95% CI = -1.46 to 1.02; p = 0.72).

Figure 5-16 Box plots summarising the distribution of Calculate Route Distance scores for N = 10 participants equally allocated into the Job Applicants and Tourists groups. P1 (Tourists) is an outlier.

(b) Number of times route duration was calculated;

A Poisson regression was performed, which found the difference in number of times the route duration was calculated between the two groups was not statistically significant (b = 0.69; SE = 0.69; 95% CI = -0.66 to 2.07; p = 0.31). The box plots (Figure 5-17) show that P1 (Tourists) was an outlier, calculating route duration on four occasions. After removing the outlier, Poisson regression was again completed, which also showed no difference between the groups (b = -0.22; SE = 0.63; 95% CI = -1.46 to 1.02; p = 0.72).
Figure 5-17 Box plots summarising the distribution of Calculate Route Time scores for N = 10 participants equally allocated into the Job Applicants and Tourists groups. P1 (Tourists) is an outlier.

(c) Number of times a landmark was confirmed
A Poisson regression was performed, which found the results to be overdispersed (φ = 1.83). Therefore, a negative binomial regression was completed, which found the difference in number occasions a landmark was confirmed between the two groups was not statistically significant (b = -0.19; SE = 0.73; 95% CI = -1.62 to 1.23; p = 0.79). The box plots (Figure 5-18) show that P1 and P10 (Tourists) were outliers, confirming landmarks on 10, and one occasion, respectively. After removing the outliers, a Poisson regression was again completed, revealing the results were no longer overdispersed and no significant difference existed between the groups (b = 0.34; SE = 0.49; 95% CI = -0.62 to 1.29; p = 0.49).
Figure 5-18 Box plots summarising the distribution of Confirms Landmark scores for $N = 10$ participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution; P1 and P10 (Tourists) are outliers.

(d) Number of times confusion was expressed

The box plots (Figure 5-19) show the Tourists group did not express any confusion during the route-planning activity. Three participants in the Job Applicants group expressed confusion once (P3, P7, P9), while P10 expressed confusion on three occasions and P8 did not express any confusion. Participants in the Job Applicants group were advised to plan the most direct route as opposed to participants in the Tourists group who were advised to plan a route that allowed them to visit other points of interest if they wished. Therefore, since there were more constraints for planning a route for participants of the Job Applicants group, it is not surprising that they expressed confusion. Given that participants in the Tourists group did not express confusion, further statistical analysis are not suitable.
Figure 5-19 Box plots summarising the distribution of Confusion scores for N = 10 participants equally allocated into the Job Applicants and Tourists groups. P4 and P8 (Job Applicants) are outliers.

(e) Number of fixations to the scale bar

A Poisson regression was performed, which found the difference in number of times participants looked at the scale bar between the two groups was not statistically significant ($b = -2.08; SE = 0.1.06; 95\% CI = -4.16 to -0.00; p = 0.05$). The box plots (Figure 5-20) show that P4 (Job Applicants) was an outlier, looking at the scale bar on one occasion. After removing the outlier, there were no other participants who made fixations to the scale bar, and therefore further statistical analyses cannot be performed.
Figure 5-20 Box plots summarising the distribution of Looks at Scale Bar scores for N = 10 participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution; P4 (Job Applicants) is an outlier.

**Number of times participants searched for a landmark on the map**

A Poisson regression was performed, which found the results to be overdispersed ($\phi = 1.28$). Therefore, a negative binomial regression was completed, which found the difference in number occasions participants search for a landmark between the two groups was not statistically significant ($b = 0.06; SE = 0.72; 95\% CI = -1.36 \text{ to } 1.48; p = 0.93$). The box plots (Figure 5-21) show that P3 and P8 (Job Applicants) and P1 (Tourists) were outliers, searching for landmarks on two, six, and eight occasions, respectively. After removing the outliers, a Poisson regression was again completed finding the results were no longer overdispersed and, which also showed no difference between the groups ($b = 0.41; SE = 0.49; 95\% CI = -0.54 \text{ to } 1.36; p = 0.40$).
Figure 5-21 Box plots summarising the distribution of Looks for Landmark scores for N = 10 participants equally allocated into the Job Applicants and Tourists groups. P3 and P6 (Job Applicants) and P1 (Tourists) are outliers.

**Number of times the map was rotated**

The box plots (Figure 5-22) show that P10 (Tourists) was the only participant to rotate the map during the route-planning activity. They rotated the map on two occasions. Given that no other participants of either group rotated the map, further statistical analyses cannot be performed and reported.
Figure 5-22 Box plots summarising the distribution of Map Rotation scores for N = 10 participants equally allocated into the Job Applicants and Tourists groups. P10 (Tourists) is an outlier.

P1 is an outlier on four occasions (Calculate Route Distance, Calculate Route Time, Look for Landmark, Confirm Landmark), P4 (Looks at Scale Bar, Confusion), P8 (Looks for Landmark, Confusion) and P10 (Rotates Map, Confirms Landmark) are outliers on two occasions each, while P3 is an outlier on one occasion (Looks for Landmark).

Figure 5-23 and Figure 5-24 show the differences between the routes planned and travelled by the Job Applicants and Tourists groups. There was more similarity in the routes taken by participants in the Job Applicants group than in those in the Tourists group. This difference between groups was expected, because Job Applicants were instructed to find the most direct way between the two locations, while the Tourists were instructed that they had plenty of time to walk past other features of interest along the way. As such, the Tourists also look longer routes than the Job Applicants.
Figure 5-23 Job Applicants’ planned (left) and travelled routes (right)
Comparison of Tourists' Planned and Travelled Routes

Figure 5-24 Tourists’ planned (left) and travelled routes (right)
Figure 5-25 illustrates the differences between the two groups in their route-planning activity, specifically in the Use of landmark and Use of street name events and samples of coded verbal statements are listed in Table 5-2. In the case of Use of landmark, the Tourists group referred to landmarks four times more often than the Job Applicants group. Conversely, the Job Applicants group referred to street names three times more often than the Tourists group. The difference in frequency between the two groups in relation to Use of landmark could be because the Tourists group members were under fewer time constraints than Job Applicants group members, they may have encountered more features, and taken longer paths, therefore leading to more opportunities to encounter landmarks. The difference in opportunity is evident by comparing the average length of routes (Table 5-3 Tourists $M = 1.54$ km, $SD = 0.22$, Job Applicants $M = 1.26$ km, $SD = 0.13$). The Tourists’ use of landmarks may be also attributed to the fact that when actual tourists travel, they often visit landmarks or points of interest, and as a result, use landmarks more frequently as a means of finding their way.

The greater use of street names by the Job Applicants group might be explained by the fact that they were directed to find their way to the destination as quickly as possible, so they were largely uninterested in landmarks or points of interest. To find their way, however, they still needed to refer to a feature of some kind for self-localisation, and so instead of using landmarks, they used street names. Another possible explanation could be that because this group had three participants in the 55-64 age group, these participants may have been familiar enough with the street names which tend to be more constant over time, as opposed to landmarks, that they preferred to use street names instead.
Table 5-2 Samples of verbalised statements with corresponding codes

<table>
<thead>
<tr>
<th>Verbal Code</th>
<th>Sample of coded statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculation</td>
<td>“so that’s like a kilometre probably yeah around eight to ten minutes according to this map”</td>
</tr>
<tr>
<td>Confusion</td>
<td>“where am I...I feel so disorientated”</td>
</tr>
<tr>
<td>Cardinal direction</td>
<td>“I'm going to go...West down Little Bourke Street”</td>
</tr>
<tr>
<td>Landmark</td>
<td>“as a tourist you wanna see Parliament House just to get the Selfie”</td>
</tr>
<tr>
<td>Street Name</td>
<td>“then could either continue up Rathdowne Street”</td>
</tr>
</tbody>
</table>

Table 5-3 shows three distances: the estimated distance of the planned routes, the measured distance of the planned routes, and the distance each participant walked. Discrepancies between the estimated and actual distances of the planned route may be because participants did not see the scale bar (Figure 5-20), used prior knowledge to estimate the distance, or used the scale bar incorrectly to calculate the distance between their origin and destination (P1).

Some participants did not deviate from their planned route, but their actual distance walked was different to their planned route distance; this can be attributed to:
- Researcher inaccuracy in translating the start and end locations participants marked on their maps into ArcGIS Pro (Esri Inc. 2021a);
- The researcher not starting and finishing the route in the exact positions of the participant; and
- GNSS measurement error.

The discrepancy shows the difference between the estimate distance of the planned route, and the correct distance of the planned route. Deviation from the planned route indicates the percentage of the walked route that was not the same as the planned route. Due to P10 becoming lost, they ended up walking longer than the original planned distance.

The planned route distance was calculated by inputting each participant’s start and end points into ArcGIS Pro (Esri Inc. 2021a) and drawing the planned route between them, then calculating the line’s length by using the Calculate Geometry function in ArcMap. The

<table>
<thead>
<tr>
<th>Participant</th>
<th>Planned route – estimated distance (km)</th>
<th>Planned route – actual distance (km)</th>
<th>Discrepancy between estimated and actual planned distance (km)</th>
<th>Distance walked (km)</th>
<th>Deviation from planned route (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 - Tourist</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1</td>
<td>3.20</td>
<td>1.42</td>
<td>1.78</td>
<td>1.53</td>
<td>0.00</td>
</tr>
<tr>
<td>P2</td>
<td>1.50</td>
<td>1.26</td>
<td>0.24</td>
<td>1.35</td>
<td>14.9</td>
</tr>
<tr>
<td>P5</td>
<td>1.40</td>
<td>1.18</td>
<td>0.22</td>
<td>1.51</td>
<td>48.5</td>
</tr>
<tr>
<td>P6</td>
<td>1.30</td>
<td>1.12</td>
<td>0.18</td>
<td>1.36</td>
<td>35.6</td>
</tr>
<tr>
<td>P10</td>
<td>1.50</td>
<td>1.48</td>
<td>0.02</td>
<td>1.96</td>
<td>109</td>
</tr>
<tr>
<td>Mean</td>
<td>1.78</td>
<td>1.29</td>
<td>0.22</td>
<td>1.54</td>
<td>41.6</td>
</tr>
<tr>
<td>Median</td>
<td>1.50</td>
<td>1.26</td>
<td>0.49</td>
<td>1.51</td>
<td>35.6</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.71</td>
<td>0.14</td>
<td>0.65</td>
<td>0.22</td>
<td>37.6</td>
</tr>
<tr>
<td>Group 2 – Job Applicant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3</td>
<td>3.00</td>
<td>1.24</td>
<td>1.76</td>
<td>1.16</td>
<td>0.00</td>
</tr>
<tr>
<td>P4</td>
<td>2.50</td>
<td>1.12</td>
<td>1.38</td>
<td>1.39</td>
<td>0.00</td>
</tr>
<tr>
<td>P7</td>
<td>0.50</td>
<td>1.23</td>
<td>0.73</td>
<td>1.38</td>
<td>28.9</td>
</tr>
<tr>
<td>P8</td>
<td>1.00</td>
<td>1.20</td>
<td>0.20</td>
<td>1.29</td>
<td>31.3</td>
</tr>
<tr>
<td>P9</td>
<td>1.20</td>
<td>1.22</td>
<td>-0.02</td>
<td>1.06</td>
<td>46.3</td>
</tr>
<tr>
<td>Mean</td>
<td>1.64</td>
<td>1.20</td>
<td>0.44</td>
<td>1.26</td>
<td>21.3</td>
</tr>
<tr>
<td>Median</td>
<td>1.20</td>
<td>1.42</td>
<td>-0.02</td>
<td>1.29</td>
<td>28.9</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.95</td>
<td>0.04</td>
<td>0.96</td>
<td>0.13</td>
<td>18.39</td>
</tr>
</tbody>
</table>
distance walked was calculated using the data collected in the Runkeeper application that the researcher used while following the participants. The travelled routes of participants shown below (Figure 5-27 (top), Figure 5-28 (top), Figure 5-29 (top), Figure 5-26 (top), Figure 5-42 (top), Figure 5-43 (top) highlight the inaccuracies of GNSS measurement. The accuracy of GNSS measurements can be affected by satellite geometry, atmospheric conditions, receiver quality and the presence of buildings which can create urban canyons (Groves 2011). Therefore, the travelled routes do not always adhere strictly to the roads that the participants walked along.

The “deviation from planned route” column in Table 5-3 shows seven of the 10 participants deviated from their planned route. P2 deviated because they had to find a pedestrian crossing (Figure 5-10 and Figure 5-11); P5 deviated because they decided to walk down a laneway where there were “less people” (Figure 5-25); neither P6 nor P7 provided reasons for their deviations (Figure 5-27 and Figure 5-28); P8 (Figure 5-30) deviated because they preferred walking through the park instead of along Rathdowne Street, P9 deviated because they wanted to take a short cut through the park, and P10 deviated because they became lost and disoriented.

Figure 5-26 shows the entrance to the Carlton Gardens at the intersection of Victoria and Rathdowne Streets. Participants can continue walking along Rathdowne Street or through the Carlton Gardens. Depending on one’s preferences, the path through the Carlton Gardens may be more desirable because it is surrounded by gardens on each side of the path. The path through the gardens is also a more direct path to the Royal Exhibition Building. This may explain why P6, P7 and P8 decided to walk through the Carlton Gardens instead of along Rathdowne Street.
Similar to P8, P6, P7 and P9 changed their route when within the vicinity of the Carlton Gardens. However, P9 (Figure 5-31) first walked along the footpath to the left of the gardens for some time before leaving the footpath and then walking through the gardens.
Comparison of P5’s Planned and Travelled Routes

End Point P5

Routes P5

Figure 5-27 P5’s planned (left) and travelled route (right)
Figure 5-28 P6’s planned (left) and travelled route (right)
Figure 5-29 P7’s planned (left) and travelled route (right)
Figure 5-30 P8’s planned (left) and travelled route (right)
Comparison of P9’s Planned and Travelled Routes

Figure 5-31 P9’s planned (left) and travelled route (right)
5.10.3 Wayfinding

To identify if map users experience challenges when using a map to find their way under time pressure (Job Applicants) or without time pressure (Tourists) the behaviours of the participants in each group were compared. These behaviours were:

(a) Number of times a landmark was confirmed;
(b) Number of times confusion was expressed;
(c) Number of times participants deviated from the planned route;
(d) Fixations to the map per minute;
(e) Number of times participants looked for a landmark;
(f) Number of times the map was rotated
(g) Number of times participants voluntarily stopped walking; and
(h) Number of times participants performed self-localisation

(a) Number of times a landmark was confirmed

A Poisson regression was performed, which found the results to be overdispersed ($\phi = 4.23$). Therefore, a negative binomial regression was completed, which found the difference in number occasions a landmark was confirmed between the two groups was not statistically significant ($b = -0.56; SE = 0.77; 95\% CI = -2.07 to 0.95; p = 0.47$). The box plots (Figure 5-32) show that P3 (Job Applicants) was an outlier, confirming landmarks on seven occasions. After removing the outlier, the results were still overdispersed ($\phi = 2.35$). A negative binomial regression was again completed, which also showed no significant difference between the groups ($b = -2.42; SE = 1.23; 95\% CI = -4.83 to 0.00; p = 0.05$).
Figure 5-32 Box plots summarising the distribution of Confirms Landmark scores for N = 10 participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution; P3 (Job Applicants) is an outlier.

(b) Number of times confusion was expressed

A Poisson regression was performed, which found the results to be overdispersed ($\phi = 3.24$). Therefore, a negative binomial regression was completed, which found the difference in number occasions participants expressed confusion between the two groups was not statistically significant ($b = -0.92; SE = 0.87; 95\% CI = -2.61$ to $0.78; p = 0.29$). The box plots (Figure 5-33) show that P3 (Job Applicants) and P10 (Tourists) were outliers, expressing confusion on four and seven occasions, respectively. After removing the outliers there were no participants in the Job Applicants group who expressed confusion during the wayfinding activity, and therefore further statistical analyses could not be performed.
Figure 5-33 Box plots summarising the distribution of Confusion scores for N = 10 participants equally allocated into the Job Applicants and Tourists groups. P3 (Job Applicants, and P5 and P10 (Tourists) are outliers.

(c) Number of times participants deviated from the planned route

A Poisson regression was performed, which found the difference in number of deviations from the planned route between the two groups was not statistically significant ($b$ = -0.69; $SE$ = 0.71; 95% CI = -2.08 to 0.69; $p$ = 0.33). Box plots (Figure 5-34) show the distribution of deviations between the two groups.
Figure 5-34 Box plots summarising the distribution of Deviation from Route scores for N = 10 participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution.

(d) Fixations to the map per minute

Using data collected from the scene camera of the eye-tracking glasses, the fixation rate (number of fixations to the map per minute) was calculated. Fixation rate was used rather than the total number of fixations because walking speed differed between participants; therefore, those who spent more time walking the route had more time to look at the map. The differences between fixation rates of the two groups were analysed using an independent-samples t-test (Field 2018). There was no significant difference ($t= 0.35; p= 0.37; df= 7.99; MD= 0.36; 95%CI= -1.96 to 2.68$) between the rates at which the groups referred to the map. Box plots (Figure 5-35) show the distribution of fixations to map per minute between the two groups.
Figure 5-35 Box plots summarising the distribution of Looks at Map scores for N = 10 participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution.

(e) **Number of times participants looked for a landmark**

A Poisson regression was performed, which found the results to be overdispersed (\(\phi = 5.31\)). Therefore, a negative binomial regression was completed, which found the difference in number occasions participants looked for a landmark between the two groups was not statistically significant (\(b = -0.24; SE = 0.75; 95\% CI = -1.71 \text{ to } 1.23; p = 0.75\)). The box plots (Figure 5-36) show P3 (Job Applicants) was an outlier, looking for landmarks on 10 occasions. After removing the outlier, the results were still overdispersed (\(\phi = 2.04\)). A negative binomial regression was again completed, which also showed no significant difference between the groups (\(b = -2.42; SE = 1.23; 95\% CI = -4.83 \text{ to } 0.00; p = 0.05\)).
Figure 5-36 Box plots summarising the distribution of Looks for Landmark scores for $N = 10$ participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution; P3 (Job Applicants) is an outlier.

**Number of times the map was rotated**

A Poisson regression was performed, which found the results to be overdispersed ($\phi = 8.02$). Therefore, a negative binomial regression was completed, which found the difference in number occasions participants looked for a landmark between the two groups was not statistically significant ($b = -1.29; SE = 0.71; 95\% CI = -2.67 to 0.10; \ p = 0.07$). The box plots (Figure 5-37) show that P10 (Tourists) was an outlier, rotating the map on 32 occasions. After removing the outlier, the results were still overdispersed ($\phi = 1.72$). A negative binomial regression was again completed, which also showed no significant difference between the groups ($b = -0.37; SE = 0.77; 95\% CI = -1.88 to 1.14; \ p = 0.64$).
Figure 5-37 Box plots summarising the distribution of Map Rotation scores for $N = 10$ participants equally allocated into the Job Applicants and Tourists groups. Error bars represent 95% confidence intervals of each distribution; P10 (Tourists) is an outlier.

**(g) Number of times participants voluntarily stopped walking**

A Poisson regression was performed, which found the results to be overdispersed ($\phi = 3.22$). Therefore, a negative binomial regression was completed, which found the difference in number occasions participants voluntarily stopped between the two groups was not statistically significant ($b = -1.95; SE = 1.24; 95\% CI = -4.38$ to 0.49; $p = 0.12$). The box plots (Figure 5-38) show that P3 (Job Applicants) and P10 (Tourists) were outliers, stopping on one and seven occasions, respectively. The remaining participants did not stop walking.
Figure 5-38 Box plots summarising the distribution of Stop Walking scores for $N = 10$ participants equally allocated into the Job Applicants and Tourists groups. P3 (Job Applicants) and P1 (Tourists) are outliers.

(h) Number of times participants performed self-localisation

The box plots (Figure 5-39) show that P10 (Tourists) was the only participant who visibly performed self-localisation. Given that they expressed confused on seven occasions, and deviated from their route twice, this is not surprising, since they had to compare the map with their surroundings to find where they had made a mistake.
When looking at the verbal code frequencies (Figure 5-40), the Tourists group expressed confusion twice as often as the Job Applicants group, but both groups experienced a low incidence of confusion. The Tourists group verbalised landmarks on more occasions on average than the Job Applicants group. This might be explained by the fact that the Tourists group generally walked longer routes, and therefore made more turns and encountered more streets and more potential landmarks. Participants in the Tourists group were also conditioned to be aware of landmarks, because they were advised that they had plenty of time and might like to see some other things on their way to the Royal Exhibition Building. Table 5-4 provides a sample of coded verbal statements.
Figure 5-40 Frequency of verbal codes identified in transcripts from the Job Applicants and Tourists groups during the wayfinding activity

Table 5-4 Samples of verbalised statements with corresponding codes

<table>
<thead>
<tr>
<th>Verbal Code</th>
<th>Sample of coded statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculation</td>
<td>“so one more block and then we turn left”</td>
</tr>
<tr>
<td>Confusion</td>
<td>“sooo I know there's a little laneway oh I think I've done the wrong thing but...sooo the laneway’s before Exhibition Street...I think”</td>
</tr>
<tr>
<td>Making a correction</td>
<td>‘we must have gone through I don't even know what garden we went through...oh it's this way”</td>
</tr>
<tr>
<td>Landmark</td>
<td>“ok that’s the Comedy Theatre”</td>
</tr>
<tr>
<td>Street Name</td>
<td>“just turning left into Russell Street”</td>
</tr>
</tbody>
</table>

The comparison of P10’s planned and travelled routes (Figure 5-41) shows a smaller deviation at the beginning, where the participant turned left prior to crossing Russell Street, instead of turning left after crossing Russell Street (deviation 1), then a large deviation from the planned route near Parliament House (deviation 2). Deviation 1 occurred due to the participant becoming confused about where they wanted to turn to walk through to Bourke Street. The participant incorrectly assumed that one of the arcades connecting Little Bourke Street to Bourke Street was one they had walked through recently. As noted earlier, Melbourne has many laneways, alleyways and arcades that connect streets to one another. Unlike laneways and alleyways, which are still technically streets, and which motor vehicles
can access in many cases, arcades tend to be pedestrian walkways that pass through a building or sequence of buildings, and if included on the map at all would not be drawn on the map in the same way that a laneway or alleyway might be. Therefore, given that P10 was looking for an arcade, which is a pedestrian walkway that passes through buildings, it is curious that they mistook this for an alleyway that is outdoors and accessible to motor vehicles. Once P10 realised this error, they made a 180-degree turn, and began walking back in the direction from which they had come. P10 became confused about their recollection of the arcade’s appearance and location; as a result, P10 decided to walk through an arcade they believed to be the one with which they were familiar, but turned out to be a different arcade altogether. Upon arriving on Bourke Street and approaching the intersection of Bourke and Russell Streets, the participant realised they were not in the expected location.

The second occasion where P10 deviated from the planned route was around the intersections of Bourke, Spring and Nicholson Streets (Figure 5-42). Depending on which side of Spring Street one is on (east or west), if one continues to follow the road, one will either continue along Spring Street or divert along Nicholson Street. In the City of Melbourne tourist map, this intersection is simplified and not entirely clear. P10 knew they had to go right at some point, so they diverted through Parliament Gardens, unaware they had already diverted to the right along Nicholson Street by crossing Spring Street – as indicated in the planned route. P10 also made the comment:

I always come to the Exhibition Centre from the same direction which is where I live so I’m like I’ve never been here before I actually don’t know where I am.

From this statement, it is evident that despite the participant thinking they knew the Royal Exhibition Building’s location well, they usually approached it from a different direction, explaining why they became confused. It was not until P10 walked past a church they were able to locate on the map that they realised their planned route did not go past this church and they therefore had deviated from their planned route. P10 then proceeded to the next intersection to confirm their location, and from that intersection was able to determine in which direction they needed to turn. At the next intersection, P10 was able to recognise the
Carlton Gardens in the distance and used the intersecting streets and surrounding landmarks to update their location on the map, confirming they were heading in the correct direction – towards the Royal Exhibition Building.
An Alternative Wayfinding Map Design for Map Illiterate Users

Figure 5-41 P10’s planned (left) and travelled route (right)
5.10.4 Post-Test Interviews

At the completion of the exercise, I engaged participants in a post-test interview. I conducted interviews to determine how participants felt about the map and how useful it was for the purposes of route planning and wayfinding. I also asked them about what they did and did not like about the map, and if they thought it could be improved in any way.

Based on the post-test interview, the main concern for participants was the labelling of street names. They felt that too many street names were missing from the map, that it was difficult to distinguish between fonts for streets or roads and fonts for other features, and that the placement of labels was unsatisfactory:

Include missing street names. (P1)
Infrequent street labelling - font, unnamed and some streets not included; street name sizes and label placement. (P3)

Names of roads written next to them and not on it. Fonts too similar for different features. (P5)

Needs clearer street labelling. (P6)

Smaller streets don’t have names, which doesn’t help if lost. (P10)

Another common theme that was evident from the post-test interviews was that participants found the inclusion of the public transport networks on the map to be confusing and distracting:

Tram logo was distracting. (P1)

Tram system on top of map is confusing. Tram map should be separate. (P6)

Tram line colours could be improved. (P3)

Transport routes are confusing. Too cluttered. Colours of stations shouldn’t be same as suburbs or toilet icons. Not include free tram zone. (P7)

These comments from participants indicate that maps need to be fit for purpose, and suggest that separate maps should be developed depending on the context in which they will be used. For pedestrians, the public transport information was irrelevant and therefore could be considered noise. Including public transport information on a map for pedestrians who are not using public transport means they need to filter out that information in order to find information that is relevant to them and their task.

In the route-planning activity, P3 made the comment “I don’t actually know if that’s a road or not“. P3 was referring to Spring Street, which is shown in Figure 5-43. Placing a label on the street itself could alleviate this confusion, but this was not done because public transport routes were already overlaid on Spring Street, so there was not enough space.

Melbourne includes locations where tram tracks and streets coincide. Some portions of the tram lines share street space with cars. In other locations tram tracks exist on their own and
are therefore unsuitable for use as a walking path. For people unfamiliar with Melbourne, it would be difficult to decipher from the map where tram tracks coincide with streets and where they do not. This distinction is more easily learnt by direct experience. In addition to this, the label for Parliament train station on the map is placed on and along Spring Street, further adding to the confusion about the street’s identity. The labelling of Parliament train station on the map defies the cartographic conventions for labelling a point. Not only is the label not placed in the correct location according to cartographic principles, but the orientation of the label is also incorrect. Point features should be labelled horizontally, and only linear features should have labels running alongside them.

The City of Melbourne tourist map (Figure 5-43) also includes the location of train tracks located beneath the streets of Melbourne. The train tracks themselves cannot be seen from ground level; only signage to the stations is visible. Three of the five city stations are located below street level, so including the location of the train tracks on the map is unnecessary. When using underground transport systems, people only need to know where they can
access train stations, and then determine which stations are connected to one another. Furthermore, schematic diagrams of Melbourne’s train and tram networks already exist and are easily accessible online, at train stations and other locations around the Melbourne CBD. Hence, including such information in this map is not only unnecessary but is likely to overwhelm and confuse map users.

Interestingly, on the City of Melbourne tourist map, some street labels are placed on and along the street and others are not (Figure 5-44). Inconsistent labelling practices mean that map users must think harder about what they are looking at and to what each label refers.

Figure 5-44 Examples of inconsistent labelling: Victoria St and Spring St

Figure 5-44 shows inconsistencies in labelling. For example, Victoria Street is labelled on and along the road, whereas all the other streets, roads and laneways have labels alongside them. The label for the Greek Precinct is placed similarly to those for elements of the road network and could easily be taken to be a street name, since the difference in typography
between it and other map features is minimal. Moreover, many symbols are also offset quite a distance from their labels, making it difficult to relate the two.

5.11 Findings

Whilst all participants successfully completed the tasks, it is evident that some map designs are not straightforward and include many sources of confusion. From the data collected, four new key findings can be identified:

Finding 4: Street labelling was inconsistent in its placement and similarity of label typography among different feature types on the map is a source of considerable confusion and frustration for map users.

Complaints about street labelling on the map were the most common type of complaint among the map users tested. Because of label placement, similarity of label typography among different feature types, or the lack of street name labels, it sometimes took a long time for participants to identify their location on the map at street intersections.

Finding 5: Overlaying public transport networks leads to confusion and distraction.

The second most common type of complaint was about the distraction introduced by the public transport networks shown on the map. Participants felt that the symbols used for the public transport networks made identifying the roads more difficult and added too much information to the map.

Finding 6: Excessively simplified road networks increase the difficulty of pedestrian navigation.

The map does not show where pedestrians can cross the road safely at complex road intersections. This meant that the routes participants planned did not reflect the complexity of the environment, and that they had to walk further to find an appropriate crossing.

Finding 7: Among those with lower SBSODS scores, confusion about their location was expressed more often than those with higher SBSODS scores.
P3 (Job Applicant) and P10 (Tourist) scored quite low on the SBSODS compared to the other participants and both experienced confusion about their location on more occasions than the other participants in their group. It is possible, then, that map users with poorer spatial abilities need be provided with maps that include appropriate features for self-localisation. It was also observed, that between long stretches of road, map users seem to prefer using landmarks to update their locations as opposed to intersections with minor streets, perhaps because of unclear labelling on the map. At major street intersections, however, street names tend to be used primarily, and landmarks are used to validate their current position in the environment.

5.12 Limitations

A limitation that was evident during recruitment was that it was difficult to find potential participants who were unfamiliar with the study location. Whilst Melbourne hosts many tourists and international students, being unable to offer a financial incentive made it difficult to attract them to participate in research. Two of the participants were not born in Australia; however, they had been living in Melbourne for a substantial amount of time. As a result, all participants had considerable prior experience in the testing location.

The second limitation is that some participants were reluctant to speak their thoughts aloud, particularly in the wayfinding exercise. Therefore, the frequencies of verbal events I observed underrepresent actual cognitive processes in some cases. Only three participants were able to be verified as updating their location but updating one’s location is a critical component of wayfinding. This means that all other participants would have done this too but did not do it in a way that could be captured in the data, or perhaps they were unaware that they were doing this.

The third limitation was the interference of sunlight with the eye-tracking glasses. Despite conducting a great deal of this data collection over the late autumn and early winter months, sunlight still had a significant effect on the quality of gaze data collected. As discussed in section 5.6.2, gaze samples ranged between 27% and 86%, therefore reducing the feasibility of comparing participant behaviours through gaze analyses. The day on which
the 86% of gaze samples were collected had significant cloud cover, but it also began to rain during the experiment, resulting in breaks to wait under cover until the rain had ceased. As noted earlier, using low-level gaze samples to create heat maps or derive fixation results would be problematic.

**Summary**

This chapter described the data collection process and outcomes in Melbourne, Australia including the development of the case study, the methods used to recruit participants, equipment used, and difficulties associated with data analysis. The results were provided and discussed, and five key findings identified (section 5.12):

- **Among those with lower spatial ability scores, frequency of looking at the map is quite high. This caused participants to miss important environmental features that would assist with wayfinding and spatial knowledge acquisition.**
- **Street labelling is a source of considerable confusion and frustration for map users; street names were not located in convenient locations on the map, for example at key decision-making locations.**
- **Using house numbers as opposed to larger features such as streets and landmarks was a common method used for self-localisation for those having lower spatial abilities**
- **Overlaying public transport networks leads to confusion and distraction; and**
- **Excessively simplified road networks increase the difficulty of pedestrian navigation.**

Chapter 6 details how the findings of the studies outlined in Chapter 4 and Chapter 5 were applied to develop a proof-of-concept app to enable map-illiterate users to perform effective and efficient wayfinding in an unfamiliar urban area.
Chapter 6 – Designing a Wayfinding Solution for Map-Illiterate Users

Chapter 5 detailed the data collection and analysis processes of the Melbourne Case Study. The key findings of both case studies (Enschede 2016 and Melbourne 2017–18) were outlined. This chapter presents solutions to the findings, followed by a design brief used to guide the development of a proof-of-concept smartphone app for supporting map illiterate users to find their way and finally, the development of the proof-of-concept app is discussed.

6.1 Potential Solutions to the Problems Identified

The research conducted in Enschede resulted in three findings:

- **Finding 1:** Looking at the map frequently caused participants to miss important environmental features that would assist with wayfinding and spatial knowledge acquisition;
- **Finding 2:** Street names were not located in convenient locations on the map, for example at key decision-making locations; and
- **Finding 3:** Using house numbers as opposed to larger features such as streets and landmarks was a common method used for self-localisation for those having lower spatial abilities.

The research conducted in Melbourne resulted in a further four findings:

- **Finding 4:** Street labelling was inconsistent in its placement and similarity of label typography among different feature types on the map is a source of considerable confusion and frustration for map users;
- **Finding 5:** Overlaying public transport networks leads to confusion and distraction;
- **Finding 6:** Excessively simplified road networks increase the difficulty of pedestrian navigation; and
- **Finding 7:** Among those with lower SBSODS scores, confusion about their location was expressed more often than those with higher SBSODS scores.
Issues relating to street labelling and heavy reliance on the map by individuals with low spatial abilities are common to the Enschede and Melbourne case studies. Therefore, these seven findings can be condensed into five key findings, listed below.

**Key Finding 1:** Looking at the map frequently caused participants to miss important environmental features that would assist with wayfinding and spatial knowledge acquisition.

**Key Finding 2:** Street names were not located in convenient locations on the map, for example at key decision-making locations.

**Key Finding 3:** Among those with lower SBSODS scores, confusion about their location was often expressed, and house numbers were often used for self-localisation as opposed to larger features such as streets and landmarks.

**Key Finding 4:** Overlaying public transport networks leads to confusion and distraction.

**Key Finding 5:** Excessively simplified road networks increase the difficulty of pedestrian navigation.

The above findings relate to challenges that participants experienced during the wayfinding phases of the case studies. The route-planning phase did not provide evidence that participants experienced difficulty when planning their routes. These results suggest that the participants in the two case studies experience difficulty at the environmental scale, but not the figural scale (Section 2.3.1). Therefore, the solution developed to support wayfinding by map-(il)literate users excluded the requirement for users to plan their route.

I reviewed the scientific literature to determine if any of these findings had been addressed by other researchers. The next five sections outline the literature that relates to each finding.
Key Finding 1: Looking at the map frequently caused participants to miss important environmental features that would assist with wayfinding and spatial knowledge acquisition.

If looking at a map excessively causes map users to miss important environmental features that would assist with wayfinding, then a solution is to develop a map product that encourages map users to look up and be aware of their surroundings. Elias, Hampe and Sester (2005), Gartner et al. (2011), Kettunen et al. (2015), Röser et al. (2012) and Sarjakoski and Nivala (2005) suggested landmarks appropriate for use in navigating could be selected as features the map user should look for. In addition, haptic feedback could be employed to alert the user of a map on a smartphone or other digital device that they are approaching a landmark or a decision-making location (Giannopoulos, Kiefer & Raubal 2015; Me, Biamonti & Saad 2015). This would allow the user to keep their gaze and attention on the environment around them, rather than on the map, therefore building their spatial knowledge acquisition.

Another possible solution would be to give the user the experience of travelling along a particular route without physically doing so. Evidence shows that map users who have travelled along a route previously are less likely to depend on an external map, because they can utilise their cognitive map (Brügger, Richter & Fabrikant 2017). Direct experience could be replicated by incorporating simulated navigation experiences into online mapping and navigation applications. A user would be able to input their starting and finishing locations, then on their screen (or perhaps using a virtual reality or augmented reality headset), they would be able to view the route as they would from the perspective of a pedestrian. This way, they could experience the environment and gain familiarity with it before physically travelling along a particular route. Another alternative, is to include photographs of landmarks so that participants can become familiar with the landmarks they are looking for, and be actively engaged during wayfinding (Haig 2019). Being confident about correctly matching a landmark on the map with a landmark in the environment may also allow for easier self-localisation.
Haque, Kulik and Klippel (2006) developed the shortest most reliable path algorithm. This algorithm finds the shortest route that contains the least navigational complexity, thereby reducing the risk of a person taking a wrong turn. This type of solution requires less visual attention on the map, because the intersections people would encounter would be less complex and therefore easier to navigate.

Paelke and Elias (2007) suggested using stories to describe routes. They argued that remembering linear stories is easier than remembering route descriptions or the information included on a map. Stories can include information about the locations of decision points and the direction in which a user would need to turn. By increasing the ability to remember a route’s description via a story, people can rely less on textual information or a map, and keep their attention focused on the environment around them. This would limit the time they look at a map, thereby increasing their situational awareness and spatial knowledge acquisition.

It has been found that global landmarks can successfully support wayfinding activities for individuals with low spatial abilities (Credé & Fabrikant 2018) and are also likely to be helpful for map users who are temporarily experiencing reduced cognitive ability due to stress or mental illness. Credé and Fabrikant (2018) proposed the development of a system that could respond to a user’s stress levels in real time whilst navigating. In looking at how stress affects spatial knowledge acquisition during navigation, Credé et al. (2018) studied two groups of participants navigating an unfamiliar virtual city. One group was subjected to stress, the other was not. Both groups were subjected to three landmark configurations within the city—the first with local landmarks along the route highlighted, the second with local landmarks highlighted and global landmarks present in the virtual environment, and the third with global landmarks highlighted. The researchers expected that participants experiencing acute stress would acquire more spatial knowledge when global landmarks were highlighted, because global landmarks are experienced from different perspectives while navigating along a route, while local landmarks tend to be greater in number and only perceived from one perspective. The researchers stated that the overall aim of their research was to “develop guidelines for the design of stress resistant navigation assistance”
(Credé et al. 2018, p. 29). The results of this research indicated that contrary to the expectations of the researchers, having global landmarks in the distance is not particularly beneficial to spatial knowledge acquisition. However, the researchers suggested highlighting landmarks in a traditional static survey map from an egocentric perspective using augmented reality, or providing icons of the landmarks in 3D on the survey map (Credé et al. 2019).

To facilitate improved spatial learning and increase a map user’s visual attention on the environment Giannopoulos, Kiefer and Raubal (2015) developed a system they called GazeNav. The aims of the system were to dissolve navigation ambiguities, increase usability of navigation systems and improve local spatial learning; these aims were achieved with mobile eye-tracking glasses and the GazeNav system on a smartphone. When a user of the system reached a decision point, they could look around the environment, and the smartphone using GazeNav would vibrate to indicate the user was looking at the street that they needed to take to proceed along their route. This system was tested in a virtual simulation, where participants used a joystick to move throughout an unfamiliar urban environment.

**Key Finding 2: Street labelling was a source of considerable confusion and frustration for map users; street names were not located in convenient locations on the map, for example at key decision-making locations.**

Whilst automated map labelling has progressed over time, for example, with the development of the Maplex Label Engine (Esri Inc. 2021d), there is still room for improvement. Due to the small screen size of handheld devices such as smartphones and tablets, roads may be labelled along segments that are not visible within some extents of the map within the screen. As outlined in section 4.9.2, being unable to see road names led to participants having to pan and zoom the map so that they could identify which road they were on, or at which intersection they were standing. A possible solution for this is to create dynamic labelling which labels linear features according to the current position of the map user.
In Google Maps’s labelling, point symbol labels appear to take precedence over those for linear features such as roads (Figure 6-1). The rules for labelling change depending on the scale at which the map is displayed. Figure 6-1 (left) does not include any street names, with the label of a pharmacy covering a segment of road. Figure 6-1 (right) does include one road name, but a label on an intersecting road would give a map user a better indication of the location being displayed on the screen.

The feature which should take precedence in labelling is the one which best facilitates wayfinding and self-localisation. My research in Enschede and Melbourne showed that participants preferred to use a large and salient landmark for self-localisation rather than a road, but in lieu of such a landmark, they would reference a main road before trying to
match their location to a minor point feature such as a house or building number, except in the case of those with poor spatial abilities. Davies and Peebles (2010) came to the same conclusion. Therefore, labelling algorithms used in wayfinding applications should take the ability for self-localisation into account when determining how, where and when to label features.

**Key Finding 3:** Among those with lower SBSODS scores, confusion about their location was often expressed, and house numbers were often used for self-localisation as opposed to larger features such as streets and landmarks.

My empirical research conducted using a mobile map application (section 4.10) and a paper map (section 5.12), shows that some map users feel the need to update their location on the map regularly. Instead of updating their location on the map at decision points, they appear to need frequent reassurance that they are heading in their intended direction. Therefore, along stretches of road where there are few intersections with other roads, or intersections are so minor that they are unnamed (in the case of walkways), landmarks need to be included, even if they are not a point of interest, but used only to help the map user to understand their location. Wang and Ishikawa (2018) recommended that maps show landmarks at intermediate points along any path longer than 200 metres to allow self-localisation.

Nuhn and Timpf (2017) discussed people’s differing use of landmarks; they stated that “A geographical object that is salient for one person may have no importance at all for another person. Thus, there is a need to incorporate more personal dimensions into a comprehensive model of landmarks” (p. 129). These researchers identified four elements that contribute to the personal dimensions of landmarks: spatial knowledge, personal interests, personal goals and personal background. The personal dimensions were established with the intention of using them to determine the “landmarkness” or salience of a geographic feature for a unique user. This would allow for different users to consider different features as landmarks, depending on their relevance. Similarly, research undertaken by Srinivas and Hirtle (2006) and Quesnot and Roche (2015) showed that when in familiar environments, users prefer landmarks that have some sort of sentimental value to them.
Franke and Schweikart (2017) also argued the case for a landmark-based navigation system, stating that “the visualization of landmarks on maps optimizes the use of maps for navigation, whereby more landmark objects transfer to long-term memory and the mental map” (p. 105). The importance of landmarks is also highlighted in research by Kiefer, Giannopoulos and Raubal (2014), who found that during successful self-localisation, participants fixated on landmarks on the map for longer and used the landmarks to align themselves in the environment. In addition to this, Röser et al. (2012) found that at decision points, the preferred location of a landmark is the inner angle of a route. In relation to landmarks, Elias, Hampe and Sester (2005) proposed a small screen pedestrian wayfinding system that emphasises landmarks using adaptive visualisation techniques, due to extensive research that suggests that humans prefer to navigate using terms such as “turn left after the hospital” as opposed to “turn left in 300 metres”. They argued that due to the limitations of small visual displays, multiple methods of effectively communicating spatial information need to be developed.

Researchers have identified numerous factors that could contextualise wayfinding activities, including the skills and experience of the wayfinder, the mode of wayfinding, the reason for the activity, and the time of day and weather conditions (Sarjakoski & Nivala 2005). Using these factors, they determined which components of each of these factors related to pedestrian wayfinding. For example, pedestrians are not bound to road networks; they use footpaths and can access walkways that vehicles cannot, so their degree of freedom to move is high, and not all walkways are named in the same way that roads are. Given the pace at which pedestrians move, they also have a greater choice of landmarks. Michon and Denis (2001) revealed that the landmarks pedestrians use include features such as roads, squares, buildings, shops and parks. Identifying these features is useful to determine which kinds of landmarks should be displayed on maps used for pedestrian wayfinding. Extending this research, Elias, Hampe and Sester (2005) noted that colour is a less important attribute of a landmark at night because it cannot be perceived as effectively as in the day. Their system therefore took into consideration the various factors that can influence the degree to which a feature can be considered a landmark depending on the context. Another aspect of their research was the visibility of a feature at the time at which it is indicated on the map.
or in the instructions. To investigate this, they created a digital surface model from laser
data to track the visibility of potential landmarks along a given route. Combining these
characteristics, Elias, Hampe and Sester (2005) proposed highlighting relevant landmarks to
ensure speedy recognition of the landmark in the environment and concurrently
generalising background information. Therefore, the relevant features in the map would be
displayed with higher levels of detail than those features deemed unimportant or not useful
for the purpose of wayfinding.

The research discussed above suggests that it is useful for maps to display salient landmarks
that the user will encounter along their way as well as decreasing the complexity of the map
by only displaying relevant features. This would provide something for the user to look for
while they are moving from one place to another. The solutions described for Finding 1
would also be appropriate for addressing problems identified in this finding. Providing more
effective landmarks, or a simulated direct experience of the route, would give the user
confidence in knowing and understanding their location. Rather than displaying each house
number, it would be better to emphasise more salient features, since they should be more
recognisable, and not all houses have their numbers displayed.

**Key Finding 4: Overlying public transport networks leads to confusion and distraction.**

This finding emerged from the Melbourne case study, in which the underground network of
train lines was depicted on the map. Also included was the boundary of the free tram zone,
and tram routes were depicted by lines overlayed on the roads on which they operated,
making it difficult to notice the roads beneath.

The solution to the issue of the underground train lines is to remove them altogether from
the map. There is no need for tourists to know where the train tracks are located when they
are beneath the street surface. The only feature of relevance is the train station, and train
station access points. Removing the train lines from the map would reduce the clutter of the
map’s contents.
A potential solution for the free tram zone boundary is to change the symbology to make it less distracting, or to enable this feature to be switched off if it is not relevant to the user. The routes of the trams could still be colour-coded as in the Melbourne map, but the lines could be thinner, thereby allowing the road to be clearly visible beneath the tram lines.

**Key Finding 5: Excessively simplified road networks increase the difficulty of pedestrian navigation.**

This finding relates to the design of the road networks on the paper tourist map of Melbourne. This can be overcome easily by using a digital map to display information at different scales. At the smaller scale, the road networks will be simplified, but as the user increases the scale at which they view the map, the complexity of the road networks will emerge, thereby presenting a more accurate depiction of the road configuration. This would assist users in understanding the complex nature of the road network and where it is best to cross a road, or to plan more appropriate routes.

**Other applicable solutions**

According to Schöning, Hecht and Kuhn (2014), online and mobile map systems tend to take a one-size-fits-all approach to their map designs. To overcome the limitations of this, they introduce the concept of location-aware cartography, in which “*the design of a map intelligently adapts to the type of location*” (p. 766). The researchers compared locally made maps to those provided in online environments, and found that the former tended to have better and more relevant information displayed on them. Another finding was that many of the locally made maps deemphasised the areas outside of the areas of interest, whereas online maps did not. Deemphasising areas on the map that are beyond the area of interest causes the map-user to focus more on information relevant to them. Similarly, Zipf and Richter (2002) proposed simplifying map reading by using focus maps, which aim to guide the map-user’s visual attention to the areas of the map that are important to them. This can be done by increasing the cartographic generalisation of the regions beyond the focus area of the map (van Dijk et al. 2013), by fading the colours of the region beyond the focus area (Zipf & Richter 2002), schematisation (Klippel et al. 2005), or by decreasing the map scale of the region beyond the focus area. The idea is that map users will then only focus on the area of the map that is applicable to their task.
Kiefer et al. (2017) proposed using eye tracking to identify the features in a map that are relevant to the user, resulting in the map automatically adapting to the user’s needs. Their research indicates that users prefer being able to initiate the adaptation of the map because it gives them more control. One of the cases in their experiment involved test participants searching for hotels. During the search, the map adapted to fade out all other information displayed apart from hotel icons, causing the contrast between hotels and surrounding information to be greater, and enabling the user to find hotels more easily. This experiment was conducted using a desktop computer, and the maps were not actually able to adapt in relation to eye movements, rather, the map would change based on time, however participants believed it to change based on their eye movements. In theory, this could be an effective technique for assisting map users. However, until mobile devices can interpret a user’s eye movements, or until eye-tracking glasses are compatible with mobile devices, this is currently not a feasible solution to the issues experienced by map-(il)literate users when navigating and wayfinding within a complex urban environment.

Maps can be designed with the primary aim of depicting features as precisely as possible (data driven), or with the primary aim of conveying spatial information to users for the purpose of solving a particular task, in a cognitive conceptual approach (Klippel et al. 2005). Klippel et al. (2005) proposed combining both the data-driven and cognitive conceptual approaches to produce focus maps. They argued that such an approach should reduce the information processing aspect of wayfinding significantly. The wayfinding choreomes fit within the cognitive conceptual approach by highlighting relevant information, while the focus map aspect of the product retains the integrity of the data while simultaneously decreasing the importance of irrelevant information.

As already discussed in Chapter 1, map users can differ in a multitude of ways, one of which is cultural background. Korpi and Ahonen-Rainio (2015) conducted a study of how cultural differences and referent characteristics affect the design of pictographic map symbols. They engaged 75 students from 18 countries in a course called Visualization of Geographic Information. The students designed pictographic symbols for themes including agriculture and forestry, industry, administrative services, health services, social services,
transportation, cultural services, educational services, commercial services, and environmental care. The results of the study suggested that culture strongly influences the choice of referents for pictographic symbols, and therefore, the researchers argued that “culturally independent symbols” (Korpi & Ahonen-Rainio 2015, p. 14) should be designed.

Kettunen et al. (2015) argued that landmarks displayed on maps should change in accordance with temporal and illumination changes due to the variations in visual saliency of landmarks as lighting is increased or decreased (e.g., day versus night or clear skies versus overcast conditions). Sarjakoski and Nivala (2005) and Reichenbacher (2005) suggested a map could show the locations of stores, restaurants and so on which are open at the current time. Using these concepts, a map can be simplified by only displaying content that is relevant to the user at that point in time. Filtering out unnecessary content would encourage users to focus on features that will directly support wayfinding, providing less opportunities for participants to become distracted by irrelevant map features, and potentially reducing the frequency map consultation.

Nowadays, mobile maps can display information that is centred on the user. For example, opening a mapping application on a smartphone often results in the user’s location being positioned in the centre of the map, which in cartography is referred to as the egocentre. Meng (2005) and Reichenbacher (2005) separately extended this notion of the egocentre by including in it the user’s pragmatic and hedonistic requirements. Meng (2005) identified two aspects which contribute to the identification of the egocentre of a map user: location dependence and location independence. Location-independent characteristics include the goal of the user, their personal background (education, age, gender), preferences, habits, visual literacy, spatial cognitive ability, and experience with the device and domain knowledge. These location-independent variables often remain unchanged through the process of wayfinding, but Meng (2005, p. 92) suggested that determining the egocentre of...

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1 Hedonistic requirements refer to those that are subjective and independent of the map itself, e.g., how the user is feeling; pragmatic requirements are objective and refer to those which are measurable and purposeful – they relate to the effectiveness and efficiency of the map itself.
a user accurately “requires a continuous contact with the user in his mobile usage context”. Meng (2005) also posited:

*Depending on the mobile usage context, the ego centre is reflected in various aspects, such as (1) the current user location in form of a point, a route or region of varying size, (2) one or many locations that are currently of interest to the user, (3) data items that are current of interest to the user, (4) actions or operations that are frequently performed by the user, (5) symbolisation styles preferred by the user, and (6) interaction modalities preferred by the user.* (p. 92)

Despite this knowledge and existing technological capabilities, it remains a difficult – if not yet possible – task for mapping systems and devices to be able to adapt to user requirements instantaneously, and for them to change instantaneously should the context change. As a result, Meng (2005) recommended developing scenarios whereby technology can be configured to suit those scenarios, a concept which Reichenbacher (2005) also proposed. Figure 6-2 demonstrates the variables to consider when developing scenarios for adaptive wayfinding.

![Figure 6-2 Context model for mobile cartography (Reichenbacher 2005, p. 145)](image-url)
Meng (2005) and Sarjakoski and Nivala (2005) also recommended consulting with mobile users in the design process in accordance with participatory design principles. The concept of designing maps to conform to the egocentres of map users aligns with the overall aim of this research because, as Meng (2005, p. 102) stated, “map use is always a personal activity”, and as such, maps should be able to deliver tailored and targeted information to a map user in a way that is easy for them to interpret and that facilitates successful wayfinding. Sarjakoski and Nivala (2005) undertook similar research, their aim being to “identify preliminary design principles for maps on small displays” (p. 107) and to “identify the design principles for adaptive maps to be implemented on mobile devices” (p. 109). In representing spatial information on small displays, Reichenbacher (2005, p. 154) posited that “the design should be controlled by the primacy of relevance over completeness”. Because devices like smartphones have such small screens, it is undesirable to include any and all information that may be relevant to any user, as is often done with a paper map. However, the dynamic and interactive capabilities of devices such as smartphones permit flexibility in what is displayed for an individual user or specific context.

Navigation system designs can interfere with the spatial knowledge acquisition of the user (Brügger, Richter & Fabrikant 2017), specifically harming the allocation of attention (Gardony et al. 2013; Koletsis et al. 2017). To investigate how navigation systems could promote spatial knowledge acquisition, Brügger, Richter and Fabrikant (2017) had participants use a navigation system to find their way in an unknown urban environment, and then find their way along the same route without any assistance. The participants were distributed across four groups, each group having a different level of user engagement with the navigation system or environment. The researchers found that those participants who:

... used the navigation system with a higher level of user engagement acquired better spatial knowledge without harming navigation efficiency. Participants who collected their own environmental information simultaneously improved their spatial mental representation during the learning phase. Conversely, those participants whose attention was guided by the navigation system (lower level of user engagement) made significantly more errors in the recall phase. (p. 21)
Brügger, Richter and Fabrikant (2017) did not provide information about the ways in which the levels of user engagement with the navigation system or environment differed between the four groups.

Despite the earth and the environment being 3D spaces, most map products that people use to find their way in the world are provided in 2D form. As such, these representations are depicted at a “scale we cannot directly comprehend” (Hervey, Phillips & Kuhn 2017, p. 63). To understand these representations of the earth and the environment, people use cognitive processes to make sense of the information they see in the map product. Hervey, Phillips and Kuhn (2017) posited that map products would be more useful if they reflected the cognitive scales at which spatial information is stored in the mind. Similarly, Vanclooster et al. (2014); Vanclooster et al. (2013) argued that more intuitive maps result in fewer instances of a map user becoming lost, are easier to interpret and are perceived by map users to be more comfortable. Furthermore, they stated that when routes more accurately reflect the mental structure of the user, cognitive load is minimised. Hence, it is necessary to inform the map design process from a cognitive perspective.

Given the range of possibilities for addressing the five findings of this research, it is preferable to apply solutions that address multiple findings rather than developing individual solutions for each individual finding. Table 6-1 shows which potential design solutions are applicable to each of the findings and was used to select the most appropriate solutions to apply to prototype designs.

From Table 6-1, it is evident that many of the design concepts outlined in section 6.1 could be applied to prototype map designs. Of the 11 design concepts, six offer solutions to problems identified in three or more of the key findings. To be able to effectively implement these solutions, a multi-scale interactive map on a smartphone should be developed and tested.
Table 6-1 Design concepts as they relate to the key findings.

<table>
<thead>
<tr>
<th>Finding Number</th>
<th>Design Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Generalisation of regions beyond the AOI, by creating focus maps</td>
</tr>
<tr>
<td>2</td>
<td>Including context-specific landmarks on the map – only including landmarks that are relevant to the context, for example, landmarks salient at that time of day, and that are located at inner angles of the decision points</td>
</tr>
<tr>
<td>3</td>
<td>Reducing the amount of information on the map to display only what is necessary for a particular user</td>
</tr>
<tr>
<td>4</td>
<td>Simulated direct experience – participants would know what to look for and would be less reliant on knowing street names</td>
</tr>
<tr>
<td>5</td>
<td>Displaying global landmarks on the map – providing global landmarks will help users identify their relative location at all points along the route. This may decrease the need to know street names</td>
</tr>
<tr>
<td></td>
<td>Dynamic labelling using user location and map extents. Street labelling should take precedence over point labelling, when there are no prominent landmarks</td>
</tr>
<tr>
<td></td>
<td>Highlighting relevant landmarks on the map – this will help map users to know which landmarks are relevant to them and their route</td>
</tr>
<tr>
<td></td>
<td>Including user-specific landmarks on the map – landmarks that are salient to the map user are easier for them to remember</td>
</tr>
<tr>
<td></td>
<td>Integrating a haptic feedback system – this would alert users when they are approaching a decision point or are off course, helping them keep their gaze on their surroundings</td>
</tr>
<tr>
<td></td>
<td>Designing culturally appropriate symbols</td>
</tr>
<tr>
<td></td>
<td>Creating stories that represent route directions</td>
</tr>
</tbody>
</table>
6.2 Design Brief

6.2.1 Project Overview and Background

Existing maps used for pedestrian wayfinding in unfamiliar urban environments can be considered insufficient for map-illiterate users. As a result, these users struggle to use maps successfully to find their way when travelling between unfamiliar locations (section 1.1). Developments in the design and function of navigation assistance technologies, such as smartphones, digital maps, 3D geovisualisations, voice guidance, haptic feedback and GNSS means there is potential to create representations of geography that map-illiterate users will find useful. However, first it is necessary to understand the unique challenges map-illiterate users experience when navigating and wayfinding in unfamiliar urban environments. By understanding these challenges, holistic solutions can be provided. Consequently, in this research a design solution was developed to overcome the challenges map-illiterate users experience (as identified in the Enschede and Melbourne case studies).

To develop a design solution, the following steps were performed:

- A review of literature pertaining to map literacy and spatial skill assessments (Chapter 2);
- Establishment of a classification of map literacy and how map-illiterate users can be identified (section 2.5);
- Development of a methodology for and testing of map-illiterate users to discover challenges they experience when using maps for wayfinding (Chapter 3);
- Formulation of solutions to problems identified in empirical studies of map-illiterate user behaviour (section 6.1);
- Development of a conceptual design for a proof-of-concept app for wayfinding by map illiterate users (section 6.2);
- Development of a proof-of-concept app and methodology for testing it (section 6.3); and
- Testing of the proof-of-concept app with map-illiterate users (Chapter 7).
The most important feature of this smartphone app is that the map design was guided by empirical research on map-illiterate users.

6.2.2 User Overview

The key users of the smartphone app are pedestrian map users who experience confusion when using existing wayfinding maps/apps and who cannot utilise them to find their way effectively and efficiently between two unfamiliar urban locations (section 2.2.5). Map-illiterate users want to be reassured that they are following the correct path (section 6.1.3). They will use the app because it displays spatial information in a way that is meaningful and understandable to them (Chapter 4 and Chapter 5).

6.2.3 Functional Requirements

To be effective for this user group, the research findings showed that the application must:

- Display clear routing without affecting the legibility of other information such as road labels (section 6.1.6);
- Display road labels in locations on the map that are useful to the user – not off the screen (section 6.1.2);
- Display points of interest and road labels depending on their salience (sections 6.1.1 and 6.1.2) along the route; and
- Display images of landmarks to increase recognisability and decrease instances of looking at the map, causing environmental features to be missed (6.1.1).

A smartphone app was deemed to be the most appropriate way to satisfy the requirements listed above since more data can be presented at multiple scales, allowing for necessary complexity to be displayed at appropriate scales. Users need the app to be comfortable, clean, and simple. The app should reassure users that they know where they are and where they are going.
6.2.4 Content/data

The main component of the proof-of-concept app needed to be a map that is readable on smartphones. The map had to highlight the route to be followed and include landmarks the users can rely on to orient themselves and assist with decision-making at key points, such as which way to turn. Photographs of these landmarks had to be included so users could familiarise themselves with them before encountering them along the route.

6.3 Proof-of-Concept Smartphone App Development

It was neither technologically feasible, nor appropriate, to integrate all design strategies outlined in section 6.1 into one product. This section discusses the design strategies that were brought together to create a single design solution in the form of a proof-of-concept smartphone app. While none of the design strategies is novel in itself, the combination of design strategies to support map-illiterate users to find their way in unknown urban environments is novel.

Based on the results of the empirical work outlined in Chapter 4 and Chapter 5, design guidelines were developed. These are provided in Table 6-2.

Overall, this design consists of four guiding principles:

1. Detail is added at larger scales;
2. Important features are visually salient;
3. Unnecessary complexity is reduced; and
4. Symbols that support map/environment matching are used.
Table 6-2 Results of empirical work alongside corresponding design solutions.

<table>
<thead>
<tr>
<th>Key Finding</th>
<th>Design Solution</th>
</tr>
</thead>
</table>
| 1. Among those with lower spatial ability scores, frequency of looking at the map was high. This caused participants to miss important environmental features that would assist with wayfinding and spatial knowledge acquisition (section 6.1.1). | • The route between the origin and destination will adhere to the shortest, most reliable path principle so that the number of turns is reduced, and turns are made at the least complex intersections.  
• Limiting the information displayed on the map to relevant and environmentally salient features will limit the interpretation required and encourage the map user to look about their environment.  
• Including photographs of salient landmarks that the user will encounter will familiarise them with the environment, and encourage them to look for the landmarks, rather than too frequently at the map. |
| 2. Street labelling is a source of considerable confusion and frustration for map users; street names were not located in convenient locations on the map, for example at key decision-making locations (section 6.1.2). | • Street name labels should be placed along the road within the visible map extent, rather than somewhere beyond the visible extent. |
| 3. Using house numbers as opposed to larger features such as streets and landmarks was a common method used for self-localisation for those with poor spatial abilities (section 6.1.3). | • Between decision-making locations, salient landmarks should be selected for display on the map, to assist the user in understanding their current location and to reassure them that they are still following the correct route. |
| 4. Overlaying public transport networks leads to confusion and distraction (section 6.1.4). | • Where public transport networks are not relevant to the map user, they should be omitted from the map. |
| 5. Excessively simplified road networks increase the difficulty of pedestrian navigation (section 6.1.5). | • Where complex road networks exist, the data should reflect this complexity at appropriate scales. |
6.3.1 Detail is Added at Larger Scales

Web maps have the ability to display data at 24 levels of detail (zoom levels) from 1:591,000,000 to 1:70 (Buckley 2017). Depending on the size of geographic area for which a map is created, the relevant zoom levels will change. Therefore, it is necessary to design the map at the scales at which the map will be used. For this proof-of-concept app, the map was designed at four scales (Figure 6-3): 1:18,000, 1:9,000, 1:4,500, and 1:2,250.

At **1:18,000**, the entire route is visible on the screen of the smartphone (Figure 6-3, top left). This allows the user to see the overall context in which the route is situated. By seeing the entire route at once, they may be able to better orient themselves, and understand they will be moving in a north-easterly or south-westerly direction (depending on start location) during the wayfinding activity. Point symbols are included for the intersection of Little Bourke Street and Tattersalls Lane and the Royal Exhibition Building; these locations are the endpoints of the route. The route may be traversed in either direction, so both locations act as origin and destination, depending on the start location.

The roads used for the route are symbolised so that they stand out from the rest of the map (section 6.1.6), and the main roads, Lonsdale Street and Spring Street, are labelled. The polygons displayed are the building outlines of the Royal Exhibition Building (origin/destination), Carlton Gardens (the gardens in which the Royal Exhibition Building is located), the building that houses the Royal Australasian College of Surgeons (RACS), and the College of Surgeons Gardens in which the RACS is located (to the East of Spring Street). The Royal Exhibition Building is labelled because it is the origin/destination.

At **1:9,000**, more information is added to the map (Figure 6-3, top right). Point symbols for the salient landmarks – QV Shopping Centre, Touchè Hombre (a restaurant), a traffic light, Wesley Uniting Church, 7-Eleven, Comedy Theatre, and 2 Lonsdale Street – are introduced to provide information to the user about the landmarks they will be looking for (section 6.1.1, 6.1.3).
At \textbf{1: 4,500}, the user can only see portions of the route and needs to be able to pan across the map to reveal more of the route (Figure 6-3, bottom left). More detail relating to features that the user will encounter on their route is included. The point symbols are labelled, so the user can clearly understand what they should look for. Additional streets of interest, such as Exhibition Street, are labelled at this scale (Figure 6-4). The labels are not as bold as the labels for the route because the information is supplementary and should not distract the user from the route (section 6.1.2).

At \textbf{1: 2,250}, building footprints are displayed for each of the landmarks (Figure 6-3, bottom right).
Figure 6-3 Wayfinding app at the four scales clockwise from top-left; 1:18,000, 1:9,000, 1:2,250, 1:4,500
6.3.2 Important Features are Visually Salient

The features selected as landmarks in the proof-of-concept app were based on the landmarks participants used during the wayfinding components of the Melbourne case study (Chapter 5). Since these landmarks had already proved useful to previous participants, they could be considered to be visually salient. In the absence of an empirical study, other researchers’ algorithms for computing visual saliency and therefore selecting appropriate landmarks (Albrecht & von Stülpnagel 2021; Dong et al. 2020; Röser et al. 2012; Takemiya & Ishikawa 2012) could be used to identify suitable landmarks for other routes.

6.3.3 Unnecessary Complexity is Reduced but Necessary Complexity is Retained

To reduce the complexity of the map, the basemap contains only two types of features: roads, and relevant land-use features such as parks and gardens, retail precincts, and education or medical facilities. These land-use features are displayed as polygons and are included in the map for context, and to avoid the impression of a featureless landscape. The polygons are semi-transparent to ensure they do not distract the user from the polygons that are relevant to their route (section 6.1.6).
The data chosen to represent the roads in this location was determined by the character of Melbourne’s road network. The main roads are wide and often have median strips to separate the lanes along which traffic travels in opposite directions (Figure 6-5 and Figure 6-6). Showing this street configuration in the basemap gives the user a good idea of the complexity of the environment. Roads that do not form part of the route should be categorised and symbolised in the same way as those on the route but made semi-transparent to increase visual contrast between the route and surrounding roads (section 6.1.5, 6.1.6).

![Figure 6-5 Photo of Lonsdale Street showing lanes divided by a median strip](image)

The route was designed to stand out from the basemap, thus encouraging the user to focus their attention on the route. This has been achieved by using colour and line weight (section 6.1.6). Only features that are relevant for facilitating the wayfinding between the intersection of Little Bourke Street and Tattersalls Lane and the Royal Exhibition Building are included. These features include the road segments that form the route, salient landmarks the user will encounter along the route, and labels for the roads and landmarks (section 6.1.1, 6.1.6).
To ease navigation in this complex environment, the route highlights which side of the road is optimal for travelling between the intersection of Little Bourke Street and Tattersall’s Lane and the Royal Exhibition Building. Using data that shows the complexities of the road network accurately is especially useful at the intersection of Spring Street and Victoria Parade (section 6.1.5). As described in Chapter 5, this intersection was a source of confusion for one research participant (section 5.10 – Figure 5-14); displaying the data in this manner is likely to reduce the potential for other users to experience the same confusion. The lines that form the route are symbolised according to their class (i.e., highway, main road, minor road), and 100% opacity and greater line widths were applied to the route segments, ensuring they contrast with the roads in the basemap (section 6.1.6).

6.3.4 Symbols that Support Map/Environment Matching are Used

To support map/environment matching, symbols were selected to depict each of the landmarks (QV Shopping Centre, Touchè Hombre, Wesley Uniting Church, 7-Eleven, Comedy Theatre and 2 Lonsdale Street) (Figure 6-7). All landmarks, except for 7-Eleven and the QV shopping centre, were given iconic symbols. 7-Eleven was given a pictographic symbol.
because it is a recognisable and familiar brand to many people (section 6.1.1), while the QV Shopping Centre has a distinct logo that is visible from the point where the user will encounter it along the route. The QV Shopping Centre is also a very large complex, and it is not immediately obvious that the building is a shopping centre due to the many smaller shops located on the exterior of the building. Including the logo in the point symbol provides familiarity with the brand and allows for easier recognition of the shopping centre. The remaining landmarks lack distinct branding, so iconic symbology is more appropriate.

All landmarks, except for Wesley Uniting Church, are located at decision points where the user either needs to change direction (i.e., turn left or right) or continue across an intersection while maintaining the same direction of travel. Wesley Uniting Church, located between Russell and Exhibition Streets, is displayed to ease potential anxiety by providing users with assurance they are proceeding in the correct direction (section 6.1.3). 2 Lonsdale Street is a tall building with an open-air entrance. It stands out due to its shape, and is labelled ‘2 Lonsdale Street’ because it has a simple sign with the address that can easily be read from the opposite side of the street (Figure 6-8). An image of each of the landmarks is accessible to the user by clicking on the corresponding point symbol for the landmark (Figure 6-9). Each image is displayed from a perspective similar to that in which it will be encountered if the user is progressing successfully along the route.

Features that are too large to be shown as point symbols – including the Royal Exhibition Building, Carlton Gardens, and the College of Surgeons Gardens – have been displayed using
polygons. At 1: 2,250, the building footprints for each of the landmarks were introduced to provide extra information to the user about the size and shape of the landmarks (section 6.1.1). 100% opacity was applied to the colours of each of these features to ensure they stand out from other polygon features contained in the basemap (section 6.1.6).
Figure 6-8 Visible signage for 2 Lonsdale Street
6.3.5 Software and Design Procedure

Esri software was used to develop the proof-of-concept app. Specifically, ArcGIS Pro (Esri Inc. 2021a), ArcGIS Online (Esri Inc. 2022b), ArcGIS Experience Builder (Esri Inc. 2022a) and ArcGIS Vector Tile Style Editor (Esri Inc. 2022c) were used to build different components of the app.

The World Street Map (Esri Inc. 2022f) basemap was selected to create the basemap for the app because it had suitable data granularity for the road network and could be customised using ArcGIS Vector Tile Style Editor (Esri Inc. 2022c).
The data for the route was obtained from an official government dataset (Department of Environment, Land, Water and Planning 2021c) and was symbolised using ArcGIS Pro (Esri Inc. 2021a) along with the symbols and building footprints for each of the landmarks.

Labelling for roads and landmarks were developed in ArcGIS Online (Esri Inc. 2022b) and enhanced using ArcGIS Arcade (Esri Inc. 2022d). Arcade provided greater flexibility in the design and placement of labels than the Maplex Label Engine (Esri Inc. 2022e).

Once the map design was completed, ArcGIS Experience Builder was used to create the app that would be used by participants. Additional features to enhance the user experience were incorporated into the app, including:

- A compass;
- Zoom buttons;
- A default view button; and
- A locator button.

Limitations of ArcGIS Experience Builder include the following:

- The map cannot turn according to the direction the user is facing – users must turn the map manually;
- The user’s location is not updated in real time – the user must click the locator button to obtain their current location; and
- A landmark must be selected for an image to be displayed.

**Summary**

This chapter provided the design brief for the proof-of-concept app developed to solve the problems identified in the case studies outlined in Chapters 4 and 5. Using the design brief, a solution was proposed which was then developed into a proof-of-concept app.

Chapter 7 discusses the testing of the proof-of-concept app and uses the outcomes of this study to propose guidelines for the design of a wayfinding solution for use by map-illiterate users.
Chapter 7 – Designing Maps for Map-Illiterate Users in Urban Locations

This chapter describes the strategy used to identify and recruit participants to test the proof-of-concept app. The testing of the app is discussed along with the findings of the study. Finally, guidelines that describe how maps should be designed to enable easier interpretation by map-illiterate users in urban locations are provided.

7.1 Identifying Participants Who are Map-Illiterate

For participants to be considered eligible for this study, they were required to meet the following criteria:

- At least 18 years of age (to provide informed consent in accordance with RMIT University’s College Human Ethics Advisory Network);
- Be map-illiterate (SBSODS score less than 4.0);
- Be unfamiliar with or have limited experience with the study location;
- If they have corrected-to-normal vision, must be able to wear contact lenses; and
- Speak and understand English at the proficiency level of a native English speaker.

A difficult task in this research was to establish whether potential participants could be considered to be map illiterate. In the previous map evaluation activities, participants could only be ranked according to the study population’s spatial ability, using the SBSODS. This means that while it was possible to determine a mean value of the SBSODS scores among the sample populations, it was not known how these scores compared to those of the wider population. Without a mean score for the wider population, it can be difficult to determine where along the spectrum of spatial abilities an individual would fit. Therefore, it is useful to establish a baseline of spatial ability/map literacy, to determine whether potential participants had low enough spatial ability scores to be considered appropriate for
evaluating the new map design. Before recruitment of participants could take place for the map evaluation task, a study was undertaken to establish a baseline of map (il)literacy.

7.1.1 Similar Studies

The SBSODS is commonly used to assess the environmental spatial ability of individuals (section 2.3.1). While many studies have implemented the SBSODS, they have usually drawn on small sample populations. One exception is the study by Montello and Xiao (2011).

Montello and Xiao (2011) investigated the extent to which spatial abilities differ across language and cultural groups. To do this, the SBSODS was translated into three languages: German, Japanese and Mandarin Chinese. 550 university students located in Santa Barbara (USA), Freiburg (Germany), Saarbrücken (Germany), Tokyo (Japan) and Beijing (China) took part in the research. Sense of direction was found to be a common concept among each of the language and cultural groups. The mean SBSODS score across all groups was 4.22 (standard deviation: 1.06).

Ishikawa and Zhou (2020) studied how cognitive mapping in people with a poor sense of direction could be improved. To define participants as having a poor sense of direction, they established an SBSODS score threshold of 4.0, based on the results of the study by Montello and Xiao (2011). While this study administered the SBSODS to a large number of participants, they were all university students. Hence, to accurately estimate the mean SBSODS score among the wider population for the purposes of the current research, it was necessary to conduct an independent study.

7.1.2 Recruitment Process

Participants were recruited via the commercial company Prolific (https://www.prolific.co/), which provides a platform for recruiting participants for scientific research. The critical parameter for determining potential candidates’ eligibility was native speaker-level comprehension of the English language, because the SBSODS was to be distributed in English. It was estimated that at April 2022, the global English-speaking population was
approximately 1.5 billion (Szmidgiera 2022). Therefore, a sample of 385 (Equation 6-1) was needed to ensure the results would approximate those for the global native-English speaking population.

Equation 6-1 Sample Size Calculation

\[
\text{Sample size} = \left(\frac{Z\text{-score}}{(\text{margin of error})^2}\right)^2 \times \left(\frac{\text{StdDev} \times (1 - \text{StdDev})}{\text{Standard Deviation}}\right)
\]

\[
\text{Sample size} = \left(\frac{1.96^2 \times 0.5(0.5)}{0.05^2}\right)^2 = 385
\]

Prolific sent the participants a link to complete the questionnaire (Appendix S), which was published using Qualtrics (Qualtrics 2021). Completion of the questionnaire took approximately 10 minutes, and participants were paid £1.35 (A$2.43, April 2021) to do so. The questionnaire was reviewed and approved by RMIT University’s College Human Ethics Advisory Network and consent was implied by the completion of the survey (Approval #24103, approved 31/03/2021, Appendix T).

7.1.3 Test instrument

The questionnaire comprised the SBSODS, three mental rotation questions, and 10 demographic questions to enable measurement of the diversity of the respondents.

7.1.4 Data Analysis

Data was exported from Qualtrics (Qualtrics 2021) to SPSS 26 (IBM 2021). SPSS syntax for computing the SBSODS scores was obtained from Hegarty et al. (2002).

7.1.5 Results and Discussion

Most respondents were aged between 18 and 34 years, with 47.4% aged between 25 and 34, and 43% aged between 18 and 24 (Figure 7-1). Of all respondents, almost two-thirds identified as male, about a third as female, and 2% of respondents self-identified as neither male nor female or did not want to provide this information (Figure 7-2). The most common country of residence for respondents was Mexico (23.1%) (Figure 7-3). For the highest
completed level of education, nearly half of respondents had completed an undergraduate degree, and more than a quarter had completed a secondary degree (Figure 7-4). Of those who had completed a tertiary degree, computer science was the most common discipline among the respondents, followed by engineering and information technology (Figure 7-5). Finally, the most common occupation among the respondents was “student”, followed by “unemployed” and “software developer” (Figure 7-6).

The demographic information provided above and in the following charts (Figure 7-1 to Figure 7-6), demonstrates that respondents came from a more varied and wide range of backgrounds than those in previous studies. Whilst it would be interesting to use the demographic information to compare SBSODS results across (for example) age groups, levels of education or countries of residence, doing so was beyond the scope of this research project.

The results of the SBSODS were normally distributed and had a mean score of 4.25 (standard deviation: 1.04), consistent with that computed by Montello and Xiao (2011). Therefore, a decision was taken to use an SBSODS score threshold of 4.0, as adopted by Ishikawa and Zhou (2020) to determine eligibility to participate in the proof-of-concept app evaluation. Of the 385 survey respondents, 40.78% were found to score below 4.0 on the SBSODS and could therefore be considered to be map illiterate.
An Alternative Wayfinding Map Design for Map Illiterate Users

Figure 7-1 Percentage of respondents by age

Figure 7-2 Percentage of respondents by gender
Chapter 7 – Designing Maps for Map-Illiterate Users in Urban Locations

Figure 7-3 Percentage of respondents by country of residence

Figure 7-4 Percentage of respondents by highest level of education
Figure 7-5 Most common fields of study among respondents

Figure 7-6 Respondents by occupation
7.2 Testing of the Proof-of-Concept App

7.2.1 Recruitment Process

To evaluate the usability of the proof-of-concept app, a recruitment company, Askable (askable.com), was engaged to find suitable participants. As noted in the previous two studies that formed part of this research, finding map-illiterate participants who were also unfamiliar with the study location was challenging. Using the Askable platform, potential participants were advised of the requirements of the study and were able to register their interest; they were then sent a message via Askable with the link to the Qualtrics (qualtrics.com) survey (Appendix U). Results from this survey were then assessed, and participants who received an SBSODS score below 4.0 and visited Melbourne’s CBD less than once per week were invited to participate in the wayfinding activity (Approval #24085, approved 25/03/2021, Appendix V).

7.2.2 Participant Selection

Participants were selected provided they:

- Were 18 years or older (to provide informed consent in accordance with RMIT University’s College Human Ethics Advisory Network);
- Had normal, or corrected-to-normal vision and wore contact lenses;
- Did not have any physical disabilities that would affect their ability to use a smartphone or move around outdoors;
- Specified that they were at most only somewhat familiar with Melbourne’s city centre; and
- Did not visit Melbourne’s city centre more than 2–3 times per month.

It proved very difficult to find participants with the level of familiarity with Melbourne’s city centre described above, so the criteria were relaxed to include participants with some familiarity. 182 responses were received from people invited to complete the recruitment survey. Of the 182 respondents, 26 (14.29%) received an SBSODS score below 4.0 and were therefore eligible to participate. Due to recurring COVID-19 restrictions, the activity was
postponed on three occasions, and some eligible participants did not wish to participate during periods when high numbers of COVID-19 cases were being reported. Ultimately, the wayfinding activity was completed with 16 participants, but the eye-tracking glasses failed to capture data for two participants, meaning eye-tracking data was collected successfully for 14 participants.

7.2.3 Participant Demographics

Data was collected over four months (December 2021 to March 2022). 14 participants were randomly assigned to either Route AB (n=7) or Route BA (n=7). Route AB participants used the map to walk the predefined route from the corner of Tattersalls Lane and Little Bourke Street to the Royal Exhibition Building. Route BA participants walked the reverse route.

Table 7-1 summarises the participants' demographic data and SBSODS scores in a reorderable matrix (Mengistu 2015), which shows the distribution of participants between the two groups according to their characteristics.
Table 7-1 Participant demographics in the two study groups.

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Age Bracket</th>
<th>Gender</th>
<th>Country of Origin</th>
<th>Occupation Industry</th>
<th>Familiarity with Study Area</th>
<th>Experience in Study Area</th>
<th>SBSOD Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>18-25</td>
<td>Male</td>
<td>Australia</td>
<td>Student</td>
<td>Very unfamiliar</td>
<td>Once a year</td>
<td>1.73</td>
</tr>
<tr>
<td>P3</td>
<td>25-34</td>
<td>Female</td>
<td>Outside of Australia</td>
<td>Unemployed/Retired</td>
<td>Somewhat unfamiliar</td>
<td>Once 10 times per year</td>
<td>3.60</td>
</tr>
<tr>
<td>P6</td>
<td>35-44</td>
<td>Male</td>
<td>Australia</td>
<td>Construction</td>
<td>Very familiar</td>
<td>2-3 times per month</td>
<td>3.73</td>
</tr>
<tr>
<td>P7</td>
<td>45-54</td>
<td>Male</td>
<td>Australia</td>
<td>Human Resources</td>
<td>Somewhat familiar</td>
<td>2-3 times per month</td>
<td>3.80</td>
</tr>
<tr>
<td>P11</td>
<td>55-64</td>
<td>Male</td>
<td>Australia</td>
<td>Marketing</td>
<td>Somewhat familiar</td>
<td>Once a month</td>
<td>3.73</td>
</tr>
<tr>
<td>P14</td>
<td>Above 65</td>
<td>Female</td>
<td>Australia</td>
<td>ICT</td>
<td>Very familiar</td>
<td>Once a month</td>
<td>3.80</td>
</tr>
<tr>
<td>P16</td>
<td>18-25</td>
<td>Female</td>
<td>Outside of Australia</td>
<td>Healthcare</td>
<td>Very familiar</td>
<td>2-3 times per month</td>
<td>3.9</td>
</tr>
<tr>
<td>P4</td>
<td>18-25</td>
<td>Male</td>
<td>Australia</td>
<td>Education</td>
<td>Very familiar</td>
<td>Once a month</td>
<td>2.27</td>
</tr>
<tr>
<td>P5</td>
<td>25-34</td>
<td>Male</td>
<td>Outside of Australia</td>
<td>Hospitality</td>
<td>Somewhat familiar</td>
<td>2-3 times per month</td>
<td>3.3</td>
</tr>
<tr>
<td>P9</td>
<td>35-44</td>
<td>Male</td>
<td>Australia</td>
<td>Construction</td>
<td>Somewhat familiar</td>
<td>2-3 times per month</td>
<td>3.5</td>
</tr>
<tr>
<td>P10</td>
<td>45-54</td>
<td>Male</td>
<td>Australia</td>
<td>Marketing</td>
<td>Very familiar</td>
<td>2-3 times per month</td>
<td>3.1</td>
</tr>
<tr>
<td>P13</td>
<td>55-64</td>
<td>Male</td>
<td>Australia</td>
<td>ICT</td>
<td>Very familiar</td>
<td>2-3 times per month</td>
<td>3.9</td>
</tr>
<tr>
<td>P15</td>
<td>Above 65</td>
<td>Female</td>
<td>Australia</td>
<td>Healthcare</td>
<td>Very familiar</td>
<td>2-3 times per month</td>
<td>2.2</td>
</tr>
</tbody>
</table>

7.2.4 Exercise Development

The route is 1.3 km long and includes six decision points (Figure 6-3). At each of these decision points, the participants need to make a turn or continue in the same direction.

The salience of landmarks may vary depending on the direction of travel because their visibility differs according to direction of travel. To test the sensitivity of the design solution to this situation, two versions of the map application were created to display the route in each direction. The images of each landmark were displayed so that they matched the perspective from which the participants would encounter them along their route. Figure 7-7 shows the photos used for the Comedy Theatre for the Route AB group (left) and Route BA group (right). The ⋆ symbol in each image indicates the locations where each photo was taken from.
Participants were required to follow the route as shown on the proof-of-concept app while wearing eye-tracking glasses and speaking their thoughts aloud (Appendix W). At the end of the activity, participants completed the Post-Test Interview (Appendix X) with the researchers. Participants received A$70 (approx. US$50.74, February 2022) for their participation in the activity, which took approximately 30 minutes, as well as their participation in the screening procedure and preparatory activities (watching a video that demonstrated the app’s functionality).
7.2.5 Equipment

Mobile Eye Tracking

As with the two previous studies, the Tobii Pro Glasses 2 (Figure 4-11) were used during the wayfinding activity (section 4.5.2) to capture the participants’ eye movements and verbalisations.

Smartphone

A Samsung Galaxy S20 smartphone was used to display the proof-of-concept map app and to record GNSS data describing the route taken by the participants using the Runkeeper app.

7.2.6 Pilot Testing

A pilot test was completed in December 2021, involving one participant (P1). Due to the similarities with the two previous studies, the pilot test was successful as most potential problems were anticipated and mitigated, so the pilot data was included in the final dataset.

7.2.7 Wayfinding

The wayfinding activity was scheduled with each of the participants independently via the participant recruitment website. Prior to attending the activity session, participants were emailed a copy of the Participant Information and Consent form to read and asked to return a signed copy by email. A video demonstrating the functionality of the proof-of-concept app was also sent to participants. They were asked to view the video before attending the activity session, and this was confirmed before beginning the activity. For the video demonstration, a map of a different location was used to ensure participants would not have any exposure to the map they would use in the session.

Participants completed the wayfinding activity individually and met the researcher at a location near the beginning of their route. To ensure the safety of the participants and researchers, COVID-19 vaccination certificates were shown to one another before moving to
the start location. At the start location, participants were again shown the main functions of
the application and invited to ask any questions. The researchers then set up the eye-
tracking glasses and performed the calibration. The Runkeeper app was then set to begin
recording GNSS points, and the smartphone was handed to the participant with the map
oriented in the correct direction and the first image loaded in the top left of the screen.
Once participants confirmed that they were comfortable with the equipment and task, they
were told to begin the activity. The researchers followed along behind the participants at a
distance of approximately five metres. The activity was concluded when the participant
stopped and was satisfied that they had reached their target destination. At the conclusion
of the wayfinding activity, the researcher completed the Post-Test Interview with the
participant.

7.2.8 Data Processing

The Tobii Pro Glasses 2 captured the eye movements of participants, video of the
environment as participants encountered it, and participants' verbalisations. To analyse
these data, it was necessary to undertake some data processing. Using Tobii Pro Lab, the
eye movements of participants were manually coded according to Table 4-8. In addition to
the actions outlined in Table 4-8, the timestamps when participants commenced looking at
the map, concluded looking at the map, commenced a voluntary stop, concluded a
voluntary stop, commenced a forced stop and concluded a forced stop were also coded.
Once the coding was completed, the data was exported to Microsoft Excel for further
processing. The amount of time spent looking at the map in each instance was calculated for
each participant, as was the time spent on voluntary stops, and the time spent on forced
stops. The proportions of time spent consulting the map while walking and time spent
consulting the map during forced stops were computed and used in analysis rather than raw
data, because not all participants walked at the same pace nor were all participants forced
to stop for the same length of time at traffic lights. SPSS (IBM 2021) was used to undertake
statistical analysis. The verbalisations recorded by the eye-tracking glasses were transcribed
into Atlas.ti (Scientific Software Development 2020), in which they were coded. The post-
test interviews were also imported into Atlas.ti and coded.
Chapter 7 – Designing Maps for Map-Illiterate Users in Urban Locations

7.3 Results

7.3.1 Map Literacy

As discussed, participants were allocated randomly to either the Route AB or the Route BA group. SBSODS scores for the two groups were examined to determine whether there were differences in map literacy between them. The Shapiro-Wilk test was first used to check for normality. The SBSODS scores of group ROUTE AB ($D(7) = 0.88$, $p = 0.24$) were normally distributed, as were the scores of group ROUTE BA ($D(7) = 0.96$, $p = 0.84$). After testing for normality, SBSODS scores of the two groups were analysed using an independent-samples t-test, which showed that there was no significant difference ($t = -0.91$; $p = 0.39$; $df = 9.44$; $MD = -0.37$; $95\% CI = -1.30$ to $0.55$) between the two groups. Box plots (Figure 7-8) show the distribution of SBSODS scores between the two groups. P17’s SBSODS score (2.2) is an outlier in the Route BA group. The t-test was repeated after removing this outlier, again revealing no significant difference between the mean SBSODS scores of the two groups ($t = -1.38$; $p = 0.21$). This result suggests that any differences in performance between the two groups are not due to differences in map literacy.

![Box plots summarising the distribution of Santa Barbara Sense of Direction Scale scores (SBSODS) for N = 14 participants equally allocated into AB and BA routes. Error bars represent 95% confidence intervals of each distribution. P17 is an outlier.](image)

Figure 7-8
Participants were considered successful if researchers did not have to intervene during the wayfinding activity. Interventions occurred during four route traversals: P6, P7, P10 (Route AB) and P16 (Route BA). Interventions occurred when participants stopped and asked for help because they were confused, or when they made an incorrect decision. Two participants (P6 and P10) received interventions due to confusion, and P7 and P16 when they made incorrect decisions.

The SBSODS scores for the 10 successful participants were compared against those of the four unsuccessful participants. The Shapiro-Wilk test was used to check for normality: the SBSODS scores of the Successful group \(D(10)= 0.99, p= 0.99\) were normally distributed, while the scores of the Unsuccessful group \(D(4)= 0.72, p= 0.02\) were not. Since the Unsuccessful group’s scores were not normally distributed, a Mann-Whitney test (Laerd 2015c) was used to check for differences in SBSODS scores between the groups. The SBSODS scores for the Successful group \(Mdn = 2.97\) did not differ significantly from those for the Unsuccessful group \(Mdn = 3.63, U =14.00, z = -0.849, p =0.45, r =-0.23\). Box plots (Figure 7-9) show the distribution of SBSODS scores for the two groups.
7.3.2 Wayfinding Behaviour Between Routes

It was of interest to determine if the proof-of-concept app would be effective along more than just the initial route for which it was designed (Route AB). Therefore, the route was also tested in the reverse direction and the behaviours of Route AB and Route BA groups were compared. These behaviours were:

(a) The mean time to complete each route direction;
(b) Deviations from the route;
(c) The number of stops made;
(d) Fixations to the map per minute;
(e) Matching landmarks on map with the environment;
(f) Time spent looking at the map in proportion to travel time; and
(g) Number of interactions with the map application.
(a) The mean time to complete each route direction
A gamma regression (Laird 2015c) was used to check for differences in mean time to complete each route. Since this is a measure of time, the results were of a strictly positive magnitude and are better described by a gamma than a normal distribution. The results did not differ significantly ($p = 0.84; 95\% CI = -0.15$ to $0.12$) between the two route directions. Therefore, the effects of map design and landmark selection on travel time were similar in both directions. The box plots (Figure 7-10) show an outlier in each group, P16 (Route AB) and P13 (Route BA), who completed the route in 730 seconds (12.16 minutes) and 689 seconds (11.48 minutes), respectively. After excluding the outliers, the gamma regression was repeated. Again, results did not differ significantly ($p = 0.45, 95\% CI = -0.08$ to $0.04$).

![Figure 7-10 Box plots summarising the distribution of Time to Walk route scores for N = 14 participants equally allocated into the AB and BA routes. Error bars represent 95% confidence intervals of each distribution; P16 (Route AB) and P13 (Route BA) are outliers.]

(b) Deviations from the route
Participants who deviated from the route and asked the researcher for help, or had confidently made an incorrect decision, were redirected back to the previous decision point so they could reorient themselves before continuing along the correct route. Participants received one point for each incorrect decision they made. Using the Mann-Whitney test
(Field 2018), the distributions of scores for the two groups were compared. The number of deviations made by the Route AB group ($Mdn = 0$) did not differ significantly from Route BA group ($Mdn = 0$), $U=24.5$, $z=0$, $p=1.0$, $r=0$. The box plots (Figure 7-11) show the distribution of deviations across both groups was the same.

![Box plots summarising the distribution of number of deviations from route scores for N = 14 participants equally allocated into AB and BA routes. Error bars represent 95% confidence intervals of each distribution.](image)

Figure 7-11

(c) The number of stops made
Participants received one point for each stop made. A stop was recorded when the participant stopped or hesitated for longer than five seconds (Stähli, Giannopoulos & Raubal 2020). These stops were considered to be voluntary, because the participant chose to stop to focus on the map or the environment. These types of stops contrast with involuntary stops, which were stops imposed by traffic lights at intersections. A Poisson regression was performed, which found the results to be overdispersed ($\phi = 2.70$). Therefore, a negative binomial regression was completed, which found the difference in number of stops between the two groups was not statistically significant ($b = 0.69$; $SE = 0.69$; 95% CI = -0.66 to 2.07; $p = 0.31$). The box plots (Figure 7-12) show that P1 (Route AB) was an outlier, stopping on eight occasions. After removing the outlier, the results remained overdispersed ($\phi = 1.85$). A
negative binomial regression was again completed, which also showed no difference between the groups ($b = 0.15; SE = .75; 95\% CI = -1.31$ to $1.62; p = 0.84$).

![Box plots summarising the distribution of Number of voluntary stop scores for N = 14 participants equally allocated into AB and BA routes. Error bars represent 95\% confidence intervals of each distribution. P1 (Route AB) is an outlier.](image)

(d) **Fixations to the map per minute**

Using data collected from the scene camera of the eye-tracking glasses, the fixation rate (number of fixations to the map per minute) was calculated. Fixation rate was used rather than the total number of fixations because walking speed differed between participants; therefore, those who spent more time walking the route had more time to look at the map. The differences between fixation rates of the two groups were analysed using an independent-samples t-test (Field 2018). There was no significant difference ($t = -.94; p = .19; df = 9.05; MD = -.79; 95\% CI = -2.68$ to $1.11$) between the rates at which the groups referred to the map. The box plots (Figure 7-13) show the fixation rate varied more among the Route AB participants than the Route BA participants.
Figure 7-13 Box plots summarising the distribution of frequency of looking at map per minute, scores for N = 14 participants equally allocated into AB and BA routes. Error bars represent 95% confidence intervals of each distribution.

(e) Matching landmarks on the map with the environment

Using data collected from the scene camera of the eye-tracking glasses together with eye fixations, the number of times participants matched landmarks in the environment with those on the map was calculated. A Poisson regression was performed, which found the number of landmark matching events to be overdispersed ($\phi = 3.17$). A negative binomial regression was completed, and did not find a significant difference in landmark matching between the two groups ($b = 0.02; SE = 0.57; 95\% CI = -1.12 \text{ to } 1.16; p = 0.97$). The box plots (Figure 7-14) show that the distribution of landmark matching across the two groups was similar.
(f) Time spent consulting the map was calculated and analysed in two ways: (i) while walking, and (ii) during forced stops. This is because not all participants would be forced to stop for the same length of time at traffic lights.

\[ t = 0.44; \, p = 0.34; \, df = 10.87; \, MD = 1.26; \, 95\% \, CI = -5.08 \text{ to } 7.60 \]

After excluding this outlier, the t-test was repeated. Results did not differ significantly \( p = 0.48; \, 95\% \, CI = -6.04 \text{ to } 5.79 \).
Figure 7-15 Box plots summarising the distribution of the proportion of time participants spent looking at the map while walking for N = 14 participants equally allocated into AB and BA routes. Error bars represent 95% confidence intervals of each distribution. P17 is an outlier in group Route BA.

An independent samples t-test was used to compare the time spent consulting the map during forced stops at intersections with traffic lights between the two groups. It was important to consider whether participants were spending time looking at the map while stopped at traffic lights, since this could influence how much time was spent looking at the map while walking. No significant difference between the two groups was identified ($t = -0.85; p = 0.21; df = 9.28; MD = -3.09; 95\% CI = -11.24 to 5.06$). The box plots (Figure 7-16) show the dispersion of data across both groups. P1 (Route AB) is an outlier, spending considerably less time looking at the map while stopped at traffic lights. After excluding the outlier, the t-test was repeated. Again, the results did not differ significantly ($p = 0.44; 95\% CI = -6.43 to 5.55$).
Figure 7-16 Box plots summarising the proportion of time spent looking at the map during forced stops for N = 14 participants equally allocated into AB and BA routes. Error bars represent 95% confidence intervals of each distribution. P1 is an outlier in group Route AB.

(g) **Number of interactions with the map application**

When users are required to complete several actions (clicking, panning, zooming) before obtaining the information they seek, the system is said to have a “high interaction cost” (Nielsen & Budiu 2013, p. 80). A high interaction cost can lead to user dissatisfaction.

Interactions with the map application (zoom, pan, rotate, locate, landmark selection and route extent) were coded from the scene video captured by the eye-tracking glasses. A Poisson regression (Field 2018) was first run which found the results to be overdispersed ($\phi = 20.63$). Therefore, a negative binomial regression was completed, which found the difference in map-use interactions between the two groups was not statistically significant ($b = 0.11; SE = 0.54; 95\% CI = -0.95 to 1.17; p = 0.84$). Figure 7-17 shows the distribution of map interaction counts between the two groups.
7.3.3 Wayfinding Behaviour of Successful and Unsuccessful Participants

P6, P7, P16 (Route AB) and P10 (Route BA) were deemed to be unsuccessful in the wayfinding activity since they were unable to complete it without intervention from the researchers.

Given that the map was originally designed for Route AB with landmarks chosen because previous study participants fixated on them when walking in that direction, it is interesting that three out of seven participants required intervention along this route, while only one out of seven participants required assistance along Route BA.

P6 was intervened because they continued along Victoria Street, past the entrance into Carlton Gardens as indicated by the map. During the post-test interview, P6 stated that they could not see the path into the Carlton Gardens on the map due to glare on the phone screen.
P7 was intervened because they failed to turn left on to Spring Street from Lonsdale Street; rather, they crossed Spring Street and continued along Lonsdale Street. They had interpreted the landmark symbol for 2 Lonsdale Street as representing Parliament House, which is located on Spring Street, south of the route. The participant had not clicked the landmark symbol to see the image of the landmark, and therefore was unable to match the image with the environment. They had also stated prior to the activity that they normally wear reading glasses (despite having negatively answered a screening question about whether they wore glasses), which may account for not noticing the label either.

P10 was intervened when they stopped due to confusion. The map design indicates which side of the road users should walk along, but some users did not realise this at the beginning. This was particularly noticed with participants in the Route BA group, who – rather than crossing Lonsdale Street before turning right from Spring Street – turned right at the 2 Lonsdale Street landmark. The selected landmarks and their associated images were taken from the perspective of walking on the southern side of Lonsdale Street. This meant that those who proceeded down the northern side did not encounter the landmarks as they were displayed on the app. For P10, this was a source of confusion because they were unable to match any of the landmark photos with the environment. In their post-test interview, they stated that they could not relate to the landmark photographs.

P16 was intervened when they turned left into Exhibition Street. They mistook Exhibition Street for Spring Street. While walking along Lonsdale Street, they panned along the map to see the route ahead, however they failed to pan the map back to their current location. Therefore, they misread themselves as being further along the route than they really were. From the map interaction data, it is evident that they only used the Locator function of the app once at the beginning of the route, which could be why they were unsure of their location. After making the first turn from Tattersalls Lane on to Lonsdale Street, they clicked on landmarks to reveal the images for landmarks that were beyond Russell Street (the next main intersection to be crossed) and therefore skipped the landmark image for the Russell Street intersection. This mistake indicates the need for user location to be updated in real time on the map.
Despite using an anti-glare screen protector, the glare was still distracting for P6. A potential solution would be to increase the contrast of the route with the surrounding road network. P7 did not use landmark images and therefore incorrectly interpreted the symbol for 2 Lonsdale Street. Potential solutions include ensuring the participant understood the function and value of the landmark images, using a different symbol for that feature or dynamically updating the landmark images based on the user’s location and position. P10’s performance could be improved with more use of the app and understanding the importance of crossing to the correct side of the road as indicated by the route, or text/voice guidance could advise users they need to cross the street before turning. P16 would benefit from having their location constantly displayed in real time so they can see their location on the map, thereby reducing the chance they will misread their location.

The explanations provided above about why participants required assistance have no commonalities, therefore the solutions to each of the problems they encountered would likely be different.

To determine whether any different behavioural patterns exist between the Successful and Unsuccessful participants, wayfinding behaviours were again compared as follows:

(a) The mean time for participants to complete their route;
(b) The number of stops made;
(c) Fixations to the map per minute;
(d) Matching landmarks on map with the environment;
(e) Time spent looking at the map in proportion to travel time; and
(f) Number of interactions with the map application;

During the participant recruitment phase, participants were required to provide information about how frequently they visited Melbourne’s city centre. To test if visit frequency affected whether participants were successful in completing the wayfinding activity, visit frequency was included as a covariate in the below analyses.
(a) The mean time for participants to complete their route
A gamma regression was used to determine if the mean time to complete the activity differed between the Successful and Unsuccessful participants. The results did not differ significantly ($p=0.83; 95\% CI=-0.06$ to $0.05$). The box plots (Figure 7-18) show the distribution of times to complete the activity for the Successful and Unsuccessful participants. P13 (Successful) is an outlier, completing the activity in significantly less time than the other successful participants. After excluding P13, the gamma regression was repeated; again, results did not differ significantly ($p=0.56, 95\% CI=-0.55$ to $0.03$).

![Box plots summarising the distribution of time to walk route scores for N = 14 participants allocated into the Unsuccessful (n=4) and Successful (n=10) groups. Error bars represent 95% confidence intervals of each distribution; P13 (Successful) is an outlier.](image)

(b) The number of stops made
A Poisson regression was completed, which showed the counts of stops were overdispersed ($\phi=2.82$). Therefore, a negative binomial regression was performed which did not find a significant difference in number of stops between the two groups ($b=-0.21; SE=0.30; 95\% CI=-0.81$ to $0.38; p=0.49$). The box plots (Figure 7-19) show that P1 and P9 were both outliers in the Successful group, stopping on eight and four occasions, respectively. After removing these outliers, a Poisson regression was run, finding the counts were no longer
overdispersed, and no significant difference was found between the two groups ($b = -0.39; SE = 0.25; 95\% CI = -0.87 to 0.10; p = 0.12$).

![Box plots summarising the distribution of number of voluntary stop scores for N = 14 participants allocated into the Unsuccessful (n=4) and Successful (n=10) groups.](image)

Figure 7-19 Box plots summarising the distribution of number of voluntary stop scores for N = 14 participants allocated into the Unsuccessful (n=4) and Successful (n=10) groups. Error bars represent 95\% confidence intervals of each distribution. P1 and P9 are outliers in the Successful group.

(c) Fixations to the map per minute

An ANCOVA was used to compare the fixation rates between the Successful and Unsuccessful groups, with visitation frequency to Melbourne’s city centre included as a covariate (Field 2018). Fixations of map per minute between each group did not differ significantly, $F(1,11) = 0.00, p = 0.98$, partial $\eta^2 = 0.00$. The box plots (Figure 7-20) show the dispersion of fixation frequencies between the two groups. These results indicate that some of these participants are very nervous and/or lack confidence in their map-reading abilities since they consult the map quite frequently.
Figure 7-20 Box plots summarising the distribution of frequency of looking at map per minute scores for N = 14 participants, Unsuccessful (n=4) and Successful (n=10). Error bars represent 95% confidence intervals of each distribution.

(d) Matching landmarks on map with environment

The number of times participants matched landmarks in the environment with those on the map was compare between the two groups. A Poisson regression was performed, finding the landmark matching counts to be overdispersed ($\phi = 1.70$). Therefore, a negative binomial regression was completed, which did not find a significant difference in number of times the groups matched landmarks on the map with those in the environment ($b = 0.09; SE = 0.27; 95\% CI = -0.43 to 0.61; p = 0.74$). The box plots (Figure 7-21) show the distribution of scores between the two groups.
Chapter 7 – Designing Maps for Map-Illiterate Users in Urban Locations

Figure 7-21 Box plots summarising the distribution of matching landmark scores for N = 14 participants, Unsuccessful (n=4) and Successful (n=10). Error bars represent 95% confidence intervals of each distribution.

(e) Time spent consulting the map: (i) while walking, and (ii) during forced stops.

i. Time spent looking at the map while walking was analysed using an ANCOVA, with visitation frequency to Melbourne’s city centre included as a covariate (Field 2018). Time spent looking at the map while walking did not differ significantly between the two groups, $F(1,11) = 0.34, \ p = 0.57, \ partial \ \eta^2 = 0.03$. The box plots (Figure 7-22) show the distribution of time spent looking at the map while walking for the two groups.
ii. Time spent looking at the map during forced stops was analysed using an ANCOVA, with visitation frequency to Melbourne’s city centre included as a covariate (Field 2018). The time spent looking at the map during forced stops did not differ significantly between the two groups, $F(1,11)= 0.63, p = 0.44$, partial $\eta^2 = 0.05$. The box plots (Figure 7-23) show the distribution of time spent looking at the map while walking for the two groups.
Figure 7-23 Box plots summarising the proportion of time spent looking at the map during forced stops for N = 14 participants, Unsuccessful (n=4) Successful (n=10). Error bars represent 95% confidence intervals of each distribution.

(f) Number of interactions with the map application

A Poisson regression (Field 2018) was performed, finding the counts of interactions to be overdispersed ($\phi = 16.50$). Therefore, a negative binomial regression was completed, which did not find a significant difference in map-use actions between the two groups ($b = 0.27; SE = 0.24; 95\% CI = -0.20$ to $0.74; p = 0.26$). The box plots (Figure 7-24) show the dispersion of map interactions between the two groups. Participants in the Unsuccessful group interacted less with the map, but this difference was not statistically significant.
To determine if any particular map interaction (Table 4-6) had an effect on wayfinding success, the number of times participants interacted with the map were compared between the two groups. One map interaction was found to differ significantly in frequency between the two groups: zooming the map. A Poisson regression (Field 2018) was performed, finding the counts of zooming the map to be overdispersed ($\phi = 9.04$). Therefore, a negative binomial regression was completed, which found a significant difference in zooming the map between the two groups ($b = 0.62; SE = 0.28; 95\% CI = 0.07 to 1.18; p = 0.03$). Box plots (Figure 7-25) show that P4 and P5 are outliers in the Successful group, zooming the map 40 and 35 times, respectively. After removing these outliers, a Poisson regression was run, finding the counts were still overdispersed ($\phi = 9.04$). Again, a negative binomial regression was completed, revealing no significant difference between the two groups ($b = 0.49; SE = 0.31; 95\% CI = -0.12 to 1.10; p = 0.11$).
Figure 7-25 Box plots summarising the number of times participants zoomed the map in or out for N =14 participants, Unsuccessful (n=4) and Successful (n=10). Error bars represent 95% confidence intervals of each distribution. P4 and P5 are outliers in the Successful group.

7.3.4 Verbalisations

As with the case studies (Chapter 4 and Chapter 5), verbalisations were recorded with the microphone of the eye-tracking glasses and transcribed. Atlas.ti (Scientific Softare Development 2020) was used to code the verbal data using categories such as cardinal direction, confusion, positive comment, negative comment, street name and landmark. From this coding, the number of times each measure was verbalised was calculated. Table 7-2 provides a list of the verbal codes and samples of each.
Table 7-2 Samples of verbalised statements with corresponding codes

<table>
<thead>
<tr>
<th>Verbal Code</th>
<th>Sample of coded statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardinal direction</td>
<td>Okay, so we're going South, I assume south from the Royal Exhibition Building</td>
</tr>
<tr>
<td>Confusion</td>
<td>So, if I'm trying to work out where I am, I can't work out where I am here</td>
</tr>
<tr>
<td>Negative comment</td>
<td>...the blue dot is still behind the Cathedral. So, I could see that tripping me up.</td>
</tr>
<tr>
<td>Positive comment</td>
<td>Yeah, that's pretty cool. It gives me a still snapshot of whatever the point of interest is on the map</td>
</tr>
<tr>
<td>Street Name</td>
<td>So, we can see we'll pass two lanes and then the third left will be Tattersalls</td>
</tr>
<tr>
<td>Landmark</td>
<td>So, I can see that the Church is there that I can look for a little bit later on</td>
</tr>
</tbody>
</table>

Figure 7-26 shows the total number of verbalisations in each category for the Route AB and Route BA groups. One member of the Route BA group verbalised cardinal directions. Confusion was expressed on more occasions by members of the Route AB group, as were Negative and Positive comments. The Route BA group verbalised street names on more occasions than the AB group, however the AB group verbalised landmarks more often.
Since the map was designed using salient landmarks for Route AB, it is unsurprising that participants in the Route AB group relied on them more than group Route BA. Likewise, it is reasonable that participants in the Route BA group relied more on street names because the landmarks were less salient for the Route BA group, particularly for those who travelled down the northern side of Lonsdale Street. The route was designed to show participants that they should travel down the southern side of Lonsdale Street, because it was on this side of the road that the landmarks were most visually salient and corresponded to the perspective at which the landmark photos were captured.

Figure 7-27 shows the distribution of verbalisations between successful and unsuccessful participants. A factor of 2.5 was applied to all verbalisations in the Unsuccessful group, to account for having 2.5 times fewer participants than the Successful group. From this graph it is evident that the unsuccessful participants did not verbalise street names, verbalised landmarks less frequently than successful participants, and verbalised confusion and negative comments more than the successful group. Participants in the Unsuccessful group may have not verbalised street names due to not being at the correct scale to see them. As indicated in Figure 7-27, participants in the Unsuccessful group used the zoom function of the map significantly less than those in the Successful group.
7.3.5 Post-Test Interviews

A post-test interview was completed by asking participants to score the map against four criteria and to provide feedback on how they felt about the map. This questionnaire was the same as that provided in the Enschede and Melbourne case studies (sections 4.9.4 and 5.11.4).

(a) The first four questions asked participants to score the map on a scale of 1 to 5 according to:
   i. How easy did you find the product to use?
   ii. How satisfied were you with the product for the purpose of navigation and wayfinding?
   iii. How comfortable did you feel using the map to find your way?
   iv. How satisfied were you with the amount of time it took you to find your way from the origin to the destination?

(b) The next three questions were open-ended questions:
   i. What did you like about the map?
   ii. What didn’t you like about the map?
   iii. How could the map be improved?

(a) The mean score of each question was computed for each group. Figure 7-29 summarises the results of each of these questions between Route AB and Route BA groups. The scores for each question were similar across the two groups, with the overall mean scores being 4.14 for Route AB and 4.18 for Route BA, showing that the two groups perceived the usability of these maps similarly.
Figure 7-28 summarises the results of each of these questions between the Successful and Unsuccessful groups. The scores for each question were lower for the Unsuccessful group, with the overall mean scores being 4.33 for the Successful group and 3.75 for the Unsuccessful group. An independent samples t-test was used to compare the overall mean scores. No significant difference between the two groups was identified ($t= 1.47; p= 0.22; df = 13.77; MD= 0.58; 95% CI= -0.53 to 1.68$).
The three qualitative questions revealed the following insights:

i. What did you like about the map?
The most common feature participants liked about the map were the landmarks and their corresponding images. P1 commented that they liked the landmarks because they allowed them to split the route into smaller segments. P6 stated that they liked the lanes of the roads being shown as split lanes, so they knew which side of the road they should walk on. P3 said the route was clear and easy to follow, therefore supporting the decision to use the shortest and least complex route (Table 6-2). P4 mentioned that they also liked that they could see the start and end locations of the route, and that they could choose how to orient the map by rotating it themselves.

ii. What didn’t you like about the map?
The most common complaint was that the “blue dot” (the GNSS-enabled icon which showed user location on the map) did not update in real time. This was a comment made across both route groups and both un/successful groups. The next most common comment was that the landmark images were too slow to load. This is evident also in the voluntary
stopping behaviour of participants, because waiting for images to load was the most common reason for stopping. Members of the Route BA group also made comments about the lack of street names, which supports the findings of the verbalisation data, which showed that Route BA group relied more heavily on street names than landmarks.

iii. How could the map be improved?

The most common suggestion for improving the map was for the “blue dot” to update in real time, followed by faster loading of the landmark images. P6, who was unsuccessful in walking Route AB, suggested that better contrast between the route and other roads, adding arrows at turning points and including verbal instructions would support their wayfinding. P16, who was also unsuccessful in walking Route AB said they would have liked some more landmarks and street names. P11, who walked Route AB successfully, suggested improvements to the landmark photos would be helpful, since some of the landmarks were blocked by trees in the photos. P15, who walked Route BA successfully, suggested that having the map rotate to correspond with the direction of travel would be helpful, and P17, who walked Route BA successfully, said they would have found finding their way easier if it had been clearer that they should cross to the other side of Lonsdale Street when turning right at Spring Street.

The paper map study in Melbourne asked participants the same map scoring questions. Using these responses, the scores obtained using the Route AB map can be compared to those obtained using the paper map. In the paper map study, participants only walked in one direction between the two locations, beginning at the intersection of Tattersalls Lane and Little Bourke Street, therefore comparisons with the Route BA score cannot be made.

Figure 7-31 shows the mean scores for each question for the Paper Map and Route AB groups, normalised to account for the difference in participants numbers between the two studies: Paper Map (N= 10), Route AB (N= 7).
The overall score for the paper map was 4.06. While this score is similar to that for the proof-of-concept app, it is noted that the participants in the paper map study had a higher mean SBSODS score and were reasonably familiar with the study location. Therefore, these factors may partially account for the relatively high score of the paper map. SBSODS scores between the Route AB and Paper Map groups were analysed using an independent-samples t-test, which showed there was no significant difference between the two groups (t = -1.81; p = 0.09; df = 13.99; MD = -1.01; 95%CI = -2.20 to 0.19). The box plots (Figure 7-32) show P3 is an outlier in the Paper Map group with an SBSODS score of 1.27. After excluding this outlier, the t-test was repeated, resulting in a significant difference between the two groups (t = -2.74; p = 0.02; df = 12.6; MD = -1.32; 95%CI = -2.37 to -0.28), with the Paper Map group having a significantly higher SBSODS score.
7.3.6 Discussion of Findings

Route Direction

Analyses of behaviours for the two direction groups, Route AB and Route BA, were completed to determine if the proof-of-concept app designed for one direction could be implemented for the reverse direction. Statistical analysis indicated no significant differences in performance between the two groups. Therefore, it can be concluded that even when the map is designed for one route direction, it is likely to be usable for the reverse route.

The verbalisation data analysis found that the Route AB group relied more on landmarks, and the Route BA group relied more on street names. This is a logical finding, because the landmarks were selected based on previous traversals along Route AB (Melbourne paper map case study). Route BA participants remarked during the post-test interview that too few street names were labelled in the map. Since it is known that those on the reverse
route relied more heavily on street names than landmarks, it could be beneficial to include more street names on the map.

Of the seven Route BA participants, just two correctly crossed at Spring x Lonsdale Street and of the five that did not cross, two became confused. Since five failed to understand that they should cross to the other side of Lonsdale Street from Spring Street, this action should be indicated more clearly in the map design.

**Wayfinding Success**

Analyses were completed to identify whether differences in behaviour existed between participants who successfully (n= 10) completed the wayfinding activity and those who were unsuccessful (n= 4). After controlling for visitation frequency to Melbourne’s CBD, one measure – the number of times participants zoomed in/out of the map – returned significantly different results.

The Unsuccessful participants were found to have significantly under-utilised the zoom function of the map, and therefore would have missed important information such as labels and building footprints for the landmarks, because additional information is added as the scale increases. Analysis of the verbal data confirmed that those in the Successful group used landmarks far more often than did the Unsuccessful group. The Unsuccessful group did not verbalise any street names, indicating that their reliance on street names was minimal.

Of the unsuccessful participants, three were in Route AB group, and these participants travelled along the southern (correct) side of Lonsdale Street. Therefore, they encountered the landmarks as intended. P6 successfully found their way along Lonsdale Street, faltering only when they reached the entrance to the Carlton Gardens. P7 did not use the landmark images and therefore failed to turn left at Spring Street, after misinterpreting the symbol for 2 Lonsdale Street for Parliament House, which is also a salient landmark in the Melbourne CBD. P16 mistook their location on the map early in the activity and therefore turned left along Exhibition Street, rather than Spring Street. The errors these participants made suggest that having their location displayed and updated in real time on the map would
provide the additional support required to successfully find their way. For those in the Route BA group, walking down the northern side of Lonsdale Street meant that unless they crossed to the southern side at a different intersection, they would not encounter any of the landmarks from the intended perspective. This was the case with P10, who became disoriented because the landmark images they were looking out for did not correspond with what they saw in the environment. In this instance, it may have been useful to provide more labels for street names to counterbalance the more limited support provided by the landmarks. A potential technical solution would be to have a range of images available in the application, and from the user’s location and position, the most appropriate image could be displayed for a given landmark.

Post-Test Interviews

Qualitative analysis of the post-test interviews revealed common themes in what participants found to be positive and negative aspects of the map design. The feature most frequently commented on was the locator button. Participants who mentioned this feature spoke about how they would have preferred the “blue dot” to update in real time and track their position on the map without having to press the button. Another feature participants remarked on was that the map did not automatically rotate to face the correct direction. The confusion participants experienced is evidence to suggest that including these functions would benefit map-illiterate users.

When remarking about the landmarks and their corresponding images, most participants commented that they found these landmarks to be very helpful, but many commented that the images were too slow to load. Only one participant (P10) remarked that they did not find them to be relatable (as discussed above).

7.3.7 Limitations

This experiment was completed during dry and sunlit conditions, and therefore it is not known if this solution would be effective at night, or during adverse weather events. As noted in the previous studies, the eye-tracking glasses were unable to collect eye movement
data during the entire activity due to changing lighting conditions. Where possible, the activities were scheduled at times when sunlight would be less intense, such as in the morning, but this was not always achievable. Reflection from the screen of the smartphone, and the position at which participants sometimes held the smartphone meant the screen was not always visible in the scene camera of the eye-tracking glasses. This means that participant interaction with the map was not always visible. A potential solution for this would be to record the screen of the smartphone using a screen recording app and aligning the times of the video from the screen recording of the smartphone with the times of the video from the scene camera. This would allow for map interactions to be more accurately coded in the video of the scene camera.

When recruiting participants, familiarity and experience in the study location could not always be controlled for to the desired degree. Travel restrictions imposed as a result of the COVID-19 pandemic meant that tourists could not visit Melbourne and therefore only local residents were able to participate. Therefore, all participants had at least some degree of familiarity with the Melbourne CBD. Finding sufficient participants with an acceptable SBSODS score often meant there was a trade-off with familiarity or experience in the study location, although this was minimised as much as possible.

Despite all participants being sent the same instructional video on how to use the app, confusion about the functions of the application was common. It would have been beneficial to have the participants demonstrate their competency in using the app prior to beginning the activity. This would have ensured competency with the features and functions and reduced the potential for confusion.

The grid-like layout of the road network in Melbourne’s CBD may have influenced the results of this study. It would therefore be useful to undertake the same study in a location with an irregular road network.

7.4 Guidelines

Guidelines are provided for basemap design and route design.
7.4.1 Basemap Design

The data chosen to represent the roads of a given location will depend on the complexity of the area. In complex locations, road data should reflect that complexity by displaying lanes that are divided (e.g., by a median strip) and complex road intersection geometries accurately. Using single lines in complex environments can cause confusion for the map user (section 5.12). Roads that do not form part of the route should be displayed using the same categories and colours as those that do, but some transparency should then be applied to ensure the route contrasts with the surrounding roads. Maintaining road categories (e.g., highway, main road, laneway, or by amount of traffic) provides additional context and supplementary information about the characteristics of the roads, which may provide additional wayfinding support.

Features such as parks and gardens, retail precincts, education or medical facilities should be included in the basemap for context and to avoid the appearance of a featureless landscape (section 6.1.1). The symbology of features that the user will not encounter directly in the environment should match that of features that will be encountered, but some transparency should be applied to reduce their visual salience.

For non-route roads, labels should only be displayed for those that the user will encounter, such as roads at intersections (section 6.1.2). These labels should be lower in the visual hierarchy than the labels for roads that form the route since they are secondary to the route and should not draw the user’s attention away from the route. The proof-of-concept app did not include labels for all streets that were encountered, however given the reliance on street names by the participants in Route BA group (section 7.2.7), and the feedback provided in the post-test interviews, labels should be included for all streets users will encounter.

7.4.2 Route Design

The route must attract the user’s attention. This can be achieved using colour, line weight, or patterns/texture (section 6.2).
Only data that is relevant in facilitating wayfinding along the route should be included. For example, displaying landmarks on the map that are not visible to the viewer while they are travelling along the route should be avoided. Such features will distract the user’s attention away from the route they need to follow (section 6.2).

In addition to removing point features that are not visible from the route, it is important to limit the visible features, even though the user will encounter them. Too many point features may pull the user’s attention back to the map too often, causing them to miss important environmental cues (section 6.1.1). Rather, salient landmarks should be displayed on the map at decision-making locations, such as when the user needs to change direction – that is, turn left or right, or continue across an intersection while maintaining the same direction of travel (section 6.1.3). In this way, the content of the route on the map is similar to the manner in which route information is stored in a user’s cognitive map (Jonsson 2002). To reassure users of their location, salient landmarks should also be included along stretches of the route between decision-making locations.

Images of the landmarks should be accessible to the user. The user should be able to click on the symbol for a given landmark and see a picture of the landmark from a perspective similar to that from which they will encounter it (section 6.2.4). Ideally, the images would capture the landmark at the same time of day the user is accessing the map for less effortful image–environment matching. While most participants responded positively to the inclusion of landmark images in the proof-of-concept app, a main concern was the time it took for images to load, which often caused participants to stop walking while they waited. Therefore, it is important to ensure that images can load quickly, so as not to disrupt the user’s wayfinding.

If opposing lanes are divided (e.g., by a median strip or car parking), the road carriageway adjacent to the footpath the user will be travelling on should be selected for the route. This will encourage the user to walk along the most suitable side of the road, ensuring they encounter the landmarks from the correct perspective. Like the roads of the basemap, the
lines that form the route should be symbolised appropriately, for example, according to their class (highway, main road, minor road, etc, or other relevant category). Symbolising the roads in this way will give the user additional information about the roads they will encounter. The route should have 100% opacity, and its line should have a heavier weight than the corresponding roads in the basemap, to ensure it stands out to the user (section 6.2). In testing the proof-of-concept app, P10 and P17 (Route BA) experienced confusion because they did not realise they should have crossed to the southern side of Lonsdale Street from Spring Street until later in their route traversals. Therefore, when a route is designed to specify the most appropriate side of the road to travel along, it is important that this is clear. If an intersection should be crossed prior to changing direction, an arrow or crossing symbol could be added to the map to further encourage the user to cross to the other side of the road.

Features that are too large to be shown as point symbols, such as large buildings and gardens, should be displayed as polygons, but only when the map is displayed at a suitable scale. These polygons should be symbolised so that they are visually salient and contrast with the basemap polygons that will not be encountered by the user. This may be achieved using colour, a patterned fill, labels, or a combination of these (section 6.1.6). Displaying the shape of the feature can assist the user to match the map feature with the environment (section 6.2).

When the user views the initial overview of the route, the only features that should be labelled are the origin and destination, and the main roads that form the route (section 6.1.2). Additional landmark and street name labels should be introduced as the user zooms in on the map. Labels for major roads should appear at smaller scales, before labels for minor roads are introduced at larger scales (6.2). Labels for roads should also be displayed within the visible extent of the map and at decision points (section 4.10) to ensure the user does not have to pan away from the route and their location on the map to find the label. Labels for route segments should be more visually salient than those for non-route segments; this can be achieved using font size, weight, colour, and transparency (section 6.1.6). Landmark labels should be introduced at scales that allow for appropriate label
placement so that they do not obscure street name labels. Displaying too many labels at once may overwhelm the user and create label conflicts (section 6.1.2).

Results from the proof-of-concept app study (section 7.2.7) show that users expect to have their location displayed and constantly updated on the map at all times, and seeing their location on the map provides reassurance about their location and can reduce the risk of making a mistake at a decision point. Therefore, inclusion of an icon depicting the user’s location via GNSS, such as the blue dot used by Google Maps, is a necessary feature in modern wayfinding solutions. It is noted, however, that in the presence of urban canyons with poor GNSS signal visibility, heavy reliance on a locator icon could have the opposite effect, and increase the risk of users making a mistake. Hence, it is important to have multiple sources of information such as landmarks and street names so the user can triangulate the information on the map with the environment to confirm they are making the correct wayfinding decision. Since the map must be designed at multiple scales, it is also necessary to ensure users can zoom in and out of the map and pan their way along the route.

**Summary**

Using the findings from the two case studies, and the subsequent evaluation of the proof-of-concept app, this chapter provided guidelines for how wayfinding maps should be designed for map-illiterate users in urban locations. Chapter 8 outlines the main conclusions of this research and shows how the research questions were answered. Finally, it provides recommendations for future research.
Chapter 8 – Conclusion

A summary of the main findings from the three studies conducted in this research is provided in this chapter. The research questions and their outcomes are presented, and finally, opportunities for further research are proposed.

8.1 Summary of Main Findings

This research produced five main findings.

1. Sources of ambiguity in existing map designs for map-illiterate users

The maps used in the studies presented in this thesis contained several sources of ambiguity for map-illiterate users, the most common being the placement of street name labels. In digital maps on mobile devices, street names were often placed beyond the extent of the screen, requiring users to pan and zoom to find a label which contributes to the keyhole problem (Haig 2019; Willis et al. 2009). The keyhole problem refers to the use of a small screen to view a larger map. Only through zooming and panning, can users view all information displayed on the map. As such, the information required to make a decision at a given location should be represented within the current display of the map.

The paper map confused participants with its inconsistent label placements; some labels were placed on the road, while others were placed alongside them. This led participants to confuse them with labels for other features. On the paper map, complex road networks were highly generalised and did not provide sufficient information for map users to be able to navigate at complex intersections (section 5.11). These sources of ambiguity led map-illiterate users to look at the map too frequently and therefore miss important environmental cues such as signs, that would support their wayfinding. Designers of maps for map-illiterate users must consider and address these sources of ambiguity.

2. Features needed to support map-illiterate users when wayfinding

Map-illiterate users like to know exactly where they are in geographic space at all times. During the digital map study, the location services were switched off so participants would
need to rely on the design of the map and features within the environment to determine their location on the map. Map-illiterate users performed self-localisation, looking at the map, more often than map-literate users. Since self-localisation is a frequent action performed by map-illiterate users, it is important to include a YAH locator symbol of the user’s location on the map. Being able to see their location on the map supports map-illiterate users in understanding their location and aids in decision-making. To further support map-illiterate users when wayfinding, photos of landmarks from the perspective in which the landmarks will be encountered should be included in the map design. Photos of landmarks give map-illiterate users some familiarity with them prior to directly encountering them in the environment. This familiarity assists with matching features on the map with those in the environment, and provides map-illiterate users with confidence that they are following the route correctly. In addition, only labelling roads users will encounter, and placing the labels within the extent of the screen prevents users from panning the map to find the relevant road name, or from being distracted by labels that are not relevant to them. The proof-of-concept app limited the number of labels for intersecting roads on the map, however it was found that users sought labels on other intersecting roads also, and that this would be particularly useful for users traversing the reverse route, since the roads, rather than the landmarks are more relevant to them.

3. Classification of map illiteracy

To appropriately evaluate maps designed for map-illiterate users, research participants representative of this user group need to be identified. Using the SBSODS, data was collected from 385 English-speaking participants via an online platform. The mean score of participants’ spatial ability was 4.25, consistent with results reported by Montello and Xiao (2011). To be considered map illiterate, a respondent must score below 4.0. Of the 385 participants who completed the SBSODS, 40.8% scored below 4.0 and can be considered to be map illiterate, suggesting that map illiteracy affects a substantial minority of the wider population.
4. **Maps can be designed to support map-illiterate users**

Providing map-illiterate users with a map that has been designed to overcome their particular set of challenges supports successful wayfinding. The proof-of-concept app successfully supported most participants to find their way between two locations. For those who were unsuccessful, the reasons were varied, but additional functions could be added to the map’s design to support these users. Most of the participants who evaluated the proof-of-concept app found the landmarks and their corresponding images to be valuable components of the application. Likewise, most participants expressed a desire to have their location displayed on the map and updated in real time. This sentiment was also supported by the results of the behavioural measures, which indicated that confusion and mistakes often occurred due to participants being unsure of their location within the map. Therefore, developers of future wayfinding solutions for map-illiterate users should include a location icon that updates in real-time.

Reducing the complexity of the map can also encourage users to focus on features that are relevant to their task. Reducing complexity can be achieved by limiting the features displayed in the map, which was done in the proof-of-concept app by only displaying landmarks at decision points, and between stretches of route where a landmark is useful to confirm to the user they are following the correct path. Reducing complexity by limiting the features displayed on the map supports findings by Wilson, Bertolotto and Weakliam (2010) who developed a prototype GIS which ‘personalised’ the map content according to the user by omitting irrelevant features in the map, and assessing task completion efficiency. Testing of the prototype GIS with participants \(N=20\) found that those who had their maps ‘personalised’ completed tasks much faster than those whose maps displayed all features.

5. **Choosing an optimal route between two locations can be used to support wayfinding in the reverse direction**

Comparison of the two wayfinding groups in the proof-of-concept app study showed that users can wayfind with similar levels of success in both directions along a route, despite the landmarks having been chosen for their salience from the perspective of unidirectional travel. This implies that the app design is capable of wider implementation than would be
8.2 Research Questions and Outcomes

Research Question 1: What is map literacy?
This question was answered by investigating various definitions of the term “literacy” (section 2.1), particularly as it applies to interpreting graphical information. While definitions of “map literacy” have been proposed in previous studies (Clarke 2003), they were insufficient for this specific purpose. This research focused on using maps for wayfinding purposes within the environment, therefore a definition for “map literacy” as it applies to this scenario was required. The investigation of definitions relating to literacy resulted in a definition of map literacy being used for this research:

*the ability to use wayfinding maps to walk from an origin to a destination in an efficient and satisfying way.*

Research Question 2: What methods already exist to measure map literacy?
Several methods that measure people’s spatial and map reading abilities exist. Five methods were reviewed (section 2.3), and the research found that the Santa Barbara Sense of Direction Scale (SBSODS) was the most appropriate method to use to establish the map literacy level of a user. The SBSODS has a particular focus on spatial abilities at an environmental scale (Hegarty et al. 2002) and is found to be particularly appropriate for measuring one’s ability to perform self-localisation (Hegarty et al. 2006; Ishikawa et al. 2008). Since being able to successfully perform self-localisation is a fundamental activity during wayfinding, those who are poorly skilled at this would struggle to use maps to find their way. Therefore, the SBSODS was deemed to be an effective measure of map literacy as defined in this study, and could be used to determine eligibility to participate in this research.

Research Question 3: How can an individual be identified as map (il)literate?
An empirical study was completed to establish a baseline of spatial ability (section 7.1). 385 people completed the SBSODS via the online platform Prolific. The results of this study (mean: 4.25; standard deviation: 1.04) were consistent with those of a similar study by Montello and Xiao (2011) whose population was less diverse, but had a larger sample size (N = 550; mean SBSODS 4.22; standard deviation: 1.06). Ishikawa and Zhou (2020) used the results of the study by Montello and Xiao (2011) to determine that a score below 4.0 reflected poor spatial ability. Since the results of this empirical study were consistent with those of Montello and Xiao (2011), the threshold established by Ishikawa and Zhou (2020) was adopted and a person was deemed to be map illiterate if their SBSODS score was below 4.0. Therefore, in future studies looking to identify map-illiterate participants using the SBSODS, a score below 4.0 can be adopted.

**Research Question 4: How can the challenges that map users encounter when using maps for wayfinding be determined?**

This question was answered by observing participants while they completed route-planning and wayfinding activities in an urban environment using a digital map (Chapter 4) and a paper map (Chapter 5). Participant behaviour was measured using eye-tracking glasses and having participants speak their thoughts aloud while completing the activities. These methods generated rich data that provided insights into the behaviours of these participants. The eye-tracking glasses provided a non-invasive method for collecting participants gaze data, so features participants looked at during the activities could be identified. The concurrent think aloud technique provided additional information about what participants were thinking while they were completing the activities. These techniques have been applied in similar studies (Giannopoulos, Kiefer & Raubal 2015; Keil et al. 2020; Kiefer, Giannopoulos & Raubal 2014).

**Research Question 5: What wayfinding behaviours do map-illiterate map users exhibit?**

In the digital map study (Chapter 4), map-illiterate users looked frequently at the map, causing them to miss important environmental features that would assist with wayfinding and spatial knowledge acquisition, and used house numbers as opposed to larger features such as streets and landmarks for self-localisation.
In the paper map study (Chapter 5), participants with poor spatial abilities performed self-localisation more frequently than those with better spatial abilities.

**Research Question 6: Which map elements are sources of ambiguity for map-illiterate users?**

In the digital map case study (Chapter 4), labelling of street names was found to be a source of ambiguity. Labels for road names were not located in convenient locations on the map (e.g., at key decision-making locations); this required participants to pan the map until the road label appeared. After finding the road label, participants were then required to find their location on the map once more. This led to participants becoming confused about their location on the map.

In the paper map case study (Chapter 5), the following map elements were sources of ambiguity:

1. Labels for road names were applied inconsistently to the map, leading to confusion and frustration for some participants;
2. Public transport information that was not relevant to the users was distracting and led to confusion in some participants; and
3. Some of the road network had been excessively simplified and did not reflect its real-world complexity, particularly at intersections participants needed to cross.

**Research Questions 7: How best can wayfinding maps be designed to work with the compromised abilities of map-illiterate map users?**

A proof-of-concept app was developed to overcome the challenges map-illiterate users experience, as identified in the empirical case studies outlined in Chapter 4 and Chapter 5. Testing of the app found that when provided with a map that addressed their particular set of challenges, most map-illiterate users were able to find their way successfully. Evaluation of the proof-of-concept app provided additional insights into features sought by map-illiterate users. For example, most participants commented on the lack of YAH symbol updating in real time, and the omission of many of the intersecting street names in the map.
was also a common complaint. From the case studies in Chapter 4 and Chapter 5, and the subsequent experiment to evaluate the proof-of-concept app (Chapter 7), map design guidelines were developed that prescribe the design requirements for wayfinding maps for map-illiterate users in urban locations.

8.3 Future Research

The outcomes of these studies highlighted several opportunities for future research related to placement of road labels, the selection of salient landmarks, landmark density and map complexity, and the degree of spatial knowledge acquisition from this map design.

Placement of road labels in the mobile app (Chapter 4), and paper map (Chapter 5) was a consistent source of frustration for users. This was addressed in the proof-of-concept app in Chapter 6, resulting in the finding that with appropriate label placement, map users are less likely to experience confusion from poorly placed road labels. To rectify this in the app, the road labels had to be manually placed at each scale, to ensure that users would always see the relevant road labels within the extent of the screen. There would be great benefit in improving the automation of label placement for road names to ensure that map users do not need to pan or zoom the map to find this information.

The landmarks selected for display in the proof-of-concept app were based on those used by participants in the paper map study (Chapter 5). However, researchers could use salience models (Albrecht & von Stülpnagel 2021; Dong et al. 2020; Röser et al. 2012; Takemiya & Ishikawa 2012) to identify suitable landmarks for different routes and locations. While most participants in the proof-of-concept app study completed the activity successfully, it could be useful to determine how different or additional landmarks would affect the ability of map-illiterate users to find their way. For example, is there an ideal density of landmarks/map complexity that should be displayed? Do map-illiterate users find certain types of landmark characteristics more useful than others? Some research suggests that increased map complexity can improve memory performance, however this is a non-linear relationship whereby there appears to be a threshold at which increased complexity can deteriorate memory performance (Bestgen et al. 2017; Edler et al. 2014). Conversely,
Wilson, Bertolotto and Weakliam (2010) found task completion times were significantly reduced when irrelevant features were omitted from a map. Therefore, it would be worthwhile pursuit to investigate how changing the density of landmarks displayed in the map, and therefore the map complexity affects wayfinding by map-illiterate users. If an optimum density can be identified, whereby memory performance is enhanced and task completion time is reduced, users may spend less time looking at the map, increasing their opportunities to notice environmental cues, and acquire spatial knowledge. By identifying minimum and maximum density landmark thresholds future wayfinding solutions could ensure they display only the information needed to support map-illiterate users. Another potential method for reducing map complexity could be to base the display of features on a user’s previous experience. Schmid (2008) proposed map features could be displayed according to the user’s familiarity with a location, where familiar segments of a route could display less detail and detail could be emphasised along unfamiliar segments.

The landmarks selected for display in the proof-of-concept app were based on wayfinding during daytime hours when the landmarks were illuminated by sunlight. Another avenue of research would be to assess these landmarks and the proof-of-concept app for their suitability to support wayfinding at night.

Evaluation of the proof-of-concept app was undertaken in a mid-sized city with a regular road network. Therefore, it would be useful to evaluate this design in locations with different geographic characteristics to ascertain how this design could be applied to different locations. Additionally, the evaluation of the app was completed with participants who had some degree of familiarity with the study location. As such, it would be beneficial for this design to be evaluated by participants who have not previously visited the study location to determine if the map design is also useful for people in completely unfamiliar locations.

Assessing the spatial knowledge acquired after using the proof-of-concept app was beyond the scope of this research, but it would be beneficial to understand whether this tool is also effective in promoting the acquisition of spatial knowledge in map-illiterate users. Some
studies have found that use of GNSS-enabled wayfinding systems can lead to reliance on such solutions and a decline in spatial memory, thereby reducing people’s ability to find their way independently (Dahmani & Bohbot 2020; Willis et al. 2009). Therefore, while this research found that map-illiterate users want to have their location displayed on the map at all times, the inclusion of landmark photos may help these users to remember the route they followed, and allow them to develop a cognitive map of the route (Haig 2019).

The study completed to define a threshold of map literacy suggests that a not insignificant proportion of the population struggle with interpreting maps for wayfinding. 40.78% of respondents scored below 4.0 on the SBSODS, classifying them as map-illiterate. Repeating a similar study would be worthwhile to validate these findings.

The efficacy of this map design could be further evaluated by assessing wayfinding performance of map-literate users (defined by an SBSODS score of 4.0 and above). The results could be compared to those obtained in the study in Chapter 7, to determine if this map design results in comparable wayfinding abilities between these two groups.

For this map design to be implemented and applied to real-world maps, street name label placement algorithms require improvement whereby labels are placed within the extent of the screen, and close to the user’s position on the map. Shortest most reliable path or similar algorithms could be used to determine the most suitable route for map-illiterate users. Salience models could then be used to identify suitable landmarks, and photos of these landmarks could be acquired from online image hosting services. These solutions could be integrated with existing wayfinding solutions as a way of increasing their usability. Map-illiterate users could be identified by having users complete the SBSODS, and depending on their score, the wayfinding solution could be adapted to display the map in the most appropriate way.

8.4 Findings

This research demonstrated that identifying the challenges that map-illiterate users experience can assist the design of wayfinding solutions that support these users
successfully in an urban location. Improvements in the design are still required, for example, including an icon that indicates the user’s location on the map in real-time, improving the speed at which landmark images are displayed, including information/symbols to indicate the correct side of the road the user should travel along, and including labels for all intersecting roads. This map design is by no means the definitive design for all map-illiterate users; some users may wish to have, and benefit from, additional features such as verbal instructions, to have more/fewer landmarks displayed. It does, however, create a starting point from which additional design elements can be incorporated and evaluated. The outcomes of this research highlight the need to continue reviewing map designs for different user groups. The map-literacy threshold study found 40.78% of respondents were map-illiterate. If this statistic is indeed representative of the wider population, there are many people struggling to find their way on a regular basis, and therefore significant work should be done to address this gap by developing suitable wayfinding solutions for these map-users.

While many studies involving people with different spatial abilities have been completed, their aims have been to identify gaps in skill or knowledge, and to improve the skills/knowledge of such people. In this research, the focus was on how to best design a wayfinding map for this user group, rather than teaching them to use wayfinding maps in their current forms.

**Summary**

This chapter summarised the main findings of this thesis and showed how the research questions were answered, and outlined suggestions for future research into the design of maps/wayfinding solutions for map-illiterate people.


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Appendix A1: Santa Barbara Sense of Direction Scale

SANTA BARBARA SENSE-OF-DIRECTION SCALE

This questionnaire consists of several statements about your spatial and navigational abilities, preferences, and experiences. After each statement, you should circle a number to indicate your level of agreement with the statement. Circle "1" if you strongly agree that the statement applies to you, "7" if you strongly disagree, or some number in between if your agreement is intermediate. Circle "4" if you neither agree nor disagree.

Questions to reverse code in bold.

1. I am very good at giving directions.
   strongly agree 1 2 3 4 5 6 7 strongly disagree

2. I have a poor memory for where I left things.
   strongly agree 1 2 3 4 5 6 7 strongly disagree

3. I am very good at judging distances.
   strongly agree 1 2 3 4 5 6 7 strongly disagree

4. My "sense of direction" is very good.
   strongly agree 1 2 3 4 5 6 7 strongly disagree

5. I tend to think of my environment in terms of cardinal directions (N, S, E, W).
   strongly agree 1 2 3 4 5 6 7 strongly disagree

6. I very easily get lost in a new city.
   strongly agree 1 2 3 4 5 6 7 strongly disagree

7. I enjoy reading maps.
   strongly agree 1 2 3 4 5 6 7 strongly disagree

8. I have trouble understanding directions.
   strongly agree 1 2 3 4 5 6 7 strongly disagree

9. I am very good at reading maps.
   strongly agree 1 2 3 4 5 6 7 strongly disagree

10. I don’t remember routes very well while riding as a passenger in a car.
    strongly agree 1 2 3 4 5 6 7 strongly disagree

11. I don’t enjoy giving directions.
    strongly agree 1 2 3 4 5 6 7 strongly disagree

12. It’s not important to me to know where I am.
    strongly agree 1 2 3 4 5 6 7 strongly disagree
Appendix A2: Santa Barbara Sense of Direction Scale

13. I usually let someone else do the navigational planning for long trips.
   strongly agree 1 2 3 4 5 6 7 strongly disagree

14. I can usually remember a new route after I have traveled it only once.
   strongly agree 1 2 3 4 5 6 7 strongly disagree

15. I don't have a very good "mental map" of my environment.
   strongly agree 1 2 3 4 5 6 7 strongly disagree
Appendix B1: Functional Map Literacy Test

Functional Map Literacy Test as obtained from (Clarke 2007, pp. 182-186)

<table>
<thead>
<tr>
<th>a) Identify a symbol(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify a single symbol on the map, with its characteristics (size, shape, colour, orientation, etc.), using a symbol legend (that is, match it to the legend).</td>
</tr>
<tr>
<td>Identify symbol groupings and their characteristics.</td>
</tr>
<tr>
<td>Interpret the meaning/concept of the symbol; and relate the symbol to the referent phenomena (in the real world); and infer knowledge from the symbol.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>b) Search for a particular symbol(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Given a single symbol, locate an occurrence of this symbol on the map (that is, find it on the map).</td>
</tr>
<tr>
<td>Locate a grouping of symbols, or associated but not identical symbols on the map.</td>
</tr>
<tr>
<td>Search for the location of an occurrence of a real-world phenomenon on the map.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>c) Discriminate between different symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discriminate between two colour/pattern areas on a thematic map (e.g. different soil types on a soil map).</td>
</tr>
<tr>
<td>Discriminate between colours/patterns on a multi-phenomena thematic map (e.g. soil and rainfall and slope).</td>
</tr>
<tr>
<td>Interpret the relationship between different symbols/patterns.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>d) Describe the phenomena represented by a symbol(s) / pattern at a location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Describe a single symbol (phenomenon) at a location (relate the representation by the symbol to the real world).</td>
</tr>
<tr>
<td>Describe a grouping of symbols (phenomena) at a location.</td>
</tr>
<tr>
<td>Describe the phenomenon at a location.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>e) Orientate a map</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientate the map with North at the top.</td>
</tr>
<tr>
<td>Orientate the map in a specified direction – North not at the top but at any direction.</td>
</tr>
<tr>
<td>Orientate the map so that it corresponds with the surrounding landscape.</td>
</tr>
</tbody>
</table>
### Appendix B2: Functional Map Literacy Test

**f) Understand the scale of a map**

- **Basic understanding of the meaning of scale of a map.**
- **Full understanding of map scale.** Have an appreciation of the meaning of various map scales, and use the scale bar to measure distances.
- Determine the scale of a map from ground measurement or from the coordinate grid on the map, and relate information from maps of different scales.

**g) Determine direction / bearing**

- **Basic understanding of the meaning of direction/bearing and the cardinal (main) points of the compass.**
- **Determine the direction between two points** (e.g., point A is NW of point B, or the direction from C to D is 90° - relative to north).
- **Measure the direction between two points using the graticule (latitude, longitude lines) or grid.**

**h) Navigate a route**

- **Navigate from a given start point along a simple given route.**
- **Navigate from a given start point along a more complex given route.**
- **Search for the optimum route between the start and end points.**

**i) Describe the topography/ terrain of a location/area**

- **Determine elevation (height) from the contours on a map.**
- **Analyse the topography of an area from the contours; and calculate the slope/gradient between two points.**
- **Interpret and infer knowledge of the topography of an area (including landforms and slope).**

**j) Discern/explain patterns of occurrence of phenomena**

- **(Not applicable at the entry level).**
- **Analyse the occurrence (spatial location) of a phenomenon.**
- **Explain/infer knowledge from the occurrence of phenomena.**
### Appendix B3: Functional Map Literacy Test

<table>
<thead>
<tr>
<th>k) Compare the characteristics of symbols/patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make a simple comparison between two symbols/patterns from their characteristics.</td>
</tr>
<tr>
<td>Make comparisons between more complex symbols/patterns from their characteristics.</td>
</tr>
<tr>
<td>Infer knowledge from the comparison between more complex symbols/patterns from their characteristics.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>l) Interpret/infer knowledge from the spatial interrelationship of symbols/phenomena</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Not applicable at the entry level). Analyse/interpret the spatial relationship between adjoining or nearby symbols/phenomena (why do they occur next to each other).</td>
</tr>
<tr>
<td>Interpret/infer knowledge from the spatial relationships between symbols/phenomena in a region.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>m) Determine the coordinate/geographical position of a place on the map</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Not applicable at the entry level). Determine a grid square on a map using the grid locator (e.g. A6).</td>
</tr>
<tr>
<td>Determine the co-ordinate of a point from the grid ((X,Y)) or gacticule (lat., long.) on the map.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>n) Locate a place/position on the map from its coordinates/geographical position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Given the grid square ((C5)) of a point, locate its position on the map.</td>
</tr>
<tr>
<td>Given the geographical coordinate ((lat., long.)) of a point locate its position on the map.</td>
</tr>
<tr>
<td>Given the grid coordinate ((X,Y)) of a point locate its position on the map.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>o) Determine the distance between two positions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use the scale bar to measure the distance between two points.</td>
</tr>
<tr>
<td>Measure the distance between two points using a scale rule.</td>
</tr>
<tr>
<td>(Not applicable at Level 2).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>p) Determine the area (extent) of a region</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Not applicable at the entry level). Estimate the area (extent) of a region/polygon.</td>
</tr>
<tr>
<td>Calculate the area (extent) of a region/polygon.</td>
</tr>
</tbody>
</table>
Appendix B4: Functional Map Literacy Test

<table>
<thead>
<tr>
<th>q) Determine the length of a linear feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Not applicable at the entry level)</td>
</tr>
<tr>
<td>Estimate the length of a curvilinear symbol (line).</td>
</tr>
<tr>
<td>Measure the length of a curvilinear symbol (line).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>r) Understand the map projection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic understanding of elementary characteristics of a map projection (representation of the Earth on a flat surface introduces distortions).</td>
</tr>
<tr>
<td>Understand characteristics and differences between map projections (equal area, equidistant, conformal).</td>
</tr>
<tr>
<td>High level of understanding of map projection, and transform/convert coordinates of points/lines from one projection to another.</td>
</tr>
</tbody>
</table>

Appendix C1: Spatial Thinking Ability Test

Spatial Thinking Ability Test

(A)

BASELINE - July 2013
Appendix C2: Spatial Thinking Ability Test

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Question #9 and #10 are adapted from Albert and Gallego (1999)

This test has been modified from the original with permission for use in Rwanda.

This test is intended for use in the Innovation for Education project known as "Promoting spatial thinking in natural resource management through community mapping: the case of urban and rural secondary schools of Rwanda" by project partners: the Rochester Institute of Technology (RIT); the Rwanda Environmental Conservation Organization (RECOR); and the Centre for Geographic Information Systems and Remote Sensing at the National University of Rwanda (CGIS-NUR).
Appendix C3: Spatial Thinking Ability Test

Questionnaire

Student: Please fill out all items below:

1. Family Name:
   Given Name:
   ID Number:

2. Gender: □ Female / □ Male

3. What is your grade level?
   Senior 4 □
   Senior 5 □
   Senior 6 □

4. What is the name of your school?
   Groupe Scolaire Officiel de Butare □
   Groupe Scolaire Officiel Filipe Neri □
   Groupe Scolaire Officiel de Kalutare □

Test Administrator Only: Please assign an IFE ID to the student who just completed the test using the following format:

School code + number.

School Codes:
Groupe Scolaire Officiel de Butare = B
Groupe Scolaire Officiel Filipe Neri = F
Groupe Scolaire Officiel de Kalutare = K

Example: The first student from Groupe Scolaire Officiel de Butare would have an IFE ID of B1, the second would have an IFE ID of B2

IFE ID: ____________________________

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Appendix C4: Spatial Thinking Ability Test
Appendix C5: Spatial Thinking Ability Test

**DIRECTIONS:** Answer questions 1 and 2 on the basis of the street map below.

![Street Map Diagram]

1. If you are located at point 1 and travel north one block, then turn west and travel three blocks, and then turn south and travel two blocks, you will be closest to which point (circle one choice below)?
   
   (A) 2  
   (B) 3  
   (C) 4  
   (D) 5  
   (E) 6

2. If you are located at point 1 and travel west one block, then turn left and travel three, then turn west and travel one block, and then turn right and travel four blocks, you will be closest to which point (circle one choice below)?

   (A) 2  
   (B) 3  
   (C) 4  
   (D) 5  
   (E) 6
Appendix C6: Spatial Thinking Ability Test

DIRECTIONS: For question 3, refer to the map below that shows annual precipitation in Africa.

3. If you draw a graph showing change of African annual precipitation between A and B, the graph will be ______.
Appendix C7: Spatial Thinking Ability Test

Question 4: Find the best site for a flood management facility based on the following:

**Condition A.** The site must be within 50 meters of an existing electric line.

**Condition B.** The site must be located less than 220 meters elevation.

**Condition C.** The site must be located in a Park or Public Land.

*Your response: Circle the best site (A–E) for the flood management facility on the map to the right.*

*Final Answer – circle one site on this map.*

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Appendix C8: Spatial Thinking Ability Test

DIRECTIONS: For question 5, imagine you are standing at location X, as shown in the image below, and are looking in the direction of A and B.

Among 5 slope profiles (A-E) below, which profile most closely represents what you would see (circle one option below)?

(A)  
(B)  
(C)  
(D)  
(E)  

Circle one option.
Appendix C9: Spatial Thinking Ability Test

DIRECTIONS: Your job is to identify maps that have spatial correlations. For example, in the figure below map (B) and map (D) have positive correlation (similar patterns).

6. Circle one of the maps below (A–F) having a strong positive correlation with the map on the right.

Circle one of the maps above to answer question 6.
Appendix C10: Spatial Thinking Ability Test

DIRECTIONS: The following two maps show (A) Hectares of maize production and (B) Value of pigs as percent of total market value of agricultural products sold.

Legend
Lowest Value

A

B

7. If you draw a graph showing the relationship between map (A) and (B), the graph will be. (circle one of the graphs below)

(A)  (B)  (C)  (D)
Appendix C11: Spatial Thinking Ability Test

DIRECTIONS: Question 8. If you look at the area below in the direction of the arrow, which terrain view below (A–E) most closely represents what you would see (circle one choice)?

(A)  

(B)  

(C)  

(D)  

(E)  

Circle one of these views that most closely matches the image above in terms of the terrain view from the arrow.
Appendix C12: Spatial Thinking Ability Test

Directions: Solve questions 9 and 10 based on the examples below. Please mark (✓) for your answer.

Examples

9. ( ) A and B  ( ) A or B  ( ) A xor B  ( ) A not B  ( ) B not A
(select one)

A
B

= □

10. A or B

A
B

(check one option below that represents the outcome of the A or B operation of the two shapes shown in question 10 above)

( )  ( )  ( )  ( )  ( )
Appendix C13: Spatial Thinking Ability Test

DIRECTIONS: Solve questions 11 and 12 based on the following diagram.

11. (not B) and D (check one option below that represents the outcome of this operation)

12. A and B and C (check one option below that represents the outcome of this operation)
DIRECTIONS: Real world objects can be represented explicitly by point, line (arc), and area (polygon). Based on these examples:

<table>
<thead>
<tr>
<th>Point</th>
<th>Line</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>Arc</td>
<td></td>
</tr>
<tr>
<td>Ex. trees, road intersections, poles in distribution networks.</td>
<td>Ex. roads, rivers.</td>
<td>Ex. the area extent of a city, an area of a continent.</td>
</tr>
</tbody>
</table>

Select what type of objects (point, line or area) would be represented in questions 13-16.

13. Locations of weather stations in Raboau District (circle one choice).
   (A) Lines  
   (B) Area 
   (C) Points and Lines 
   (D) Points and Area 

   (A) Lines  
   (B) Area 
   (C) Points and Lines 
   (D) Lines and Area 

15. Route of an intercity bus line (circle one choice).
   (A) Points  
   (B) Area 
   (C) Points and Lines 
   (D) Points and Area 

16. Places that can be reached by a fire brigade in 5 minutes or less (circle one choice).
   (A) Points  
   (B) Lines 
   (C) Area 
   (D) Points and Lines
Appendix D1: Geospatial Thinking Scale

Geospatial Thinking Scale

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Email: n.huynh@aag.org

Appendix D2: Geospatial Thinking Scale

Questionnaire

1. Gender:  □ Female  □ Male

2. Age:

3. Have you ever taken a Cartography, Geographic Information System (GIS) or Remote sensing course?
   □ Yes  □ No

4. How often do you use Geographic Information System (GIS) such as Arcview or ArcMap at home or at school?
   □ Never  □ A few times  □ Frequently
Appendix D3: Geospatial Thinking Scale

Question 1

Task 1: A map will be shown to you for 20 seconds. You are asked to learn as many details as possible.

At the end of 20 seconds, draw and label as many locations as you remember on Figure 1 below.

Figure 1: Replication of locations

Appendix D4: Geospatial Thinking Scale

Question 2

An infectious outbreak has been identified by the Health Department in the Region of Waterloo. The outbreak is identified by the ‘X’ symbol while residential areas are indicated as black circles.

Task 1: Please identify directly on Figure 2 the possible infection area if the disease can spread up to 300 Km from the outbreak.

![Figure 2: Infectious outbreak](image_url)

Task 2: Explain the term ‘buffer’ as used in geography.

Task 3: Select a term below that best describes the relationship between increasing distance from the outbreak source and decreasing risk of infection:

a) Nearest Neighbour  
b) Frame of reference  
c) Spatial hierarchy  
d) Distance Decay  
d) Spatial organization
Appendix D6: Geospatial Thinking Scale

Question 3

Answer the next three questions by referring to Figure 3 below.

Task 1: Which mountain has the steepest slope overall?

a) A   b) B   c) C   d) D   e) E

Figure 3: Mountains and Elevation


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Appendix D7: Geospatial Thinking Scale

Task 2: You are standing at the peak of mountain C looking south. Name in clockwise order the other mountain(s) you can see:

a) A, D, B  
b) B, D, A  
c) D, A, B  
d) C, A, D  
e) A, B

Task 3: Circle five (5) term(s) that best describe the spatial relationship(s) between features A, B, C and D.

<table>
<thead>
<tr>
<th>Above</th>
<th>Below</th>
<th>Distributed</th>
<th>Over</th>
</tr>
</thead>
<tbody>
<tr>
<td>Along</td>
<td>Beside</td>
<td>Down</td>
<td>Parallel</td>
</tr>
<tr>
<td>Among</td>
<td>Bottom</td>
<td>Far</td>
<td>Patterned</td>
</tr>
<tr>
<td>Apart</td>
<td>Buffer</td>
<td>Inside</td>
<td>Peripheral</td>
</tr>
<tr>
<td>Area</td>
<td>Centre</td>
<td>Intersect</td>
<td>Proximal</td>
</tr>
<tr>
<td>Around</td>
<td>Classify</td>
<td>Isolated</td>
<td>Random</td>
</tr>
<tr>
<td>Arrangement</td>
<td>Clustered</td>
<td>Linked</td>
<td>Tangent</td>
</tr>
<tr>
<td>Aspect</td>
<td>Connected</td>
<td>Network</td>
<td>Top</td>
</tr>
<tr>
<td>Away</td>
<td>Contour</td>
<td>Next</td>
<td>Towards</td>
</tr>
<tr>
<td>Bearing</td>
<td>Coordinates</td>
<td>Node</td>
<td>Under</td>
</tr>
<tr>
<td>Behind</td>
<td>Direction</td>
<td>Outside</td>
<td>Up</td>
</tr>
</tbody>
</table>

Appendix D8: Geospatial Thinking Scale

Question 4

Answer the next three questions by referring to Figure 4 below.

Task 1: You start at location 8 in the city map (Figure 4). You begin to travel north one street intersection, turn right one intersection, turn south four intersections and turn left one intersection. You will be closest to location:

a. 1  
b. 2  
c. 3  
d. 4  
e. 5

Figure 4: City Map


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Appendix D9: Geospatial Thinking Scale

Task 2: Estimate the TOTAL distance traveled in Task 1:

a) 1000 m  
b) 2000 m  
c) 3000 m  
d) 4000 m  
e) 5000 m

Task 3:  
You start at location 3 in the city map (Figure 4). You travel west one street intersection, south four intersections, east two intersections, south one intersection then east one intersection. You will be closest to location:

a. 1  
b. 2  
c. 3  
d. 4  
e. 5
Question 5

Trees in the province of British Columbia, Canada have undergone severe attack by a type of beetle, the Mountain Pine beetle.

Figure 5 shows the regions of British Columbia that are being attacked by the Mountain Pine beetle.

Figure 6 shows the different types of Pine trees in the same area.

Task 1: Shade in Figure 6 the largest region infected by the Mountain Pine beetle.
Appendix D11: Geospatial Thinking Scale

Task 2: Explain how you identified this area.

Task 3: Estimate the TOTAL size of beetle infestation across the whole area:

a) 100 Km$^2$  b) 300 Km$^2$  c) 500 Km$^2$  d) 700 Km$^2$  e) 900 Km$^2$
Appendix D12: Geospatial Thinking Scale

Task 4: On a summer’s day, you are looking for a campsite on which to spend the evening. The campsite must have the following characteristics:

1. Within 3 Km of a road (Figure A)
2. Within 1 Km of a water source (Figure A)
3. At least 5 Km away from any infested region (Figure B)
4. At least 5 Km away from the tree type Whitebark Pine, as there is a fire warning for the duration of your camping trip (Figure C)

Circle the campsite (1, 2, 3, 4 or 5) in Figure 7 below that is most desirable based on the criteria outlined above.

Legend
- Road
- River

Appendix D13: Geospatial Thinking Scale

Circle the campsite (1, 2, 3, 4 or 5) that is most desirable based on the criteria outlined above.

![Possible camp sites](image)

*Figure 7: Possible camp sites*

Task 5: In point form, please describe how you arrived at the answer above.


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Appendix D14: Geospatial Thinking Scale

Question 6

Task #1: Circle the diagram that represents a large-scale map:

A

B

C

D

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Appendix D15: Geospatial Thinking Scale

Task #2: Map A has a scale of 1: 20 000 000. Select a scale that would best describe Map B.

A

B

a) 1: 200
b) 1: 2000
c) 1: 20 000
d) 1: 200 000
e) 1: 2 000 000

Appendix D16: Geospatial Thinking Scale

Question 7

Task 1: The distribution of settlement areas in Kitchener, Ontario is displayed in Figure 8 below.

From the terms shown below, identify five (5) that best describe the spatial pattern of residences (Figure 8).

- Above
- Along
- Among
- Apart
- Area
- Around
- Arrangement
- Aspect
- Away
- Bearing
- Behind
- Below
- Beside
- Bottom
- Buffer
- Centre
- Classify
- Clustered
- Connected
- Contour
- Coordinates
- Direction
- Distributed
- Down
- Far
- Inside
- Intersect
- Isolated
- Linked
- Network
- Next
- Node
- Outside
- Over
- Parallel
- Patterned
- Peripheral
- Proximal
- Random
- Tangent
- Top
- Towards
- Under
- Up

Figure 8: Settlement Areas

Appendix D17: Geospatial Thinking Scale

Question 8

Real world objects can be represented in a computer by a point, a line (arc) and an area (polygon). Representative examples of these shapes are demonstrated below.

Examples

<table>
<thead>
<tr>
<th>Point: used to define a particular location in space.</th>
<th>A point represents anything that occupies a fixed location (x, y) such as: a tree, a mining site etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Point" /></td>
<td></td>
</tr>
<tr>
<td><img src="image2" alt="Point" /></td>
<td></td>
</tr>
<tr>
<td><img src="image3" alt="Point" /></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Arc or Line: used to define a length that is straight or curved, connected by points.</th>
<th>A line represents anything that occupies space with a length (but no width) such as: road, river etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image4" alt="Arc" /></td>
<td></td>
</tr>
<tr>
<td><img src="image5" alt="Arc" /></td>
<td></td>
</tr>
<tr>
<td><img src="image6" alt="Arc" /></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Polygon: used to define a closed area formed by a line(s) and points.</th>
<th>A polygon represents an area such as: pond, city, country.</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image7" alt="Polygon" /></td>
<td></td>
</tr>
</tbody>
</table>

Based on the idea of point, line and polygon, answer the following questions.
Appendix D18: Geospatial Thinking Scale

Task 1: Figure 9a best represents this type of object:

a) Lakes  b) Roads  c) Houses  d) Insects  f) Neighbourhoods

Figure 9a

Task 2: Figure 9b best represents this type of object:

a) Lakes  b) Roads  c) Houses  d) Insects  f) Neighbourhoods

Figure 9b

Appendix D19: Geospatial Thinking Scale

Task 3: Figure 9c best represents this type of object:

![Figure 9c](image)

- a) Lakes
- b) Roads
- c) Houses
- d) Insects
- e) Neighbourhoods
Answer the next three questions by referring to Figure 10A-E below.

Task 4: Identify the diagram that best represents schools ( ) that are completely within a neighbourhood.

a) A  b) B  c) C  d) D  e) E

Figure 10A-E

Suggested citation: Niem Tu Expertise, Journal of Geography, 112:1, 3-17.

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Appendix D21: Geospatial Thinking Scale

Task 5: Identify the diagram that best represents the intersection of roads and schools:

a) A           b) B           c) C           d) D           e) E

Task 6: Identify the diagram that best represents schools which are within a distance of a park:

a) A           b) B           c) C           d) D           e) E

Appendix D22: Geospatial Thinking Scale

Task 7: You are looking for campsites that are found:

1. in a provincial park and
2. close to lakes and
3. close to wetlands

Select from each pair of diagrams the sequence that would best solve the task.

Legend

- Campsites
- Lakes
- Park
- Wetland

Pair 1: A, B
Pair 2: C, D
Pair 3: E, F


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Task 8: In point form, please describe how you arrived at the answer in Task 7 above.
Question 9

Task 1:

Identify the two maps that have a strong positive spatial correlation (i.e. exhibit similar patterns).


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Question 10

Task 1:
Select the correct pair of latitude and longitude reading:

a) 100° 25' N, 160° 50' W  
b) 72° 50' N, 65° 30' S  
c) 17° 25' S, 200° 45' W  
d) 23° 45' S, 61° 30' W  
e) 158° 45' E, 125° 30' W

Task 2:
The city of Kitchener is located at coordinates 43° 26' N, 80° 30' W. You travel directly south from Kitchener to Panama City. What latitude are you located at in Panama City?

a) parallel to 80° 30' W  
b) perpendicular to 43° 26' N  
c) parallel to 43° 26' N  
d) 43° 26' N  
e) 80° 30' W


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Appendix D26: Geospatial Thinking Scale

Task 3:
Select the coordinate pair that best locates the ‘City’ in Figure 11 below.

a) 51° 50’E, 36° 10’N  
b) 36° 10’N, 51° 50’E  
c) 35° 0’N, 50° 0’E  
d) 51° 30’W, 36° 10’S  
e) 36° 10’S, 51° 30’W

Figure 11

# Appendix E1: Map Literacy Scale

Map Literacy Scale (Koc & Demir 2014)

The items in this section aim to discover how proficient you are about the procedures carried out using maps. This is not an examination. There is no right or wrong answers to the questions. You are simply asked to read the items carefully and identify the option that describes you best by putting an "X" sign next to it. Chose only one option for each sentence.

<table>
<thead>
<tr>
<th>Subscale of Carrying out Procedures in Maps</th>
<th>Never</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Generally</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I can calculate the distance between two locations in meters or kilometers by using maps.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. I can calculate the actual area of a place using a map.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. I can calculate the slope in a certain intersection of a road by using a topography map.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I can find the local time difference between two locations with the help of maps.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subscale of Reading and Interpreting Maps</th>
<th>Never</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Generally</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. I can create sketches that show the way from my house to school, from the game park to my house, and from my house to the shopping centre.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I can show the places in which I live, and was born, on small-scale and large-scale maps which have no writing on them.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. I can make use of appropriate symbols (dots, areas and lines) while showing natural and human elements such as cafés, schools, petrol stations, roads, rivers and football pitches on outline maps.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. I can easily understand the information presented with the help of the legend, the section that explains what shapes and symbols mean in a map.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subscale of Reading and Interpreting Maps</th>
<th>Never</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Generally</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>14. I can analyze the changes in lands and evaluate the factors that trigger these changes by using maps of residential areas drawn at different time periods.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. I can assess the geographical characteristics of a place by using different map types (weather maps, topography maps, geology maps, underground resource maps and maps for land use).</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. I can make sense of the relationship between geographical formations and land by using topography maps.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. By using highway and railway networks, I can identify the factors that prove influential in the distribution of transportation networks and make deductions about the relationship between transportation networks and economic activities.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. I can assess the factors that play a significant role in the distribution of natural disasters such as earthquakes, floods, landslides, and avalanches by using appropriate maps.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Appendix E2: Map Literacy Scale

<table>
<thead>
<tr>
<th>Subscale of Sketching</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9. I can draw topography maps using contour lines.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. I can draw isobaric charts using isobars.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. I can draw precipitation maps using isohyets.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### The Subscale of Map Use

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>20. I make use of road maps during journeys.</td>
<td></td>
</tr>
<tr>
<td>21. When I look for a place that I don’t know, I look at maps first.</td>
<td></td>
</tr>
<tr>
<td>22. I am accustomed to using maps when trying to find my direction.</td>
<td></td>
</tr>
<tr>
<td>23. When I hear the names of unfamiliar elements such as countries, islands, lakes, seas and dams, I immediately refer to my atlas to find out where they are.</td>
<td></td>
</tr>
<tr>
<td>25. I actively make use of maps in solving problems that disturb my daily activities (e.g., to find a solution to traffic jam or identify alternative routes if there is roadwork ahead).</td>
<td></td>
</tr>
<tr>
<td>26. I’m accustomed to using some map-related applications in my car, and on my computer and mobile phone.</td>
<td></td>
</tr>
<tr>
<td>27. I read about maps.</td>
<td></td>
</tr>
<tr>
<td>28. I make use of physical maps to learn about the holiday resort where I am planning to have a holiday, to see whether it is rugged, high or on the coastline.</td>
<td></td>
</tr>
</tbody>
</table>

Koc, H & Demir, SB 2014, 'Developing valid and reliable map literacy scale', *Review of International Geographical Education Online (RIGEO)*, vol. 4, no. 2, p. 120.
Appendix F1: Written instructions for Job Applicants

Participant Instructions – Job Applicant

The aim of this activity is to identify sources of ambiguity in maps, or in the minds of the map reader. This activity will involve two phases. The first being a route planning phase, and the second, a navigation and wayfinding phase. To assist in the analysis of these activities, the movements of your eyes will be recorded and you will be required to use think aloud protocols.

In the route planning phase, you will plan a route on a desktop computer that is fitted with fixed eye tracking equipment. In the navigation and wayfinding phase, you will wear mobile eye tracking glasses. In both phases you will use think aloud protocols which involves you speaking your thoughts as you undertake the activity. You are to voice all of your thoughts relating to the activity as they come to your mind. Try to be as clear as possible when describing what you are trying to do and what issues you may be having. It is also imperative that you speak aloud in English. Remember, identifying ambiguities is the aim of the study and therefore encountering issues is not a problem. It is the quality of the map that is being studied not your ability or performance.

In this exercise, you are to assume the identity of a person on their way to a job interview. Therefore, you want to get to your destination as quickly as possible to ensure you are not late for the interview.

Study Area:

The focus area of the study is the neighbourhood of Roomebeek in Enschede. Roomebeek is coming to be known as the ‘contemporary neighbourhood’ of Enschede.

As a tourist in Roomebeek there are numerous attractions to see and visit including Rijksmuseum Twenthe, Cultural Complex Rozendaal, Op De Brouwerij (where Grolsch previously brewed beer but is now a shopping centre), Museum TwensseWelle and Lasonderbleek just to name a few. The Lasonderbleek is the former location of the fireworks factory which exploded in 2000. A monument has been erected in the Lasonderbleek as a memorial for the disaster and the victims.

Participant Tasks in Route Planning Phase:

During the route planning phase, you are required to complete the five (5) tasks below. The route that you select in this exercise will be the one you follow to travel between the start and end points in the next exercise.

The map app used in this experiment is called Maps.Me. It is similar in function and style to Google Maps. During this experiment you will mark out three different routes on a JPEG image of the experiment area, in different colours using the software Paint. You will also have at your disposal, a tourist guide to Roomebeek which has a map showing the various tourist attractions and important landmarks in the area. You may use this map to compare it with the JPEG image on the computer screen to plan the routes.

Before executing the experiment, the researcher will demonstrate how to mark out the three routes. Should you have any questions during or at the end of the demonstration, please ask.
While completing the tasks you are required to speak your thoughts aloud so they may be recorded and analysed at a later time.

The start point is G.J. van Heekpark and the destination is Museum TwentseWelle.

1. Find where the starting point is on the map and mark it. (Note: you may begin ANYWHERE within G.J. van Heekpark)
2. Find where the destination is on the map and mark it.
3. Using different colours (red, blue and orange), mark out three different routes between the start and end points. If you cover any parts of another route, please draw the new route alongside it.
4. Select your favourite and explain why it is your favourite.
5. Determine the distance and approximate amount of time it will take you to travel between your starting and end points.

**Participant Tasks in Navigation and Wayfinding Phase:**

During this navigation and wayfinding phase you are required to travel the route you selected in the previous exercise. While travelling the route, you will complete the seven (7) tasks below. While doing so, you will be wearing the eye tracking glasses and you must speak your thoughts aloud.

Whilst completing the Navigation and Wayfinding phase we ask you to exercise caution while using the smartphone to travel between the start and end points. Make sure you look left and right when crossing roads and that you are aware of your surroundings.

1. Point to your position on the map.
2. Using the map, determine which direction you are facing.
3. If you are not already facing the direction of the beginning of the route, orientate yourself within the environment to be facing the correct direction of the beginning of the route.
4. Begin walking along your selected route.
5. At the researcher’s request, show your current whereabouts on the map.
6. At the researcher’s request, determine how much further you are required to travel until to reach your destination.
7. Notify the researcher when you are satisfied that you have arrived at your destination.
Appendix G1: Written instructions for Tourists

Participant Instructions - Tourist

The aim of this activity is to identify sources of ambiguity in maps, or in the minds of the map reader. This activity will involve two phases. The first being a route planning phase, and the second, a navigation and wayfinding phase. To assist in the analysis of these activities, the movements of your eyes will be recorded and you will be required to use think aloud protocols.

In the route planning phase, you will plan a route on a desktop computer that is fitted with fixed eye tracking equipment. In the navigation and wayfinding phase, you will wear mobile eye tracking glasses. In both phases you will use think aloud protocols which involves you speaking your thoughts as you undertake the activity. You are to voice all of your thoughts relating to the activity as they come to your mind. Try to be as clear as possible when describing what you are trying to do and what issues you may be having. It is also imperative that you speak aloud in English. Remember, identifying ambiguities is the aim of the study and therefore encountering issues is not a problem. It is the quality of the map that is being studied not your ability or performance.

In this exercise, you are to assume the identity of a tourist. Therefore, you are interested in the surroundings, and you may take your time to walk between the start and end points. You may choose to walk a route that passes something of interest to you, the choice is yours.

Study Area:
The focus area of the study is the neighbourhood of Roombeek in Enschede. Roombeek is coming to be known as the 'contemporary neighbourhood' of Enschede.

As a tourist in Roombeek there are numerous attractions to see and visit including Rijksmuseum Twenthe, Cultural Complex Rozendaal, Op De Brouwerij (where Grolsch previously brewed beer but is now a shopping centre), Museum TwemseWelle and Lasonderbleek just to name a few. The Lasonderbleek is the former location of the fireworks factory which exploded in 2000. A monument has been erected in the Lasonderbleek as a memorial for the disaster and the victims.

Participant Tasks in Route Planning Phase:
During the route planning phase, you are required to complete the five (5) tasks below. The route that you select in this exercise will be the one you follow to travel between the start and end points in the next exercise.

The map app used in this experiment is called Maps.Me. It is similar in function and style to Google Maps. During this experiment you will mark out three different routes on a JPEG image of the experiment area, in different colours using the software Paint. You will also have at your disposal, a tourist guide to Roombeek which has a map showing the various tourist attractions and important landmarks in the area. You may use this map to compare it with the JPEG image on the computer screen to plan the routes.

Before executing the experiment, the researcher will demonstrate how to mark out the three routes. Should you have any questions after the demonstration, please ask.
Appendix G2: Written instructions for Tourists

While completing the tasks you are required to speak your thoughts aloud so they may be recorded and analysed at a later time.

The start point is G.J. van Heekpark and the destination is Museum TwentseWelle.

1. Find where the starting point is on the map and mark it. *(Note: you may begin ANYWHERE within G.J. van Heekpark)*
2. Find where the destination is on the map and mark it.
3. Using different colours (red, blue and orange), mark out three different routes between the start and end points. If you cover any parts of another route, please draw the new route along side of it.
4. Select your favourite and explain why it is your favourite.
5. Determine the distance and approximate amount of time it will take you to travel between your starting and end points.

**Participant Tasks in Navigation and Wayfinding Phase**

During this navigation and wayfinding phase you are required to travel the route you selected in the previous exercise. Whilst traveling the route, you will complete the seven (7) tasks below. While doing so, you will be wearing the eye tracking glasses and you must speak your thoughts aloud.

Whilst completing the Navigation and Wayfinding phase we ask you to exercise caution while using the smartphone to travel between the start and end points. Make sure you look left and right when crossing roads and that you are aware of your surroundings.

1. Point to your position on the map.
2. Using the map, determine which direction you are facing.
3. If you are not already facing the direction of the beginning of the route, orientate yourself within the environment to be facing the correct direction of the beginning of the route.
4. Begin walking along your selected route.
5. At the researcher’s request, show your current whereabouts on the map.
6. At the researcher’s request, determine how much further you are required to travel until to reach your destination.
7. Notify the researcher when you are satisfied that you have arrived at your destination.
Appendix H1: Post-Test Interview

Post-Test Interview

Participant ID: (researcher to complete):__________

Now that you have completed all tasks for the experiment, we would like to obtain some information relating to your thoughts on the map product and task execution. Below are 11 questions that will ask you about your satisfaction in relation to certain aspects of the map and task execution. Questions 8 to 11 are open-ended and ask for your opinions on the map product.

1. On a scale of 1 to 5, with 1 being very easy and 5 being very difficult, how easy did you find the map product to use?
   - 1
   - 2
   - 3
   - 4
   - 5

2. On a scale of 1 to 5, with 1 being very satisfied and 5 being very dissatisfied, how satisfied were you with the map product for the purpose of route planning?
   - 1
   - 2
   - 3
   - 4
   - 5

3. On a scale of 1 to 5, with 1 being very satisfied and 5 being very dissatisfied, how satisfied were you with the map product for the purpose of navigation and wayfinding?
   - 1
   - 2
   - 3
   - 4
   - 5

4. On a scale of 1 to 5, with 1 being very comfortable and 5 being very uncomfortable, how comfortable did you feel using the map to plan your route?
   - 1
   - 2
   - 3
   - 4
   - 5

5. On a scale of 1 to 5, with 1 being very comfortable and 5 being very uncomfortable, how comfortable did you feel using the map to navigate and wayfind?
   - 1
   - 2
   - 3
   - 4
   - 5

6. On a scale of 1 to 5, with 1 being very satisfied and 5 being very dissatisfied, how satisfied were you with the amount of time it took to plan the route?
   - 1
   - 2
   - 3
   - 4
   - 5

7. On a scale of 1 to 5, with 1 being very satisfied and 5 being very dissatisfied, how satisfied were you with the amount of time it took for you to find your way from the origin to the destination?
   - 1
   - 2
   - 3
   - 4
   - 5

8. What were the best aspects of the map product?
Appendix H2: Post-Test Interview

9. What were the worst aspects of the map product?

10. What did you find confusing about the map product?

11. How could the map product be made easier to use?

12. Any other questions as result of completed exercises to be written here.
Appendix I1: Questionnaire to Cartography Experts

Map App Assessment

Q1 What is your professional position?

Answered: 11  Slipped: 0

<table>
<thead>
<tr>
<th>#</th>
<th>Responses</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lecturer in GIS</td>
<td>1/21/2016 10:28 PM</td>
</tr>
<tr>
<td>2</td>
<td>Senior Lecturer in GIS and Cartography</td>
<td>1/14/2016 9:20 PM</td>
</tr>
<tr>
<td>3</td>
<td>Assistant Professor</td>
<td>1/14/2016 11:23 AM</td>
</tr>
<tr>
<td>4</td>
<td>Cartographer</td>
<td>12/2/2015 12:18 PM</td>
</tr>
<tr>
<td>5</td>
<td>Mapping and Visualization Engineer/Designer</td>
<td>11/24/2015 11:47 PM</td>
</tr>
<tr>
<td>6</td>
<td>Lead Academic Developer</td>
<td>11/23/2015 9:54 AM</td>
</tr>
<tr>
<td>7</td>
<td>Freelance cartographer; sometimes adjunct cartography lecturer at a university.</td>
<td>11/21/2015 8:14 PM</td>
</tr>
<tr>
<td>8</td>
<td>I teach cartography and map design in higher education. Assistant Professor. Master's Program Director.</td>
<td>11/20/2015 5:25 PM</td>
</tr>
<tr>
<td>9</td>
<td>Product Engineer (cartography) at Esri.</td>
<td>11/20/2015 2:30 PM</td>
</tr>
<tr>
<td>10</td>
<td>Professor</td>
<td>11/20/2015 1:53 AM</td>
</tr>
<tr>
<td>11</td>
<td>Senior Cartographic Product Engineer</td>
<td>11/20/2015 12:04 AM</td>
</tr>
</tbody>
</table>
Appendix I2: Questionnaire to Cartography Experts

Map App Assessment

Q2 How many years’ experience do you have in the field of cartography?

Answered: 11  Slipped: 0

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-10</td>
<td>15.18%</td>
</tr>
<tr>
<td>11-20</td>
<td>36.36%</td>
</tr>
<tr>
<td>More than 21 years</td>
<td>45.45%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 13: Questionnaire to Cartography Experts

Map App Assessment

Q3 How often do you design maps yourself?

Answered: 11  Slipped: 0

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Often</td>
<td>54.55%</td>
</tr>
<tr>
<td>Sometimes</td>
<td>45.45%</td>
</tr>
<tr>
<td>Never</td>
<td>0.00%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>
### Appendix I4: Questionnaire to Cartography Experts

#### Map App Assessment

**Q4 What is your age?**

- **25-39**
- **40-54**
- **Above 55**

<table>
<thead>
<tr>
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Answered: 11  Skipped: 0
Appendix I5: Questionnaire to Cartography Experts

Map App Assessment

Q5 What is your gender?
Answered: 10  Skipped: 1

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Appendix I6: Questionnaire to Cartography Experts

Map App Assessment

Q6 Identifying self location and orientation
Answered: 16  Skipped: 1

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Appendix I7: Questionnaire to Cartography Experts

Map App Assessment

Q7 Colours

Answered: 16  Skipped: 1

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Appendix I8: Questionnaire to Cartography Experts

Map App Assessment

Q8 Differentiation between different features i.e. buildings, parks, roads and important features, etc.

Answered: 10  Skipped: 1

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Appendix I9: Questionnaire to Cartography Experts

Map App Assessment

Q9 Design of point symbols

Answered: 10  Skipped: 1

Map A
Map B
Map C
Map D

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Appendix I10: Questionnaire to Cartography Experts

Map App Assessment

Q10 Design of line symbols

Answered: 10  Skipped: 1

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Appendix I11: Questionnaire to Cartography Experts

Map App Assessment

Q11 Appropriateness of typography (placement, font, colour, legibility)

Answered: 10  Skipped: 1

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Appendix I12: Questionnaire to Cartography Experts

Map App Assessment

Q12 Data generalisation

Answered: 10  Skipped: 1

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Appendix I13: Questionnaire to Cartography Experts

Map App Assessment

Q13 Wayfinding or navigating between point St. Stephan’s Cathedral (also known as Domkirche St. Stephan and Stephandom) and St. Peters Church (also known as Katholische Kirche St. Peter, Peterskirche and Sankt Peter)

Answered: 10  Skipped: 1

Map A

Map B

Map C

Map D

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Appendix I14: Questionnaire to Cartography Experts

Map App Assessment

Q14 Locating of origin and destination
Answered: 9  Skipped: 2

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Map B
Map C
Map D

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Appendix I15: Questionnaire to Cartography Experts

Map App Assessment

Q15 Colours
Answered: 9  Skipped: 2

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Appendix I16: Questionnaire to Cartography Experts

Map App Assessment

Q16 Differentiation between different features i.e. buildings, parks, roads and important features, etc.

Answered: 9  Skipped: 2

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Appendix I17: Questionnaire to Cartography Experts

Map App Assessment

Q17 Design of point symbols

Answered: 9  Skipped: 2

Map A

Map B

Map C

Map D

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17 / 23
Appendix I18: Questionnaire to Cartography Experts

Map App Assessment

Q19 Appropriateness of typography (placement, font, colour, legibility)

Answered: 9  Skipped: 2

Map A

Map B

Map C

Map D

Table:

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Appendix I19: Questionnaire to Cartography Experts

Map App Assessment

Q19 Appropriateness of typography (placement, font, colour, legibility)

Answered: 9     Skipped: 2

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Appendix I20: Questionnaire to Cartography Experts

Map App Assessment

Q20 Data generalisation

Answered: 9  Skipped: 2

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Appendix I21: Questionnaire to Cartography Experts

Map App Assessment

Q21 Determining a route between point St. Stephan's Cathedral (also known as Domkirche St. Stephan and Stephandom) and St. Peters Church (also known as Katholische Kirche St. Peter, Peterskirche and Sankt Peter)

Answered: 5 Skipped: 3

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Total</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map A</td>
<td>71.43%</td>
<td>28.57%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Map B</td>
<td>28.57%</td>
<td>28.57%</td>
<td>42.86%</td>
<td>0.00%</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Map C</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>100.00%</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Map D</td>
<td>0.00%</td>
<td>37.50%</td>
<td>50.00%</td>
<td>12.50%</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>
Appendix I22: Questionnaire to Cartography Experts

Map App Assessment

Q22 Please rank these maps overall in order from best to worst, where 1 is best and 4 is worst, in terms of your preference for their suitability to navigation, wayfinding and route planning in relation to their design and explain your reasons for ranking them in this way.

Answered: 9  Skipped: 2

<table>
<thead>
<tr>
<th>Map</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Total</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map A</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>3.00</td>
</tr>
<tr>
<td>Map B</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>3.11</td>
</tr>
<tr>
<td>Map C</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>9</td>
<td>1.33</td>
</tr>
<tr>
<td>Map D</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>9</td>
<td>2.56</td>
</tr>
</tbody>
</table>
### Map App Assessment

**Q23** Please provide an explanation for why you ranked the maps in the order you provided in question 22.

<table>
<thead>
<tr>
<th>#</th>
<th>Responses</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>There is no perfect solution amongst these maps. Each has its own plusses and minuses. However, I ranked them taking into account the visibility and size of landmark icons, color contrast, easiness of identifying road/street size (order), balance between too much and too little information on the map (usability), and easiness of identifying different features e.g. parks, hospitals, churches etc.</td>
<td>1/21/2016 11:10 PM</td>
</tr>
<tr>
<td>2</td>
<td>Difficult to explain, as it's a combination of all above. The reason D=r1 is that it is the only one to depict one-way traffic at this scale, which is vital for navigation/wayfinding in cars...</td>
<td>1/14/2016 3:35 PM</td>
</tr>
<tr>
<td>3</td>
<td>Map A would be better for route planning, whereas Map B is better for navigation. Map C is unsuitable for most of the relevant aspects and map D comes third for both purposes.</td>
<td>1/14/2016 11:49 AM</td>
</tr>
<tr>
<td>4</td>
<td>Maps 1 and 2 are clean, legible, and offer just enough information at a glance. Map 3 is too sparse and generalized. Map 2 has too much information and a noisy design that would be difficult to read on a mobile device outside with sun glare.</td>
<td>12/3/2015 12:40 PM</td>
</tr>
<tr>
<td>5</td>
<td>B is the most data-dense showing things the other don't (like light rail lines), though the sparse design of Map A makes it very easy to skim and glance at. In both A and B the road network contrasts more strongly with the ground, creating a stronger figure-ground (given the importance of roads for way-finding, this is good). The exaggerated widths on the roads in C are too much, and the map is washed-out (hard to skim quickly).</td>
<td>11/25/2015 12:10 AM</td>
</tr>
<tr>
<td>6</td>
<td>Like the fall into B, C is clear but I would like more detail to work with</td>
<td>11/23/2015 10:09 AM</td>
</tr>
<tr>
<td>7</td>
<td>C is painful to look at, with the slightly pink background and all the heavy lines. A map is easier to use if it is more comfortable to look at. B is a little better, but very cluttered; the buildings are unnecessary at this scale, and there are too many colors going on. B is nice and clean and useful, but D is best because it has the same clean simplicity, and a little more label density.</td>
<td>11/21/2015 6:39 PM</td>
</tr>
<tr>
<td>8</td>
<td>The overall cleanliness and balance of the roads and buildings. The best maps made use of negative space to define the roads.</td>
<td>11/20/2015 2:51 PM</td>
</tr>
<tr>
<td>9</td>
<td>For me, detail is important. B has the tram network, clear labels and a detailed route network. D also has a nice level of detail. Neither A nor C provide the same level of detail. That said, if I were making the map for wayfinding it’s hard to beat Map A due to the clean appearance and lack of map clutter. It’s an easy map to navigate from, but personally I’d like more detail. Map C is just not at all pleasing to look at in design terms though you could navigate using it.</td>
<td>11/20/2015 12:19 AM</td>
</tr>
</tbody>
</table>
Appendix J1: Participant Recruitment Questionnaire

Welcome to My Survey

Dear Participant,

This is a study which is looking at improving map designs. Individuals differ in the way they read maps and therefore we are looking for people with varying levels of map-reading and spatial abilities.

In this questionnaire, you will be presented with three documents you should complete. It will take approximately 20 minutes to complete the documents. The first, is just some background information. Letting us know a little bit about yourself, whilst this document requires you to provide your name and contact details, this is only so you may be contacted for further work in the study. Only the researchers will have access to this information. Should you be invited, and agree to participate in further studies, you will be assigned a participant ID number so that you will remain anonymous in further testing.

The second document you will complete is the Santa Barbara Sense of Direction Scale. It’s a questionnaire that asks you questions relating to map-reading and map-use. You will agree or disagree with the statements along a scale from 1 to 7, where 1 is strongly agree and 7 is strongly disagree.

The third and final document is an investigation of spatial ability. In this document, you are provided with a diagram of a bottle which has been partially filled with water. The bottle is then rotated at various angles, and you are required to draw the water line in each of the rotated bottles.

These documents will be used to further determine your suitability to the study. If selected, you will be required to attend another session, with an approximate duration of 50 minutes to 1 hour 20 minutes. In this session, you will be asked to plan a route between two locations, and then walk this route. This session will involve the use of both fixed and mobile eye-tracking glasses. You will be required to speak your thoughts aloud while completing the tasks. Should you be selected for the second session, you are not obliged to complete it. You may exit from the study at any time, you are not required to engage in this study if you do not wish to.

I would like to stress that all information collected will be kept strictly confidential and that individual details will not be disclosed or identifiable from this survey.

For information pertaining to ethics guidelines please use click the following link: RMIT Research Integrity

For any further information or a copy of the publication resulting from this survey, please contact Ms. Erin Koletsis at erin.koletsis@student.rmit.edu.au or e.m.koletsis@utwente.nl.

Thank you for participating in our survey. Your feedback is important.
**Appendix J2: Participant Recruitment Questionnaire**

<table>
<thead>
<tr>
<th>Preliminary Information</th>
</tr>
</thead>
</table>

*Please note: all questions with an asterisk (*) must be answered before you can continue.*

<table>
<thead>
<tr>
<th>* 1. Name:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>* 2. Email Address</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>* 3. Age:</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-24</td>
</tr>
<tr>
<td>25-34</td>
</tr>
<tr>
<td>35-44</td>
</tr>
<tr>
<td>45-54</td>
</tr>
<tr>
<td>55-64</td>
</tr>
<tr>
<td>65 and above</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>* 4. Gender:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>* 5. Country of Origin:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>* 6. Occupation:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>* 7. Highest Completed Education Level:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
</tr>
<tr>
<td>Pre-university (VWO)</td>
</tr>
<tr>
<td>MA</td>
</tr>
<tr>
<td>Preparatory Vocational Secondary</td>
</tr>
<tr>
<td>(VMBO)</td>
</tr>
<tr>
<td>Bachelor</td>
</tr>
<tr>
<td>PhD</td>
</tr>
<tr>
<td>Senior General Secondary (HAVO)</td>
</tr>
<tr>
<td>MSc</td>
</tr>
<tr>
<td>Other (please specify)</td>
</tr>
</tbody>
</table>

390
Appendix J3: Participant Recruitment Questionnaire

8. What is your field of study?
# Preliminary Information

* **9.** Do you have normal or corrected to normal vision?  
  - Normal  - Corrected to normal

  **10.** If you have corrected to normal vision, do you wear glasses/spectacles?  
  - Yes  - No

  **11.** If you have corrected to normal vision, do you wear contact lenses?  
  - Yes  - No

* **12.** Do you have any physical disabilities that would affect your ability to use a computer, smartphone or move about outdoors?  
  - Yes  - No
Appendix J5: Participant Recruitment Questionnaire

<table>
<thead>
<tr>
<th>Preliminary Information</th>
</tr>
</thead>
</table>

* 13. How often would you travel to an unfamiliar location?
- ☐ Weekly
- ☐ Less than once per month
- ☐ Once per year or less
- ☐ Fortnightly (every 2 weeks)
- ☐ 5-10 times per year
- ☐ Never
- ☐ Monthly
- ☐ 2-4 times per year

* 14. When you travel to an unfamiliar location, how confident are you to travel there on your own?
- ☐ Very confident
- ☐ Neither confident nor not confident
- ☐ Not at all confident
- ☐ Somewhat confident
- ☐ Not very confident

* 15. If travelling to an unfamiliar location, do you prefer to have someone accompany you?
- ☐ Yes
- ☐ No

* 16. Do you find you are less inclined to travel on your own to unfamiliar locations due to fear of getting lost?
- ☐ Yes
- ☐ No

* 17. When travelling to an unfamiliar location, how do you normally prepare for navigating?
Appendix J6: Participant Recruitment Questionnaire

* 18. What type of map do you normally use to travel to unfamiliar locations?
   - Paper map
   - Web map
   - Smartphone or tablet map app
   - Other (please specify)

* 19. How often do you use maps?
   - Daily
   - Weekly
   - Monthly
   - 5-10 times per year
   - 2-4 times per year
   - Less than once per year
   - Never

* 20. How often do you use a map app on a smartphone or tablet?
   - Daily
   - Weekly
   - Monthly
   - 5-10 times per year
   - 2-4 times per year
   - Less than once per year
   - Never

* 21. How often do you get lost when in an unfamiliar area?
   - Never
   - Sometimes
   - Often
   - Always

* 22. How do you feel when you get lost? (tick all that apply)
   - Scared
   - Confused
   - Uncomfortable
   - Relaxed
   - Anxious
   - Excited
   - Indifferent
   - Other (please specify)
23. When you become lost, how do you find your way?

- Using a paper map
- Using a map on your smartphone
- Ask someone for directions
- Find a public map
- Take a taxi to the destination
- Other (please specify)

24. Using your answer to 23, do you find this method to be satisfactory, or would you prefer there was another way?

25. Have you ever been to the Roombeek Area? (See map below)

- Yes
- No

Roombeek Area Map

26. If yes, how often do/did you visit the Roombeek area?

- Daily
- 2-4 times per month
- 2-4 times per week
- 5-10 times per year
- Once per week
- Less than once per year
### Appendix J8: Participant Recruitment Questionnaire

#### Santa Barbara Sense of Direction Scale

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>27. I am very good at giving directions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28. I have a poor memory for where I left things.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29. I don’t have a very good “mental map” of my environment.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Santa Barbara Sense of Direction Scale

**30. My "sense of direction" is very good.**

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

**31. I tend to think of my environment in terms of cardinal directions (N, S, E, W).**

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

**32. I very easily get lost in a new city.**

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>
### Santa Barbara Sense of Direction Scale

**33. I enjoy reading maps.**

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

**34. I have trouble understanding directions.**

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

**35. I am very good at reading maps.**

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Strongly Disagree</th>
</tr>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
### Santa Barbara Sense of Direction Scale

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>36. I don't remember routes very well while riding as a passenger in a car.</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>37. I can usually remember a new route after I have travelled it only once.</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>38. I don't enjoy giving directions.</em></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Appendix J12: Participant Recruitment Questionnaire

<table>
<thead>
<tr>
<th>Santa Barbara Sense of Direction Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>* 39. I usually let someone else do the navigational planning for long trips.</td>
</tr>
<tr>
<td>Strongly Agree</td>
</tr>
<tr>
<td><img src="Image" alt="Circle" /></td>
</tr>
<tr>
<td>* 40. It's not important to me to know where I am.</td>
</tr>
<tr>
<td>Strongly Agree</td>
</tr>
<tr>
<td><img src="Image" alt="Circle" /></td>
</tr>
<tr>
<td>* 41. I am very good at judging distances.</td>
</tr>
<tr>
<td>Strongly Agree</td>
</tr>
<tr>
<td><img src="Image" alt="Circle" /></td>
</tr>
</tbody>
</table>
## Appendix J13: Participant Recruitment Questionnaire

### Spatial Ability Evaluation

Below is an image of a bottle. The level of the water in the bottle is indicated by the blue line. Underneath this bottle are five other bottles rotated at different angles. For each rotated bottle, you must select the correct water level angle.

<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>* 42.</td>
<td>[ ]</td>
</tr>
<tr>
<td>* 43.</td>
<td>[ ]</td>
</tr>
<tr>
<td>* 44.</td>
<td>[ ]</td>
</tr>
<tr>
<td>* 45.</td>
<td>[ ]</td>
</tr>
<tr>
<td>* 46.</td>
<td>[ ]</td>
</tr>
</tbody>
</table>
Appendix K: Ethics Approval

9th March 2016

Professor William Cartwright
Building 12 Level 11, Room 7
School of Science
RMIT University

Dear Professor Cartwright

ASEHAPP 11-16 CARTWRIGHT-KOLETSIS Developing a New Representation of Geography for Map Illiterate Individuals

Thank you for submitting your amended application for review.

I am pleased to inform you that the CHEAN has approved your application for a period of 12 Months from the date of this letter to 9th March, 2017 and your research may now proceed.

The CHEAN would like to remind you that:

All data should be stored on University Network systems. These systems provide high levels of manageable security and data integrity, can provide secure remote access, are backed up on a regular basis and can provide Disaster Recover processes should a large scale incident occur. The use of portable devices such as CD\n and memory sticks is valid for archiving; data transport where necessary and for some works in progress. The authoritative copy of all current data should reside on appropriate network systems; and the Principal Investigator is responsible for the retention and storage of the original data pertaining to the project for a minimum period of five years.

Please Note: Annual reports are due on the anniversary of the commencement date for all research projects that have been approved by the CHEAN. Ongoing approval is conditional upon the submission of annual reports. Failure to provide an annual report may result in ethics approval being withdrawn.

Final reports are due within six months of the project expiring or as soon as possible after your research project has concluded.

The annual/final reports forms can be found at:
www.rmit.edu.au/vmnf/research/human-research-ethics

Yours faithfully,

Dr Linda Jones
Chair, Science Engineering & Health
College Human Ethics Advisory Network

Cc CHEAN Member:  Dr. Claudia Diaz School of Health & Biomedical Science RMIT University
Student Investigator(s): Ms. Erin Kolstel School of Science RMIT University
Other Investigator(s): A/Prof Colin Arrowsmith School of Science RMIT University
A/Prof Corné van Elakker University of Twente
Appendix L: Recruitment Advertisement

Recruitment Advertisement

MAP LITERACY RESEARCH STUDY

You are invited to participate in a study evaluating map design elements, conducted by Erin Koletsis (PhD Candidate) at RMIT University, Melbourne, School of Science and Faculty of Geo-Information Science and Earth Observation, University of Twente.

The study involves completing a questionnaire to evaluate your suitability to the research and if successful, the completion of map reading tasks in location unfamiliar to the participant.

If you are at least 18 years old, have difficulty reading maps and would like more information about participating, please contact:

Erin Koletsis at erin.koletsis@student.rmit.edu.au
Appendix M1: Written Instructions for Job Applicants

Participant Instructions – Job Applicant

The aim of this activity is to identify sources of ambiguity in maps, or in the minds of the map reader. This activity will involve two phases. The first being a route planning phase, and the second, a navigation and wayfinding phase. To assist in the analysis of these activities, the movements of your eyes will be recorded and you will be required to use think aloud protocols.

In the route planning phase, you will plan three routes on a paper map. In the navigation and wayfinding phase, you will walk one of these routes. In both phases you will wear eye-tracking glasses and use think aloud protocols, which involves you speaking your thoughts as you undertake the activity. You are to voice all of your thoughts relating to the activity as they come to your mind. Try to be as clear as possible when describing what you are trying to do and what issues you may be having. Remember, identifying ambiguities is the aim of the study and therefore encountering challenges is not a problem. It is the quality of the map that is being studied not your ability or performance.

In this exercise, you are to assume the identity of a person on their way to a job interview. Therefore, you want to get to your destination as quickly as possible to ensure you are not late for the interview.

Study Area:
The focus area of the study is the Melbourne Central Business District.

Participant Tasks in Route Planning Phase:

During the route planning phase, you are required to complete the five (5) tasks below. The route that you select in this exercise will be the one you follow to travel between the start and end points in the next exercise.

The map used in this experiment was obtained from the information desk in Bourke Street Mall. During this experiment you will mark out three different routes on a paper map of the experiment area, in different colours using the pens provided.

Before executing the experiment, the researcher will demonstrate how to mark out the three routes. Should you have any questions during or at the end of the demonstration, please ask.

While completing the tasks you are required to speak your thoughts aloud so they may be recorded and analysed at a later time.

The start point is the corner of Little Bourke Street and Tattersalls Lane and the destination is the Royal Exhibition Building.

1. Find where the starting point is on the map and mark it.
2. Find where the destination is on the map and mark it.
3. Using different colours (red, blue and purple), mark out three different routes between the start and end points. If you cover any parts of another route, please draw the new route alongside it.
4. Select your favourite and explain why it is your favourite.
Appendix M2: Written Instructions for Job Applicants

4. Determine the distance and approximate amount of time it will take you to travel between your starting and end points.

Participant Tasks in Navigation and Wayfinding Phase:
During this navigation and wayfinding phase you are required to travel the route you selected in the previous exercise. While travelling the route, you will complete the five (5) tasks below. While doing so, you will be wearing the eye tracking glasses and you must speak your thoughts aloud.

Whilst completing the Navigation and Wayfinding phase we ask you to exercise caution while using the map to travel between the start and end points. Make sure you look right and left when crossing roads and that you are aware of your surroundings.

1. Point to your position on the map.
2. Using the map, determine which direction you are facing.
3. If you are not already facing the direction of the beginning of the route, orientate yourself within the environment to be facing the correct direction of the beginning of the route.
4. Begin walking along your selected route.
5. Notify the researcher when you are satisfied that you have arrived at your destination.
Appendix N1: Written Instructions for Tourists

Participant Instructions - Tourist

The aim of this activity is to identify sources of ambiguity in maps, or in the minds of the map reader. This activity will involve two phases. The first being a route planning phase, and the second, a navigation and wayfinding phase. To assist in the analysis of these activities, the movements of your eyes will be recorded, and you will be required to use think aloud protocols.

In the route planning phase, you will plan three routes on a paper map. In the navigation and wayfinding phase, you walk one of these routes. In both phases you will wear eye-tracking glasses and use think aloud protocols which involves you speaking your thoughts as you undertake the activity. You are to voice all your thoughts relating to the activity as they come to your mind. Try to be as clear as possible when describing what you are trying to do and what issues you may be having. Remember, identifying ambiguities is the aim of the study and therefore encountering challenges is not a problem. It is the quality of the map that is being studied not your ability or performance.

In this exercise, you are to assume the identity of a tourist. Therefore, you are interested in the surroundings, and you may take your time to walk between the start and end points. You will choose to walk a route that passes something/s of interest to you.

Study Area:
The focus area of the study is the Melbourne Central Business District.

Participant Tasks in Route Planning Phase:

During the route planning phase, you are required to complete the five (5) tasks below. The route that you select in this exercise will be the one you follow to travel between the start and end points in the next exercise.

The map used in this experiment was obtained from the information desk in Bourke Street Mall. During this experiment you will mark out three different routes on a paper map of the experiment area, in different colours using the pens provided.

Before executing the experiment, the researcher will demonstrate how to mark out the three routes. Should you have any questions after the demonstration, please ask.

While completing the tasks you are required to speak your thoughts aloud, so they may be recorded and analysed at a later time.

The start point is the corner of Little Bourke Street and Tattersalls Lane and the destination is the Royal Exhibition Building.

1. Find where the starting point is on the map and mark it.
2. Find where the destination is on the map and mark it.
3. Using different colours (red, blue and purple), mark out three different routes between the start and end points. If you cover any parts of another route, please draw the new route along side of it.
4. Select your favourite and explain why it is your favourite.
Appendix N2: Written Instructions for Tourists

5. Determine the distance and approximate amount of time it will take you to travel between your starting and end points.

Participant Tasks in Navigation and Wayfinding Phase:

During this navigation and wayfinding phase you are required to travel the route you selected in the previous exercise. Whilst traveling the route, you will complete the five (5) tasks below. While doing so, you will be wearing the eye tracking glasses and you must speak your thoughts aloud.

Whilst completing the Navigation and Wayfinding phase we ask you to exercise caution while using the map to travel between the start and end points. Make sure you look right and left when crossing roads and that you are aware of your surroundings.

1. Point to your position on the map.
2. Using the map, determine which direction you are facing.
3. If you are not already facing the direction of the beginning of the route, orientate yourself within the environment to be facing the correct direction of the beginning of the route.
4. Begin walking along your selected route.
5. Notify the researcher when you are satisfied that you have arrived at your destination.
Post-Test Interview

Participant ID: (researcher to complete):___________

Now that you have completed all tasks for the experiment, we would like to obtain some information relating to your thoughts on the map product and task execution. Below are 11 questions that will ask you about your satisfaction in relation to certain aspects of the map and task execution. Questions 8 to 11 are open-ended and ask for your opinions on the map product.

1. On a scale of 1 to 5, with 1 being very easy and 5 being very difficult, how easy did you find the map product to use?
   ○ 1  ○ 2  ○ 3  ○ 4  ○ 5

2. On a scale of 1 to 5, with 1 being very satisfied and 5 being very dissatisfied, how satisfied were you with the map product for the purpose of route planning?
   ○ 1  ○ 2  ○ 3  ○ 4  ○ 5

3. On a scale of 1 to 5, with 1 being very satisfied and 5 being very dissatisfied, how satisfied were you with the map product for the purpose of navigation and wayfinding?
   ○ 1  ○ 2  ○ 3  ○ 4  ○ 5

4. On a scale of 1 to 5, with 1 being very comfortable and 5 being very uncomfortable, how comfortable did you feel using the map to plan your route?
   ○ 1  ○ 2  ○ 3  ○ 4  ○ 5

5. On a scale of 1 to 5, with 1 being very comfortable and 5 being very uncomfortable, how comfortable did you feel using the map to navigate and wayfind?
   ○ 1  ○ 2  ○ 3  ○ 4  ○ 5

6. On a scale of 1 to 5, with 1 being very satisfied and 5 being very dissatisfied, how satisfied were you with the amount of time it took to plan the route?
   ○ 1  ○ 2  ○ 3  ○ 4  ○ 5

7. On a scale of 1 to 5, with 1 being very satisfied and 5 being very dissatisfied, how satisfied were you with the amount of time it took for you to find your way from the origin to the destination?
   ○ 1  ○ 2  ○ 3  ○ 4  ○ 5

8. What were the best aspects of the map product?
Appendix O2: Post-Test Interview

9. What were the worst aspects of the map product?

10. What did you find confusing about the map product?

11. How could the map product be made easier to use?

12. Any other questions as result of completed exercises to be written here.
Appendix P1: Ethics Approval Letter

College Human Ethics Advisory Network (CHEAN)  
College of Science, Engineering and Health  
Email: seh-human-ethics@rmit.edu.au  
Phone: [61 3] 9925 4620  
Building 91, Level 2, City Campus/Building 215, Level 2, Bundoora West Campus

1 June 2017

Professor William Cartwright  
School of Science  
RMIT University

Dear Prof Cartwright

SEHAPP 07-17 Developing a new representation of geography for map illiterate individuals

Thank you for submitting your amended application for review.

I am pleased to inform you that the CHEAN has approved your application for a period of 5 Months from the date of this letter to 31 December 2017 and your research may now proceed.

The CHEAN would like to remind you that:

All data should be stored on University Network systems. These systems provide high levels of manageable security and data integrity, can provide secure remote access, are backed up on a regular basis and can provide Disaster Recover processes should a large scale incident occur. The use of portable devices such as CDs and memory sticks is valid for archiving; data transport where necessary and for some works in progress. The authoritative copy of all current data should reside on appropriate network systems; and the Principal Investigator is responsible for the retention and storage of the original data pertaining to the project for a minimum period of five years.

Please Note: Annual reports are due on the anniversary of the commencement date for all research projects that have been approved by the CHEAN. Ongoing approval is conditional upon the submission of annual reports. Failure to provide an annual report may result in Ethics approval being withdrawn.
Appendix P2: Ethics Approval Letter

Final reports are due within six months of the project expiring or as soon as possible after your research project has concluded.

The annual/final reports forms can be found at:
www.rmit.edu.au/staff/research/human-research-ethics

Yours faithfully,

Associate Professor Barbara Polus
Chair, Science Engineering & Health
College Human Ethics Advisory Network

Cc: Student Investigator(s): Mr. John O’Leary, School of Science
Other Investigator(s): Prof. Colin Armstrong, School of Science
Appendix P3: Ethics Approval Letter

RMIT UNIVERSITY

College Human Ethics Advisory Network (CHEAN)
College of Science, Engineering and Health
Email: seh-human-ethics@rmit.edu.au
Phone: [61 3] 9925 4620
Building 91, Level 2, City Campus/Building 215, Level 2, Bundoora West Campus

15 June 2017

Professor William Cartwright
School of Science
RMIT University

Dear Prof Cartwright

SHEAPP 07-17 Developing a new representation of geography for map illiterate individuals

Thank you for requesting an amendment to your Human Research Ethics project titled: **Developing a new representation of geography for map illiterate individuals**, which was originally approved by Science Engineering and Health CHEAN in 2017 for a period of 6 months.

I am pleased to inform you that the CHEAN has approved your amendment as outlined in your request.

The CHEAN notes and thanks you for providing all documentation that incorporates these amendments. This documentation will be appended to your file for future reference and your research may now continue.

The committee would like to remind you that:

All data should be stored on University Network systems. These systems provide high levels of manageable security and data integrity, can provide secure remote access, are backed up on a regular basis and can provide Disaster Recover processes should a large scale incident occur. The use of portable devices such as CDs and memory sticks is valid for archiving; data transport where necessary and for some works in progress; The authoritative copy of all current data should reside on appropriate network systems; and the Principal Investigator is responsible for the retention and storage of the original data pertaining to the project for a minimum period of five years.

Please Note: Annual reports are due on the anniversary of the commencement date for all research projects that have been approved by the CHEAN. Ongoing approval is conditional upon the submission of annual reports failure to provide an annual report may result in Ethics approval being withdrawn.
Appendix P4: Ethics Approval Letter

Final reports are due within six months of the project expiring or as soon as possible after your research project has concluded.

The annual/final reports forms can be found at:
www.rmit.edu.au/staff/research/human-research-ethics

Yours faithfully,

Associate Professor Barbara Polus
Chair, Science Engineering & Health
College Human Ethics Advisory Network

Cc: Student Investigator(s): Martin Kolmis, School of Science
Other Investigator(s): A/Prof Colin Arrowsmith, School of Science
A/Prof Adeen Dyer, School of Media & Communications
Appendix Q: Participant Recruitment Poster

Do you, or does anyone you know, dislike reading and using maps?

You are invited to participate in a study evaluating map design elements, conducted by Erin Koletsis (PhD Candidate) at RMIT University, Melbourne, School of Science and Faculty of Geo-Information Science and Earth Observation, University of Twente.

The study involves completing a questionnaire to evaluate your suitability to the research and if successful, the completion of map reading tasks in the Melbourne Central Business District. The questionnaire will take approximately 15 minutes to complete and the map reading tasks in Melbourne will require no more than 3 hours.

If you are at least 18 years old and are interested in participating in this study, you may commence the experiment process with an online survey you can find at:

https://rmit.au1.qualtrics.com/jfe/form/SV_3b02817csLRzgPk

If you would like more information about participating, please contact:
Erin Koletsis at erin.koletsis@student.rmit.edu.au
Appendix R1: Participant Recruitment Questionnaire

Default Question Block

Q1. What is your name?

Q2. Do you have normal or corrected-to-normal vision?
   ○ Normal
   ○ Corrected-to-normal

Q3. Do you wear glasses/spectacles?
   ○ Yes
   ○ No

Q4. Do you wear contact lenses?
   ○ Yes
   ○ No

Q5. Do you have any physical disabilities that would affect your ability to use a smartphone or move about outdoors?
   ○ Yes
   ○ No

Q6. How familiar are you with Melbourne’s city centre?
Appendix R2: Participant Recruitment Questionnaire

Q7. How often do you visit Melbourne’s city centre?

- Daily
- 2-3 times a week
- Once a week
- 2-3 times a month
- Once a month
- 5-10 times a year
- Once a year
- I’ve never been to Melbourne’s city centre

Q8.
Below is a bottle filled with water. The level of the water is indicated by the blue line. Below this are three empty bottles rotated at various angles. In the following three questions, please select the correct water-level placement.
Appendix R3: Participant Recruitment Questionnaire

Q9. Using the options below, please select the one that best represents the placement of the water-level in this bottle.

○

○

○
Q 10. Using the options below, please select the one that best represents the placement of the water-level in this bottle.

- [ ]

- [ ]

- [ ]

Appendix R5: Participant Recruitment Questionnaire

Q11. Using the options below, please select the one that best represents the placement of the water-level in this bottle.

[Diagram of three options for water-level placement]

https://mit.au1.qualtrics.com/
Appendix R6: Participant Recruitment Questionnaire

6/16/2021 Qualtrics Survey Software

Q12. I am very good at giving directions.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree

Q13. To ensure the quality of our data, please select two to four times a year below.

☐ Daily
☐ Once a week
☐ Once a month
☐ 5-10 times a year

https://mit.au1.qualtrics.com/Q/EditSection/Blocks/Ajax/GetSurveyPrintPreview?ContextSurveyId=5V_3b0Z817cLZgPtk&ContextLibraryId=U... 6/10
Appendix R7: Participant Recruitment Questionnaire

6/16/2021

Q14. I have a poor memory for where I left things.
- 1 - Strongly agree
- 2
- 3
- 4
- 5
- 6
- 7 - Strongly disagree

Q15. I am very good at judging distances.
- 1 - Strongly agree
- 2
- 3
- 4
- 5
- 6
- 7 - Strongly disagree

Q16. My "sense of direction" is very good.
- 1 - Strongly agree
- 2
- 3
- 4
- 5
- 6
- 7 - Strongly disagree

Q17. I tend to think of my environment in terms of cardinal directions (N, S, E, W).
- 1 - Strongly agree
- 2
- 3
- 4
- 5
- 6
- 7 - Strongly disagree

Appendix R8: Participant Recruitment Questionnaire

<table>
<thead>
<tr>
<th>Question</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
<th>Option 5</th>
<th>Option 6</th>
<th>Option 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q18. I very easily get lost in a new city.</td>
<td>1 - Strongly agree</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7 - Strongly disagree</td>
</tr>
<tr>
<td>Q19. I enjoy reading maps.</td>
<td>1 - Strongly agree</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7 - Strongly disagree</td>
</tr>
<tr>
<td>Q20. I have trouble understanding directions.</td>
<td>1 - Strongly agree</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7 - Strongly disagree</td>
</tr>
<tr>
<td>Q21. I am very good at reading maps.</td>
<td>1 - Strongly agree</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7 - Strongly disagree</td>
</tr>
<tr>
<td>Q22. I don't remember routes very well while riding as a passenger in a car.</td>
<td>1 - Strongly agree</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix R9: Participant Recruitment Questionnaire

6/16/2021

Qualtrics Survey Software

Q23. I don't enjoy giving directions.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree

Q24. It's not important to me to know where I am.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree

Q25. I usually let someone else do the navigational planning for long trips.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree

Q26. I can usually remember a new route after I have traveled it only once.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
Appendix R10: Participant Recruitment Questionnaire

6/16/2021

qualtrics survey software

Q27. I don’t have a very good “mental map” of my environment.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree
Appendix S1: SBSODS Baseline Survey

Default Question Block

What is your age?
- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65-74
- 75 and above

What gender do you identify as?
- Male
- Female
- Prefer to self-identify
- Prefer not to say

What is your nationality?

In which country do you reside?

What is your occupation?

What is the highest level of education you have completed?
- No schooling completed
- Primary school
- Some secondary education (high school)
- Completed secondary education (graduated high school)
- Trade/technical/vocational training
- Undergraduate education (university or college)
- Postgraduate education (masters or doctorate)

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Appendix S2: SBSODS Baseline Survey

If you have completed a Higher Education course (education beyond high school), what was your field of study?

How often do you use GPS/Satellite Navigation technologies?

- Daily
- 2-3 times a week
- Once a week
- 2-3 times a month
- Once a month
- Never

Below is a bottle filled with water. The level of the water is indicated by the blue line. Below this are three empty bottles rotated at various angles. In the following three questions, please select the correct water-level placement.

Using the options below, please select the one that best represents the placement of water-level in this bottle.
Using the options below, please select the one that best represents the placement of water-level in this bottle.

https://mail.au.qualtrics.com/External/Files/1589/GetSurveyPreview/ContactSurveyID=6V_jcblnbeb1k2?email=contactlibraryID=URL...
Appendix S5: SBSODS Baseline Survey

Using the options below, please select the one that best represents the placement of water-level in this bottle.

1. [ ]
2. [ ]
3. [ ]
4. [ ]

Appendix S6: SBSODS Baseline Survey

I am very good at giving directions.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree

To ensure the quality of our data, please select the number five below.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree

I have a poor memory for where I left things.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree

I am very good at judging distances.

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Appendix S7: SBSODS Baseline Survey

4/2/20, 1:47 PM

Qualtrics Survey Software

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree

My "sense of direction" is very good.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree

I tend to think of my environment in terms of cardinal directions (N, S, E, W).

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree

I very easily get lost in a new city.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree

I enjoy reading maps.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4

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Appendix S8: SBSODS Baseline Survey

<table>
<thead>
<tr>
<th>Question</th>
<th>1 - Strongly agree</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7 - Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have trouble understanding directions.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I don't remember routes very well while riding as a passenger in a car.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I don't enjoy giving directions.</td>
<td></td>
<td></td>
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Appendix S9: SBSODS Baseline Survey

It’s not important to me to know where I am.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 6
☐ 0
☐ 7 - Strongly disagree

I usually let someone else do the navigational planning for long trips.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree

I can usually remember a new route after I have traveled it only once.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree

I don’t have a very good “mental map” of my environment.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree
Appendix T1: Ethics Approval Letter

Notice of Approval

Date: 31 March 2021
Project number: 24103
Project title: Establishing a baseline of environmental spatial ability
Risk classification: Negligible/Low
Chief investigator: Dr Amy Griffin
Status: Approved
Approval period: From: 31/03/2021 To: 01/04/2024

The following documents have been reviewed and approved:

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<thead>
<tr>
<th>Title</th>
<th>Version</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk Assessment and Application Form</td>
<td>4</td>
<td>31/03/2021</td>
</tr>
<tr>
<td>Participant Information Sheet and Consent Form</td>
<td>4</td>
<td>31/03/2021</td>
</tr>
<tr>
<td>Recruitment Material</td>
<td>4</td>
<td>31/03/2021</td>
</tr>
<tr>
<td>Research Instruments</td>
<td>4</td>
<td>31/03/2021</td>
</tr>
</tbody>
</table>

The above application has been approved by the RMIT University CHEAN as it meets the requirements of the National Statement on Ethical Conduct in Human Research (NHMRC, 2007).

Terms of approval:

1. Responsibilities of chief investigator
   It is the responsibility of the above chief investigator to ensure that all other investigators and staff on a project are aware of the terms of approval and to ensure that the project is conducted as approved by CHEAN. Approval is valid only whilst the chief investigator holds a position at RMIT University.

2. Amendments
   Approval must be sought from CHEAN to amend any aspect of a project. To apply for an amendment, use the request for amendment form, which is available on the HREC website and submitted to the CHEAN secretary. Amendments must not be implemented without first gaining approval from CHEAN.
Appendix T2: Ethics Approval Letter

RMIT Classification: Trusted

3. Adverse events
   You should notify the CHEAN immediately (within 24 hours) of any serious or unanticipated adverse
effects of their research on participants, and unforeseen events that might affect the ethical
acceptability of the project.

4. Annual reports
   Continued approval of this project is dependent on the submission of an annual report. Annual
reports must be submitted by the anniversary of approval of the project for each full year of the
project. If the project is of less than 12 months duration, then a final report only is required.

5. Final report
   A final report must be provided within six months of the end of the project. CHEAN must be
   notified if the project is discontinued before the expected date of completion.

6. Monitoring
   Projects may be subject to an audit or any other form of monitoring by the CHEAN at any time.

7. Retention and storage of data
   The investigator is responsible for the storage and retention of original data according to the
   requirements of the Australian Code for the Responsible Conduct of Research (R22) and relevant
   RMIT policies.

8. Special conditions of approval
   Nil.

In any future correspondence please quote the project number and project title above.

Yours faithfully,

Professor Falk Scholer
Chair, STEM College Human Ethics Advisory Network

Cc Students Investigator/s: Ms Erin Koletais
   Other Investigator/s: Prof William Cartwright AM, Prof Menno-Jan Kraak
Appendix U1: Participant Recruitment Questionnaire

Default Question Block

Q1. What is your name?

Q2. Do you have normal or corrected-to-normal vision?
   ○ Normal
   ○ Corrected-to-normal

Q3. Do you wear glasses/spectacles?
   ○ Yes
   ○ No

Q4. Do you wear contact lenses?
   ○ Yes
   ○ No

Q5. Do you have any physical disabilities that would affect your ability to use a smartphone or move about outdoors?
   ○ Yes
   ○ No

Q6. How familiar are you with Melbourne's city centre?
Appendix U2: Participant Recruitment Questionnaire

Q7. How often do you visit Melbourne’s city centre?

☐ Daily
☐ 2-3 times a week
☐ Once a week
☐ 2-3 times a month
☐ Once a month
☐ 6-10 times a year
☐ Once a year
☐ I’ve never been to Melbourne’s city centre

Q8. Below is a bottle filled with water. The level of the water is indicated by the blue line. Below this are three empty bottles rotated at various angles. In the following three questions, please select the correct water-level placement.

https://www1.qualtrics.com/Q/EdEditAnchor/Static/19960/Project/Survey/View/Survey/ID=28729197... 310
Q8. Using the options below, please select the one that best represents the placement of the water-level in this bottle.
Q10. Using the options below, please select the one that best represents the placement of the water-level in this bottle.
Appendix U5: Participant Recruitment Questionnaire

Q11. Using the options below, please select the one that best represents the placement of the water-level in this bottle.
Appendix U6: Participant Recruitment Questionnaire

Q12. I am very good at giving directions.

- 1 - Strongly agree
- 2
- 3
- 4
- 5
- 6
- 7 - Strongly disagree

Q13. To ensure the quality of our data, please select two to four times a year below:

- Daily
- Once a week
- Once a month
- 6-10 times a year

https://mail.au.qualtrics.com/Previews/Ons/1900/H观fSurvey/1900/Preview/HneySurveyID=6V_3k02m7Cal.Req3h5aConte.oryBu0yIEU0... 8/10
Appendix U7: Participant Recruitment Questionnaire

Q14. I have a poor memory for where I left things.

- 1 - Strongly agree
- 2
- 3
- 4
- 5
- 6
- 7 - Strongly disagree

Q15. I am very good at judging distances.

- 1 - Strongly agree
- 2
- 3
- 4
- 5
- 6
- 7 - Strongly disagree

Q16. My "sense of direction" is very good.

- 1 - Strongly agree
- 2
- 3
- 4
- 5
- 6
- 7 - Strongly disagree

Q17. I tend to think of my environment in terms of cardinal directions (N, S, E, W).

- 1 - Strongly agree
- 2
- 3
- 4
- 5
- 6
- 7 - Strongly disagree
Appendix U8: Participant Recruitment Questionnaire

| Q18. I very easily get lost in a new city. |
|-----|----------------|
|     | 1 - Strongly agree |
|     | 2               |
|     | 3               |
|     | 4               |
|     | 5               |
|     | 6               |
|     | 7 - Strongly disagree |

<table>
<thead>
<tr>
<th>Q19. I enjoy reading maps.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Strongly agree</td>
</tr>
<tr>
<td>2</td>
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<tr>
<td>3</td>
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<tr>
<td>4</td>
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<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7 - Strongly disagree</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q20. I have trouble understanding directions.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Strongly agree</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7 - Strongly disagree</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q21. I am very good at reading maps.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Strongly agree</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
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<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7 - Strongly disagree</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q22. I don't remember routes very well while riding as a passenger in a car.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Strongly agree</td>
</tr>
<tr>
<td>2</td>
</tr>
</tbody>
</table>

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Appendix U9: Participant Recruitment Questionnaire

Q20. I don't enjoy giving directions.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree

Q24. It's not important to me to know where I am.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree

Q26. I usually let someone else do the navigational planning for long trips.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7 - Strongly disagree

Q28. I can usually remember a new route after I have traveled it only once.

☐ 1 - Strongly agree
☐ 2
☐ 3
☐ 4
☐ 5

https://mail.siu.qualtrics.com/2/EdiG形/5RiaZUyjOnlSurveyPrintPreview/ContentSurveyID=1V_3kOZrY7cal,RegPlfIContentLibraryID=U... 8/10
Q27. I don’t have a very good “mental map” of my environment.

- 1 - Strongly agree
- 2
- 3
- 4
- 5
- 6
- 7 - Strongly disagree
Appendix V1: Ethics Approval Letter

Notice of Approval

Date: 25 March 2021
Project number: 24085
Project title: Evaluation of map design for map illiterate tourists
Risk classification: Negligible/Low
Chief investigator: Dr Amy Griffin
Status: Approved
Approval period: From: 25/03/2021 To: 30/09/2021

The following documents have been reviewed and approved:

<table>
<thead>
<tr>
<th>Title</th>
<th>Version</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk Assessment and Application Form</td>
<td>3</td>
<td>15/03/2021</td>
</tr>
<tr>
<td>Participant Information Sheet and Consent Form</td>
<td>3</td>
<td>15/03/2021</td>
</tr>
<tr>
<td>Recruitment Material</td>
<td>3</td>
<td>15/03/2021</td>
</tr>
<tr>
<td>Research Instruments</td>
<td>3</td>
<td>15/03/2021</td>
</tr>
</tbody>
</table>

The above application has been approved by the RMIT University CHEAN as it meets the requirements of the National Statement on Ethical Conduct in Human Research (NHMRC, 2007).

Terms of approval:

1. Responsibilities of chief investigator
   It is the responsibility of the above chief investigator to ensure that all other investigators and staff on a project are aware of the terms of approval and to ensure that the project is conducted as approved by CHEAN. Approval is valid only whilst the chief investigator holds a position at RMIT University.

2. Amendments
   Approval must be sought from CHEAN to amend any aspect of a project. To apply for an amendment, use the request for amendment form, which is available on the HREC website and submitted to the CHEAN secretary. Amendments must not be implemented without first gaining approval from CHEAN.

STEM College
College Human Ethics Advisory
Network (CHEAN)
Email: humanethics@rmit.edu.au
Tel: (61 3) 9925 4620

RMIT UNIVERSITY
Appendix V2: Ethics Approval Letter

3. Adverse events
   You should notify the CHEAN immediately (within 24 hours) of any serious or unanticipated adverse effects of their research on participants, and unforeseen events that might affect the ethical acceptability of the project.

4. Annual reports
   Continued approval of this project is dependent on the submission of an annual report. Annual reports must be submitted by the anniversary of approval of the project for each full year of the project. If the project is of less than 12 months duration, then a final report only is required.

5. Final report
   A final report must be provided within six months of the end of the project. CHEAN must be notified if the project is discontinued before the expected date of completion.

6. Monitoring
   Projects may be subject to an audit or any other form of monitoring by the CHEAN at any time.

7. Retention and storage of data
   The investigator is responsible for the storage and retention of original data according to the requirements of the Australian Code for the Responsible Conduct of Research (R22) and relevant RMIT policies.

8. Special conditions of approval
   Nil.

In any future correspondence please quote the project number and project title above.

Yours faithfully,

Professor Falk Scholer
Chair, STEM College Human Ethics Advisory Network

Cc: Student Investigator/s: Ms Erin Koletas
    Other Investigator/s: Prof William Cartwright AM, A/Prof Adrian Dyer, Prof Menno-Jan Kraak
Appendix W: Written Instructions for Participants

Participant Instructions

The aim of this activity is to evaluate the design of a map for pedestrian wayfinding. This activity involves using an app on a smartphone to walk between two locations as indicated by the map. To assist in the analysis of this activity, the movements of your eyes will be recorded, and you will be required to use think aloud protocols, which involves you speaking your thoughts as you undertake the activity. You are to voice all of your thoughts relating to the activity as they come to your mind. Try to be as clear as possible when describing what you are trying to do and any confusion you may experience. Remember, evaluating the design of the map is the aim of the study and therefore encountering challenges is not a problem. It is the quality of the map that is being studied not your ability or performance.

In this exercise, you can walk at your own pace, and please be sure to obey traffic signals for the safety of yourself, and the researchers. Once you are satisfied that you have reached the destination, please inform the researchers who will be walking a few metres behind you.
Appendix X1: Post-Test Interview

Post-Test Interview

Participant ID: (researcher to complete): __________

Now that you have completed all tasks for the experiment, we would like to obtain some information relating to your thoughts on the map product and task execution. Below are 7 questions that will ask you about your satisfaction in relation to certain aspects of the map and task execution. Three of the eleven questions are open-ended and ask for your opinions on the map.

1. On a scale of 1 to 5, with 1 being very difficult and 5 being very easy, how easy did you find the product to use?
   - 1
   - 2
   - 3
   - 4
   - 5

2. On a scale of 1 to 5, with 1 being very dissatisfied and 5 being very satisfied, how satisfied were you with the map product for the purpose of navigation and wayfinding?
   - 1
   - 2
   - 3
   - 4
   - 5

3. On a scale of 1 to 5, with 1 being very uncomfortable and 5 being very comfortable, how comfortable did you feel using the map to navigate and wayfind?
   - 1
   - 2
   - 3
   - 4
   - 5

4. On a scale of 1 to 5, with 1 being very dissatisfied and 5 being very satisfied, how satisfied were you with the amount of time it took for you to find your way from the origin to the destination?
   - 1
   - 2
   - 3
   - 4
   - 5

5. What did you like about the map?
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________

6. What didn’t you like about the map?
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
Appendix X2: Post-Test Interview

7. How could the map be made easier to use?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Appendix Y: Permission from Identifiable Subjects

I have obtained permission from the identifiable subject on pages 95 and 97 of my thesis to display their image.