Virtual reality methodology for eliciting knowledge about public transport accessibility for people with acquired brain injury

M Wallergård, J Eriksson and G Johansson

Division of Ergonomics, Department of Design Sciences, Lund University,
Box 118, SE 221 00 Lund, SWEDEN

mattias.wallergard@design.lth.se, joakim.eriksson@design.lth.se, gerd.johansson@design.lth.se

www.eat.lth.se/english

ABSTRACT

The aim of this study was to investigate if and how a virtual reality-based methodology can be used to elicit knowledge about public transport accessibility for people with acquired brain injury (ABI). Four subjects with ABI and four occupational therapists made a bus trip in an immersive virtual environment. Their knowledge about public transport accessibility was elicited using the think aloud technique. All subjects managed to handle the VR methodology sufficiently well. The two subject groups tended to focus on different aspects of accessibility in public transport systems. The results suggest that a VR-based methodology can be used to elicit a wide spectrum of knowledge about public transport accessibility for people with ABI.

1. INTRODUCTION

The needs and wishes of people with acquired brain injury (ABI) are scarcely considered when planning public transport systems. One reason for this is the lack of suitable design tools; questionnaires, interviews, and focus groups are in general not feasible for this population. A desirable methodology would attempt to elicit knowledge about accessibility by letting people with ABI directly experience the planned public transport system. Virtual reality (VR) technology provides a means for such a methodology since it allows the creation and visualisation of three-dimensional environments with which people can interact. The use of VR to elicit the knowledge of people with cognitive disabilities is a largely unexplored area of research. The only known effort so far, with the exception of our own research, is a collaborative project between the University of Teesside and Durham University in the UK that studies the use of VR to allow people with dementia to test outdoor environment designs. The findings suggest that a VR-based methodology can be useful in the evaluation of outdoor environments and for identifying improvements for people with dementia (Blackman et al, 2007). There is good reason to believe that a VR-based methodology could also be used to elicit the knowledge of professionals who are experts on people with ABI. According to Schön (1983), most professionals know more than they can put into words. For example, an occupational therapist might find it difficult to share his/her knowledge and experiences of the accessibility problems of people with ABI through interviews or focus groups. To directly experience the environment and reflect over its accessibility through recollections of past cases might be a better approach. The purpose of the present study was to investigate if and how a VR-based methodology can be used to elicit knowledge about public transport accessibility for people with ABI. More precisely, the following three research questions were addressed:

RQ1: How does such a VR methodology work for people with ABI?

RQ2: How does such a VR methodology work for occupational therapists?

RQ3: What type of knowledge can be elicited with such a VR methodology?

2. METHOD

2.1 Material

The VR system was composed of three screens (each 3 x 2.25 metres) on which the virtual environment was projected (Figure 1). The virtual environment contained some built environment and two bus lines, bus 1 and bus 11, which went in loops. The subjects performed actions in the virtual environment by verbally

©2008 ICDVRAT/University of Reading, UK; ISBN 07 049 15 00 6

describing them to the person controlling the VR system and/or pointing with a laser pointer. We chose this interaction method since we wanted to make it as easy as possible for the subjects to perform actions in the virtual environment. The development and an initial evaluation of the VR methodology, in which seven people with stroke participated, are described in Wallergård et al (2008).

Figure 1. *The VR system.*

2.2 Subjects

Four people with ABI and four occupational therapists were selected for participation. The subjects with ABI were selected to have their most salient cognitive impairment in language, attention, memory or spatial ability, and little or none in the other cognitive domains (Table 1). The assumption behind this sampling was that these four cognitive domains have the greatest effect on a person's ability to handle the VR methodology. Furthermore, the cognitive impairment of the subject was not to be so severe that he/she could not travel independently by bus. The following three inclusion criteria also applied to the subjects with ABI:

- At least six months since brain injury to make sure that the subject had some experience of how his/her impairment affected daily living.
- Did not easily become car sick due to the risk for simulator sickness.
- Had adequate vision to watch TV.

The subjects were assessed with *Cognistat*, a standardised instrument for screening cognitive function (Lezak et al, 2004).

Table 1. *Subjects with ABI.*

Subject	Sex	Age	Type of brain injury	Most salient cognitive impairment	Misc.	Bus experience
1	F	38	Stroke	Language	Broca's aphasia and speech dyspraxia.	One time/week
2	M	41	Stroke	Spatial ability	–	Two times/week
3	F	58	TBI	Attention	Moderately impaired vision.	Three times/month
4	M	44	TBI	Memory	–	Five times/week

The four occupational therapists had baccalaureate degrees in occupational therapy (Table 2). Our inclusion criteria specified more than three years experience of working with people with ABI. They had little or no experience of interactive 3D simulations.

Table 2. *Occupational therapists.*

Subject	Sex	Age	Experience working with people with ABI (years)	Computer experience
5	F	29	3.5	Quite good. Played computer games as child.
6	F	30	5.5	Internet and mail.
7	F	27	3.5	Internet and word processing.
8	F	28	6.0	Internet and word processing.

©2008 ICDVRAT/University of Reading, UK; ISBN 07 049 15 00 6

2.3 Procedure

First, the subject's informed consent was obtained. Then he/she was asked to sit on a chair in front of the VR system while the test leader took his place at a table with a joystick and a keyboard. The subject was then informed about the scenario:

> *You want to take the bus from your flat to a café. You will do this by taking bus 11 to the city centre and then transfer to bus 1. You will get off bus 1 at the bus stop Smörlyckan where you will find the café. The date and time is the same as in the real world. You have a wallet with a bus card inside.*

The subjects were also told that they could perform actions in the virtual environment by telling the test leader what they wanted to do and/or pointing with the laser pointer at the projector screens. The subjects were then given a memory note with written information about which buses to take so that their performance would be independent of their ability to remember the instructions. The experiment consisted of three phases that were different for the two subject groups (Figure 2):

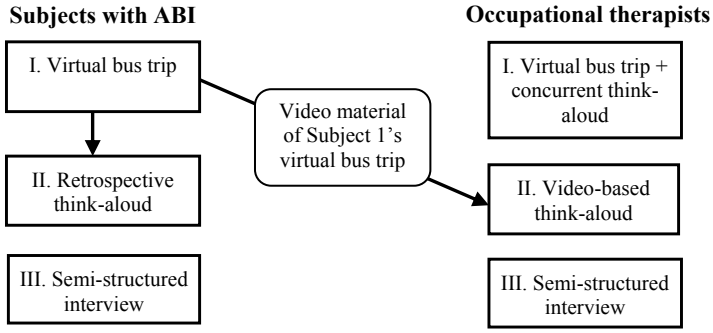

Figure 2. *The procedure.*

2.3.1 The virtual bus trip (Phase I). The occupational therapists were requested to think aloud about aspects related to accessibility for people with ABI while making the bus trip. This is called concurrent think-aloud and is extensively used in for example usability testing (Ericsson & Simon, 1993). The occupational therapists were told that they could ask the test leader to pause the simulation. This made all the events in the virtual environment come to a halt but the subject still could move around in and interact with it. The purpose of the pause function was to provide the subjects with time to reflect over something without being disturbed. The subjects with ABI were not asked to think aloud while performing the bus trip since concurrent think-aloud can interfere with task performance (Russo et al, 1989; van den Haak et al, 2003). We reasoned that this effect might be exacerbated in people with impaired cognitive ability.

2.3.2 The subsequent think-aloud session (Phase II). Immediately after phase I, the subjects with ABI were asked to think aloud about what they were thinking and feeling during the virtual bus trip while watching the recorded video material thereof. This is called retrospective think-aloud and has the advantage of not interfering with task performance since the verbalisation occurs afterwards. The four occupational therapists were shown the video material from the bus trip of Subject 1 who was judged to have the greatest difficulties to use the VR methodology and they were asked to once again think aloud about public transport accessibility for people with ABI. We reasoned that this would encourage the occupational therapists to reflect on aspects not addressed during their own virtual bus trips.

2.3.3 The semi-structured interview (Phase III). The experiment was concluded with a semi-structured interview.

Approval for the study was obtained from Lund University's ethics committee.

3. RESULTS

3.1 Research question 1: How does the VR methodology work for people with ABI?

In general, all four subjects with ABI managed to communicate their intentions well enough to complete the virtual bus trip. There were problems, however, especially for Subject 1 who had difficulties verbalising what she wished to do. On several occasions, it was difficult for the test leader to understand what she wanted.

©2008 ICDVRAT/University of Reading, UK; ISBN 07 049 15 00 6

However, on all these occasions the test leader was able to discover her intentions by posing a question, as illustrated by the following excerpt when she was searching for the outer door of the virtual flat:

S1: *There [points at the hallway]. The door [points at the toilet door]. Open [points at its door handle].*
S1: *Again [points at the outer door].*
TL: *Again..?*
S1: *Eh… Close the door [points at the toilet door].*
TL: *You close the door.*
S1: *Now [points at the outer door].*
TL: *You want to try that door instead?*
S1: *Yes. Open.*

The excerpt also demonstrates her main strategy throughout the whole experiment, namely pointing with the laser pointer in combination with one or several keywords. Another strategy she used on several occasions was to make gestures, especially when she was inserting the bus card in the bus card reader. Despite her problems to provide clear descriptions, she commented during the interview that she thought it was easy to communicate what she wanted to do. Subject 3 also communicated her intentions in a less than optimal manner. On many occasions throughout the bus trip, she just pointed at the projection screens without saying anything. She also seemed to believe that she could interact directly with virtual objects with the laser pointer and she confirmed this during the interview. Despite this, the communication between Subject 3 and the test leader worked sufficiently well. A strategy she used on several occasions during the virtual bus trip was to use words like 'here', 'there' and 'this' while at the same time pointing with the laser pointer. During the interview she revealed that she found the interaction method to be very good, since the user can show with the laser pointer if he/she has problems explaining his/her intentions. Subjects 2 and 4 used very clear verbal descriptions in combination with pointing with the laser pointer throughout the experiment. Just like Subject 3 they combined words like 'here', 'there' and 'this' with pointing with the laser pointer. During the interview, Subject 2 described the method for interacting with the virtual environment as 'not so difficult'. Subject 4 commented that the interaction method worked very well.

Subjects 3 and 4 described the virtual environment as very realistic and mentioned that the experience actually was like riding on a real bus. However, Subject 4 added that the virtual environment did not feel very real in the beginning but gradually became more realistic. One thing he experienced as unrealistic was the movements of the buses, which he perceived as very slow. On several occasions, Subject 1 also made the same observation. She mentioned that the virtual environment was empty and that there were no sounds of other people on the bus. Subject 2 commented that the virtual environment felt a bit weird and unusual and that the real world is easier. Later he developed this line of reasoning:

S2: *But then again… if I had done this a couple of times I probably would have gotten into it. The first time it is a bit… Well, one doesn't think in the right way, I guess.*
TL: *Do you mean that if you had the opportunity to get used to the virtual environment it would have become more like reality?*
S2: *Oh yes. It sure would.*

The interview revealed that all four subjects with ABI had a positive opinion of the VR methodology and seemed to believe that it can be useful.

3.2 Research question 2: How does the VR methodology work for occupational therapists?

In general, the four occupational therapists handled the VR methodology well. They all managed to think aloud in a satisfactory manner during the virtual bus trip and the video-based think-aloud session. Subjects 6 and 8 were completely self-motivated whereas the other two each needed questions from the test leader to think aloud on a couple of occasions. Subject 6 commented during the interview that thinking aloud while watching the video of Subject 1 was like analysing or assessing a patient. Subject 8 expressed that she was unsure whether she was making relevant comments. There were differences in how the occupational therapists used the pause function. Subject 5 paused the virtual bus trip just once whereas Subjects 6 and 7 paused it sporadically. Subject 8 used the pause function almost every time she had something to say. In general, the occupational therapists revealed a positive attitude to the VR methodology. Nevertheless, they also pointed out issues that might be problematic. For example, Subject 5 mentioned that being in the virtual environment felt like being inside a computer game and also made her feel 'a bit clueless'. She pointed out several times that her movements in the virtual environment were slow, which she perceived as unrealistic. Subject 6 also touched upon the issue of the virtual environment being different from the real world during the interview:

©2008 ICDVRAT/University of Reading, UK; ISBN 07 049 15 00 6

S6: *It's a different thing compared to taking the bus in the real world, I would say. One has to think more every moment and since I am not quite sure what will happen, I have to think more about each step. […] It's a little bit like doing something for the first time, because when I do it in the real world I might not think so much about (it)… Then I do it spontaneously but now I have to think about each step…*
TL: *Would it be an advantage or a disadvantage that you have to think more about what you're doing?*
S6: *In this context it's an advantage. […] I have some patient cases that I have experienced which I try to think about in every step and connect to this.*

Moreover, Subjects 5 and 6 commented during the virtual bus trip and the interview that the virtual environment was calm and quiet and empty of people and cars.

3.3 Research question 3: What type of knowledge can be elicited with the VR methodology?

All in all, the subjects with ABI made 79 utterances about public transport accessibility. The following excerpt from Subject 4's retrospective think-aloud session is a good example of what the think-aloud was like. Subject 4 is watching the video material of himself reading the bus stop sign and the timetable while waiting for bus 11:

S4: *I need to be in control so I have to… I don't trust myself and therefore… I see now that I am looking at the memory note a lot, you know. What is written on the note should be up there on the sign. It should match…*
TL: *Are you comparing, so to speak?*
S4: *That's right, I am comparing. […] Then I looked at the timetable there, to check that it's correct…where I am…since I don't know…I am not familiar with this place. I don't know the order in which the Stortorget bus stop comes. And then I check the time at which the bus should leave.*

The utterances could be sorted into five types as shown in Table 3.

The language impairment of Subject 1 made it difficult for her to provide detailed descriptions during the retrospective think-aloud session. It became more like a conversation with the test leader as demonstrated by the excerpt below, which is about her trying to understand if bus 1 was the right bus or not. She seemed to get confused that bus 1 was going in the direction she just came from and that the sign on it was 'Södra Torn' (the end station) and not 'Smörlyckan':

TL: *What were you thinking here?*
S1: *Unsure. The bus… Hmm… Café. Right way [points at the TV screen].*
TL: *Aha. Did you think it was that way? That you should have continued..?*
S1: *Yes.*
TL: *You went the other way. Did this confuse you?*
S1: *Yes. Name. Right.*
TL: *Do you mean the destination sign on the bus? It said 'Södra Torn'. Did this make you unsure?*
S1: *Yes.*

The four occupational therapists made 122 utterances regarding public transport accessibility in total. The following excerpt from Subject 6 is a good example of what the concurrent think-aloud during the virtual bus trip was like. She has just entered the bus and is preparing to pay with her bus card:

S6: *You can stop here. This is a bit of a problem… for many people. If you have spatial problems it's often hard to know the direction in which to insert the card. It should be possible to indicate it somehow. There should be better indications both on the card and on the machine, so you can put it in correctly and don't have to stand there getting nervous and stressed.[…]Everything is so dark. Here it melts into the background [points at the card reader]. I don't know if it's the seat or what, but everything is really black here. It's good with this yellow border here, however, but… I know that inserting the card correctly can be difficult. Mmm… maybe the machine should be another colour to make it stand out.*

The occupational therapists' utterances could be sorted into four types as shown in Table 4.

The utterances concerning 'Accessibility problems' could be further divided in four categories (Table 5):

- Cognitive (e.g. difficulties understanding the timetable)
- Affective (e.g. paying with the bus card is very stressful with people waiting behind you)
- Physical (e.g. difficulties reaching the stop buttons)
- Social (e.g. bus drivers who are rude to individuals with communication problems)

©2008 ICDVRAT/University of Reading, UK; ISBN 07 049 15 00 6

Table 3. *Utterances made by the subjects with ABI.*[1]

Type of utterance	Data type	Subject 1	Subject 2	Subject 3	Subject 4	Total
Accessibility problems (that might occur in public transport)	Bus trip	1	0	1	0	2
	Video	6	5	8	4	23
	Interview	2	4	1	3	10
Suggested improvements (of the public transport system)	Bus trip	0	0	0	0	0
	Video	1	0	0	0	1
	Interview	1	0	0	1	2
Positive aspects (of the public transport system)	Bus trip	0	0	0	0	0
	Video	0	2	1	1	4
	Interview	0	0	0	0	0
Strategies (used by the subject in public transport systems)	Bus trip	0	0	1	0	1
	Video	0	5	2	5	12
	Interview	0	0	0	0	0
The subject's own performance (when making the virtual bus trip)	Bus trip	0	1	0	0	1
	Video	6	5	2	6	19
	Interview	0	2	0	2	4

[1] The subjects with ABI made some utterances also during the interview.

Table 4. *Utterances made by the occupational therapists.*

Type of utterance	Data type	Subject 5	Subject 6	Subject 7	Subject 8	Total
Accessibility problems (that might occur in public transport)	Bus trip	6	11	3	14	34
	Video	5	5	5	6	21
Suggested improvements (of the public transport system)	Bus trip	0	9	0	15	24
	Video	0	2	0	8	10
Positive aspects (of the public transport system)	Bus trip	0	1	1	4	6
	Video	0	1	0	0	1
The performance of Subject 1 (when making the virtual bus trip)	Bus trip	N/A	N/A	N/A	N/A	N/A
	Video	11	2	9	4	26

Table 5. *The four categories of accessibility problem utterances*.[2]

Accessibility problem category	Number of utterances	
	ABI	OT
Cognitive	26	46
Affective	8	10
Physical	4	1
Social	0	1

[2] Some utterances could be grouped to more than one category.

In general, the occupational therapists believed that there were differences between the knowledge coming from the virtual bus trip that they took and the knowledge from the video-based think-aloud session. Subjects 5, 6 and 7 described the knowledge from the video-based think-aloud session as 'another type of understanding', 'more specific to the patient's problems' and as giving 'a completely different perspective'. Moreover, Subject 6 described the matter in the following manner:

S6: *I can only sit here and brainstorm about how I think people would experience it but when I see a patient in the (virtual) environment I am able to directly reflect on it… How was she thinking at that moment? Why*

Proc. 7th ICDVRAT with ArtAbilitation, Maia, Portugal, 2008
©2008 ICDVRAT/University of Reading, UK; ISBN 07 049 15 00 6

did it end up like that? That can give you additional insight. You can also see people's reactions. […] That is something I cannot imagine when taking the bus trip by myself.

All four occupational therapists believed there were differences between the knowledge elicited from themselves and that elicited from the subjects with ABI. Subject 5, for example, commented as follows:

S5: *When observing a patient who does this, you immediately gain empirical knowledge on how it might be, whereas when I comment on things, I generalise on the basis of my expert knowledge.*

Subjects 6 and 7 commented during the interview that people with ABI often have problems expressing what the problem really is. Subject 6 described the issue as follows:

S6: *They generally have great difficulties describing what the problem actually is. They say it's difficult, or they say something really basic like 'I can't see' or 'I can't hear'. On the other hand, if you have some knowledge about cognitive problems you can sort out the cause of the problem, and perhaps you also know how to fix it.*

4. CONCLUSIONS

The results of the present study, in combination with those from our previous research (Wallergård et al, 2008), suggest that a VR-based methodology can be used to elicit a wide spectrum of knowledge about public transport accessibility for people with acquired brain injury (ABI). The subjects with ABI as well as the occupational therapists managed to handle the VR methodology sufficiently well. Nevertheless, some problems were noted. Most importantly, Subject 1 had difficulties due to her language difficulties. Even so, she found strategies that helped her to communicate what she wanted to do. Her use of keywords in combination with pointing with the laser pointer shows that this interaction method can be a suitable for people with language impairments. Subjects 2, 3 and 4 used a strategy similar to Subject 1's keyword strategy: They combined words like 'here', 'there' and 'this' with pointing at objects or places in the virtual environment. This strategy was also observed in our pilot study: Five of the seven stroke subjects applied it (Wallergård et al, 2008). This enabled them to make simpler verbal descriptions and still communicate their intentions clearly, lowering the extraneous cognitive load the VR interface inevitably places on the user. A minimised extraneous cognitive load is very important for the validity of the VR methodology since it otherwise might be difficult to determine if the problems the user experiences are due to the VR technology or an accessibility problem in the portrayed environment. Moreover, the subjects seemed to perceive the virtual bus trip as a somewhat unrealistic experience that demanded more thinking. Nevertheless, it seemed to be convincing enough to trigger their knowledge and experiences. Furthermore, as pointed out by Subject 6, being forced to think each step over in the virtual environment could also be an advantage for this particular application.

In general, it went well for the occupational therapists to think aloud while making the virtual bus trip, which suggests that this is a feasible means of eliciting their knowledge. Nevertheless, Subjects 5 and 7 occasionally needed to be encouraged by the test leader to do so and Subject 8 was not sure if her comments were relevant. One way to remedy these problems would be to allow the occupational therapist to become acquainted with the think-aloud protocol before the actual bus trip starts. They could perform a number of daily activities while thinking aloud about accessibility for people with ABI. Thereafter they would receive feedback so there would be no doubt that they are making relevant comments during the bus trip. Even if Subject 8 was the only subject who used the possibility to pause the VR simulation in a structured manner, we believe that it should be part of the VR methodology. It seemed to facilitate her think-aloud process as she got more time to reflect over the events in the virtual environment.

As expected, the major part of the subjects' utterances about accessibility problems concerned cognitive issues. However, utterances related to emotional aspects, such as stress and insecurity, were also made. This knowledge may be just as relevant: It is crucial to understand in detail what triggers negative reactions in people with ABI when using public transport. Logan, Dyas and Gladman (2004) found that in a group of stroke patients (n=24), 11 wanted to use transport but had lost their confidence. To focus on affective dimensions when planning a public transport system can be a way to make the traveller feel more relaxed and confident.

More than a fourth of the occupational therapists' utterances were suggested solutions to accessibility problems in public transport. This is a very positive result since it suggests that the VR methodology encourages occupational therapists' ability to analyse how things can be improved. One way to develop the suggested improvements and take them one step closer to actual implementation would be to use the knowledge of engineers with expertise in information technology. By letting them directly experience the

©2008 ICDVRAT/University of Reading, UK; ISBN 07 049 15 00 6

problems that can occur for people with ABI and elaborate on the suggested solutions from the occupational therapists, they could suggest concrete technical solutions to the public transport planners as illustrated in Figure 3. Since the technology experts are familiar with the possibilities of modern information technology, they would also be able to suggest innovative solutions for long-term improvements. Such solutions could then be evaluated using the VR methodology to see how they work for the end-users and how they can be improved.

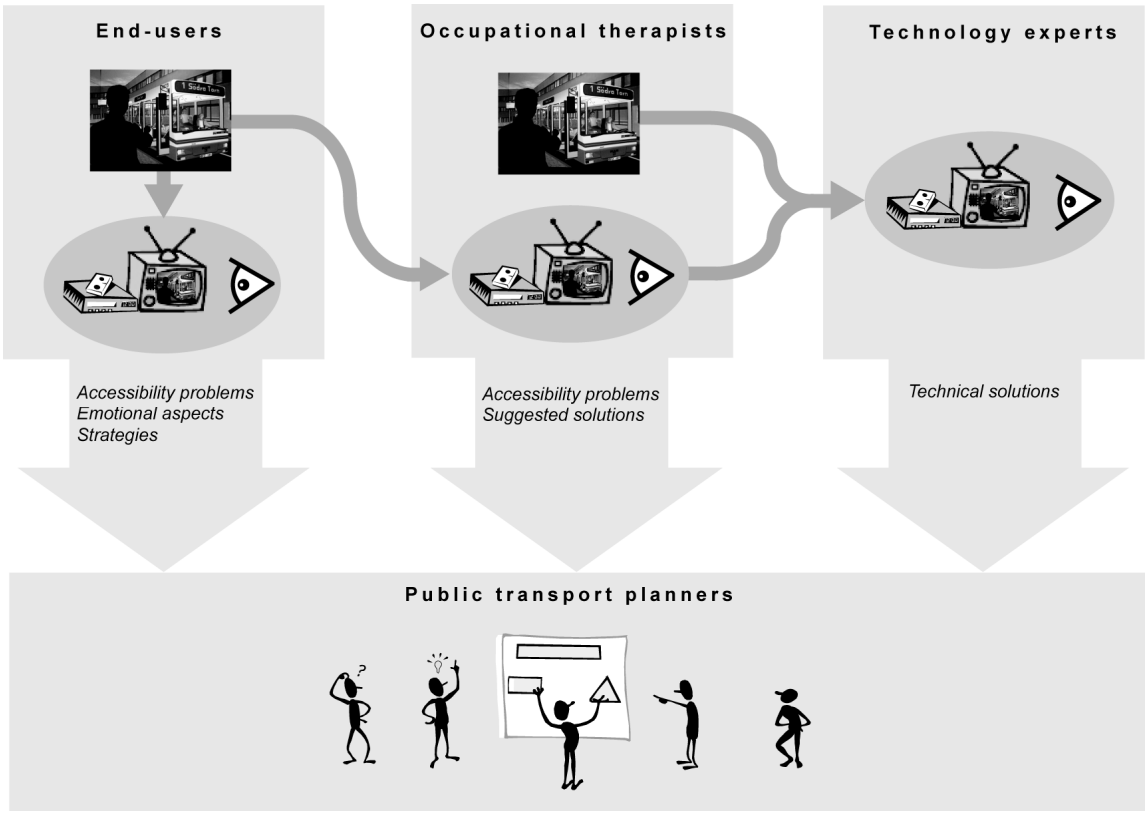

Figure 3. *Applying the VR methodology in a public transport planning process.*

The utterances regarding strategies were unique for the subjects with ABI and constitute knowledge likely to be very useful in a planning process. Sheehan, Burton and Mitchell (2006) investigated outdoor wayfinding in people with dementia by studying 13 dementia subjects on outdoor walks. The authors concluded that knowledge about the wayfinding strategies of this population is important when planning the built environment. In the context of public transport planning, supporting already existing end-user strategies can be a way to minimise the need to re-learn, which probably is particularly important for individuals with impaired memory.

The knowledge elicited from the occupational therapists during the virtual bus trip was somewhat different from the knowledge from the video-based think-aloud session. The virtual bus trip utterances regarding accessibility problems tended to rely more on generalisations based on different consequences of cognitive impairment. The video-based think-aloud utterances, instead, tended to be more focused on Subject 1. Moreover, the occupational therapists themselves believed that the video-based think-aloud session provided another type of understanding. Taken together, this suggests that both methods provide unique knowledge and should be part of the VR methodology in order to cover as many aspects as possible of public transport accessibility for people with ABI.

The language problems of Subject 1 bring up questions concerning the validity of her utterances. There were some things she wanted to communicate but never managed to explain clearly enough. Individuals with language problems may be one of the groups that will have the most difficulties contributing their knowledge through the VR methodology. Even so, they are a big population whose needs must be considered in public transport planning, especially since there is good reason to believe that many of them could use a public transport system designed to compensate for their language impairments. Even if it can be difficult to elicit detailed knowledge from this population, their holistic experience of a virtual public transport system is likely to be useful in a planning situation. Perhaps one of the most valuable contributions from the end-users

Proc. 7th ICDVRAT with ArtAbilitation, Maia, Portugal, 2008
©2008 ICDVRAT/University of Reading, UK; ISBN 07 049 15 00 6

has to do with empathy. In a real planning situation the public transport planners would be able to observe the problems, anxiety or stress of people with ABI when making virtual bus trips (Figure 3). To see this with their own eyes would make them more aware of the consequences of a badly planned public transport system and also more willing to consider the needs of individuals with cognitive impairments in the planning process.

In summary, the results of this study suggest that a VR-based methodology can be used to elicit a wide spectrum of knowledge about public transport accessibility for people with ABI. Our next step will be to try it out in a real planning process related to public transport by involving end-users, occupational therapists, technology experts and of course public transport planners.

Acknowledgements: This publication was based on data from the project *Accessibility in public transport for people with cognitive impairments – Survey, methodological development and innovative IT solutions*, funded by the Swedish Governmental Agency for Innovation Systems, the Swedish Road Administration, Banverket, and the Swedish Council for Working Life and Social Research. Thanks are extended to Prof. Jarl Risberg and Kerstin Wendel, reg. occupational therapist, for their valuable feedback. The authors are very grateful to Gerd Andersson and Helen Lindqvist, reg. occupational therapists, and their colleagues at the Neurological Unit of Malmö University Hospital for helping us contact participants and for participating as subjects. We would also like to thank the members of the reference group for their valuable input as well as the participants of this study.

5. REFERENCES

T Blackman, P Van Schaik and A Martyr (2007), Outdoor environments for people with dementia: an exploratory study using virtual reality, *Ageing Soc*, **27**, pp. 1 – 15.

K A Ericsson and H A Simon (1993), *Protocol analysis: Verbal reports as data,* MIT Press, Cambridge.

M D Lezak, D Howieson, D W Loring, J S Fisher and J Hannay (2004), *Neuropsychological assessment 4th edition*, Oxford University Press.

P A Logan, J Dyas, J R F Gladman (2004), Using an interview study of transport use by people who have had a stroke to inform rehabilitation, *Clin Rehabil,* **18**, 703 – 8.

J E Russo, E J Johnson and D L Stephens (1989), The validity of verbal protocols, *Mem Cognition,* **17**, pp. 759 – 69.

D A Schön (1983), *The reflective practitioner – How professionals think in action*, Basic Books, New York.

B Sheehan, E Burton and L Mitchell (2006), Outdoor wayfinding in dementia, *Dementia*, 5, pp. 271 – 81.

M J van den Haak, M D T De Jong and P J Schellens (2003), Retrospective vs. concurrent think-aloud protocols: Testing the usability of an online library catalogue, *Behav Inform Technol,* **22**, pp. 339 – 51.

M Wallergård, J Eriksson and G Johansson (2008), A suggested virtual reality methodology allowing people with cognitive disabilites to communicate their knowledge and experiences of public transport systems, *Technol and Disabil*, **20**, pp. 9-24.

©2008 ICDVRAT/University of Reading, UK; ISBN 07 049 15 00 6