

Usability Evaluation of Route Mate– A Route Learning System Developed on the Android OS for People with Intellectual Disability

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ABSTRACT

This study investigates the usability of a location-aware assistive technology for the Android mobile operating system which is designed to aid the development of cognitive maps in young adults with intellectual disabilities. A mixed method experimental design was created which took the heterogeneous characteristics of the participants into account. The results from the implementation of this experimental design are analysed using both quantitative and qualitative methods and conclusions about the usability of Route Mate are made. These conclusions can be used as the basis for developing a scenario of use and can also be used to benefit the future development of Route Mate; several suggestions for the development of Route Mate are briefly outlined in this paper. An expanded, longer-term, mixed-method experimental design is also proposed for future research purposes.

INTRODUCTION

The purpose of this study is to analyse the usability of Route Mate, a location-aware assistive technology for the Android mobile platform. The development of Route Mate was motivated from the desire to develop a technology which could help individuals with learning disabilities and sensory impairments gain independence when commuting; And secondly as a proof-of-concept for a mobile assistive technology for people with intellectual disabilities (McHugh 2009). Intellectual disabilities can have a detrimental effect on social cohesion and can significantly limit the independence of individuals who suffer from some form of related disability (LaGrow, Wiener and LaDuke 1990). The UK Government notes in its Valuing People Report (Department of Health 2001) that increasing access to transport is an important step towards enabling people with intellectual disabilities to lead a better quality of life. According to Szymanski and King (1999) around 1% of children between the ages of 6-16 suffer from some form of intellectual disability, with prevalence increasing to 2-3% when based upon IQ test results, with 75-80% of cases being classified as “mild”.

Developed for the open-source Android mobile platform, Route Mate is a location-aware mobile application which incorporates games based-learning (Brown et al. 2010). Route Mate is intended to aid the development of cognitive maps which, after development, can be used to gain skills which enable individuals to travel independently. The application makes use of GPS technology commonly found in modern smartphones and Google Maps to provide the mapping service which is displayed on the devices screen (Fig 2). The map can be panned in four directions via the buttons overlaid on the map and can also be manipulated by scrolling with screen touches. Zoom functionality is available via two buttons in the lower corners of the screen.

Cognitive maps are formed when individuals repeatedly navigate a specific environment (Jheng and Pai 2009). After construction, cognitive maps are later used to aid subsequent navigation to a location. Intellectual disabilities and cognitive diseases such as Alzheimer’s can prohibit the creation of fully formed cognitive maps leading to fragmented or non-existent memories of areas. An individual’s inability to form cognitive maps can lead to disorientation, confusion and anxiety and is a significant reason why people with intellectual disabilities suffer from difficulties in social integration.

A human’s navigation ability relies on two strategies, egocentric tasks and allocentric tasks. An egocentric strategy is the use of information learned in a sequential manner from a route and the landmarks on that route to effectively reach the target. An allocentric strategy or cognitive map is the use of a mental representation that includes the direction and distance between points, landscapes and targets. In this manner an individual can navigate between these places in a sequential manner (Tolman 1948).

THE CONCEPT OF ROUTE MATE

Route Mate contains three modes: Plan, Practice and Use. The purpose of each of these modes is outlined below.

Plan

Plan mode is used to create a route for future use; this task would normally be completed with the help of a carer or parent. The user gives the route a unique name (Fig. 1); they are then taken to a screen where they are able to define the start point of the route. A start point is created by entering an address or by manually specifying a point on the map screen. The user then defines the end point by either entering an address or manually choosing an area on the map screen. Furthermore, Route Mate allows the user to create alarms and specify an emergency contact number.

Plan mode also allows the user to place points of interest on the map, such as the local shop or a task to complete along the route, each of these points can be associated with a photo.



Figure 1: Route Creation



Figure 2: Map Screen & Point Menu

Practice

Before the route is enabled in Use mode the user has to run through the Practice mode. The purpose of the Practice mode is to record the route taken by the user. This route is used as a template in the Use mode to check whether the user is on the correct route.

The user is represented on screen by a small yellow figure which moves in relation to the movement of the user. As can be seen from Figure 3 the user has five menu options, available by pressing the physical menu button on the device. “Map mode” allows the user to toggle between map and satellite as well as allowing the compass to be activated.

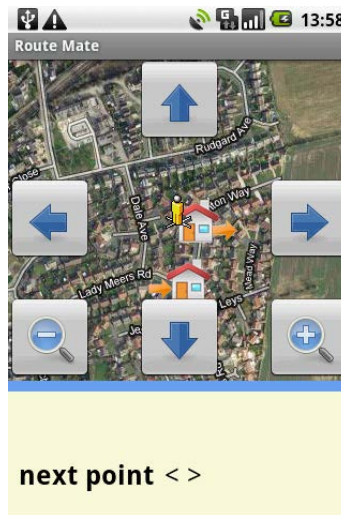


Figure 3: Practice Map

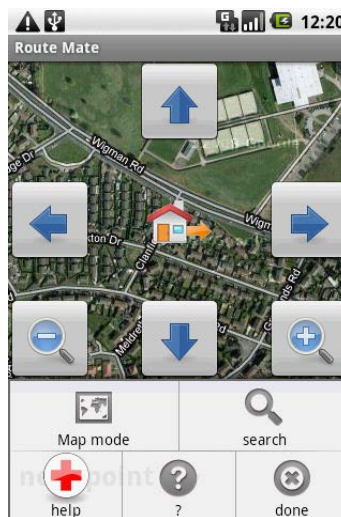


Figure 4: Practice Menu

“Help” sends a text message to the emergency contact stating the users location. Once the user has reached the end of the route they must press the Done button to commit the route to the devices memory.

Use

Use is the primary mode that users operate within during their time interacting with the application. The purpose of the Use mode is to track the movements of the user and to compare these to the route recorded during the Practice session. The aim of the application being that after continual use of the Use mode the user will need to refer to the device less for assistance, leading to the successful construction of a cognitive map. Unlike other GPS navigation systems Route Mate does not provide the user with explicit directions, it is solely up to the user to use the map on the device to make educated decisions about their position in relation to important points and how to get between these points. As can be seen from Figure 5 the application displays whether the user is following the route correctly and also shows the next point on the route, such as “Get Food” as well as whether the user is running on time.

From the start point the user should navigate to the next point on the map, once this has been done an alert is created to inform the user they are at the correct point, the alert also displays the picture related to the point. Once the user has successfully navigated to all of the points, in the order specified during the Practice stage, and has reached the end point an alert is produced informing the user of successful route completion.

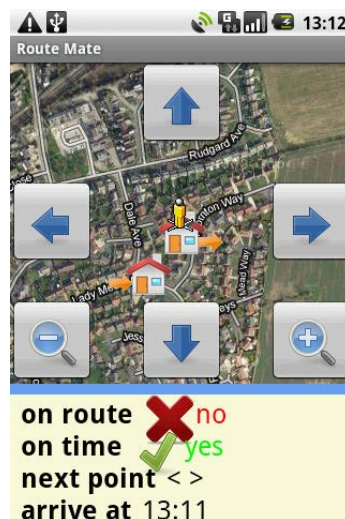


Figure 5: Use Map Screen

EXPERIMENTAL DESIGN

The experimental design consisted of a within-subject mixed method methodology (Greene, Caracelli and Graham 1989) which collects both quantitative and qualitative data and is based upon the Case Study research methodology for mobile HCI as identified by Kjeldskov and Graham (2003). A within-subject design is more common in a study involving intellectual disabilities as the experimental design needs to be designed around the disparate abilities of the participants. Quantitative data was captured using a repeated measures assessment of error and help events. Qualitative data took the form of notes based upon the quantitative measure and other events. Previous work on Route Mate (Brown et al. 2010) has suggested that the amount of help and errors made by users should decrease as the participant moves between the Practice and Use stages.

An experimental hypothesis was constructed that stated that the amount of error and help events produced by each individual would be lower in the Use test than the Practice test. A null hypothesis would be that there is no discernible difference between the amount of help and error events generated in the Practice and Use sessions.

Preliminary Testing

Prior to the creation of the experimental design several preliminary sessions took place. The purpose of these sessions was to introduce the software to three individuals who were representative of the intended participant group. As explained by Nemeth (2002) it is beneficial to an experiment to carry out preliminary testing as the outcomes can be factored into the experimental design and data capture methodology. Through the preliminary testing it was possible to identify what was likely to occur during the main testing procedure.

The Participants & Explaining Route Mate

Due to the heterogeneous needs of the students involved in the study, consideration has to be made when interacting with them and when attempting to extrapolate meaningful information from their responses to prompts and any spontaneous feedback they produce. Shea (2006) has found that children with intellectual disabilities suffer from high-levels of boredom, especially when presented with a non-engaging activity. The same paper also notes that levels of communicative ability differ significantly between individuals and an appropriate approach needs to be devised in order for the communicator to be able to operate with the child on a sufficient level to derive meaning from their activities.

It is also important to note that there is a high level of comorbidities between intellectual disabilities and other mental disorders which can affect concentration such as ADHD and depression (Di Nuovo and Buono 2007), especially in children and young adults (Wallander, Dekker and Koot 2003). This can have a significant effect on an individual's ability to store and recall information and can have an overall diminishing effect on all cognitive ability leading to a reduction in overall living skills. Di Nuovo and Buono (2007) conclude that for people with intellectual disabilities to interact successfully in daily life and to increase their level of independence it is important to "address attention, mood and anxiety".

Each participant was told that Route Mate was designed to help them in their day-to-day lives when travelling between home and school. The purpose of the study was explained to the participants, it was also explained that their performance would be anonymously measured and that notes would be made. The route was loaded on to the device and the position of the start and end points as well as other points of interest were indicated. The participants were also shown how to manipulate the map, either by dragging the map with their finger or by using the directional buttons on the map screen. They were also shown how to zoom in and

out on the map using the zoom buttons. At the start of the procedure the participants were shown the on-screen icon which represented their movements. For the first few metres of the test they were instructed to watch the device intently to understand how the yellow figure on the screen altered its position in relation to their own movements. Furthermore, the concept of the devices touch screen technology was introduced and it was stressed that only one finger should be placed on the screen in order for the device to operate properly.

Safety was also a major consideration because of the environment and the fact that the user had to concentrate on a handheld device while walking along a public road. The possibility of the participant becoming distracted and unaware of dangers such as passing cars was taken into consideration. The assistant who accompanied the participants on each test made sure that the participants followed the road safety procedures that they had learnt at school. Also one of the reasons the test route was chosen was because of its few crossings and relatively quiet roads.

The Environment & Device

The testing took place over a course of three days with a total of eight participants being assessed. Each participant was accompanied by an assistant who gave help when necessary. The assistant was allowed to interact with the participant during the course of the test to give help or explanation. The assistant was present to ensure the well-being of the participant and to ensure health and safety obligations were met. Testing only took place on days with fine weather conditions as rain could have a detrimental on the device and participant ability.

For the purpose of this experiment a HTC Magic smartphone (HTC Corporation Unknown) was used running version 1.6 of the operating system. The device uses a 3.2 inch TFT-LCD touch screen running at a HVGA resolution of 320 x 480 pixels. The physical dimensions of the device are 112 x 56.2 x 14.35 mm and with a weight of 135 grams. As well as the touch screen which acts as the primary input method the device also has six physical buttons on its front and a volume rocker on the left panel. Apart from the menu button there is no requirement for the participants to use any of the physical buttons during the test. The specification of the phone is typical of most smartphones which use the Android operating system. The testing environment offered 3G coverage meaning that maps were downloaded quickly when required.

The Task

Each participant was given the task of navigating between the same two start and end points shown in Figure 6. Figure 6 also displays the logical route to be taken between the two points and was the route participants took during the Practice mode stage.



Figure 6: Start and End Points Showing Logical Route

The start and end points were pre-defined in the Plan mode. Each user had an individual but identical route planned out. The start and end addresses were not created through the entry of a specific address, instead their creation was deferred using the Pick on Map option. The participant had no interaction with the creation of the route in the Plan mode, this ensured that each participant was evaluated on routes which were exactly the same. Because of the nature of the experiment the creation of points such as “Get Food” or “Meet Friend” would be irrelevant. Instead a number of points called “Road Sign” were created and placed at positions where road name signs were obviously visible; these points can be seen in Figure 7.



Figure 7: Map to Show Points

Each user navigated through the route twice, first in the Practice mode and secondly in the Use mode. Repeated measures for Error and Help events, were recorded on the Data Capture sheet, producing the quantitative data which needed to be derived from the study. Qualitative observational notes were made during the course of the testing sessions with all of the participants. This included recording any utterances made by the user, input from the assistant and any other miscellaneous observation.

As the Practice mode began the user was pointed in the correct direction, when they reached the first of the Decision Points (Fig 8) they were prompted to look at the map on the devices

screen and to make a decision about the direction they should head in. If an incorrect directional decision was made they were asked to re-think their decision and this was classed as one occurrence of requiring Help on the Data Capture sheet. Also, at each decision point the participant was asked to explain their navigation decision, any justification more complicated than a basic explanation or on the other hand a failure to properly communicate their decision was recorded on the Data Capture Sheet.



Figure 8: Decision Points

Once the route was completed in the Practice mode it was re-run using the Use mode. Observations and any Error or Help occurrences were recorded on a separate Data Capture sheet. Ideally the route navigated during the Use mode should be identical to the one that was navigated in the Practice mode. Similarly to the Practice phase the participants were left to make their own independent decisions about which direction to go in. If the user made an incorrect navigational decision they were asked to reconsider and provide a justification for the choice they had made. If the user still wanted to make the same navigational decision they were corrected by either the evaluator or the assistant.

Route Mate is supposed to alert a user during the Use Mode if they have made an incorrect navigational decision and are heading in the wrong direction to reach the end point. However during the preliminary testing it was found that this feature of the application worked sporadically and did not aid the user in correcting their route. Therefore it was decided that the user should be corrected immediately if they made an incorrect navigation choice. If a user was allowed to actively follow an incorrect route of their own construction it would invalidate the recorded data. Also it would be likely that the user would become severely disorientated and would be unable to self-correct the route they were taking.

Data Capture Sheet/ Classification of Errors

The data sheet was created after the preliminary testing and was designed to capture both quantitative and qualitative data. Each participant was given a unique ID number and a new sheet was used for each Practice and Use session.

Quantitative Data Capture

A frequency count was used to record the amount of instances of help and error events. A tally of these events was recorded in the Frequency Count box on the Data Capture Sheet.

A help event is where the user asked for help or where it is judged that it is required to give help. For example, the user may lose their position on the map and are unable to navigate back to the correct position, in a case such as this it would be necessary to re-centre the map for the participant but only after a reasonable period of letting them attempt to do it themselves. Another situation is where they explicitly asked for help, for example if they wish to be reminded of how to move the map or what the different points on the map mean. Moreover, if the participant needed help or correction for which way to head next, most probably at a Decision Point this would also be recorded as a help event.

An error event would be where the participant incorrectly uses Route Mate or the device. If the user pressed the wrong button on the device, for example if they pressed the physical home button and accidentally quit the application this would be recorded as an error. Another type of error would be if the participant operated the Route Mate application or the underlying operating system incorrectly, for example, they used the map navigation buttons incorrectly, zooming out too far or navigating to an area of the map which is not relevant to the route being taken. These would all be recorded as an error event. An error event may also trigger a help event to occur, for example, if the participant incorrectly used the device or the application and subsequently required help to correct the situation this would be recorded as an error event for the original incorrect use and as a help event for the assistance required in correcting the error.

Qualitative Data Capture

To meet the experimental designs objective of capturing comprehensive qualitative data the Data Capture Sheet was designed with plenty of space for recording observations and notes. The last page of the sheet was left blank for the recording of notes, furthermore for each help and error event there was space left to make observations about the nature of each event. These notes were made to be as thorough as possible, to allow for the effective elucidation of data. Walking, interacting with the participants and actually making the observations effects the practicalities of note making.

Other occurrences which are deemed notable include spontaneous feedback from the participant and their replies to directed questioning, such as when they were asked to give their justifications for taking their chosen route. Not only were the comments from the participants recorded but also from their assistant. These could prove to be particularly insightful as these people interact with the participants on a daily basis and have an intricate comprehension of their ability level, the way they communicate and their individual idiosyncrasies.

RESULTS

Issues During Testing

Several unexpected issues occurred during the testing of Route Mate, although they are only minor and did not have a significant effect on the testing procedure it is still important to note them.

After walking for about 10 metres in the Use mode the application stopped responding, this happened in the testing of each participant. When this type of error occurs the Android OS offers two options, wait for the application to begin responding again or force close the application. Fortunately, on all but one of the tests choosing the wait option caused the program to become responsive again. However on the one occasion that the application had to be forced closed the participant had to return to restart their route.

One of the primary capabilities of Route Mate is to warn the user if they are deviating away from the correct route, however during testing this feature proved to be rather unpredictable. At the beginning of the route Route Mate was able to successfully identify whether the user was correctly positioned at the start point. However it was found that during the Use mode if a participant veered off the route recorded in the Practice mode Route Mate still reported that the user was on the correct route. During several of the evaluations Route Mate reported that the user was not on the correct route even though they were. Throughout the Route Mate evaluation tests there appeared to be no consistency in Route Mates ability to correctly recognise whether the participant was on the correct route or not.

One of the objectives of the experimental design was to allow the user some freedom to make decisions about where they should go, even if they made a mistake. It was hoped that the user would be able to see that they had made a mistake using the information provided to them by Route Mate and perhaps be able to correct themselves. However Route Mate's inability to correctly report whether the participant was on the correct route or not limited the effectiveness of this part of the experiment. Therefore during the actual evaluation the experimental procedure had to be altered slightly to take this into account, as per the experimental design the user was encouraged to make a navigational decision at one of the decision points, originally it was hoped that the user would then pursue their direction of choice, if it was wrong the user would have been given a reasonable amount of time to identify that they had made a mistake before being corrected. However Route Mate could not be relied upon to return correct information to the user and could give the illusion that they were on the correct route when they were not, therefore when it came to a decision point the participant was encouraged to make a decision about the route, if they made an incorrect decision they were corrected before they were allowed to pursue it. Unfortunately this limited the evaluations ability to assess Route Mate's ability to inform and subsequently help a student correct a route choice.

Participant Ability Levels

A total of eight participants were involved in the study. By comparing the ability levels of the participants and their performance when using Route Mate it is hoped that it will be possible to identify the suitability of Route Mate for people with differing levels of intellectual disability.

ID	English				Maths			Score Totals
	Read	Write	Speaking	Listening	Number	U + A	SS +M	
1	2B	2C	2A	2A	1C	1	2A	76
2	1C	1C	P7	P7	2B	1	2C	57
3	1C	2C	2A	2A	2A	2A	2A	77
4	1C	P8	1C	1C	P8	1	1C	52
5	P8	1B	1A	1A	P8	1	P8	56
6	2A	2C	2B	2B	2C	2	2C	76
7	1B	1B	1C	1C	1C	P8	2B	60
8	P6	P7	P8	P8	P6	P8	P7	42

Table 1: Participants Results Score

P levels 1-8 scales are sub-national curriculum, levels 1c-2a then go onto National Curriculum levels. For example, 1a is a better level than 1c, 2a is better than 1c.

Maths-Number, concerns the assessment of the child's use of the four operations, as well as fractions, decimals, percentages, number ordering and place values. Maths-U+A is the application and understanding of mathematical concepts. Maths-SS+M indicate an individual's comprehension of 2D and 3D shapes and their properties.

English- Speaking/Listening are measurements of a pupil's ability to communicate verbally, understanding of what is spoken to them and their ability to respond. Along with Maths-SS+M, Speaking/Listening is potentially the most relevant criteria to this study as they show a participants level of understanding and comprehension of abstract material, an important performance criteria for human-computer interaction.

Overall Score Totals were calculated by allocating a rank to the different ability scores (as shown in Table 2 below). These were then added together for each assessment score shown in Table 1, except U + A which contained level 1 score which are not recognised on the national curriculum tables. For example participant 1 has the marks 2B, 2C, 2A, 2A, 1C, 2A that works out as 13+12+14+14+9+14 to give an overall Score Total of 76.

Mark	P1	P2	P3	P4	P5	P6	P7	P8
Score	1	2	3	4	5	6	7	8
Mark	1c	1b	1a	2c	2b	2a		
Score	9	10	11	12	13	14		

Table 2: Ranking for Ability Information

Quantitative Measures

The following sections outline the quantitative results captured from the study. Table 3 shows the amount of help and error events for both the Practice and Use tests. These are based upon the criteria outlined in experimental design.

As can be seen from Table 3 each participant took part in both a Practice and Use procedure and the occurrence of Help and Error events were recorded for each.

ID	Practice		Use	
	Help	Errors	Help	Errors
1	6	3	2	1
2	9	5	11	8
3	3	2	1	1
4	7	4	4	3
5	5	3	2	0
6	3	1	3	1
7	3	0	3	1
8	0	3	1	0

Table 3: Overall Events

Help Events

Table 4 breaks the Help events down into four subcategories: Underlying OS, Route Mate application, Physical Device and Guidance Assistance. The subcategories were formulated through an analysis of the qualitative descriptions made for each event. Underlying OS Help events are where the participant needed assistance in operating the Android OS, for example they may have pulled the notification bar from the top of the screen and required help to correct this before they can continue with the test. A Help event for the Route Mate Application involved giving the user help or advice relating directly to the operation of the application; for example, if they had lost the correct position on the map they made have needed help to correct this before they can continue using the application. A Help event involving the physical device would involve giving advice on how to operate the physical controls present on the device. Guidance assistance is where the participant has made an incorrect judgement about the route and they needed to be corrected.

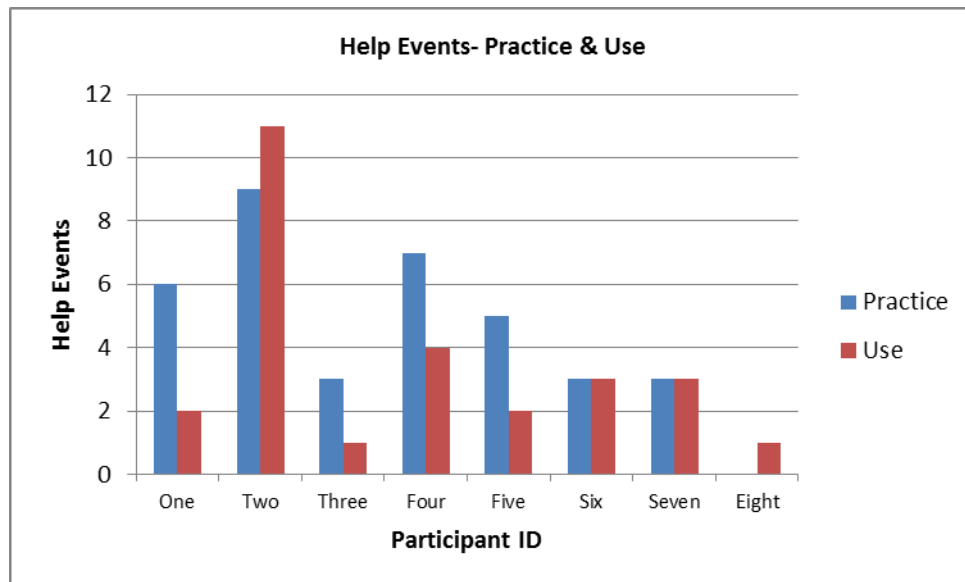


Figure 9: Graph to Show Help Events between Practice and Use Tests

ID	Type	Underlying OS	Route Mate Application	Physical Device	Guidance Assistance	Total
1	PRAC	1	1	0	4	6
	USE	0	0	0	2	2
2	PRAC	0	4	1	4	9
	USE	1	6	0	4	11
3	PRAC	0	0	0	3	3
	USE	0	0	0	1	1
4	PRAC	1	3	0	3	7
	USE	0	3	0	1	4
5	PRAC	0	2	0	3	5
	USE	0	0	0	2	2
6	PRAC	0	0	0	3	3
	USE	0	0	0	3	3
7	PRAC	0	0	0	3	3
	USE	0	2	0	1	3
8	PRAC	0	0	0	0	0
	USE	0	0	0	1	1
TOTAL:		3	11	1	38	53

Table 4: Breakdown of Help by Type

Table 5 displays descriptive statistics relating to the overall help events displayed in Table 4.

	Range	Mean	Std. Deviation	Std. Error Mean
Practice	9	4.50	2.828	1.000
Use	10	3.80	3.249	1.149

Table 5: Help- Descriptive Statistics

As can be seen in Table 5 there was a reduction in the mean help events between the Practice and Use test.

T-Test

Table 6 displays the results from a paired sample t-test analysis of the overall event results which were shown in Table 4, to show change between the results from the Practice and Use run sessions.

N	Correlation	Sig
8	.754	.031

Table 6: Help- Paired Sample Correlation

Paired Differences							
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of Difference		t	df	Sig. (2 tailed)
			Lower	Upper			
1.125	2.167	.766	-.687	2.937	1.468	7	.185

Table 7: Help Event- Paired Sample T-Test

Wilcoxon Signed Ranks Test

Table 8 shows the results from the non-parametric Wilcoxon Signed Rank Test evaluation.

Z Statistic	-1.476
p-value	.140

Table 8: Help Event- Wilcoxon Signed Ranks Test

Error Events

Table 9 shows a breakdown of the Error events into three categories, Underlying OS, Route Mate Application and Physical Device. An Underlying OS error is where the participant has incorrectly operated an item relating to the operating system, most commonly this is the notification bar at the top of each screen. A Route Mate Application error would be where the participant has incorrectly used Route Mate, for example they have incorrectly used the map navigation buttons. An error involving the Physical Device would be where they have incorrectly interfaced with the smartphone, for example by inappropriately pressing one of the buttons on the front of the device which could lead the application to quit.

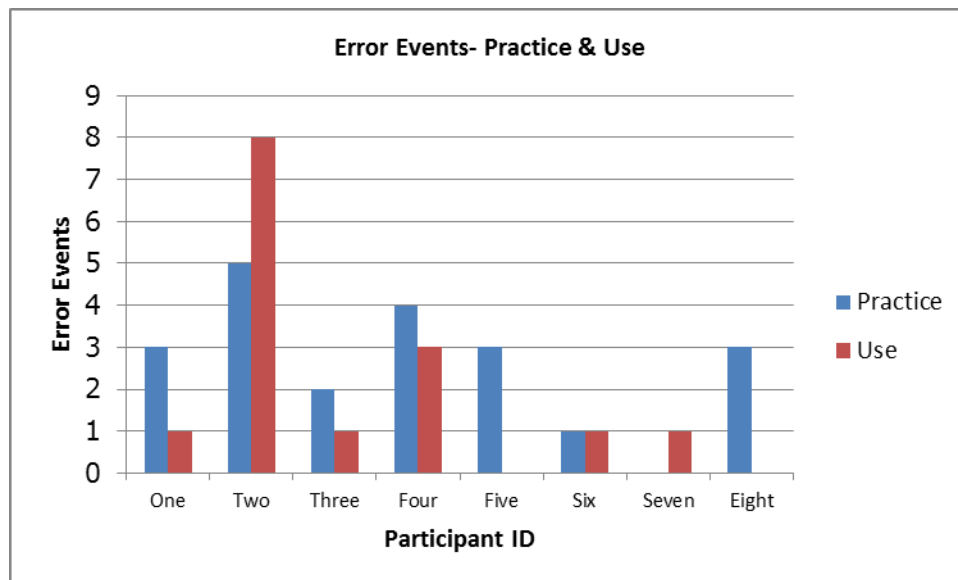


Figure 10: Graph to Show Help Events between Practice and Use Tests

ID	Type	Underlying OS	Route Mate Application	Physical Device	Misc	Total
1	PRAC	1	1	0	1	3
	USE	1	0	0	0	1
2	PRAC	1	4	0	0	5
	USE	1	6	1	0	8
3	PRAC	0	1	0	1	2
	USE	0	1	0	0	1
4	PRAC	0	3	1	0	4
	USE	0	3	0	0	3
5	PRAC	1	2	0	0	3
	USE	0	0	0	0	0
6	PRAC	0	1	0	0	1
	USE	0	1	0	0	1
7	PRAC	0	0	0	0	0
	USE	0	1	0	0	1
8	PRAC	0	3	0	0	3
	USE	0	0	0	0	0
TOTAL:		6	27	2	1	36

Table 9: Breakdown of Errors by Type

Table 10 displays descriptive statistics relating to the overall error events displayed in Table 9.

	Range	Mean	Standard Deviation	Standard Error Mean
Practice	5	2.625	1.495	.565
Use	8	1.875	2.472	.934

Table 10: Error- Descriptive Statistics

As can be seen in Table 10 there was a reduction in the mean error events between the Practice and Use test. Similarly to the results displaying the mean statistics for the help event, the results for the error events also support the experimental hypothesis in the experimental design.

T-Test

Table 11 displays the results from a paired sample t-test analysis of the overall event results which were shown in Table 9 to show change between the results from the Practice and Use run sessions.

N	Correlation	Sig
8	.754	.031

Table 11: Error- Paired Sample Correlations

Paired Differences							
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of Difference		t	df	Sig. (2 tailed)
			Lower	Upper			
.750	2.053	.726	-.966	2.466	1.033	7	.336

Table 12: Error Event- Paired Sample T-Test

Wilcoxon Signed Ranks Test

Table 13 shows the results from the non-parametric Wilcoxon Signed Rank Test evaluation.

Z Statistic	-1.029
p-value	.303

Table 13: Error Event- Wilcoxon Signed Ranks Test

Qualitative Measures

The concept of grounded theory is described by Elliott, Jones and Barker (2002) as “a strategy that can be adopted in the analysis of primary qualitative data but also quantitative data”. The grounded theory framework outlined by Glaser and Strauss (1967) is reasonably flexible and has been applied to HCI research areas in a number of ways including coding down to miniature line-by-line analysis (see Richards and Richards (1991)) to the formulation of broad categories and lower level sub-categories (see Mansourian (2008)). It is the latter of these strategies that was partially used in the analysis of Route Mate. It was hoped that the experimental design would provide enough qualitative information to complete all of the stages of grounded theory analysis as outlined by Strauss and Corbin (1998) to allow for theory generation, however the information collected has proved insufficient to do so.

However it has been possible to analyse the recorded qualitative results using Open coding analysis, the first step in grounded theory, this was used to split the qualitative observational results into contextual categories which were then subsequently broken down into sub-properties. This analysis has proved sufficient enough to act as a description generation. Subsequently the descriptions outlined below have provided sufficient information for the purposes of this study and when coupled with the quantitative data can be used to provide an overall assessment of the usability of Route Mate.

From analysis of the captured data using the Open Coding method for HCI research as outlined by Pace (2004) four contextual categories were identified: participant capabilities, underlying operating system, route mate application and the physical device. Categories were created from analysis of the data which highlighted reoccurring incidents across participants and are outlined below.

Participant Capabilities

One common issue of interest was the amount of time users spent looking at the device. Obviously the user is not required to continually look at the device as this would be both dangerous and excessive. However it was observed that when some of the users reached a street corner or one of the designated Decision Points they failed to even look at the device

when asked to make a judgement about the direction they should go in. Particularly participants 1, 2, 4, 5 made very little effort to consult the device. On the other hand participants 3 and 6 often paid too much attention to the device and had to be reminded by their assistant to check roads before crossing.

Large amounts of help were required to correct the participant's incorrect navigational choices. However there was a reduction in the amount given between the Practice and Use sessions, all together the participants required a total of 36 pieces of help in the Practice stage relating to guidance assistance but only 27 in the Use mode. However, with an average of 3.8 guidance related events in the Use mode this is quite high especially considering the route was relatively short and not too complex.

One common observation was the participants often struggled to distinguish between the points on the map and which one they should head towards. On several occasions guidance had to be supplied to the participant about which point on the map they should be moving towards.

Underlying Operating System

The participants had very little to do with the devices underlying operating system throughout the tests. However one of the most common errors made by the participants was to “pull down” the notification bar at the top of the screen, as shown in Figure 11.

The notification bar is present throughout the Android OS and is used to display system messages, such as a new text message, email etc. and is easily activated by a downward stroke at the top of the screen. Pulling down the notification bar has no detrimental effects on the state of the application but it does become inoperable as the whole screen is covered by the notification area. There is a high probability that the commonality of this type of error was caused by the close proximity between the upwards map navigation arrow and the notification bar. The notification bar can be dismissed by swiping upwards, however only one participant managed to do this, on the other occasions that this occurred the assistant or evaluator had to step in to dismiss the notification screen for the participant.

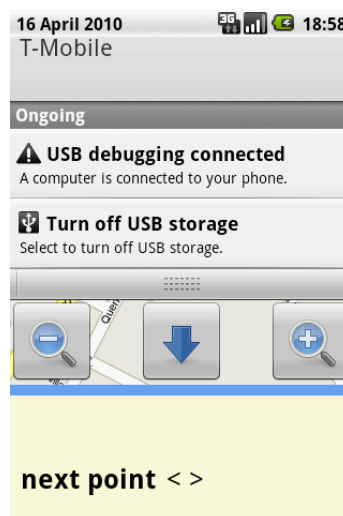


Figure 11: Notification Bar Pulled over Route Mate

The only other time that the participants had to interact with the OS was when they accidentally exited the program and needed to restart it. As can be seen from Table 9 participant 2 incorrectly used the physical device by pressing the Home button, therefore it was necessary for the participant to restart the application. However, even though he was shown how to do this in the introductory session the participant became confused and the device had to be taken off him and the application restarted by the evaluator.

Route Mate Application

Many participants struggled to correctly navigate the map, often their interaction with the map resulted in loss of position and disorientation. As previously noted the map can be moved either by dragging with a finger or by pressing one of the map navigation buttons. The four large map buttons are predominately placed on the map interface, taking up a large proportion of the map. It was found that users were drawn to these buttons and pressing them was one of the first things they did when given the device. More often than not the user was unable to self-correct and the evaluator had to step-in to reposition the map. Interestingly even though they are the same size as the map buttons, the zoom in/out buttons gained little attention from the users and no errors were made from their misuse. A great majority of the Route Mate application error events (27 out of an overall of 36) and Help (11 out of an overall of 53) events involved having to intervene to reposition the map for the participant after they incorrectly used the map navigation buttons. There were a total of 27 out of 36 error events relating to the misuse of the map navigation buttons, all but one occurred because the participant used the map buttons incorrectly, the other because they dragged the map in the wrong direction.

The participants showed some level of vacillation when faced with on-screen prompts, such as those produced when a defined point was reached on the map. Even when shown how to dismiss these screens, with a single button press, they often hesitated on their reoccurrence and subsequently looked for reassurance from the evaluator or their assistant. Although for anyone being introduced to a new technology it is presumed that some level of reassurance will be required.

The Physical Device

Although Route Mate can be installed on a multitude of devices the HTC Magic is a typical example of the types of smartphone devices which run Android OS. All but one of the participants managed to grasp the concept of the phone touch screen interface. Participant ID1 did not manage to interface well with the device as he was also physically disabled and had dexterity problems with his hands which meant he could not point or extend a finger in a manner which was suitable for interacting with the interface.

The tests did not require the use of any of the physical buttons on the front of the device, however several of the participants did use these. Pressing the Menu button makes a menu appear at the bottom of the application, doing so does not stop the application from functioning properly and can be easily dismissed by pressing the menu again. However several of the participants did press some of the other physical buttons on the device, most commonly the Home and Back button. Pressing the Home button exits the application and returns the user back to the Home Screen. This is easily rectified by opening the application again which returns back to the application in same state as when it was exited. Of the two participants who quit the application by pressing the Home button neither of them was able to re-open the application, they both needed help to do it. One participant pressed the Back

button which resulted in the application returning to the pick route screen. Again the device needed to be taken off the user and the route restarted.

DISCUSSION/CONCLUSION

User Applicability & Scenario of Use



Figure 12: Graph to Show Relation between Ability and Generated Errors

Using the participants' ability information and results it is possible to evaluate the correlation between a participant's examination scores and their ability to use Route Mate. As can be seen from Figure 12 there is little correlation between the ability levels of the participants and their ability to use Route Mate to generate as few errors and help events as possible. A particular anomaly is that the participant with the worst ability scores managed to produce the least amount of error and help events.

Based upon the results in Figure 12 and observations made during the study it appears that it is difficult to create a profile of a user who will deal with Route Mate well, based upon scores from traditional academic tests.

In a previous document about Route Mate (Brown, McHugh & Sik Lanyi 2009), it was stated that the Plan mode should be "carried out with a teacher or trainer", based upon the observations made during this study this seems a reasonable recommendation which should also be applied to editing the route. Before the creation of a route the teacher/trainer should identify the start and end points and also any points of interest they wish to include. The relevant pictures should then be taken in preparation for use in the route creation. The creation of a new route or the editing of an existing one requires the use of a software keyboard which many users struggled to use effectively during the preliminary testing. The placing of the start and end point, if not previously defined, on the map screen is also quite an exact procedure and is more suitable to completion by a teacher/trainer. The information required to create points of interest is also quite specific and again is more suitable to completion by an assistant. However this is not to say that a user should be excluded from the Plan stages. During the preliminary testing where the participants were encouraged to investigate the Plan stage the majority engaged well with the planning procedure. This can also prove to be a valuable experience as it allows users to acquaint themselves with the map screen and its navigational controls within a comfortable environment.

Once the route has been created the primary user should be handed the device and told to select the route from the Use mode. The Use mode will be used most often, it is important that the amount of menus between the start page and the map screen is kept to an absolute minimum. The existing system places only one menu, route selection, between the start page and the map screen. The following redesign supports this structure. The user should be accompanied during the first couple of times on the route, especially the first session to ensure that the proper logical route is recorded by the application.

Hardware Platform

Route Mate can be installed on a multitude of devices of varying physical specification. As the physical construction of a mobile device can have a significant impact on a user's ability to interact with software (Jin and Ji 2010) it is valuable to outline some recommendations for the device that Route Mate should be installed on.

During the testing the HTC Magic was used, this device has a 3.2 inch screen operating at a resolution of 320 x 480. The assistant with the participants remarked that the map on the screen was perhaps too small and that the participants would find it easier if the map was larger, other assistive technologies used at the participant's school tend to have bright, large and high resolution displays. The HTC Magic specification is typical of many devices running the Android operating system, although there are devices available with larger screens offering higher resolutions which will allow the user to see more map information on the screen. However, it is not just the physical dimensions that limited the size of the map area but also the way the interface was designed. Redesigning the interface to give the map area more predominance and removing inessential items will go some way to negate some of the problems experienced because of the small size of the devices screen.

The testing environment had 3G coverage meaning the maps were quick to download when needed. However when a trial use of the application took place in 1G coverage areas maps were slow to download, nearly taking a minute. This slow response time could prove frustrating for a person with intellectual disabilities, it also has serious consequences for the usability of the device. When the map is loading the user is presented with a blank grey screen with no information, this could prove detrimental to a user's concentration and orientation. It is therefore recommended that Route Mate should only be used in an area with 3G coverage unless some method can be devised to cache the required maps to the phones memory before the route begins.

Future Development & Proposed Expanded Experimental Design for Future Research

Route Mate has the potential to be a very beneficial assistive technology for people with intellectual disabilities. This study has evaluated the usability of the initial version of Route Mate using a mixed-method experimental design which took the participants heterogeneous characteristics into consideration. It was found that the participants struggled to operate several components of the application, most notably the map screen used in the Use mode. Many of the issues identified during this usability study can be addressed through a redesign of Route Mate structure and interface.

For example amalgamating the Practice and Use functions would streamline the functionality of the application without significantly altering its primary principles. A thorough redesign of the interface was made after this study and includes altering the use of button, lists and removing items from the map screen. Furthermore it was suggested that the function of the

points of interest could be altered to act as way points, it is believed that this would aid navigation without giving explicit instructions.

Testing of an assistive technology is an iterative process (Bühler, 1996), therefore Route Mate should undergo further analysis before it is distributed for use. If smartphones could be supplied to between nine and twelve individuals an evaluation could be designed to produce high levels of quantitative and qualitative data. The participants would have a route set-up in the device, such as the route from their home to place of work, whatever the route it should be one they have to follow at least three times a week. A record should be kept by the participants' guardians and teachers to track the participants' usage of Route Mate. They should be encouraged to use Route Mate each time they have to navigate the route. Points should be set-up at the beginning of the month and remain unchanged throughout the month. Evaluation sessions should be set-up at defined stages throughout the month to measure the development of the user's cognitive map. It would also be possible to assess the usability of the application during the evaluation sessions and measure how well participants adapt to using Route Mate after continual usage. Evaluation sessions should be conducted at the beginning of the month when the application is being introduced to the participant, mid-way through the month and at the end of the month. Ideally if Route Mate is helpful to people with intellectual disabilities to construct cognitive maps the participant should be able to travel the route virtually unassisted.

It is felt that the mixed-method experimental design used in this study was the most appropriate way to evaluate the participants; with a few changes for a long-term study it could return more useful results. In a long-term study quantitative research methods could be used to evaluate the effects on cognitive map creation, while an expanded qualitative research methodology could be used to further assess the usability of the device. It would have been useful to expand the qualitative data capture methods used in the experimental design. It would be particularly beneficial if the testing sessions had been recorded on video, this would have allowed for the conversations to be transcribed, one of the biggest problems with the experimental design used in this study was the difficulty of making observational notes while interacting with the participant while walking. It would also be more effective if two people were involved in the data capture, one could make notes while the other interacted with the participant when needed. This would also introduce a useful moderating factor to the research. Furthermore post-trial interviews with both participant and their accompanying assistant should also be introduced, which may also involve them filling out a questionnaire. The interview could cover general impressions, likes and dislikes and any suggestions for improvement. It would also give people a forum to air any opinions which they may have felt not suitable to make during testing.

The use of grounded theory does have a lot of potential in the paradigm of human-computer interaction (Arcs and Razali 2009) (Mansourian 2008) (Cairns and Cox 2008) and it would be particularly novel to use it in an empirically driven usability assessment method of individuals with intellectual disabilities. The literature shows little or no use of it in an assessment of assistive technology for people with intellectual disabilities. Particularly if used in an experiment with enough participants, with comprehensive external validity and rich qualitative data it could be used to enable theory generation, within the research context, compared to this study where only the first stage of the process was used to enable description generation. It is felt that grounded theory as an analytical technique is highly suitable in this context as it allows for high levels of variation in the data and heterogeneous data sources. Grounded theory is also highly adaptable (Mansourian 2006).

However grounded theory is no panacea, and does leave work open to some criticisms, particularly Elliott, Jones and Barker (2002) says that before grounded theory is applied the researcher needs to consider what a traditional HCI design approach would bring to the study. However Elliott, Jones and Barker (2002) concede that the vast majority of HCI studies fail to “result in anything beyond detailed observation”. Arguably if Elliott, Jones and Barker (2002) assertions are true, grounded theory is particularly well placed in HCI studies because it gives comprehensive outlines for the analysis of these “detailed observations”. However what is disconcerting is that Glaser and Strauss (1967) assert that researchers should have “no preconceived ideas”. This is especially mystifying as spontaneous questioning, questionnaires and interviews are advocated as suitable data capture methods. However this could be interpreted as the requirement of keeping an open mind (Strauss and Corbin 1998), avoiding bias and constructing open, axiomatic free questioning techniques to allow any data extrapolated to be free of interference from the researcher. Allan (2003) reports that when he applied grounded theory to his research he found ambiguity in the recommended method of creating coding, especially as he had “no hypothesis on which to focus”. However he concludes “Grounded Theory method is recommended as a powerful way to collect and analyse data and draw meaningful conclusions. The recommendation applies to any researcher in the hard sciences as well as the social sciences”. Therefore, it is proposed that a multifaceted qualitative data-capture method with grounded theory analysis is the best way to establish the usability of Route Mate in a long-term study, especially factoring in the considerations that intellectual disabilities bring to the study.

The applications effectiveness at constructing cognitive maps is better assessed using quantitative measures. Cognitive map measurement can be quite challenging (Billinghurst and Weghorst 1995), partly because cognitive maps are highly subject-specific. The assessment of a participant’s topological understanding of the route, the placement of things along a route, is more relevant to Route Mate than metrical spatial knowledge. Golledge (1976) identifies four methods of extracting information about an individual’s cognitive map:

- “Experimenter observation of subject behaviour”
- “Historical reconstruction”
- “Analysis of external representations”
- “Indirect judgement tasks”

Therefore one possible way of measuring cognitive maps include using “sketch maps” and making a user point to the relevant area on a map after being shown an image of a location. However these are challenging assessments and may be unsuitable for a person with intellectual disabilities because a participant may struggle to represent mental three dimensional maps, in a two dimensional sketch. Therefore a system of using printed cards and the photos used in the application for the points is proposed. The photos which are used as points in the application are printed onto paper, at evaluation sessions throughout the month these are given to the participants and they are asked to put them in order of occurrence along the route. The participant’s ability to successfully order the cards can be taken as an indicator of how successfully they have constructed a map. Recordings of success and errors in this task throughout the month can be placed into a statistical test such as a t-test to assess the improvement across the sessions.

Another way of measuring the cognitive maps could be to quantize the data in the video by measuring the amount of time spent looking at the device throughout the evaluation sessions. If a map is being constructed the amount of time spent looking at the device will decrease

across the sessions. However considering the variability in the participants who took part in the initial usability study it could be difficult to receive measures which carry much validity.

Although statistical analysis was used in this study, the analysis produced results which were of little help to the overall usability investigation, the qualitative result which led to descriptions of the test outcomes were of more use to this study. Although a hypothesis was made that stated the mean amount of help and error events would reduce on the second run through (the Use stage) the validity of such results would be stronger if they were derived from a long-term study. Any reduction in help events in this study could be put down to participants remembering the route from the Practice stage, which is of course the whole point of Route Mate, however these memories are probably short-term and if the participants were tested the next day the amount of guidance of help may increase again. Capturing quantitative data over a period of a month and then analysing that with appropriate statistical analysis will be the only way of properly determining the long-term benefits of Route Mate.

It is suggested that before the study begins the participant candidates are grouped according to intelligence (IQ) scores. Wong, et al. (2009) also suggests that these figures are verified using the Test of Non-verbal Intelligence (TONI-3), this would be especially relevant to evaluating Route Mate because a user does not need to interact verbally with the application. It may be valuable to group these participants into three groups; low, mid and high ability. It would also be appropriate to determine whether the individuals had any previous experience using mobile phones, more specifically phones with touch screen interfaces. Past experience with such devices may make these people more adept at using Route Mate. Moreover, any experience with a touch screen interface is likely to have a beneficial effect to an individual's learning curve when using Route Mate (Huang and Lai 2008). This would be an important factor to take into consideration when comparing results across participants.

By collecting IQ and TONI-3 results it may be possible to create a profile of the type of individual who would be able use Route Mate effectively (Wong, et al. 2009), something that this study failed to achieve.

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