Abstract
The research reported here is part of a larger project which seeks to combine serious games (or games based learning) with location based services to help people with intellectual disability and additional sensory impairments to develop work based skills. Specifically this paper reports on where these approaches are combined to scaffold the learning of new routes and ultimately independent travel to new work and educational opportunities. A phased development methodology is applied in a user sensitive manner, to ensure that user feedback drives the ongoing development process. Methods to structure this include group feedback on conceptual storyboards, expert review of prototypes using usability heuristics relating to the main system goals, and finally co-discovery methods with student pairs exploring all three modes of the system in real world contexts. Aspects of developmental and cognitive psychological theories are also reviewed and it is suggested that combining games based learning approaches with location based services is an appropriate combination of technologies for an application specifically designed to scaffold route learning for this target audience.

Keywords
Cooperative/collaborative learning; cross-cultural projects; human-computer interface; navigation; public spaces and computing.

Introduction

In the UK around 25 people in every thousand have mild or moderate intellectual disabilities and about four or five per thousand have severe intellectual disabilities (Department of Health, 2001). These disabilities are often combined with additional impairments (e.g., mobility or fine motor control and additional sensory impairments) and help will often be needed with almost every aspect of daily living (Brown et al, 2009a). People with intellectual disabilities often face a lack of control and opportunity in their everyday lives (Brown et al, 2009a), with less than 10% having jobs and few living in their own homes or having real choice over who cares for them (Department of Health, 2001). It is however, the intention of current policy (Department of Health, 2001) to enable people with intellectual disability and additional impairments to have as much choice and control as possible over their lives, be involved in their communities and to make a valued contribution to the world at work. Several major reviews have recognized that this can only be achieved via appropriately designed educational courses that equip them for independent living, and that also develop communicational skills (Tomlinson, 1997; National Development Group for the Mentally Handicapped, 1977).

One of the core skills required for leading an independent life and accessing the world of work is the gaining of independent travel skills and having the confidence to learn and travel new routes. Such skills are a key prerequisite to many of the recommendations of the UK Government's Valuing People Report (Department of Health, 2001): facilitating access to transport will enable people with intellectual disabilities to access a wider range of leisure opportunities and opportunities for education and lifelong learning (p 78). These activities will in turn enable them to lead full and purposeful lives (p87), increase their quality of life, facilitate social inclusion, encourage healthy life styles (p90) and enhance their chances of employment (p84).

Our solution to this problem is the development of an accessible location based services learning tool using the Android Operating System (such as on T-mobile's G1 phone) combined with games based learning approaches. The aims of the tool are to allow our target audience to plan and rehearse new routes to work, leisure and learning opportunities, and then to carry these out independently in a safe manner. According to Prasad (2006, p1) "Location Based Service or LBS, is the ability to find the geographical location of the mobile device and provide services based on this location information". Games based learning or 'serious games' can either be 3D immersive environments or "simpler games such as quiz games" (Down, 2008). This approach extends some earlier solutions based on flexible virtual environments (Brown et al, 2005; Sanchez & Saenz, 2006; Lloyd et al, 2006), where new routes and the generic skills involved in travel training could be practiced in preparation for real world experience. Evaluation illustrated good transfer to real world abilities.

Moving the environment of learning to a real world and real time context might help to compensate for the poor memory skills often associated with this target audience (Burack & Zigler, 1990) and ensure that learning takes place in a context similar to that in which it is required. This is important for a target audience described as 'concrete thinkers' whose performance is characterised as rigid, context dependent or as blind rule following and for whom generalization of learnt skills from one setting to another is unreliable (Gow et al, 1990). 'Context aware learning' is therefore particularly important for our target audience and 'mobile devices are especially well suited to context-aware applications simply because they are available in different contexts, and so can draw on those contexts to enhance the learning activity' (NESTA Futurelab Series Report 11, 2004, p15).

A location based service would also be able to offer real time support should route divergence occur or some other error be made. Location based services systems can track users' performance on previously trained routes and indicate significant divergence in terms of time or distance via a user specified alarm and offer advice for correction. Lindström (2007) states that for users with disabilities it is necessary to assimilate a mental map of the route to be taken. Importantly, if this mental map can be built in a mobile environment, then users will be less affected by unforeseen circumstances that may force a route change.

Parents and caregivers of people with intellectual disability are often prone to over-protection which can sometimes affect their personal freedom. Such a mobile device offering a system for independent route learning and real time support using location based services may help to mitigate some of these fears by allowing a user's position to be tracked, safe in the knowledge that should they get lost this system can be programmed to automatically text their GPS position with a street name to a nominated other's mobile device, or call a nominated helper to help them conversationally to navigate to safety. Users with disabilities often stress the importance of having some way to locate them when they can no longer orientate themselves during a journey (Lindström, 2007).

Using game based learning has several documented advantages. One of the primary advantages of serious games in learning is their ability to engage the learner voluntarily in sufficient repetitions of the activities to ensure learning takes place (Pivec, 2007). Persistent reengagement is the situation in which the player returns to the task unprompted (Garris et al, 2002). Serious games can also be particularly effective at engaging and motivating certain groups of learners with intellectual disabilities, such as offenders (Brown et al 2009b). Further evidence of the motivational powers of computer games for our target audience are emphasized by other researchers where such games were used in the successful retention of testers with intellectual disability in a study to evaluate a navigational device over a period of eighteen months in order to complete a baseline evaluation and to test each version of the prototype (Standen et al, 2006).

Serious games can be structured with different levels of challenge. One of the primary functions of tutoring, according to Wood et al, (1976), is to allow the learner to make progress by initially providing scaffolding, for example by controlling those elements of the task that are initially beyond the beginner's capability. As the beginner becomes more familiar with elements of the task and develops the ability to carry it out independently the tutor intervenes less. The secret is to ensure a balance between success and challenge and the different levels that can be built into games provides this. Systems for new route learning using location based services can be appropriately structured to heavily scaffold the planning of new routes and the first instances of traveling these new routes (and additionally in collaboration with peers including teachers), and then be programmed to offer less intervention as the user develops the confidence and skills to, ultimately, travel these routes independently. The situated learning paradigm emphasizes that learning is as much a process of social participation (Lave et al, 1991, in NESTA Futurelab Series Report 11, 2004, p13). Whilst other researchers offer similar arguments to Wood et al (1976) and ‘emphasise the idea of cognitive apprenticeship, where teachers (the experts) work alongside students (the apprentices) to create situations where the students can begin to work on problems even before they fully understand them’ (Brown et al (1989), in NESTA Futurelab Series Report 11, 2004, p13)

Serious games can provide immediate feedback so that an activity is easily linked with a learning outcome, in Pivec’s (2007) words: “the debriefing process between the game cycle and the achievement of the learning outcomes”.

Other researchers have also noted the potential of combining location-based experience with game-based learning, to “enable radically new forms of learning experience” Benford (2005, p4), and the importance of “accessing learning materials in the particular context where and when they are most immediately relevant…” Developing a learning-oriented system rather than a basic guidance system is a more appropriate approach for this target audience.

The development of virtual environments (VE) and 3D serious games for new route training can involve high development costs resulting mainly from programming costs. In an attempt to counteract this researchers have produced adaptable VE so that different town/road/building/road crossing layouts can be practiced (Brown et al, 2005), However this leads to teaching general travel training skills rather than learning specific new routes. Using location based services systems to plan and practice new routes involves relatively low costs, with set up costs involving mainly the purchase of a suitable mobile device (e.g., T-mobile’s G1 phone), and then staff or teacher costs to support a user in first planning and personalizing a route and then rehearsing this route. These costs are relatively small in comparison with the programming time to develop a bespoke VE or 3D serious game which can run into weeks and months.

2. User Sensitive Inclusive Design

A suitable development methodology for a route learning systems aimed at people with learning disabilities is the Phased Development methodology. Dennis and Wixom (2003, p11) state “The phased development methodology breaks the overall system into a series of versions that are developed sequentially”. The analysis phase identifies the overall system concept, and then the requirements are broken into a series of versions with the most important and fundamental requirements put into the first version (McHugh, 2009).

The route learning system is part of the development of a wider European project to develop games based learning approaches to teach work based learning for people with intellectual disability and additional impairments. User sensitivity is crucial to this project, and so the analysis phase was carried out with project stakeholders and user representatives (at the Birmingham Institute for the Deaf and the Shepherd School Old Students’ association). This process ensured that the overall system concept was appropriate to the needs of the target audience, and that the design requirements were actually derived via analysis of the user characteristics, the route learning tasks to be performed and their environment of action. The ways in which these design requirements could then be met by specific features of the route learning system (called Route Mate) were represented using conceptual storyboards, allowing early feedback in the design process via demonstrating these at facilitated user group meetings.

Early stage prototypes containing the important and fundamental requirements were also tested within facilitated user group sessions to ensure that the important usability and accessibility issues and other issues relating to the main system goals were corrected early on before they became major issues. Later, co-discovery methods were used with student pairs testing the prototype system in a real route learning situation. In this way, each stage of the Phased Development Methodology was applied in a user sensitive way and offered opportunities for the target audience to trial low fidelity and prototype versions to ensure the original goals of the overall system were met.

3. Analysis phase and iterative design with users

3.1 User scoped design requirements

Design requirements were scoped with trainers at the Birmingham Institute for the Deaf and teachers at the Shepherd School, Nottingham. These design requirements are shown in table 1.

Design Requirement Indicator	Design Requirement: The system should:
DR1	Assist users with planning and using a personalised route independently
DR2	Encourage users to use their own skills and not rely on the device
DR3	Reinforce learning objectives of the wider EU project curriculum
DR4	Not require the user to carry additional technology other than a mobile phone
DR5	Be accessible to users with learning difficulties and sensory impairment
DR6	Assist the user with other required skills development areas related to cognitive disability (such as memory)
DR7	Provide an easy facility to get help from a parent or carer when required

Table1: User scoped design requirements

3.2 Further design requirements

It was felt that a set of more focused accessibility-related design requirements were required for a system aimed at users with multiple cognitive and sensory impairments. Guidelines aimed at such users were reviewed including those using text in interactive systems aimed at people with a learning disability (Evett & Brown, 2005) and in the design of serious games for this same target audience (Brown et al, 2009a) combining recommendations from main resources (W3C 1999, 2008a; Horton, 2006) and various other notable resources (TechDis, 2009; Tiresias, 2008; BDA, 2008; NLN, 2003; Evett et al, 2006; Fields, 2009). In reviewing these guidelines with trainers from the two user-representative organizations the following additional design requirements were defined. These design requirements are shown in table 2.

Design Requirement Indicator	Design Requirement: The system should:
DR8	**Ensure presentation at appropriate speed –** it is essential that speed of presentation is appropriate for the particular target group, and may be modified during the iterative user-centred design process
DR9	**Allow users to go back –** essential for all users, and especially those who may have organisational, information processing and/or memory difficulties
DR10	**Allow User Control –** allow for user customisation based on user preference; for example, some users with dyslexia or visual impairment have distinct colour and contrast requirements, others may wish to slow things down, or to use keyboard access
DR11	**Text** – make any text plain text (rather than images or graphics), follow Clear Text for All guidelines (Evett & Brown, 2005, and see WCAG 2.0, W3C, 2008a), no dense blocks of text, plain English
DR12	**Text Alternatives**: Provide text equivalents for non-text content, including auditory and visual components, so that it can be changed into other forms people need, such as Braille, speech, symbols, other languages including sign language
DR13	**Colour –** never convey information by colour alone

DR14	**Contrast** – ensure sufficient contrast so that it is easier to distinguish items, both visual and auditory (cf. WCAG 2.0, W3C, 2008a)
DR15	**Navigable –** help users navigate, find content and know where they are: by placing navigation information in the same place (usually at the top) and ensuring that it is consistent and simple, using maps when appropriate, using home and back buttons, providing context and orientation information
DR16	**Maintain organisation –** instructions, buttons, clearly displayed and in the same place (often at top) throughout presentations
DR17	**Design simply –** in simple layouts, it is relatively easy to draw attention to important features and differences; in more complex layouts it becomes harder to highlight features, thus making presentations even more complex
DR18	**Robust –** make systems consistent and error free, provide appropriate error messages and error catching
DR19	**Aim for compatibility with assistive technologies –** e.g., screenreaders, text-to-speech, zoom features
DR20	**Seizures –** do not include elements that are known to cause seizures, for example by having elements that flash or have particular spatial frequencies

Table 2: Design requirements derived from published guidelines

3.3 First and second design with user feedback

The proposed solution to meet these design requirements is a location-aware application for a mobile phone (DR4) that allows users to plan their route in advance, rehearse the route before their first day at work, and use the route when traveling independently to work (DR1). Additional learning objectives should address route planning and time management, with the use of the system also promoting the development of memory, concentration, stress-management and confidence-related skills (DR3, DR6).

In addition to using GPS technology, the solution will also make use of the mobile phone's camera, to allow users to add their own pictures to the map (DR10), and a digital compass, to help communicate the direction in which the user is heading (DR1, DR2 & DR17). Table 3 shows other proposed system features to meet these design requirements.

Proposed System Features	Meeting Design Requirements
Setting a time to leave alarm with the program assisting/suggesting adjustments when the user arrives late for work	DR1, DR2, DR3, DR6 & DR10
An off-course alerter, to remind the user to stay on course	DR1, DR2 & DR7
An estimated time of arrival, to help users with time-management and allow the user to judge if they are going to arrive to work on time and react in an appropriate manner	DR1, DR2, DR6 & DR7

Personalised location-based reminders to compensate for poor memory skills of this target audience	DR6, DR7 & DR10
A 'play' mode to engage and scaffold users independently traveling new routes in a safe manner	DR1, DR2, DR3, DR7 and DR10

Table 3: Proposed system features to meet user and published guideline design requirements

This application is designed for the Android Operating System from Google, which is currently used by the HTC Dream & HTC Hero (available as T-mobile's G1 and G2 phones), the HTC Magic (available from Vodaphone & Orange), Samsung's I7500 (aka Galaxy) and InstinctQ from (available from O2). Google claim there will be at least 18 models using Android worldwide by the end of 2009 (DR4).

To help meet these accessibility-related design requirements text-to-speech (DR5, DR12 &DR19) is proposed, to be activated by long pressing on the text (to demarcate it's activation from the function of a button it may be attached to). A suitable tool would be Google's eyes-free project, which aims to turn Android mobile devices into eyes-free communication devices.

This solution was detailed in a project design document and represented in a series of conceptual storyboards. The visual nature of these storyboards made them ideal to scope feedback from a group of users with intellectual disability and additional impairments. The storyboards were projected onto an interactive whiteboard, and feedback invited for each mode of the design by a facilitator experienced in working and communicating with the research and design user group. 8 members of this group participated in this feedback, across two sessions. They ranged from late teens to early thirties, and their disabilities included Down's Syndrome, William's Syndrome and non–specific learning disabilities. This consultation exercise yielded the following improvements for the second design before physical prototyping of the system began, thus offering early opportunity for user evaluation and iteration of the proposed design (table 4)

Proposed system improvement	Relating to design requirement
Use symbols familiar to the target audience, e.g., Widget or Makaton	DR12
Remove compass and replace with a rotating map which orientates itself depending on the direction of travel	DR1, DR7 & DR17
Add street entry field to locate the position more precisely	DR1, DR6, DR8 & DR9
Add option to select type of reminder, e.g. cross road	DR1 & DR10
Provide help screen relevant to the type of reminder	DR1 & DR7
Text in lower-case and Comic Sans MS or Berlin Sans FB for easier reading	DR5 & DR11
Add description of where the user should enter the 'time of arrive at work'	DR1, DR5 & DR11
'E.T.A' changed to 'arrive at'	DR1, DR5 & DR11

Table 4: Second design iteration of low fidelity prototype

4. Phased Implementation
For reasons of brevity, the final phase (of a two phase) implementation is described here. The three modes of Route Mate remained stable across these two implementation phases, but some design features within these modes have either been removed or added to based on user based evaluation as described in section 5 (both expert review and testing with users).

The system (from now on called Route Mate) is implemented using Eclipse, a multi-language software development platform comprising an IDE and a plug-in system to extend it (Wikipedia Contributors; 2009). The Android SDK is a development kit that utilises the Eclipse plug-in system, using a variety of custom tools to help develop mobile applications, and most importantly the Android Emulator (Android, 2009).

4.1 Main Menu

The first screen (Figure 1) of the Route Mate application allows the user to choose between the Plan mode, Practice mode, Use mode or Language selection (DR1DR14, DR15 & DR17). A BSL button, common throughout the application, can also be selected to view a video describing the current screen in British Sign Language (DR5, DR12 & DR16). The Language selection button will change the language of the application to deliver the learning objectives in a variety of European languages (English, Greek, Lithuanian and Hungarian) (DR3, also Figure 1).

Insert Figure 1: Mode and language selection on Route Mate

4.2 Plan Mode

The Plan mode allows the user to set-up a route for future use with the help of a parent, carer or trainer. The user is given the option to create a new route, or load and modify an existing route (Figure 2, DR1). In addition, the user also has the option to go back to the previous screen, which is a common feature throughout the application, and is fully user controlled (DR8 & DR9). Selecting new prompts the user to enter the start address via entering a postcode or selection on a map (Figure 2). The screens are designed simply (DR17), with text, BSL and symbol alternatives (DR12), with appropriate contrast (DR14), with consistent organization and navigability (DR14 & DR16). No flashing elements are used (DR20). Appropriate error messages are shown and spoken if an appropriate address is chosen (DR5, DR12 & DR18). The user can also enter the start time of their journey, set daily alarms, and end address of their new route (Figure 2, DR1 & DR10).

Insert Figure 2: Selecting and personalizing a new route.

An emergency contact can be specified with appropriate error messages (Figure 3, DR5, DR 7, DR9, DR12, DR15, DR16 & DR18). The map mode shows the locations of the user, their start address, end address and points of interest using icons (also Figure 3, DR1, DR5 & DR10).

Insert Figure 3: Emergency contact and map mode

Points of interest can also be set between the start and end points using the phone's camera to break the journey up into a number of smaller routes connected by key landmarks and more effectively scaffold its learning (DR1 & DR10). When creating a point of interest, the user must enter a title for it, either using the text field or selecting an appropriate symbol, and add a picture using the phone's camera (DR5, DR10 & DR12)

Figure 4: Adding and personalizing key points on a new route

4.3 Practice & Use Mode

The Practice and Use modes are described together here, as they are very similar but with a few important differences. The 'Practice Mode' reinforces the learning of new routes, rehearsing the route a number of times accompanied by a trainer or teacher before independent travel (DR1). The 'Use Mode' allows the user to travel more independently, rely less on the application (which might be otherwise dangerous – for example looking down at the screen whilst crossing a road unaccompanied) and relying more on their own skills and not solely the device (DR1 and DR2).

To facilitate this, the screen turns off while travelling between points of interest in the ‘Use Mode’, with the device’s location awareness being used as the basis of a serious game to challenge the user to select their next key landmark from a variety of possibilities (the user’s own pictures).

On the first instance of traveling a previously prepared route the ‘Practice Mode’ will record that instance of the route to allow the system to provide help in terms of future divergence (distance or time) from this ‘ideal route’ (Figure 5, DR1, DR2, DR6, DR7 & DR18). When the user gets close to a point of interest, a window reminder appears displaying the relevant image. The phone also alerts the user through audio and vibration (DR2 & DR10).

In ‘Use Mode’, the user will be quizzed on the next point of interest. This game involves displaying three pictures they themselves have personalized their route with. The user is challenged to select the picture that relates to the next point of interest they must reach, or the activity they must do when reaching this point (Figure 5). In this more independent usage mode, the user is encouraged to use their own skills to successfully navigate the route (albeit broken down into a series of smaller and more easily traversed journeys, DR2 & DR6). This mode of usage is also more appropriate for independent use, with less time spent staring at the screen in a peripatetic environment. When the journey is complete, Route Mate will calculate their travel time and prompt the user to reflect on their journey if they have strayed from an ideal path, or taken too much time potentially making them late (Figure 5, DR1, DR2, DR3 and DR6).

Insert Figure 5: Games based mode and reflection in Route Mate

5. User based evaluation

5.1 Expert Review

The goals of the wider European project were that the serious games being developed (of which Route Mate was one example) should be accessible, effective in developing work based skills, innovative, and culturally appropriate. Formative evaluation via expert review was carried out at this stage of development. This approach is the most widely used form of expert review, where experts check the application against ‘heuristics’ for good design (Benyon et al, 2005). 12 international experts (serious games and assistive technology designers, trainers of the target audience, psychologists and accessibility specialists) described and reviewed a set of heuristics for each system goal (Table 5). As a group they then made a first pass through Route Mate’s three modes, reviewing each of the modes against each heuristic in some detail. The evaluators then produced a consolidated list of prioritised problems linked to these heuristics and suggested solutions.

System Goal for Route Mate	Heuristics to achieve these goals
Accessibility	Equitable use- does it disadvantage any of our user groups Flexibility - The design accommodates a wide range of individual preferences and abilities Simple, intuitive use- design is easy to understand, regardless of user's experience, knowledge, language skills or concentration levels. Perceptible Information - Design communicates necessary information effectively to the user, regardless of ambient conditions or user's sensory abilities. Tolerance For Error - The design minimises hazards and adverse consequences of accidental or unintended actions. Low physical effort - the design can be used effectively and comfortably, and with a minimum of fatigue.
Effectiveness	The games deal with appropriate themes of basic skills, personal development and employment preparation.
Engagement	Flexibility - The games allow multiple ways of doing things so as to accommodate users with different levels of experience and interest. Personalisation - They provide users with the opportunity to change the way things look or behave so that they can personalise the system. Style - Designs should be stylist and attractive
Innovation	Alternative software - is it already available?
Cultural Appropriateness	The metaphors used in the games are appropriate in UK, Bulgaria and Greece and for the various target groups. Translated language is appropriate and without error.

Table 5: Heuristics for good design

5.2 User Review

The standard approach of watching single users interacting with technologies and 'thinking aloud' as they do so, can be extended to allow users to evaluate technologies in pairs, termed co-discovery (Benyon et al, 2005). Co-discovery is a particularly powerful technique for people with learning disabilities who perhaps feel more confident in exploring new technologies with a peer, where feedback is gathered in real time rather than relying on post immersion recall. Testers were given the tasks of planning and rehearsing a route. Subtasks included:

1. Set a start and end location
2. Set an alarm
3. Set points of interest along the way
4. Add a picture to a point of interest using the camera
5. Use text to speech
6. View a point of interest reminder.
7. Send an SOS message
8. Change map mode

The pool of testers included 12 people aged 15-32 years, with a range of disabilities including Down's Syndrome (4), Williams Syndrome (2), Apert's Syndrome (1), and non-specific learning disabilities (5). In this case testing was fairly informal and the users were a heterogeneous group making comparison between the pairs difficult; this phase is part of system development and more formal evaluation is taking place now that the system is stable.

5.3 Results and discussion

5.3.1 Expert Evaluation

In general, the consensus was that Route Mate would be extremely beneficial to the target audience. There were two issues in the consolidated list of prioritised problems linked to the selected heuristics that should be addressed to produce a final version for evaluation in use.

The first is the use of Widgit symbols (arising from accessibility heuristics). Although using Widgit symbols increases accessibility to users with low literacy levels, this may only be the case to those who are already familiar with them. Users who have not used Widgit symbols before may not experience any benefits from their use (e.g., users outside the UK, and UK users of other symbolic communication systems). Unfortunately there is not an international (or even European standard) for such symbolic systems so a set of symbols were created specifically of use in this application, and made available for other mobile applications (see figures 1-5 for examples). A BSL signing track was also created for each screen as an alternative for Deaf students. All text in Route Mate was also checked as a result of this evaluation to ensure it's readability by Deaf students recognizing that English might not even be the second language of such students reflecting a recent plea made at the Accessibility 2.0 conference in London (Herrod, 2009)

The second problem to be addressed is the need for community safety (arising from effectiveness heuristics). Community safety addresses learning objectives such as when it is safe to cross a road, and when it is safe to look at the application for route support. It is recognized that an application designed to promote independent travel skills such as Route Mate, provides opportunity for greater freedom, but also greater personal risk, and these risks should be quantified and guidance given in Route Mate to prepare the user for their potential occurrence.

5.3.2 Co-discovery

Analysis of the observational checklist results of the co-discovery student pairs trialing the three modes of Route Mate yielded three areas for improvement to produce the version for evaluation in use.

The first concerned Accessibility. Route Mate should only require one input or data entry per screen. This reduces screen clutter and allows the user to focus on one specific task at a time. In addition, this results in more screen space to use for representing additional text as symbols and more comprehensive descriptions on what is needed for the input. This improvement was identified after some users seemed overwhelmed when reaching screens that required them to enter more than one piece of data. It should be made obvious which data entry method is required. As the system uses more than one method of entry, this is necessary to reduce confusion. In the case of text entry, the keyboard is hidden behind the screen, and the system should inform users that in order to enter text, they should slide the screen open.

The use of touch gestures should be rationalized for this target audience. Android uses touch gestures to allow users to scroll screens or pan the map. This method of controlling did not seem appropriate for this target audience in testing, as some found it difficult to understand concepts such as to scroll to the bottom of the screen, they must push the screen up. In the case of screen scrolling, this may not be an issue when the previously mentioned one input per screen rule is applied. However when interacting with the map, other controls should be supplied to pan. Testers also often found it difficult to perform tap touch events instead of long press touch events. The result of this was instead of activating the behaviour of a button (e.g., go to next screen), text-to-speech was activated causing frustration. Text-to-speech is activated in a more appropriate way in the final version, activated at the same time as the behavior of the object to also provide validation of users' intentions.

The buttons embedded into Route Mate should be of an appropriate size for the target audience. Observation of testing pairs revealed they were not of suitable size for the general level of hand-eye coordination skills of the testing group, with activation of a particular button difficult and a number of attempts necessary.

Route Mate should make use of simple, clear and concrete language. Examples of specific text changes as a result of co-discovery observation included ‘set as start’ and ‘set as end’ changed to ‘start point’ and ‘end point’.

The second area for improvement concerned engagement and cognitive load. Route Mate should provide a different interface and types of real time support when configured for independent use as compared with rehearsal mode. When rehearsing a saved route, the system is highly scaffolding their new route learning, with lots of feedback, high cognitive load and resulting in the user following the screen more intensely. In this case such a mode of use is appropriate (for their learning task) and safe (as they are accompanied by a trainer). When using a route independently, the cognitive load should be decreased so users can travel safely and only need to look at the phone for support or when an alert is issued.

The final area for improvement concerned ease of use. Initial training in the features of Route Mate should be given by a trainer. During co-discovery testing, users seemed to struggle when planning a route, and there may always be learning tasks for this target audience that should be accompanied by a trainer. Many testers also found it difficult to see which direction they should be heading in when the next point of interest or end location was in a position situated outside of the screen. Although users could set more points of interest so there is less distance between them, they should not be forced to. The last two areas for improvement accord with the situated learning paradigm, and the ideas of cognitive apprenticeship (NESTA Futurelab Series Report 11, 2004, p13).

5.3.3 Current Testing

Expert and user testing during design and development has produced a version of Route Mate suitable for more formal evaluation of use in the field. This testing is currently underway. A within subjects repeated measures design is being used. Each participant will do one run through of three components of one route (plan back at school, practice and run outside). Outcome measures (help, errors etc) for practice and run within a participant will be compared. It is expected that errors and help will be no higher, and will probably be lower, on run phase than on practice phase, and that participants will look at the screen less. It is expected that this first phase of testing will be completed by April 2010, and that this evaluation will inform the next stage of development of Route Mate.

6. Conclusions

There is evidence from both developmental and cognitive psychological theories, and from initial studies using co-discovery methods that games-based learning combined with location-based services can be effective in planning, rehearsing and then independently traveling new routes in people with intellectual disability and additional sensory impairments. Because these systems emphasise the learning of new routes rather than reliance on guidance systems their use might be particularly important for this target audience and potentially for users with a wider range of disabilities.

Route Mate has been iteratively developed and usability tested by both experts and users in a phased and user sensitive approach, following recently developed design guidelines. This formative evaluation identified a number of areas for improvement resulting in a prototype for more formal evaluation in the field. This further testing stage is currently underway to evaluate Route Mate’s effectiveness in practice for new route learning for the target audience. This will allow more effective assessment of its potential benefits. Route Mate utilizes cheaper pervasive technology to train in real environments and contexts, offering real time support for user error and sudden environmental changes, and potentially offers greater independence and choice for people with intellectual disability.

References

Android. (2009). Tools Overview. Retrieved 8th April, 2009, from http://developer.android.com/guide/developing/tools/index.html

BDA (2008). British Dyslexia Association Dyslexia Style Guide. Retrieved May 5, 2009, from http://www.bdadyslexia.org.uk/extra352.html

Benford, S. (2005). *Future Location-Based Experiences*. JISC Report, www.jisc.ac.uk

Benyon, D., Turner, P., and Turner, S. (2005). *Designing Interactive Systems: People, Activities, Contexts and Technologies.* Addison- Wesley.ISBN-13: 978-0-321-11629-1

Blamires, M. (Ed.), (1999). *Enabling Technology for Inclusion.* London: Paul Chapman Publishing.

Brooks B, M., Rose F. D., Attree E. A., Elliot-Square A. (2002). An evaluation of the efficacy of training - people with learning disabilities in a virtual environment. Disability and Rehabilitation 2002; 24(11-12): 622-626.

Brown, JS, Collins, A and Duguid, S. (1989). Situated cognition and the culture of learning. Educational Researcher, 18(1): 32-42

Brown, D.J., Battersby, S. and Shopland, N. (2005). Design and evaluation of a flexible travel training environment for use in a supported employment setting. *International Journal of Disability and Human Development* 2005, 4(3), 251-258.

Brown, D.J., McIver, E., Standen, P.J. and Dixon, P. (2008). Can Serious Games Improve Memory Skills in People with ID? *Journal of Intellectual Disability Research*. Vol. 52, Parts 8&9, 678. August 2008. ISSN 0964-2633.

Brown, D.J., Standen, P.J., Evett, L., Battersby, S., and Shopland, N. (2009a - In press). Designing Serious Games for People with Dual Diagnosis: Learning Disabilities and Sensory Impairments. In *Educational Gaming*. Chapter in Zemliansky, P and Wilcox, D. M., (eds), Educational Gaming, IGI Global.

Brown, D.J., Shopland, S., Battersby, S., Tully, A. and Richardson, S. (2009b). Game on: accessible serious games for offenders and those at risk of offending . *Journal of Assistive Technologies*, *3(2),* 15-30.

Burack, J. A., & Zigler, E. (1990). Intentional and incidental memory in organically mentally retarded, familial retarded, and nonretarded individuals. *American Journal on Mental Retardation, 94*, 532–540

Department of Health (2001). *Valuing People: a new strategy for learning disability for the 21st century*. London: HMSO.

Dennis & Wixom. (2003). *Systems Analysis and Design, Second Edition, Hermitage Publishing Services*, ISBN: 0-471-07322-9, 11 & 16

Down, K.A. (2008). Game-based Learning. Retrieved 10th January 2008 from: http://www.jisc.ac.uk/publications/publications/pub_gamebasedlearningBP/pub_gamebasedlearningBP_content.aspx.

Evett, L., and Brown, D.J. (2005). Text formats and web design for visually impaired and dyslexic readers: Clear Text for All. *The Journal of Interacting with Computers, 17*, 453-472

Evett, L., Brown, D., Smith, P., Hibberd, R., (2006). Cleaning up the environment – Accessible PowerPoint Presentations. *Proceedings of NTU 6th Annual Learning and Teaching Conference*, 26-44. March 2006, Nottingham, UK. Nottingham Trent University

Fields, G. (2009). Designing accessible mobile user interfaces. Accessibility 2.0 Conference - A million flowers bloom, London, 2009. Retrieved 12th April, 2010, from http://www.abilitynet.org.uk/accessibility2/wp-content/uploads/2009/09/blackberry-session.pdf

Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, motivation and learning. *Simulation & Gaming; An Interdisciplinary Journal of Theory, Practice and Research*, *33*, 4, 43–56.

Gow LP, Balla J, Butterfield E (1990) The relative efficacy of cognitive and behavioural approaches to instruction in promoting adaptive capacity. In: Key Issues in Mental Retardation Research. Fraser WI ed. Routledge: London UK 366-376

Green, C.S. & Bavelier, D. (2007). Action-Video-Game Experience Alters the Spatial Resolution of Vision. *Psychological Science, 18*, (1), 88–94*.*

Herrod, L. (2009). Understanding Deafness. Accessibility 2.0 Conference - A million flowers bloom, London 2009. Retrieved 12th April, 2010, from http://www.abilitynet.org.uk/accessibility2/wp-content/uploads/2009/09/blackberry-session.pdf

Horton, S. (2006). *Access by Design: A Guide to Universal Usability for Web Designers*. New Riders, Berkeley CA. Retrieved January 3, 2009, from http://universalusability.com/index.html

Lave, J and Wenger, E (1991). Situated Learning: Legitimate Peripheral Participation. Cambridge, England: Cambridge University Press

Lindström, J., (2007). *Towards an inclusive future: Impact and wider potential of information and communication technologies* – Chapter 2.2. Retrieved 2nd April 2009, pp.14, 17 & 19, from, http://www.tiresias.org/cost219ter/inclusive_future/inclusive_future_book.pdf

Lloyd, J., Powell, T.E., Smith, J., and Persaud, N.V. (2006). Use of a virtual-reality town for examining route-memory, and techniques for its rehabilitation in people with acquired brain injury. *Proc. 6th Intl Conf. Disability, Virtual Reality & Assoc. Tech., Esbjerg, Denmark, 2006; ISBN 07 049 98 65 3, 167-174*

McHugh, D. (2009). Commuting with GPS Mobile Assistive Technology, Undergraduate Thesis, Nottingham Trent University.

National Development Group for the Mentally Handicapped. (1977). *Day Services for Mentally Handicapped Adults.* London: Department of Health and Social Security.

NESTA FutureLab Series Report 11. (2004). Literature Review in Mobile Technologies and Learning. Authors: Naismith L, Lonsdale P, Vavoula G and Sharples M. Retrieved on 12th April 2010, from http://elearning.typepad.com/thelearnedman/mobile_learning/reports/futurelab_review_11.pdf

NLN (2003). Paving the Way – Developing standards for e-learning, National Learning Network. Retrieved May 14, 2008, from http://www.nln.ac.uk/

Pivec, M. (2007). Editorial: Play and learn: potentials of game-based learning. *British Journal of Educational Technology*, *38*(3), 387-393.

Prasad, M. (2006). Location Based Services, GIS Development, Retrieved 29th March 2009, pp.1 & 2, from <http://www.pelagis.net/gis_con/paper/Location%20based%20services.pdf>,

Sánchez, J.H., and Sáenz, M.A. (2006). Assisting the mobilization through subway networks by users with visual disabilities. *Proc. 6th Intl Conf. Disability, Virtual Reality & Assoc. Tech., Esbjerg, Denmark, 2006*; ISBN 07 049 98 65 3, 183-190.

Standen, P.J., Brown, D.J., Anderton, N., & Battersby, S. (2006). A systematic evaluation of current control devices used by people with intellectual disabilities in non-immersive virtual environments. *Cyberpsychology and Behaviour, 9* (5), 608-613.

TechDis (2009), Accessibility Essentials Series, JISC TechDis. Retrieved January 16, 2009, from http://www.techdis.ac.uk/index.php?p=3_20

Tiresias (2008). Checklists. Retrieved January 3, 2009, from http://www.tiresias.org/research/guidelines/checklists/index.htm

Tomlinson, J. (1997). Inclusive learning: the report of the committee of enquiry into the post-school education of those with learning difficulties and/or disabilities, in England 1996. *European Journal of Special Needs Education 12,* 184-196.

Wikipedia Contributors, (2009). Eclipse (software), Wikipedia, The Free Encyclopedia. Retrieved 8th April 2009, from <http://en.wikipedia.org/w/index.php?title=Eclipse_(software)&oldid=282140368>,

Wood, D.J., Bruner, J.S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychiatry and Psychology*, *17*, 89-100.

W3C (1999). Web Content Accessibility Guidelines 1.0, W3C Recommendation 5.5.1999. Retrieved July 7th 2007, from www.w3.org/TR/1999/WAI-WEBCONTENT-19990505, W3C

W3C (2008). Web Content Accessibility Guidelines (WCAG) 2.0, W3C Recommendation 11 December 2008. Retrieved May 4, 2007, from http://www.w3.org/TR/WCAG20/

Figure 1: Mode and language selection for Route Mate

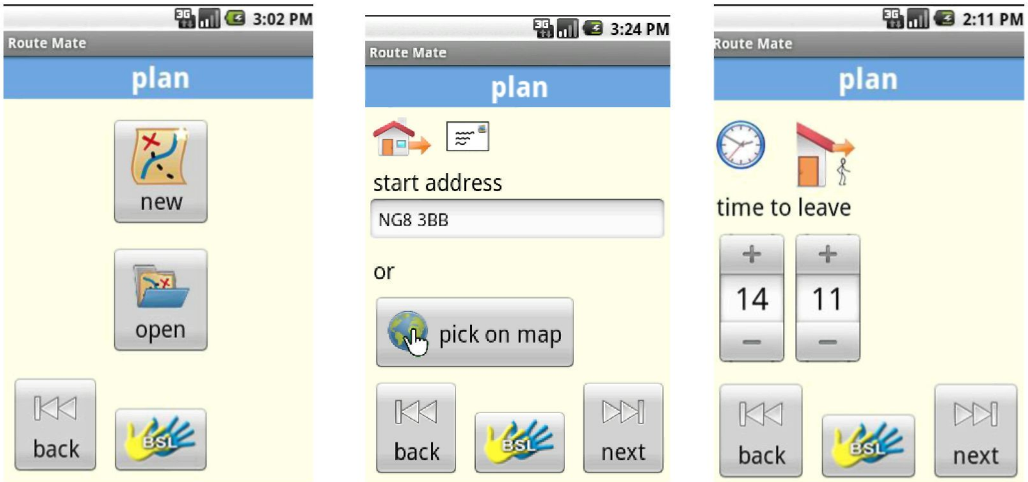

Figure 2: Selecting and personalizing a new route

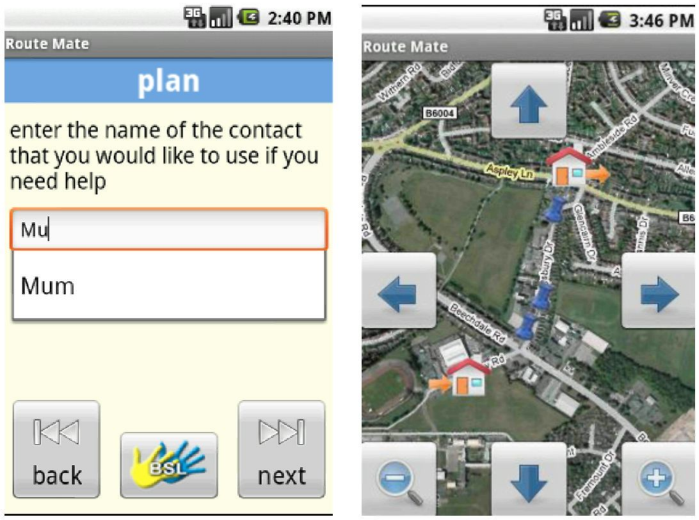

Figure 3: Emergency contact and map mode

Figure 4: Adding and personalizing key points on a new route

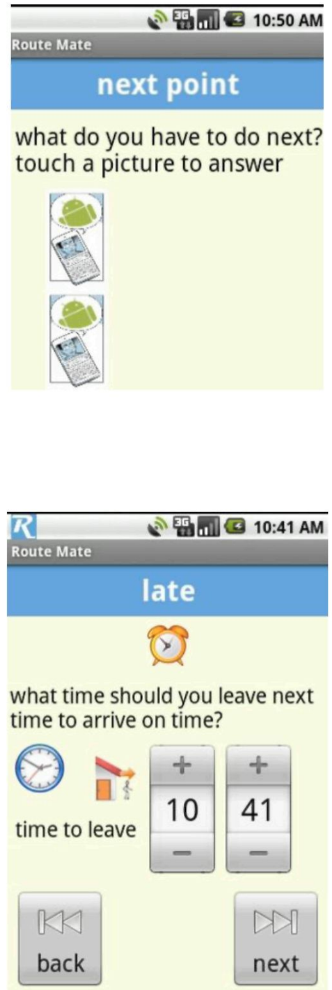

Figure 5: Games based mode and reflection in Route Mate