



Enhancing electronic assistive technology prescription.

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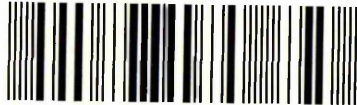
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Enhancing Electronic Assistive Technology Prescription

PETER RORY O'NEILL

A thesis submitted in partial fulfilment of
the requirements of
Sheffield Hallam University
for the degree of
Doctor of Philosophy

September 2006

Collaborating Organisation: Barnsley Hospital NHS Foundation Trust

&

Madhouse Software Productions Ltd.

Dedication

Mum,

I do not have the words to express what I want to say so this will have to do,

Thanks!

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It goes without saying that a considerable number of people have guided and supported me during the undertaking of this research:

I, Peter O'Neill would like to record my appreciation to the following individuals and organisations.

(It is important to note that these do not appear in any particular order unless stated)

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Jawed Siddiqi
Mark Hawley

Participants and Family

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It's a simple word and really not adequate but,

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Sheffield Hallam University, Sheffield. September 2006.

Abstract

With the inherent functional flexibility of the computer it seemed inevitable that these machines would be put to use in assisting individuals with less functional ability such as the severely physically disabled. These functions would include Speaking, Writing, Controlling their surroundings and moving within those environments. The software applications which provide these functions have collectively become known as Integrated Electronic Assistive Technology (IEAT).

This research investigation focused on the prescription of an IEAT prescribed for a particular individual using the Barnsley Wheelchair Interface (BWI) to enable the individual's function of mobility. The BWI controlled an electric wheelchair via a single switch pressed by the user, using her head and was prescribed using the "Multi-Disciplinary Service Model" process created and described by Hawley (1995).

The subsequent enhancement of this prescription, from the model-based analysis of the automatically generated usage data logs, that were introduced by the PhD Research student and are one of the novel features of this work. The chosen method, using the analysis of data logs came about as a result of the PhD Research student's own severe physical disability rendering conventional techniques difficult and in some cases impossible. It is the model-based analysis processes that have been developed during this research and which inform the Assistive Technology Professional (ATP) with general information on the prescription, along with comprehensive information on 'Whole System Information', 'Functional Level Information' and 'Interface Level Information', which in all instances had previously been unavailable from assistive technology stakeholders.

It is speculated that with the use of these analysis processes (tools) in addition to a software application called "Switch Environment Assessment Tool" (SEAT), in conjunction with the iterative process within the service model, the prescription should be enhanced, resulting in an increase in the user's quality of life.

Content

Chapter 1. Introduction	1
1.1 Motivation of Interest.....	1
1.2 Project Structure	4
1.3 Aims and Objectives	5
1.4 Structure of Thesis.....	6
1.5 Research Project's Scope	7
1.6 Chapter Summary.....	8
Chapter 2. The Stakeholders.....	9
2.1 The Primary System Users	9
2.1.1 Historical Classification.....	9
2.1.2 Present Classification	10
2.1.3 The Classification for this Dissertation.....	11
2.1.4 Primary Users Contribution to the Prescription	13
2.2 The Secondary System Users	13
2.2.1 The Professional Bodies' Contribution to the Prescription.....	14
2.2.2 Social Assistants' Contribution to the Prescription.....	15
2.3 Chapter Summary.....	16
Chapter 3. The Research Area Identified	17
3.1 The Research Questions	17
3.2 Related Research within the Domain	17
3.3 Discussion.....	24
3.4 Chapter Summary.....	26
Chapter 4. The Available Systems	27
4.1 Purpose	27
4.2 Inaugural Stage.....	27
4.2.1 Integration	30
4.2.1.1 BASIS-C	30
4.2.1.2 Barnsley Active Switching Environment (BASE).....	30
4.2.2 Speech Aids	31
4.2.3 Environmental Control System's (ECS's).....	32
4.2.4 Mobility Aids	33
4.2.4.1 Barnsley Wheelchair Interface (BWI).....	34

4.2.4.1.1 Interface.....	34
4.2.4.1.2 Input Methods.....	35
4.2.4.1.3 Scanning Methods	36
4.3 Chapter Summary.....	38
Chapter 5. The Research Methodology	39
5.1 Overview the Methodology	39
5.2 Why This Methodology Was Used.....	40
5.3 The Methodology	41
5.3.1 Field Study.....	42
5.3.2 Controlled Laboratory Study	46
5.3.3 Comparison of Field Results with Controlled Study Results	46
5.4 The Multi-Disciplinary Service Model	46
5.5 Chapter Summary.....	47
Chapter 6. The Field Studies	49
6.1 Introduction	49
6.2 The approach undertaken within the field study	50
6.3 The Rationale	52
6.4 The Analysis Process.....	54
6.5 The Hypotheses	56
6.6 Chapter Summary.....	58
Chapter 7. The Laboratory Experiments	60
7.1 Introduction	60
7.2 The Approach Taken.....	61
7.2.1 Introduction.....	61
7.2.2 The Experiment Variables.....	62
7.2.3 Participants	62
7.2.4 BWI Configuration and Participant's Participation	63
7.2.5 Environment (the course being driven).....	63
7.2.6 Observational Methods.....	64
7.2.7 Conduction of the Studies	67
7.2.8 Cleaning Preparation of the Raw Data	67
7.3 Analysis Processes	68
7.3.2 Description of ATP's knowledge enhancement: Processes and Their Relationship.....	70

Chapter 8. Comparison of the Field and Laboratory Studies	73
8.1 Introduction	73
8.2 Comparison of Field and Laboratory Study Results	74
8.2.1 Field Study Description of ATP's knowledge enhancement.....	75
8.2.1.1 Field Study Assumptions	75
8.2.1.2 Laboratory Study Comparison	75
8.2.2 Field Study Description of ATP's knowledge enhancement.....	78
8.2.2.1 Field Study Assumptions	78
8.2.2.2 Laboratory Study Comparison	78
8.2.3 Field Study Description of ATP's knowledge enhancement.....	79
8.2.3.1 Field Study Assumptions	79
8.2.3.2 Laboratory Study Comparison	80
8.2.4 Field Study Description of ATP's knowledge enhancement.....	81
8.2.4.1 Field Study Assumptions	81
8.2.4.2 Field and Laboratory Study Comparison.....	82
8.2.5 Field Study Description of ATP's knowledge enhancement.....	83
8.2.5.1 Field Study Assumptions	83
8.2.5.2 Field and Laboratory Study Comparison.....	83
8.2.6 Field Study Description of ATP's' knowledge enhancement.....	85
8.2.6.2 Field and Laboratory Study Comparison.....	85
8.2.7 Field Study Description of ATP's knowledge enhancement.....	86
8.2.7.1 Field Study Assumptions	86
8.2.7.2 Field and Laboratory Study Comparison.....	86
8.2.8 Field Study Description of ATP's knowledge enhancement.....	88
8.2.8.1 Field Study Assumptions	88
8.2.8.2 Field and Laboratory Study Comparison.....	88
8.3 Other Processes and Computational Techniques	89
8.4 Chapter Summary.....	90
Chapter 9. Additional Tools to Aid the Prescription	91
9.1 Introduction	91
9.2 The Tools	91
9.2.1 Investigated Analysis Techniques	92
9.2.2 Timed Petri Nets	93
9.3 The Switch Environment Assessment Tool's Background.....	94

9.3.1 SEAT Overview.....	94
Chapter 10. Contribution to Knowledge.....	100
10.1 Evaluation Before Data Logs.....	100
10.2 The Contribution to knowledge (The Inclusion of Data Logs)	101
10.3 The Future Focus	102
10.4 Chapter Summary	103
Chapter 11. Future Work and Conclusions	105
11.1 Motivation for Change.....	105
11.2 Inhibitors of these Changes	106
11.3 Answers to the Original Research Questions	106
11.4 Future Developments.....	107
11.4.1 Already Undertaken and the Immediate Future Work.....	108
11.4.1.1 Additional Interaction.....	108
11.4.2 Up to Five Years Ahead	111
11.4.3 Five Years and Beyond	112
References	115
Bibliography.....	119
Appendix A Service Model.....	1
Appendix B Making a Cup of Tea	3
Appendix C Methods for Formulating the Data Logs.....	5
Appendix D Barnsley Wheelchair Interface's Configuration during each of the Experimental Process	20
Appendix E The Experimental Processes Raw Data Logs.....	26
Appendix F Modelling Using Petri-Nets	43
Appendix G Transfer Document From MPhil To PhD	45

Figures Content

Figure 1. PhD Research student using Barnsley Wheelchair Interface (BWI) through a head located switch.	12
Figure 2 Evolution of the Assistive Technology from 1995 to 2005, including the Increasing Volume of Information from the Assessment Methods.	29
Figure 3 Pictorial Scanning Menu within BASE	30
Figure 4 An example extract of BASE data log.....	31
Figure 5 Pictorial Representation of GEWA PROG III and Control Capabilities.....	33
Figure 6 The Barnsley Wheelchair Interface.	35
Figure 7 BWI Interface Showing Items as Numerical Items.	36
Figure 8 Overall Methodology.....	39
Figure 9 Field Study Methodology	42
Figure 10 Client-Centred Multi-Disciplinary Service Model with Data Logging Analysis Procedures Incorporated.....	47
Figure 11 Example of Stepping in the Path Profile.....	55
Figure 12 Overview of the Experimental Procedure undertaken by the 'Able-bodied Novice' and 'Able-bodied Expert', when undergoing the experiment with the BWI in different configurations.	61
Figure 13 The Course's Physical Characteristics.....	64
Figure 14 The Course's Physical Dimensions.	64
Figure 15 Video View.	65
Figure 16 Examples of the Path Profile When Plotted on Graph Paper.	69
Figure 17 Comparison of Users Number of Selections.	76
Figure 18 Average Duration of Selection for each Participant in All Zones.	76
Figure 19 Frequencies of the Durations of Selections	79
Figure 20 Frequencies of Duration of Selections for each Participant in Zone 1 Only Magnified by 5 for Direct Comparison with All Zones.....	80
Figure 21 Duration to Complete All Zones for each Participant	80
Figure 22 Duration to Complete Zone 1 for each Participant Magnified by 5 for Direct Comparison with All Zones	81
Figure 23 Frequency of Selection for All Zones for each Participant.	82
Figure 24 Hypothetical Generated Scan Duration from Real Usage Data Logs and the Real Scan Times.....	86
Figure 25 Accumulated Duration of Selections Able-Bodied Expert.....	87

Figures Content

Figure 26 Accumulated Duration of Selections Novice.	88
Figure 27 Accumulated Duration of Selections Disabled Expert.	88
Figure 28 Disabled Expert's Path Profile.....	89
Figure 29 Able-Bodied or Novice's Path Profile.....	90
Figure 30 SEAT's Location Within The Client-Centred Multi-Disciplinary Service Model.	96
Figure 31 User Model using a Petri-Net	109
Figure 32 Multiple Layers per Item Within The Ultimate Switching Environment (USE).....	110

Tables Content

Table 1. Conventional and Suitability of Analysis Techniques for the Evaluation Method of people that have physical, sensory, visual and auditory disabilities. .	3
Table 2 Research Team.....	4
Table 3 Professional Bodies and their Organisational or Affiliation Groups.....	14
Table 4 Switch Functionality	35
Table 5 Scanning Method Sequences	37
Table 6 The experiments Individual Characteristics.....	63
Table 7 Processes used within the analysis of each Description of ATP's knowledge enhancement	71
Table 8 The Novices Consecutive Selections	77
Table 9 The Able-bodied Experts Consecutive Selections.....	77
Table 10 The Disabled Experts Consecutive Selections	77
Table 11 Number of Selections For and Against the Veers for each of the.....	84
Electric Wheelchairs for each Zone and each Participant	84

Chapter 1. Introduction

Chapter Structure:

The structure of the project and the general area of research are identified. A general definition of Assistive Technology and the definition within this dissertation of Electronic Assistive Technology are explained. The aims and objectives of the research are outlined and concluded by bringing together these aims and objective with the multi-disciplinary approach.

1.1 Motivation of Interest

On completing a Software Engineering degree at Sheffield Hallam University in 1996, the PhD Research student was offered a full-time position at, what was then, Barnsley District General Hospital NHS Trust, in the Clinical Engineering Service (CES), to develop non-conventional 'Human Computer Interaction' software applications for the severely physically disabled. These applications were to enable them to conduct everyday tasks and are now commonly referred to as 'Assistive Technology' (AT), as opposed to conventional interaction such as mouse and keyboard (Card *et al*, (1980)). 'Assistive Technology' is defined by the "Public Works and Government Services of Canada", as:

"Assistive technology includes any item, piece of equipment or system that is used to increase, maintain, or improve how a person performs some task of daily living."

[www.communication.gc.ca/glossary.html]

It is important to note that within this definition, no reference is made towards disability as assistive technology can be everything that assists an individual within their day-to-day living. Items that may be included can be a light switch, a window, to a pair of shoe laces. Each of these items can assist the individual under different circumstances, from helping them to turn a light on, to see in the dark, to let natural light in but keep the weather out and finally, to keep their shoes on their feet. However, within this dissertation the PhD Research student means a device or system that undertakes a function on behalf of the physically disabled individual (see a fuller definition in Chapter 2 'The Stakeholders') In particular software applications run on a Personal Computer (PC) are therefore defined as 'Electronic Assistive Technology'

(EAT), as the medium is electronic based. Thus EAT provides such functionalities as speaking, writing, controlling mobility devices and the environment that surrounds the individual user.

With the procurement of the position at CES, a personal interest began to develop not only with regard to the functional restriction of these software applications but, in addition, the validation processes for individuals who often had no other way of speaking but through the system itself. This in turn can limit the individual in what they say for two reasons. Firstly that often the individual they are communicating with is the same individual who created the system. This puts the user in the uncomfortable position of having to tell the individual who maintains the system, what is wrong with the system that they have created. Secondly, if an item does not exist with the statement which describes the user's feelings with regard to the system, then it can take a great deal of effort and time by the disabled individual to spell out word for word their concerns. Due to the physical demands of spelling word for word, eventually physical exhaustion ensues and this, together with an element of frustration at not being able to say what they wish to say, the user will often not express their feelings and will stop trying completely - leaving the creator no wiser than when they started. Thus, from the invention of EAT, individuals such as Assistive Technology Professionals¹ (ATP's) and funding organisations² have sought to be able to evaluate EAT systems usage (Cherry *et al.*(1996), Churchill (1998), Keats *et al.*(2000), O'Neill *et al.* (2000)). Their rationale for validating these devices is three fold:

- To ensure that the existing prescription process is capturing the functional requirements of the user;
- To ensure that the systems fulfil the user's requirements;
- To validate giving such an extensive amount of resources to such a small number of users.

Substantiating the usage of these devices, in itself, substantiates the utilisation of these valuable resources for this small user domain.

¹ An ATP can be any one of the following: Speech Therapist; Physiotherapist; Occupational Therapist; Rehabilitation Engineers; Clinical Engineers; Teachers; IT Co-ordinators; Researchers and Clinician or any combination of these individuals. (This group of stakeholders are described in detail in Chapter 2.)

The key points are shown below:

- Validate the system is being used;
- Review the prescription in order to enhance the system's configuration to increase the user's usage and thus their productivity.

At the beginning of this project, the method by which the PhD Research student was going to obtain this validation of usage was unclear. However, an observational method was required which would involve minimal intrusion to the System User³ and also minimal visitation and time consumption on behalf of the ATP's, who would be required to undertake these processes once the research was completed. The aim was not to increase the workload of what is already a limited and pressured workforce.

The PhD Research student undertook an extensive investigation of different methods to obtain the required information on system usage and user preferences. The evaluation methods and their suitability for the stakeholder group are shown below.

Analysis Techniques	Conventional Methods Suitable for General User Group					Conventional Methods Suitable for Chosen User Group				
	User Notebook	Computer Logging	Video Recording	Audio Recording	Pencil and Paper	User Notebook	Computer Logging	Video Recording	Audio Recording	Pencil and Paper
Think Aloud	-	-	✓	✓	-	-	-	×	×	-
Post Walkthrough	✓	-	✓	✓	-	-	-	×	×	-
Query	✓	-	✓	✓	✓	×	-	⊙	×	×
Questionnaire (Scaleable)	-	-	-	-	✓	-	-	-	-	⊙
Questionnaire (Multi-Choice)	-	-	-	-	✓	-	-	-	-	⊙
Questionnaire (Open ended)	-	-	-	-	✓	-	-	-	-	×
Questionnaire (Ranked)	-	-	-	-	✓	-	-	-	-	⊙
Computer Data Logs	-	✓	-	-	-	-	✓	-	-	-

Symbol Explanation:

Where: - is None Applicable, ✓ is Possible, × is NOT Possible and ⊙ is With Difficulty.

Table 1. Conventional and Suitability of Analysis Techniques for the Evaluation Method, of people that have physical, sensory, visual and auditory disabilities.

² An Organisation can be any one or a number of the following: Local Education Authority's (LEA's); Health Authorities; Social Services; Charities and other Institutes.

³ System Users are individuals who have a disability and use the device within the field. This may also include third party individuals commenting on behalf of the system user, such as Parent/s, Sibling/s, Carer/s, Partner, Teacher/s and/or Peer/s. (This group of stake-holders is described in more detail in Chapter 2.)

Each method shown above has advantages and disadvantages, and this is highly dependent on the type of analysis required (Dix *et al*, (1998)) and numerous other literary sources. However, a general consensus of opinion is that they all intrude on the usage of the device or require some considerable effort on behalf of the participant. In all instances, it became evident to the researcher that the above methods required the participant to possess a physical or vocal attribute, and in some cases both, in order to undertake the chosen method. These physical and vocal attributes are often the attributes that the chosen stakeholder group does not possess, therefore removing that particular method from the equation. During this investigation the researcher came across 'data logging', conducted within the application. This internal data logging, conducted by the application, soon became the main focus of the researcher's attention (Rogers L, (1996)) and it quickly became apparent to the researcher that this method of data logging required no physical interaction, other than what was required to use the device already and, in addition, no vocal requirement to express what they had selected. Therefore, the outcome of this investigation was a data collection module, which was created and installed within the System User's primary software applications (please see Chapter 3). The researcher also acknowledged early within the research that this method, like other methods, had its advantages and disadvantages. The means of overcoming some of these disadvantages are investigated within Chapter 7 'The Laboratory Experiments'.

1.2 Project Structure

This research project team included the following members, listed here together with their positions within the project:

Name	Designation
Prof. Jawed Siddiqi	Director of Studies
Dr. Mark Hawley	Supervisor at CES
Dr. Chris Roast	Academic Supervisor
Mr. Peter O'Neill	PhD Research student

Table 2 Research Team.

The team initially met to discuss the essence of the research to be investigated. As the primary researcher's interest was focused on his work at CES the Barnsley District General Hospital NHS Trust released him from other duties. The consensus of opinion was that the research should concentrate on the evaluation of the prescription process

and usage of EAT. In addition, the work should examine the model created by Hawley (1995) and the possibility of creating tools which could enhance 'The Provision of Integrated Assistive Systems: A Client-Centred Multi-Disciplinary Service Model'. After much discussion and debate, it was decided that particular attention should be paid to single switch users who are forced to use scanning interfaces to interact with the EAT. This was then incorporated into "The Research Proposal" as explained below, Section 1.3 'Aims and Objectives'. Following initial discussions between the whole team, Dr. Chris Roast and the PhD Research student met on a monthly basis. Where necessary meetings would be held more frequently and could involve all members of the research project. Where this could not be accommodated due to other commitments, comprehensive discussions took place by telephone and documentation was exchanged as e-mail attachments. Additionally where submissions for publications were imminent, e-mails with relevant attachments would be circulated to all members of the group. As the research progressed, the frequency of meetings increased and the emphasis of steering the research and undertaking the research activities was placed on the PhD Research student.

1.3 Aims and Objectives

An inaugural meeting was arranged with the supervisory team (see Section 1.2 'Project Structure') and the PhD Research student to discuss the initial aims and objectives. The aims and objectives were agreed and then included within 'The Research Proposal' which was submitted to Sheffield Hallam University's Research Committee. The aims and objectives were subsequently accepted and are shown below:

Aims

- To develop a better understanding of the issues surrounding service prescription in integrated computerised systems for people with severe physical disabilities.
- To develop a toolset supporting prescription.

Objectives

- To develop a model of use and toolset to assist in improving usability requirements specification and reduce prescription time.
- To develop a data collection tool which aims to provide information regarding usage of Assistive Technology devices.
- To evaluate the model and toolset developed based upon the “real time” usage data.

As the initial focus of the proposal was the areas stated above the following title was chosen:

“An investigation into enhancement of service prescription of integrated computerised systems for people with disabilities.”

However, with the evolution of the research and seeking to convey a more familiar and general term which would enhance the dissemination of the research findings, the title was changed to:

“The Enhancement of the Prescription of Electronic Assistive Technology.”

Finally, for the sake of conciseness the title adopted was as follows:

"Enhancing Electronic Assistive Technology Prescription"

1.4 Structure of Thesis

Chapter Description

- | | |
|---|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 | The structure of the project and the general area of research are identified. A general definition of Assistive Technology and the definition within this dissertation of Electronic Assistive Technology are explained. The aims and objectives of the research are outlined and concluded by bringing together these aims and objectives with the multi-disciplinary approach. |
| 2 | Identification of the two main user groups : “System Users” and “Assistive Technology Professionals” (ATP’s) - including “Therapists” and “Clinicians”. An explanation of the “System Users” limitations, such as “Motor”, “Vocal”, “Visual” and “Cognitive Impairments” plus the impact these have on the individual’s ability to interact with these systems. Additional consideration was given to the limitations of ATP’s with respect to resources e.g., time, funding and knowledge required to assess system’s usage and reconfigure them. |

- 3 In this Chapter the research questions to be considered in the thesis are posed and the historical and present methods used to assess the multifaceted requirements of the user in order to prescribe these systems. The Chapter concludes with an explanation of how it was possible to include data logging and the rationale behind using this method of information collection.
- 4 This Chapter provides an overview of the assistive technology at the beginning of this project, their functionalities and means by which they can be configured. The technology used within this research was identified, including the way these technologies were integrated.
- 5 This Chapter presents the research methodology used during the undertaking of this research project in order to answer the research questions presented.
- 6 This Chapter describes the empirical field studies that were conducted over a number of years and explains the processes of analysis which were developed to answer questions from ATP's, within the department of "Medical Physics and Clinical Engineering Services" at Barnsley Hospital. Additionally the analysis processes are identified which were deemed to be useful within the process of the enhancement of the prescription. The Chapter concludes with a number of hypotheses and descriptions of ATP's knowledge enhancements revealed during the field studies and highlights the means by which they are to be investigated further.
- 7 This Chapter takes the hypotheses and descriptions of ATP's knowledge enhancements from Chapter 6 and details a series of experiments with users of differing abilities and knowledge of wheelchair and system usage.
- 8 This Chapter compares and combines the results from Chapter 6 'the field studies' with those from Chapter 7 'laboratory study'.
- 9 A description of the additional tools required to aid the prescription process that were created as a result of this study and the ways in which these tools can be used within the multi-disciplinary approach to enhance the accuracy and speed that a prescription can be fulfilled.
- 10 This Chapter defines the contribution to knowledge this study has made and the way this knowledge could be used to enhance the system user's quality of life.
- 11 The final Chapter brings together the preceding Chapters and, based on the evidence presented in this thesis, answers the original research question. In addition, this Chapter suggests other research areas and ways forward within this domain.

1.5 Research Project's Scope

Due to the wide variety of functionality that can be made available to the system users and the different methods and stakeholder's differing functional capabilities it was decided by the PhD Research student and his team to focus the project on a particular stakeholder with single switch access (see Chapter 2) undertaking the function of

movement using an electric wheelchair with the Barnsley Wheelchair Interface (BWI) to control it (see Chapter 4 Available Systems). In addition, methods to evaluate the stakeholders interaction with the system were investigated, for example 'UserFit' but these methods were excluded for two reasons. First 'UserFit' requires more than one system user and secondly, a method was required that could be integrated within the Hawley (1995) multi-disciplinary approach and thus the present way in which ATP's prescribe present systems.

1.6 Chapter Summary

Within this Chapter of the dissertation, the motivation of interest was outlined by explaining the primary researcher's employment within CES, configuring, developing and prescribing EAT for the disabled within Barnsley District General Hospital's NHS Trust area.

The Chapter continued with a brief explanation of the definition of Assistive Technology (AT); the way this definition has been refined for the purpose of this dissertation and how it has been extended by adding 'Electronic' before 'Assistive Technology', therefore giving us 'Electronic Assistive Technology' (EAT). EAT is used here to refer to the software applications which enable the disabled. In addition, a brief description of the major stakeholders is given. These stakeholder groups are explained in more detail in the next Chapter, along with their role/s within the prescription process and the way/s in which they influence this prescription process. The next part of the Chapter reviews the mainstream methods for evaluating software applications and explains that many of these methods are not possible due to the users of the systems having no vocal ability.

In the following section of this Chapter, members of the research team are listed together with their role/s and the way/s they would contribute to the overall project. One of the areas in which they contributed is evidenced in the next section which describes the aims and objectives of the research project. An extract of 'The Research Proposal' which was submitted to the Research Degrees Committee at Sheffield Hallam University is also included in the next section. The Chapter concludes with the structure and a tour of the thesis.

Chapter 2. The Stakeholders

Chapter Structure :

The two main user groups are identified as “System Users” and “Assistive Technology Professionals” (ATP’s) - including ‘Therapists’ and ‘Clinicians’. The limitations of ‘System Users, such as ‘Motor’, ‘Vocal’, ‘Visual’ and ‘Cognitive Impairments’ are identified as well as the impact these have on the individual’s ability to interact with these systems. Additionally we look at the limitations of ATP’s with respect to their resources e.g. time, financial and knowledge, to assess the system’s usage and re-configure them.

2.1 The Primary System Users

A description of the primary user group is provided in this section. Initially this appeared to be a simple task, however the classification of this user group has been attempted on numerous occasions as “historically this group of users began where health ended” (World Health Organisation, 2002). The PhD student’s own interpretation of this statement is that historically disability was excluded from health and was contained within its own classification which was often interpreted by different individuals in differing ways depending on their understanding of disability as explained below.

2.1.1 Historical Classification

In the past most attempts at classification have become somewhat complex due to the inclusion and exclusion of physical differences even within one disability group and the classifier’s personal interpretation of these physical differences. These classifications have worked on the negative aspects of disability e.g., what the individual cannot accomplish rather than their abilities. For example, if an individual disability group is examined, such as cerebral palsy (CP), this is described by “Scope”, the registered charity working on behalf of these individuals, as follows:

“Cerebral palsy (CP) is not a disease or an illness. It is the description of a physical impairment that affects movement. The movement problems vary from barely noticeable to extremely severe. No two people with CP are the same; it is as individual as people themselves.

‘Cerebral palsy’ includes a variety of conditions. The three main types correspond to injuries to different parts of the brain:

People with spastic CP find that some muscles become very stiff and weak, especially under effort. This can affect their control of movement.

People with athetoid CP have some loss of control of their posture and they tend to make unwanted movements.

People with ataxic CP usually have problems with balance. They may also have shaky hand movements and irregular speech.

What are the effects?

The main effect of CP is difficulty in movement. Many people with CP are hardly affected, others have problems walking, feeding, talking or using their hands. Some people are unable to sit up without support and need constant enabling.

Sometimes other parts of the brain are also affected, resulting in sight, hearing, perception and learning difficulties. Between a quarter and a third of children and adolescents, and about a tenth of adults, are also affected by epilepsy.

People with CP often have difficulty controlling their movement and facial expressions. This does not necessarily mean that their mental abilities are in any way impaired. Some are of higher than average intelligence, other people with CP have moderate or severe learning difficulties. Most, like most people without CP, are of average intelligence.”

[SCOPE, 2005]

2.1.2 Present Classification

CP in itself can therefore have numerous levels of severity and this is just one disability. The classification of all disabilities at their differing levels of severity would be impossible to collate. However, with the World Health Organisation’s (WHO), International Classification Functioning, Disability and Health (IFC) publication, a new classification was created for the following reasons:



“ICF is WHO's framework for health and disability. It is the conceptual basis for the definition, measurement and policy formulations for health and disability. It is a universal classification of disability and health for use in health and health related sectors. ICF therefore looks like a simple health classification, but it can be used for a number of purposes. The most important is as a planning and policy tool for decision-makers.

ICF is named as it is because of its stress is on health and functioning, rather than on disability. Previously, disability began where health ended; once you were disabled, you were in a separate category. We want to get away from this kind of thinking. We want to make ICF a tool for measuring functioning in society, no matter what the reason for one's impairments. So it becomes a much more versatile tool with a much broader area of use than a traditional classification of health and disability. This is a radical shift. From emphasizing people's disabilities, we now focus on their level of health. ICF puts the notions of 'health' and 'disability' in a new light. It acknowledges that every human being can experience a decrement in health and thereby experience some disability. This is not something that happens to only a minority of humanity. ICF therefore 'mainstreams' the experience of disability and recognises it as a universal human experience. By shifting the focus from cause to impact it places all health conditions on an equal footing allowing them to be compared using a common metric – the ruler of health and disability.”

[World Health Organisation, ICF, 2002]

This new classification includes all disabilities from the loss of half a finger to someone who is fully incapacitated and incorporates numerous disability levels between these points. This new classification **DOES NOT** classify disability, but outlines the individual's ability and what intervention could be undertaken to enhance these abilities. Interestingly, WHO in their wisdom have included environmental factors that can contribute to an individual's incapacitation. These environmental factors include items such as steps and the lack of drop down kerbs etc., the lack of which can incapacitate a wheelchair bound individual's mobility within and between buildings.

2.1.3 The Classification for this Dissertation

In accordance with the WHO the primary user's required functionalities must be described to enable them to interact with their peers and to live within their social environment. These primary users are disabled individuals who rely upon these systems to provide the following functionalities, to enable them to participate in every aspect of their day to day lives, including but not always inclusive of:

- Speech Aid
- Mobility Aid
- Environmental Controls



Figure 1. Stakeholder using Barnsley Wheelchair Interface (BWI) through a head located switch.

However, the stakeholder above would be medically described as an individual with severe Athetoid Cerebral Palsy, with highly limited ability to interact physically with her surrounding due to lack of motor control. In fact, due to involuntary muscle movement of this stakeholder, the only body part capable of activating a switch in this instance is the user's head. With the computer turned on and the head switch located, the stakeholder waits while the required item is highlighted (see Chapter 4. The Available Systems, for a fuller description). The switch is depressed with the side of her head to make the selection. Additionally, in this instance the primary user, on choosing the correct item from the interface, can select to go to her "Talking Screen for Windows"⁴, which can also control her environment *via* an infra-red sender called a

⁴ "Talking screen for Windows" is an Augmentative Alternative Communication Aid e.g. a software application to enable auditory communication.

“GEWA Prog⁵”, enabling her to turn the television on/off etc. Again these different functions are described in Chapter 4 ‘The Available Systems’. Due to the complexity of the stakeholder's system it is important to note that, in this instance, the stakeholder was not cognitively impaired.

2.1.4 Primary Users Contribution to the Prescription

It is important that the primary user not only takes part but also feels that they have contributed to the creation of their own system. This inclusion ensures that ‘learned helplessness’ is not caused or reinforced (Abramson *et al*, (1978), Gargiulo *et al*, (1986), Maier *et al*, 1976, Weisz, (1979)). In ‘learned helplessness’ the individual learns that they cannot achieve because of their physical disability. Ensuring that the individual takes part gives them the motivation to use the equipment provided as well as the confidence and self-belief that they have a large role to play within the prescription process. This in some cases may include, in addition to other areas of the prescription process, a training element with regard to the new system as suggested by Hawley (1995). This inclusion is important as it will be the individual who will spend many hours looking at the screen and having to interact with it. Therefore the layout on the screen in terms of images, text, including colours, font sizes etc., needs to be aesthetically pleasing and something that they personally feel comfortable with and happy to use.

2.2 The Secondary System Users

The secondary user group includes individuals that in this instance are labelled ATP's. An ATP can be any one of the following people: Speech Therapists, Physiotherapists, Occupational Therapists, Rehabilitation Engineers, Clinical Engineers, Teachers, Teaching Assistants, IT Co-ordinators, Researchers, Clinicians, Parents, and in some cases, the primary user's peers - or any combination of these individuals.

⁵ A “GEWA Prog” is a hardware device that is connected to the RS232 communication port of the Personal Computer (PC) and on receiving a code from the PC it will broadcast an infra-red signal. For more information visit <http://www.gewa.se/english/products/prodfra2.html>

However, this group of people can be sub-divided into two smaller groups with their differing levels of responsibility for the AT system. The first group are the professional bodies and they deal with the analysis and creation processes (Hawley (1995)) and are shown on the Table 3. The other group is the group of individuals labelled here as 'Social Assistants' and with the exception of the primary users it is the other group of individuals who come into contact with the system on a day-to-day basis.

Professional Body	Organisational or Affiliation Group
Clinical Scientists	Institute of Physics and Engineering in Medicine
Speech Therapists	Royal College of Speech & Language Therapists
Occupational Therapists	British Association of Occupational Therapists College of Occupational Therapists
Physiotherapist	The Chartered Society of Physiotherapy
Rehabilitation Engineers	Institute of Physics and Engineering in Medicine
Teachers	Government Special Needs In Education Course
Researchers ⁶	NHS

Table 3 *Professional Bodies and their Organisational or Affiliation Groups.*

2.2.1 The Professional Bodies' Contribution to the Prescription

The difficulty of bringing all of these professional bodies together is substantial due to their high workload and other commitments. In addition, a financial strain is placed on the funding bodies. The cost of these systems is substantial when taking into account the cost of the individuals' time and the other resources required in building such a system. Therefore, in general, a Clinical Scientist will coordinate the prescription process to minimise the time required by the other professional bodies. This process is described by Hawley (1995). A brief description of this process is given below.

After visiting the user, the hardware and software is purchased or created depending on the user's functional needs and then the system assembled. First, the Clinical Scientist will bring each of the components together to ensure that the communication protocols work together. Once this is achieved each professional will take the system and configure their component for the user. When the final professional has configured their component, the Clinical Scientist fully tests the system and delivers the system to the user.

⁶ In this instance the Researcher was included as he had been working as an ATP at Barnsley Hospital for eighteen months in this capacity prior to the commencement of this research. However, generally this would not be the case.

On delivery the Clinical Scientist will, if necessary, spend considerable time showing the user new attributes and functionalities they may have requested. At this point small changes to the system are made in order to ensure that the user can operate the system as prescribed. Frequent visits are made to the user over the following weeks to ensure that the system and user are getting on well. Should this not be the case then alterations will be made or the user will be educated in the use of that functionality.

2.2.2 Social Assistants' Contribution to the Prescription

It is important to note that often the individuals that deal with these systems on a day-to-day basis are not those stated above in Table 3 'Professional Bodies and their Organisational or Affiliation Groups', but may be anyone, or a number, of the following individuals: wife; husband; parents; carers; Teaching Assistants and in some cases peers. Peers include siblings and close friends of the primary user. Here we refer to this group of individuals as Social Assistants. They come into contact with the Primary user in a social capacity. Additionally, invariably these Social Assistants do not have any professional status with regard to EAT and often are shown by one or a number of the professional bodies above the general configuration capabilities of the system and the way by which these changes are made. Occasionally due to wear and tear on hardware (see Chapter 4 . 'The Available Systems') and accidents of dropping the machine etc., the system will need reinstallation which would require one of the above professionals. Due to these individuals' workload it may be some time before this can be achieved, although if the user needs the device for communication then it will be dealt with immediately. The Social Assistants who come into contact with the user and system on a day-to-day basis may be asked to change the configuration in order to give the user some of the functionality they require until the system can be reinstalled.

In addition, these individuals deal with the general maintenance and ensure that the system continues to provide the functionality required by the user. They will often report any additional functionalities or system difficulties after which one of the members from the professional groups may visit.

2.3 Chapter Summary

This Chapter began by explaining the historical difficulties of classifying the primary stakeholder group and how, in the past, disabled individuals had been classified outside of health. It reviewed the means by which SCOPE, the organisation that promotes an understanding of the disability CP describes and explains the differing limitations this disability can cause. At this point the World Health Organisation's (WHO) new classification was reviewed. This brings disability into the main stream of classification by introducing the notion of providing the individual's missing functionality. This is achieved by looking at what is required to enable individuals to interact within our society, rather than how their disability limits their ability to integrate. The next part of this Chapter stressed why it is so important that the primary users must be part of the prescription process if we are first to ensure that the prescription fulfils the user's requirements and that we limit or reduce the possibility of 'learned helplessness'.

The following groups were reviewed: Assistive Technology Professionals (ATPs) and the way this group is subdivided into two - Professional Bodies and Social Assistants, along with a description of the different constraints each of these groups may have.

Finally, the Chapter concludes with a description of these individuals' contribution towards the prescription process and the maintenance of the system along with any possible future enhancements.

Chapter 3. The Research Area Identified

Chapter Structure:

In this Chapter the research questions to be considered in the thesis are posed and the historical and present methods used to assess the multifaceted requirements of the user in order to prescribe these systems. The Chapter concludes with an explanation of how it was possible to include data logging and the rationale behind using this method of information collection.

3.1 The Research Questions

The first research questions were asked in order to provide additional knowledge to the professionals. These should in turn enable us to ask the second question which when answered will impact on the system user's usage. The questions are outlined below:

- “Can we provide system usage knowledge to the Assistive Technology Professional (ATP) while minimising their need to observe the system and the user within their environment, as well as the need to spend a considerable amount of time conducting analysis on the observational results?”
- “Can this system usage knowledge then be used to enhance the prescription of this system, therefore increasing the ease of use and the productivity of these systems?”

In order to answer these questions historical knowledge from within this domain was required and an initial literature search was conducted. The findings from this initial literature search are reported in Section 3.2 ‘Related Research within the Domain’.

3.2 Related Research within the Domain

In this section the literature which was considered to be pertinent to the research being undertaken was reviewed. Throughout the project subsequent literature searches were conducted in new areas of investigation as they became relevant to the research these are subsequently referred to within this dissertation. Initially the literature selected focused on assessing the individual's abilities, which in turn showed their limitations and the extent to which their disability affected their ability to fulfil their day-to-day

living needs, which would then become their prescription. In addition, searches were conducted on any possible method that showed that the prescription met those functional requirements plus possible enhancements to this prescription to maximise the user's productivity. The results of these searches are shown below.

The Tufts-MIT Prescription Guide (Rosen *et al*, (1989)) is essentially aimed at targeting the input requirements for the individual's needs with regard to communication aids. The assessment tools are described in the paper as:

"It is comprised of a computer-driven set of client-assessment procedures, a library of files that fully specify devices to be considered, and a number of computer programs that operate on client and device data."

[Rosen *et al*, (1989)]

The ethos of the Tufts MIT prescription guide is to reduce the time required to prescribe a communication aid with any one desired input device which will fulfil the individual's functional needs in the long term. The prescribed device must take into account their physical and mental capabilities. This is a highly complex prescription process due to the extensive number of variables. Therefore the clinical motivation for the prediction assessment tools is outlined in the four areas below:

1. There are too many commercially available systems to allow trial-and-error clinical evaluation of all those that are of potential benefit for a particular client.
2. The speed that new devices and software are being created.
3. Lack of accuracy with regards to motor abilities e.g. positioning, environment, familiarity with devices, cognitive and degenerative physical ability etc..
4. Trade-offs with client's characteristics and the device's features and operations.

The paper substantiates the fact that it is impossible to measure every possibility with regards to movement, angle and pressure that may be required - even when the experiment is carried out several times. It is also important to note that the device selected by this prescription guide may not initially be the fastest communication aid available within the selection set on the database for that individual at the present time.

However, the prescription guide ascertains the device that in the long term will provide the individual with the appliance that will grow with the individual's needs and maximise their potential input to output.

A further paper found was “Providing rehabilitation integrated system using existing rehabilitation technology” (Cherry *et al*, (1996)). This describes an integrated system and the way in which such a system was created, much like the system used within this study. The paper describes ‘Rehabilitation Integrated System’ (RIS) as a collection of hardware and software components brought together to create a single input to a multiple response capable system. The paper describes four categories of RIS and these are:

1. *‘Mechanical’ integration: a group of separate assistance devices as an individual input device;*
2. *‘Hard-wired’ integration: a group of separate assistance devices where two or more or all of these are operated from a single device usually via a ‘selection and switching’ interface;*
3. *‘Computer’ integration: a single input device accessing via an intelligent and readily re-configurable interface, a number of assistive functional outputs; at least indirect access to standard computer applications;*
4. *‘Multi-model’ computer integration: a choice of input devices is available to operate a number of assistive devices (still with an intelligent and readily re-configurable interface), direct access to standard computer application possible.”*

[Cherry *et al*, (1996)]

The paper is mainly concerned with the categories 3 & 4. The author then goes on to say that his recent work concentrates around a Personal Computer and DOS based RIS which is contained within the description of category 3, and is where this study resides. In addition, the author explains that it is a highly complex procedure to prescribe a RIS and it is important that the user is placed in the centre of this process as described by Hawley in “**The Service Model**” Hawley (1995) and discussed later within this Chapter.

Cherry goes on to describe the ‘**Integrated Current Assistive Application on a PC**’. This is where the Electronic Assistive Technology (EAT) systems are at the commencement of this research project. Finally, Cherry concludes that there is a need for quantitative assessment tools, not only to assist with the initial settings for the

applications but also to ensure that when RIS is set up it will meet the needs of the individual as comprehensively as possible.

“Quantitative assessment tools which were automatic and generated the parameters used in the configuration of the RIS would greatly assist the provision process.”

[Cherry, *et al*, (1996)]

The need for a multi disciplinary team is also acknowledged in the paper, one or more of which should have a considerable knowledge of possible configurations of RIS's, as only applications for assessments of communication aids are available (Rosen *et al*, (1989), Horstmann *et al*, (1990)). It reiterated the need for standardisation with regard to both software and hardware if substantial progress is to continue within this domain.

The next paper found during the search became an extremely important paper with regard to the research reported within this dissertation, **“A Client-Centred Multi-Disciplinary Service Model”** Hawley (1995). The main aim of the Service Model is to present the professionals with a formal method of generating an integrated system, and ensuring the system fulfils the needs of the individual. The Service Model diagram can be found in (Appendix A of this work, “Service Model”).

This service model is divided into two sections and these are the aspects of “Human Computer Interaction” and “Device Hardware and Software”; the processes within the model “Specify equipment and trial” which are HCI, (Human Computer Interaction) and below are “Hardware/Software Implementation”. In many instances with this stakeholder group lack of any one, or numerous combinations of the three main abilities, Perception, Cognition and Motor ability can prevent interaction, not only with computers but also with their peers etc. The process “Define abilities/disabilities”, therefore concentrates on the individual's physical and mental abilities, which in turn shows their disabilities. This process focuses on the individual's abilities in respect of:

- Perceiving colour
- Perceiving shapes
- Tactile capabilities
- Verbal communication
- Moving limbs
- Head control

- Dexterity of hand and/or feet
- Understanding things that are happening around them
- Applying pressure with limbs, head etc., and at quantity

During this process it is also important to acknowledge the individual's environment. For example, if the individual is in a strange environment they may have less co-ordination, due to being uncomfortable in their present surroundings. Other factors that must be taken into consideration include: the individual's position e.g., sitting, lying or standing, as these elements may be enabling or prohibiting movement, or visual clues. Often the process "Previous equipment usage" can be examined at the same time as the process "Define abilities/disabilities" while the professionals are in the company of the individual concerned. "Previous equipment usage" can in general assist in defining the individual's potential. This process may give the assessor ideas of possible alternative avenues to investigate with regard to the individual's ability to interact. This in turn will reduce the required time for completion of the prescription. In addition, although the equipment previously used may have been the latest technology when it was provided, that technology may now be out of date and the technician may suggest more up to date technology that he/she would consider being a suitable alternative. For example, in the past an individual may have been using a scanning system with a switch (Vanderheiden, (1988)) to word process. However, the individual could have vocal ability to use speech recognition that is now available. It may be that both speech recognition and switch control could give the user a higher potential. In this case speech recognition does not replace, but supplements, the user interface.

Once the processes "Define abilities/disabilities" and "Previous equipment usage" have been assessed and a view of the individual's physical and mental abilities reached, the next process of "Analysis of task" can begin. The process of "Analysis of task" investigates the procedures that will be necessary to carry out any required action. For example, the making of a cup of tea would be broken down into small sub-tasks and even smaller sub-tasks. An example of these procedures can be found in **Appendix B "Making a cup of tea"** in this dissertation. In our example, this would be related to the interface, both the way in which the individual is going to indicate that an action is required and the sensory information that will be provided. The sensory information may be vocal, visual and tactile in any or all combinations, depending on previous

information obtained. Within the process 'Analysis of task' particular focus is paid to the individual as often people with disabilities may be prone to:

- Bounce
- Anticipation

Bounce is due to the individual's motor skills prohibiting the individual from making a direct action and maintaining that action. For example, the individual may be able to close the switch at the required time but not able to maintain the closure of the switch for some period. 'Anticipation' is due to the individual seeing that a motor action is going to be required such as closing of a switch. With the looming required action, the user loses an element of motor co-ordination and misses the time slice. Often with 'Anticipation' the user requires training and familiarising with the system to eliminate this problem.

When the previous processes are completed and the knowledge obtained has been assembled, the user interface type is specified. An example is shown to the future user and professional team ensuring that the chosen interface matches the individual's skills and abilities in the areas of:

- Perception
- Cognition
- Motor abilities

At this point in the process of the '**Service Model**' the interface is purely sensory with no functionality. The choices of interface types include Vocal, Visual and Tactile. It is during the process of 'Specify user interface' that the assessment or reassessment of the user is brought to the attention of the team. This may result in more action taken in the following areas:

- User training with system
- Changes in environmental factors (since the original assessment)
- Carer's understanding of the system
- Teacher's knowledge of the system (if a system is for a child)
- Re-evaluation of abilities (due to progression of disability)

Hence the service model becomes iterative, carrying out each of the processes until an adequate solution becomes apparent. In some circumstances, the future user may require training with the interface because they may have never used a computer, or the type of interface specified before. With an adequate specification, the computer technician may begin the process of discussing with other members on the team the functions that will be required.

At this point in the service model, the information already gathered from 'Previous equipment usage' and the reason for the referral gives the team a good idea of the functional requirements of the integrated system. They will discuss these functional requirements along with the individual, and a list of possible required functions will be created. Often the functions may contain processes e.g. turn on/off lights, control television, drive electric wheelchair, speech aid and writing facilities, etc. This list of functions and the information already gathered from the previous processes are used in the generation of the system, in the process 'Specify equipment and trial'.

'Specify equipment and trial' is the point at which all the equipment required is purchased. In some cases finding the financial resources for this can be difficult (Rosen and Goodenough-Trepagnier, (1989), Hawley, (1995), Cherry *et al*, (1996)). It is important to note that these authors were requesting and suggesting data capture as a means of evaluating the device prescription. The computer technician brings all of the information that has been correlated from the other processes together and creates the integrated system. This may take considerable time as many of the applications are designed to standalone. Conflicts with regard to the way two applications communicate can often cause problems, and changes to parameters with regards to communication may be required or a change of application could even be necessary. In an ideal world all applications and hardware would use the same, or be aware of, each others' protocols (Cherry *et al*, (1996)).

Once the integrated system is completed and delivered to the user, a period of verification and validation begins. On delivery of the system members of the team will watch the user with regard to their interaction, assisting where necessary, showing the user and persons around them the system as a whole. The process of "Equipment

matches abilities?" is carried out over a number of months with members of the team revisiting the user and asking them how they are getting on. At this point, the user or persons in constant contact may suggest changes to any section of the integrated system. This may include things like:

- Different mappings from items
- Different ordering of items
- New items on selection sets
- Functions changing
- Functions removing
- New functions included

Any of these changes may require the user and/or persons around them to be retrained. In some instances, a re-evaluation of the user's abilities may be necessary. This re-evaluation may not be due to the changes made to the system but changes with regard to the individual's abilities, surroundings, posture, etc., (as explained earlier within this section of this dissertation).

3.3 Discussion

Finally, this Chapter concludes by reviewing the major papers that have influenced this work and explaining where the models, software applications and methods created within this research, are to be located within the framework of Hawley (1995).

The Service Model (Hawley (1995)), provides the professional bodies with a formal structure to assist with the assessment of people that have a disability and their abilities to interact with the technology. The model requires a multi-disciplinary team, each member with a comprehensive knowledge of their own particular area. The Service Model's strongest asset is that it structures the team, ensuring that each of the required elements will not be forgotten, ignored or disregarded without a full and comprehensive investigation beforehand.

With the investigation in process "Specify equipment and trial" of the individual's perceptual, cognitive and motor skills, the model relies on the professional individual's abilities to assess by way of observation. This means of assessment does not provide

the required rigidity, as different assessors have different perceptions and makes different assumptions. This process at present is often ascertained using 'trial and error' (Rosen and Goodenough-Trepagnier, (1989), Horstmann *et al*, (1990), Cherry *et al*, (1996), O'Neill *et al* (2000a)), creating a simple system and letting the user try it out in the presence of the assessor. The proposed research 'Switch Environment Assessment Tools' (SEAT) described within this dissertation (see Chapter 9 'Additional Knowledge Obtained') is aimed at removing some of these professionals individual assumptions.

Another area of the model that relies solely on observation and discussion is the process "Equipment matches abilities" and is implemented by and with the user, parent, teacher, carer and members of the team. This process is intended to provide a validation and verification of the system but due to lack of qualitative and quantitative data, again a 'trial and error' process of the configuration of items used begins. This dissertation focuses on the creation and analysis of these recordings from within these applications tools. Such tools are described in Chapter 4 'The Available Systems' and include the Barnsley Active Switch Environment (BASE) and the Barnsley Wheelchair Interface (BWI).

The overall structure of the model is well formed, however, when considering the model as a whole the author would suggest that another component is required. This component is the disabled person's 'wish and/or need' to carry out a particular function. Without this vital requirement the creation of the system would be pointless as the individual may not use the equipment. It is therefore enlightening to see that the model is iterative, giving the individual the opportunity to request changes to the system. This iterative process, in conjunction with the training element and discussion with the individual throughout the processes, and in particular in the processor's "Specify equipment and trial" and "Equipment matches abilities", ensures that the system motivates and complies with the individual's original request.

Finally, it is "The Provision of Integrated Assistive Systems: A Client-Centred Multi-Disciplinary Service Model" Hawley (1995) research framework (reviewed here) within which the research reported in this dissertation is intended to be placed. Therefore, the out comes from this research for example models, software applications

and methods created should be located in the iterative process of the framework and should provide the missing information, which in turn should enhance the prescription process.

3.4 Chapter Summary

The Chapter started by outlining the research questions, of can we obtain system usage information and can that information be analysed to give answers to questions regarding the fit of the prescription for that particular user.

The next section of the Chapter looked at papers publish by researchers from the domain and brought to the readers attention particular authors whom were found to be the main contributors to our knowledge of the domain at that time along with their particular focus of interest. One of these author's work became of particular interest to the PhD Research student, Hawley (1995) as it was this author's model he was to place the research discussed within this thesis.

Finally, this Chapter concluded with a section which discussed so of the issues raised by the other authors and the ways in which these results may have influence the work, then under investigation.

Chapter 4. The Available Systems

Chapter Structure:

This Chapter contains an overview of the assistive technology used at the beginning of this project, its functionalities and means by which it can be configured. The technology used within this research is identified as well as the way this technology has been integrated.

4.1 Purpose

This Chapter of the dissertation is intended to give the reader some historical knowledge as well as an overview of the Electronic Assistive Technology (EAT) available before the start of this research project. It also provides the foundations on which this research work is built. Furthermore it continues to build on the knowledge obtained and describes the methods used to evaluate the prescription of an Integrated Electronic Assistive Technology (IEAT) system in 1995 and how this has changed with the inclusion of data logs and analysis.

4.2 Inaugural Stage

At the beginning of this research project the Electronic Assistive Technology [EAT] systems being provided were mainly isolated software applications. This greatly limited the ATP with regard to their configuration; in particular the “BASIS-C” constructed and described by (Cherry *et al*, (1996)). In addition, Cherry had also created the first version of the wheelchair driving application which was an application interface with all of the complexity of controlling the wheelchair constructed in hardware. This driving application and BASIS-C could only be configured by manually making changes within the ‘INI’ file and even then the configuration was limited to two scanning methods of ‘Clockwise’ and ‘Anti-clockwise’ together with the speed at which the applications would scan, as shown in 4.2.4.1 ‘Barnsley Wheelchair Interface’. The only means of analysis in 1995 was by observing the individual using the system within the field or laboratory situation. This was however to change in 1996 with the creation of the Barnsley Wheelchair Interface (BWI) as described in 4.2.4.1

'Barnsley Wheelchair Interface' and the Barnsley Active Switching Environment (BASE) as described in 4.2.1.1 'Barnsley Active Switching Environment'. For the first time the inclusion of data logging within a complete EAT system became viable.

In addition the EAT system moved from being primarily a DOS and hardware system to Windows[®] and primarily a software system. However, the BWI remained a DOS application to ensure its integrity due to it being a critical safe application.

On the following page, Figure 2 shows the evolution of the assistive technology from 1995 to 2005. Moreover this diagram includes the assessment methods and the way these methods have increased in line with the functional abilities and inclusion of data logging within the EAT system. It is important to note that the research reported within this dissertation does not include the 'Complete System USE¹', 'USE⁷' being the 'Ultimate Switching Environment' and 'Talking Screen for Windows', which is an Augmentative and Alternative Communication (AAC) aid. These applications were not included as USE¹ only became available in 2003 and AACs require such knowledge as linguistics etc. which is an area this research project did not propose to include. However, a comprehensive study on AAC has subsequently been conducted and is reported by (Hill, K. J, (2001)).

⁷ USE does not include the wheelchair driving functionality

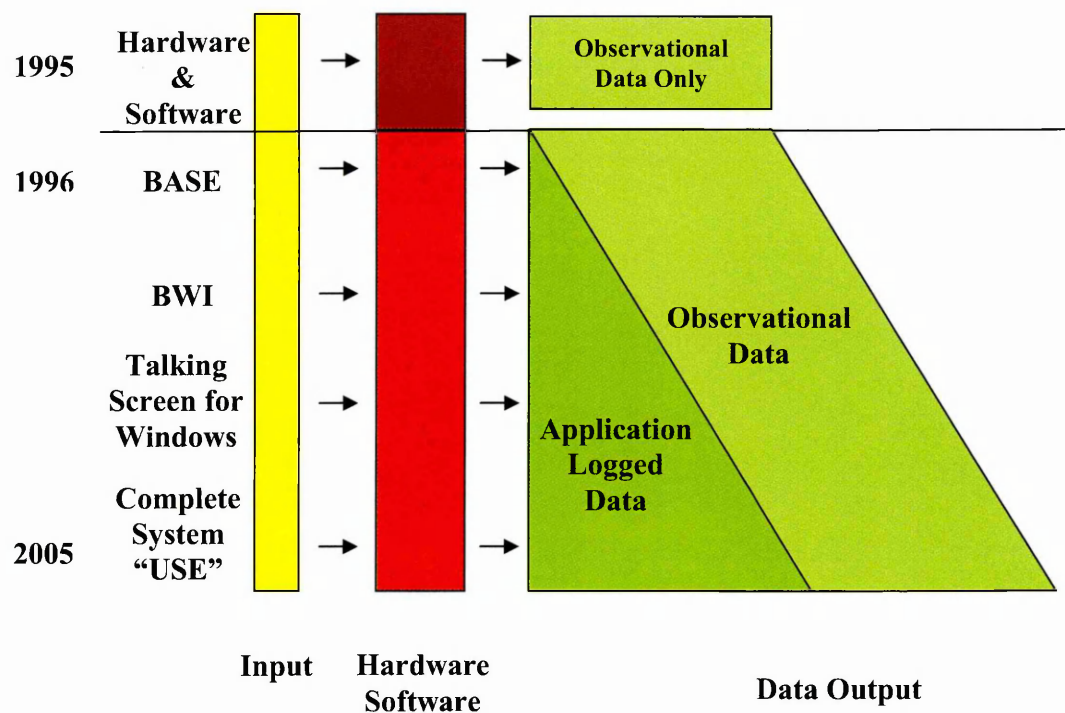


Figure 2 Evolution of the Assistive Technology from 1995 to 2005, including the Increasing Volume of Information from the Assessment Methods.

Historically, and to the present day, the Integrated Electronic Assistive Technology (IEAT) can be split into five core functional areas as listed below:

- Integrator Application
- Speech Aids
- Mobility Aids
- Environmental Control
- Computer Keyboard, Mouse Emulators

In addition, each of these core functional areas contains an application. These applications are described in more detail in subsequent sections. Each of these sections will describe the main attributes, which in some cases covered later within this study could be changed through a fully developed interface.

4.2.1 Integration

4.2.1.1 BASIS-C

The first attempt at integration was the **BASIS-C** which was developed, created and described by Cherry (Cherry *et al*, (1996)). BASIS-C was mainly a hardware construction with a computer-based interface which enabled the user to select between driving the electric wheelchair or using a speech aid. At this stage all of the software was DOS based and it was quite difficult to configure for the non-computer literate individual. Following requests from a number of professionals to use Windows®-based applications in order to aid the configuration of the prescription, a move was made to update the system and the development of the Barnsley Active Switching Environment (BASE) was undertaken. This is described below.

4.2.1.2 Barnsley Active Switching Environment (BASE)

An IEAT is a collection of existing assistive technology products, which in this instance is connected together by one application called BASE. The BASE application essentially enables severely disabled users, who are only able to operate a single switch input device, to swap between applications using a pictorial scanning menu. (For example, see Figure 4.2.1.2.1). Associated with each of the pictures is an application to enable the individual to perform a particular function, such as 'Speak', 'Write' or 'Move'. In the example reported within this dissertation, only the wheelchair and face symbols were being used - for movement and speech respectively. With the particular item highlighted and the user input switch closed, the selection is made. The selected application is then brought into the foreground. BASE may be recalled with the termination or the continuation of a switch closure for a predetermined period of time.

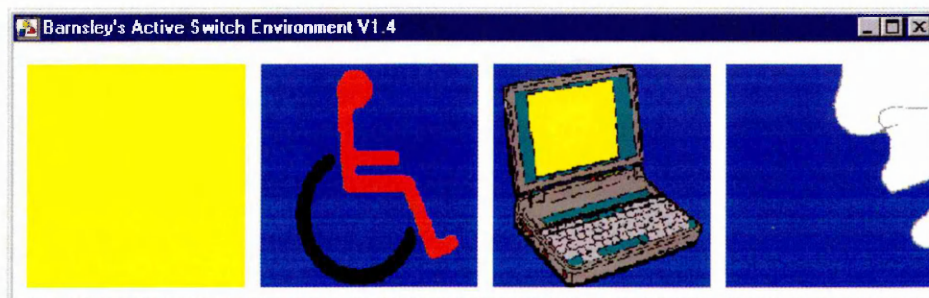


Figure 4.2.1.2.1 Pictorial Scanning Menu within BASE

With each selection made by the user, as described in the preceding paragraph, a log is generated. The following attributes are recorded by the data log: session number, date, time and selection (see Figure 4).

```
1,1,Thu,Aug,19,16:29:56,1999,Start
2,1,Thu,Aug,19,16:35:59,1999,Scanning
3,1,Thu,Aug,19,16:36:04,1999,drive
4,1,Thu,Aug,19,16:37:29,1999,Scanning
5,1,Thu,Aug,19,16:37:29,1999,End
```

Figure 4 *An example extract of BASE data lo.*

The inclusion of data logs for the first time within this high level application resulted in an ability to conduct analysis as described by (Hawley *et al*, (1999)) on the general usage of the complete system. This analysis provided useful information which showed that not only every part of the system was used, but more interestingly that the system was in use for 96% of the days that were analysed and on average 7.4 hours per day (Hawley *et al*, (1999)). This validates the considerable financial investment for creating and configuring such a system and fulfilled the primary research activity: “To develop a data collection tool which aims to provide information regarding usage of assistive technology devices” – the objective described within Chapter 1 of this dissertation.

4.2.2 Speech Aids

Initially the system contained the DOS version of ‘Talking Screen’. However, with the creation of BASE, as described in the previous paragraph the DOS version was replaced with ‘Talking Screen for Windows®’. Like BASE, ‘Talking Screen for Windows®’ consisted of a pictorial grid of items which can be scanned using any one of the following methods:

- Single Step
- Row Column
- Column Row
- Top Half Bottom Half
- Left half Right Half

Each of these methods is reduced with each selection down to a single item which when selected actuates the associated action. Each of these methods is described in detail by (Vanderheiden, (1988)) (which also describes formulas), enabling analysis of the time required to select any given item without having to conduct an empirical study. 'Talking Screen for Windows[®]' which is a software application that is a dynamic Augmentative and Alternative Communication (AAC) aid - where an item within a set can call another set of items instead of the user vocally saying something. The quantity of data that can be (and is) output to a data log is extremely large as shown in the Figure 2 in this dissertation 'Evolution of the Assistive Technology from 1995 to 2005, including the Increasing Volume of Information from the Assessment Methods.'

Therefore, at the initial stage of this research project both the supervisory team and the PhD Research student felt it would be best to concentrate on an application with a set number of items, where each item can be clearly defined as to the action resulting from its selection. Therefore the integrator BASE already described in 4.2.1.2 'Barnsley Active Switching Environment and Barnsley Wheelchair Interface' (BWI) as described in 4.2.4 'Mobility Aids' was selected. It was mutually understood that these two applications would provide a comprehensive understanding of the system's usage, both functionally and with regard to the human computer interaction. This proved to be the case and was subsequently reported in (Hawley *et al*, (1999)). At the time, it was the first evidence based information to provide any substantial evidence to funding bodies that the systems were being used for extensive periods of time and that the considerable amount of resources e.g. finance to purchase the components of the system and the ATP's time was reasonable.

4.2.3 Environmental Control System's (ECS's)

At the beginning of this research project the environmental control elements which could be included within a system were not considered as the user did not request this functionality due to family members physically fulfilling these tasks on her behalf. However, it is important to note that an application is available which enables the system user to send infra-red codes via a ⁸'Gewa Prog III' connected through the PC's 'RS232', Communication Port. The required infra-red code is recorded and stored

⁸ <http://www.gewa.se/english/english.html>

within the 'Gewa Prog III' and when sent these infra-red codes the user can be offered the ability to control their environment, in any of the ways shown in Figure 5 'Pictorial Representation of Gewa Prog III and it's Control Capabilities'.

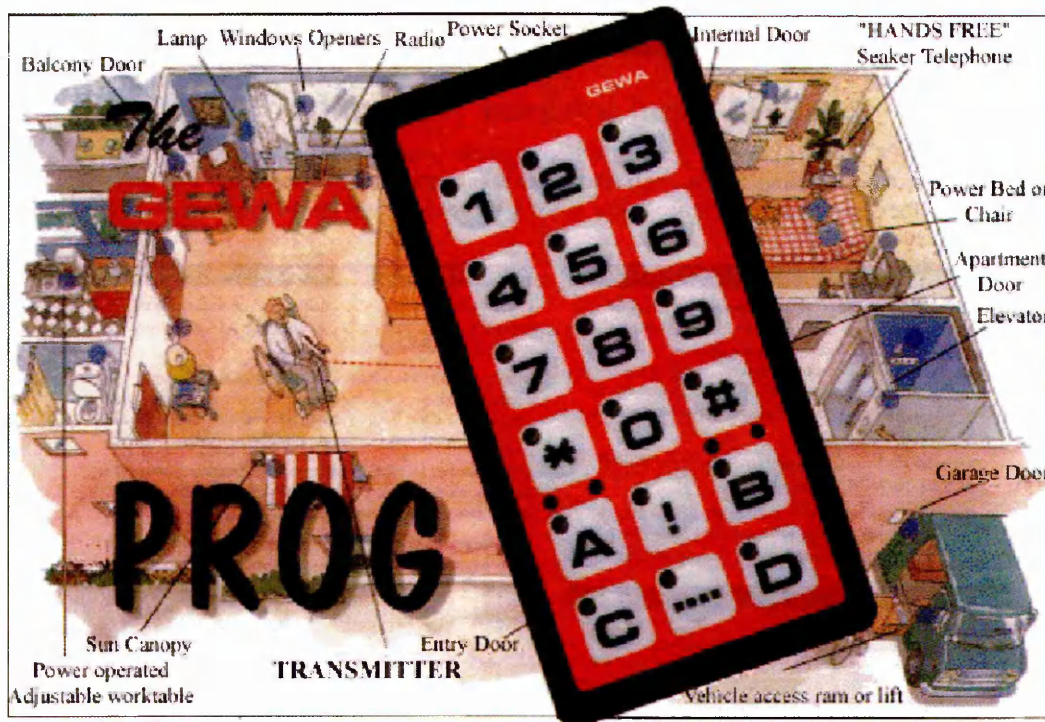


Figure 5 Pictorial Representation of GEWA PROG III and Control Capabilities.

It is unlikely that any single user would require all of the functions shown here. However, the transmitter is capable of storing up to one hundred and forty-four individual codes.

4.2.4 Mobility Aids

At the beginning of the project the only mobility aid available to single switch users was the prototype of the BWI, created and described by Cherry (Cherry *et al*, (1996)) as part of his integrated system for the one individual.

However, in 1996, the PhD Research student developed a commercial version of the Barnsley Wheelchair Interface (BWI) at what was then, Barnsley District General

Hospital NHS Trust. He was working for David Mason, then of 'Cambridge Adaptive Communication' - the company that brought an ⁹AAC to Professor Stephen Hawkins.

A hardware device to drive an electric wheelchair was made commercially available much later. ¹⁰'Click 2 Go' enabled a single switch user to control an electric wheelchair via a DX control module. However, the 'Click 2 Go' device does not generate data logs of the selections made by the user. The BWI's ability to generate data logs of the stakeholder's movement is the primary focus of this dissertation. The next section reports BWI's primary configuration and attributes and these are explained and discussed in the following section.

4.2.4.1 Barnsley Wheelchair Interface (BWI)

In order to give the reader an understanding of the way the BWI looks visually, and to describe other configuration attributes of the BWI, the description is divided into three parts as listed below, and then outlined in more detail in subsequent paragraphs:

- Interface
- Input Methods
- Scanning Methods

4.2.4.1.1 Interface

With the wheelchair symbol selected from the BASE interface (see Figure 4.2.1.2.1 Pictorial Scanning Menu within BASE), the BWI application is executed and the following interface is displayed (see Figure 6 'The Barnsley Wheelchair Interface') on the screen of the PC.

⁹ <http://www.hawking.org.uk/disable/dindex.html>

¹⁰ <http://www.click2go.ie/clicktogo/index.htm>

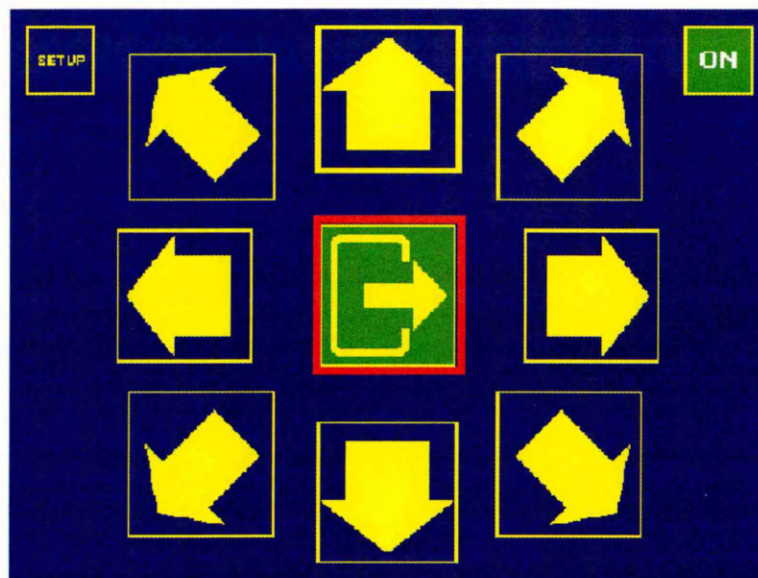


Figure 6 The Barnsley Wheelchair Interface.

Furthermore the application starts a communication protocol with the electric wheelchair controller ensuring that both devices agree as to each others status. Should at anytime the status of these two devices conflict, then the communication of ‘stop’ and ‘turn off’ the wheelchair will be sent, ensuring the wheelchair occupant always remains safe. In addition, this information is also reported within the data log as an application termination.

4.2.4.1.2 Input Methods

The BWI can be configured to respond to one, two, three and four switches and the functionality of these switches is shown in the table below:

Functional No. of Switches	Switch One	Switch Two	Switch Three	Switch Four
One Switch	Selection	-	-	-
Two Switches	Selection	Next in Sequence	-	-
Three Switches	Selection	Next in Sequence	Previous in Sequence	-
Four Switches	Selection	Next In Sequence	Previous in Sequence	Set Up

Table 4 Switch Functionality

It is important to note that each of these switches can have two dampeners applied to them. The first dampener is the “Hold Down Time” and the second is the “Post Acceptance Delay”. The first dampener of “Hold Down Time” is the time that the user must hold the switch closed before the closure will be accepted as a genuine closure. The second is the “Post Acceptance Delay” and this is the time that the switch must remain open after a genuine closure before a following closure will be considered as a closure. Both of the attributes now appear to be standard variables within EAT.

In addition, when one switch interaction is selected it can be noted from the above table that there seems to be no way to move to the next or previous item. However, when one switch interaction was selected, a timer set at a predetermined duration of scan would move the highlight to the next item within the sequence. The next section of this dissertation focuses upon these numerous Scanning Methods.

4.2.4.1.3 Scanning Methods

A comprehensive number of scanning methods are available within the BWI and these are described in the table below (see Table 5 ‘Scanning Method Sequences’). The Figure below (Figure 7 ‘BWI Interface Showing Items has Numerical Items’) shows which direction is highlighted:

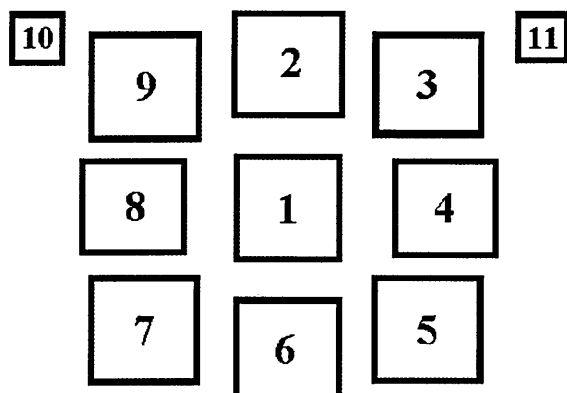


Figure 7 BWI Interface Showing Items as Numerical Items.

In the Figure above, item 1 = Exit, 2 = Forward, 3 = Forward Right, 4 = Right, 5 = Backward Right, 6 = Backward, 7 = Backward Left, 8 = Left, 9 = Forward Left, 10 = Call Set Up and 11 = On/Off.

The BWI can be configured not to highlight item 10 which is the Call Set Up application, as this enables the user (using a switch/es) to change the configuration of the driving interface.

The table below shows the sequence of the highlight for each of the scanning methods available within the BWI. It should be noted that item 10, Call Set Up can be excluded if this function is not required by the user.

Scan Method	Sequence of Items									
	1	2	3	4	5	6	7	8	9	10
Forward First Clockwise	2	3	4	5	6	7	8	9	1	10
Forward First Anti-Clockwise	2	9	8	7	6	5	4	3	1	10
Exit First Clockwise	1	2	3	4	5	6	7	8	9	10
Exit First Anti-Clockwise	1	9	8	7	6	5	4	3	2	10
Forward Bias Forward First Clockwise	2	3	4	5	6	7	8	9	1	10
Forward Bias Forward First Anti-Clockwise	2	9	8	7	6	5	4	3	1	10
Forward Bias Exit First Clockwise	1	2	3	5	7	9	8	6	4	10
Forward Bias Exit First Anti-Clockwise	1	9	8	7	6	5	4	3	2	10

Table 5 Scanning Method Sequences

It is also important to note that item 11 - the On/Off item, is only highlighted once the attribute 'Circuits' is true. 'Circuits' is the number of times the highlight must complete before the application puts itself into sleep mode and turns itself, and the electric wheelchair, off. For example, if 'Circuits = 3, then the sequence of highlights must have been completed three times before this is true and at this point the status item 11 is changed to the opposite of its present state and is highlighted. Item 11 also remains highlighted until the user depresses the selection switch for a predetermined period of time. On this selection, the status of item 11 is changed to its opposite state and the scanning sequence commences once again.

Additionally, where the scan method includes 'Forward Bias' and when the user completes a selection, then the highlight will always return to the item 2 (Forward) see Figure 7 'BWI Interface Showing Items has Numerical Items.' Once the highlight period is completed, then the scan will continue with the sequence stated within Table 5 'Scanning Method Sequence'.

4.3 Chapter Summary

The Chapter first cites other researchers within this domain and there calls for integration and evaluation methods.

Then the Chapter shows the diagram of the evolution of AT and describes this diagram and its elements in full, starting with the first IEAT 'BASIS-C' and the limitation of that system. The next section within this Chapter then moved onto 'BASE' and the inclusion of data logs which a sample extract is shown along with its elements and the way these elements were analysed to give ATP's their first glimpse into the way the system was used.

In addition, it was reported that difference scanning methods can influence the user's productivity. In the following section, is described the different functional attributes a system may have e.g., Mobility, Talking and Environmental Controls etc., that could be made available, but it then explains why the PhD Research student focussed his attention on the Mobility aspects of the system.

The next part of the Chapter showed a picture of the BWI interface (the mobility aspect of the IEAT) and describes the different scanning methods available with that application also described are other attributes, that may influence the user's usage of the system, which in turn bring us to this section, which concludes this Chapter.

Chapter 5. The Research Methodology

Chapter Structure:

In this Chapter the PhD Research student presents the research methodology used during the undertaking of this research project in order to answer the research questions presented.

5.1 Overview the Methodology

This Chapter provides an overview of the methodology used within this research project and reported within the following Chapters of the dissertation in order to answer the research questions proposed and stated in Chapter 1 'Introduction' The overall methodology proposed is shown in Figure 8. It provides a diagrammatical representation of the method used within this dissertation in order to enhance the prescription process of the "Multi-Disciplinary Service Model" created and described by (Hawley (1995)). This model is described and referred to in detail in Chapter 3 of this work.

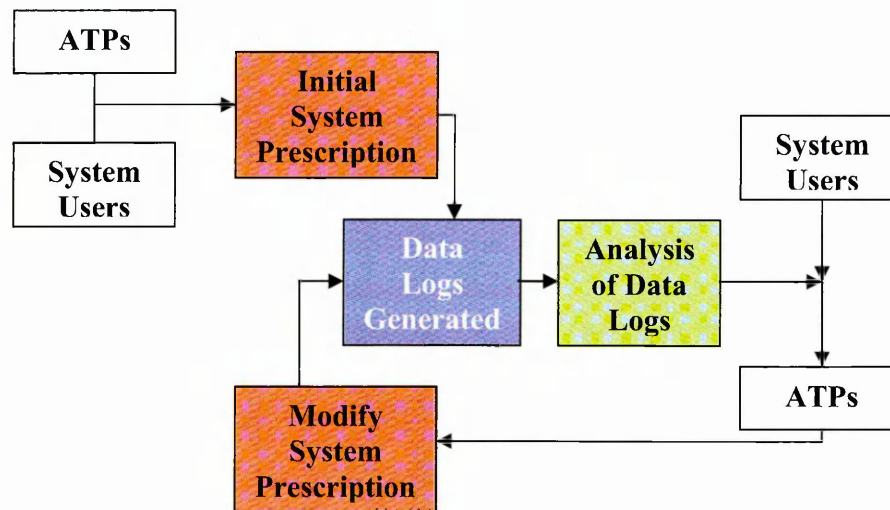


Figure 8 Overall Methodology

With the exception of the 'ATP's', 'System User's and 'Initial System Prescription', the remaining elements within Figure 8 illustrate an overview of the procedures described within this dissertation. In addition to the Figure, which demonstrates the elements' interaction, each of the elements is described in more detail below:

- The top left hand elements within Figure 1, 'Assistive Technology Professionals' ('ATP's'¹¹), 'System User's'¹² and 'Initial System Prescription', are a condensed representation of the "Multi Disciplinary Approach" created and described by Hawley (1995).
- On completion of the 'Initial System Prescription' data logs are generated by the applications during their everyday usage, depicted by the blue 'Data Logs Generated' element.
- These data logs are periodically retrieved by the ATP and analysis procedures conducted, represented by the green element labelled 'Analysis of Data Logs'. It is these analysis processors and their interpretation that form the main essence of this work.
- With the results from the analysis processes and discussion between ATP's and System User, the 'Modify System Prescription' element takes place and the iterative procedure begins once again.

It is important to note that Figure 8 does not have an 'Out Gate', as the iterative procedure continues for the life of the device or system user.

In addition, the first component from this methodology uses the work described within 'A Client-Centred Multi-Disciplinary Service Model', by Hawley (1995) which is used within the department of Clinical Engineering Services (CES) at Barnsley Hospital NHS Foundation Trust.

5.2 Why This Methodology Was Used

Other methods such as 'UserFit' were investigated but due to this method requiring a number of user which as already explained in section 1.5 this was not going to be the case within this research project. Therefore the methodology presented in 5.3 was the consequence of a number of factors. Firstly, a method that would be easy and

¹¹ An ATP can be anyone of the following people, Speech Therapist, Physiotherapist, Occupational Therapist, Rehabilitation Engineers, Clinical Engineers, Teachers, IT Co-ordinators, Researchers and Clinician or any combination of these individuals.

¹² System User's are the individual who have a disability and use the device within the field. This may also include third party individual commenting on behalf of the system user, such as Parent/s, Sibling/s, Carer/s, Partner, Teacher/s and Peer/s.

convenient for ATP's to incorporate into their daily routine was required. This would (a) ensure the minimal inconvenience to all parties, (b) keep the additional resources required to a minimum and (c) encourage the use of the method for these reasons. Secondly, it quickly became apparent that it was going to be extremely difficult to find multiple participants because individuals requiring these comprehensive systems are few in the UK.

Although others could be found throughout the world, it would have been logistically and financially prohibitive. For this reason it would not have reflected the real world scenario, as often an ATP may only work with one client within their career who may require such a comprehensive system. It was for these reasons we had decided on a single participant student as explained in section '1.5 The Project's Scope'.

In addition there was a requirement to validate the findings for the purposes of this study, hence the introduction of Part 2 'the laboratory study' and comparison of findings from Part 3 'the field and laboratory studies'. Rather than just conducting the field studies alone the two latter parts would be used to validate the field study and would also provide valid guidance to the ATP's,

5.3 The Methodology

Throughout this project the following methodology was used, constructed out of the following components:

1. Field Study
2. Controlled Laboratory Study
3. Comparison of Field Results with Controlled Study Results

These three components are described in more detail on the following pages. However, the first component which contains components of its own, is integrated within the method for prescribing an Electronic Assistive Technology (EAT) system by Hawley (1995). In addition, in 5.4 'The Multi-Disciplinary Service Model' the diagram presented by Hawley shows where the first component from this methodology is located within the Hawley model.

5.3.1 Field Study

The methods described within this part of the Chapter are those suggested by the PhD Research student which should be used within the field by ATP's wishing to investigate the EAT Systems that they have prescribed. This would ensure that the prescription is fulfilling the user's functional needs and letting them attain their productivity rate.

It is important to note that during the field studies the PhD Research student also undertook the role of an ATP, which he had originally been employed to fulfil by Barnsley Hospital NHS Foundation Trust prior to embarking on the research reported within this work.

The first component is made up of a number of subsidiary components, and these, along with the way they are linked are shown in the following Figure 9 'Field Study Methodology':

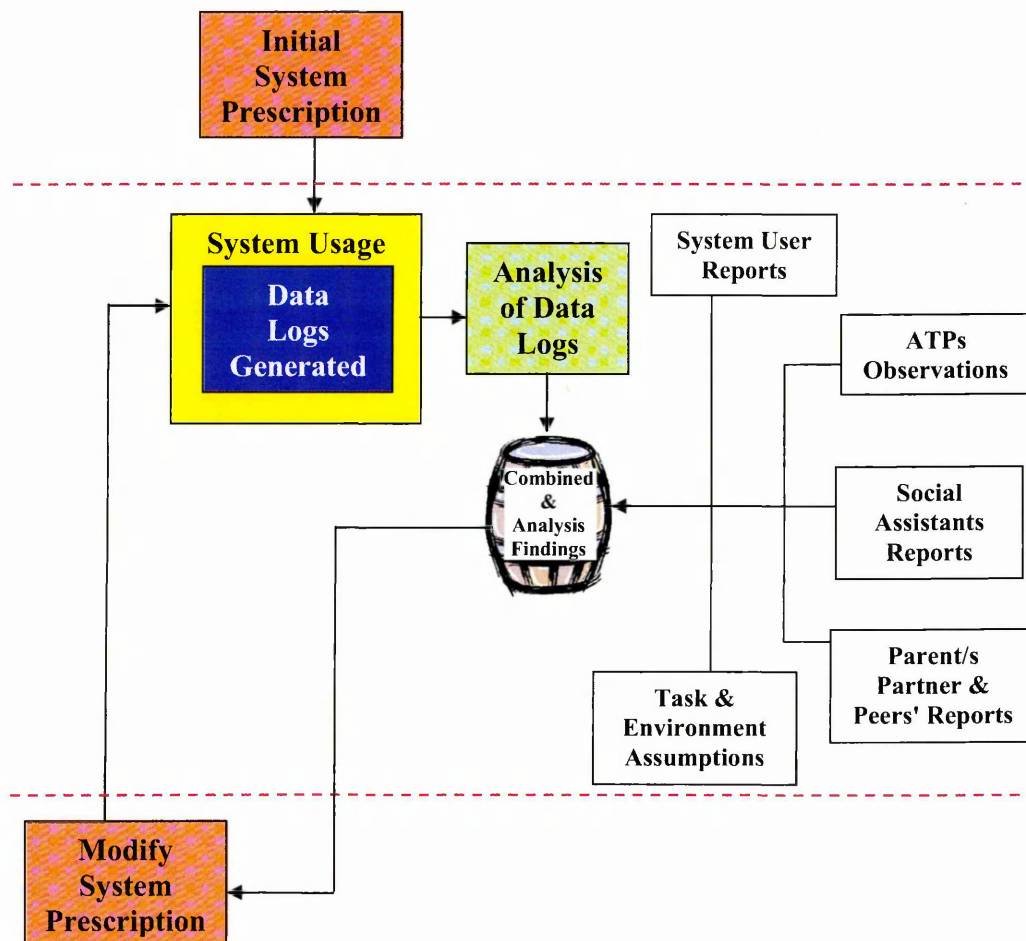


Figure 9 Field Study Methodology

The components positioned above and below the dotted pink line are elements from 'A Client-Centred Multi-Disciplinary Service Model'. A brief description of each component contained between the two pink dotted lines is given below:

System Usage

This is the usage of the EAT System which, when the EAT is being used, automatically creates the Data Logs. It is necessary to retrieve the Data Logs periodically and this visit provides an excellent opportunity for the ATP to observe the user and to talk to them and their Social Assistants about the system in general. (See 'System User Report', 'Social Assistants Report', 'Parent/s Partner & Peers' Reports' in the following sections of this Chapter)

Analysis of Data Logs

The Data Logs, when retrieved from the System User, can be analysed using the processes described within this dissertation to provide information to the ATP about the general system usage and the related topics of:

- *Whole system information*
- *Functional level information*
- *Interface level information*

The three levels of information are discussed in greater detail in Chapter 6 'The Field Studies' of this work.

System User Report

Often the process of obtaining information from the user can be very difficult and extremely time consuming. This is not because the user does not want to express their wishes and provide the requested information, but because the system is often their primary communication aid. This means that a required phrase may not be available on the communication aid, or an explanation of the

difficulty is not possible. For example, if the ATP has not had the foresight or even thought of this difficulty the user may have to write the answer in full. This can be both time consuming and physically challenging for the user.

Within this work, the PhD Research student obtained information from the “System User” by providing them with boolean questions. For example, questions with a simple “Yes” or “No” response. The System User would indicate their answer by looking to her left for “Yes” and right for “No”. If the answer was “Maybe” or “Unsure”, then she would look down, indicating to the PhD Research student to be more exact in what he required, to re-phrase the question and to make it answerable with a boolean reply. In addition, over the years the PhD Research student came to know the participant quite well and could perceive what the response was going to be from the look on her face. Checking about the system and her usage of it therefore became easier over time. In addition, the boolean answers obtained were compared with the results from the analysis of the data logs and field observations as well as comments by peers and social assistance with regards to the usage of the system, therefore providing a triangulation and thus confirmation of the information obtained was not due to the PhD Research student asking the questions.

ATP's Observations

Again during the visit to collect the Data Logs from the system, the ATP had the opportunity to observe the user using the system within their environment in the following ways:

- Un-notified Observations
- Notified Observations

These are described in more detail in Chapter 6 ‘The Field Studies’ of this dissertation.

Social Assistant's Report

It is often this group, along with the following group, who provide the ATP with the comprehensive knowledge about the system usage. For example, initially they will provide information on the following areas:

- Social Activities that restrict or embellish the user's usage
- Lack of functionality
- Changes to functions
- Changes to Interface
- Changes to input type and or location (Switch location, size, etc.)
- System Mounting
- General usage difficulties

Parent/s Partner & Peers' Reports

Invariably personal changes with regard to the user are disclosed by this group, especially if they consider that these changes may be influencing the user's ability to use the system, e.g. changes in medication.

Task & Environment Assumptions

These processes are based on evidence from the analysis procedures with the data logs and the different types of observation and require validating by discussing and undertaking additional observations within the field before changes to the system are made.

Combined & Analysis Findings

The processes included within this section are described comprehensively in the subsequent Chapters of this work and are not therefore covered here. (See Chapter 8 'Comparison of the Field and Laboratory Studies' and Chapter 9 'Additional Knowledge Obtained'.)

5.3.2 Controlled Laboratory Study

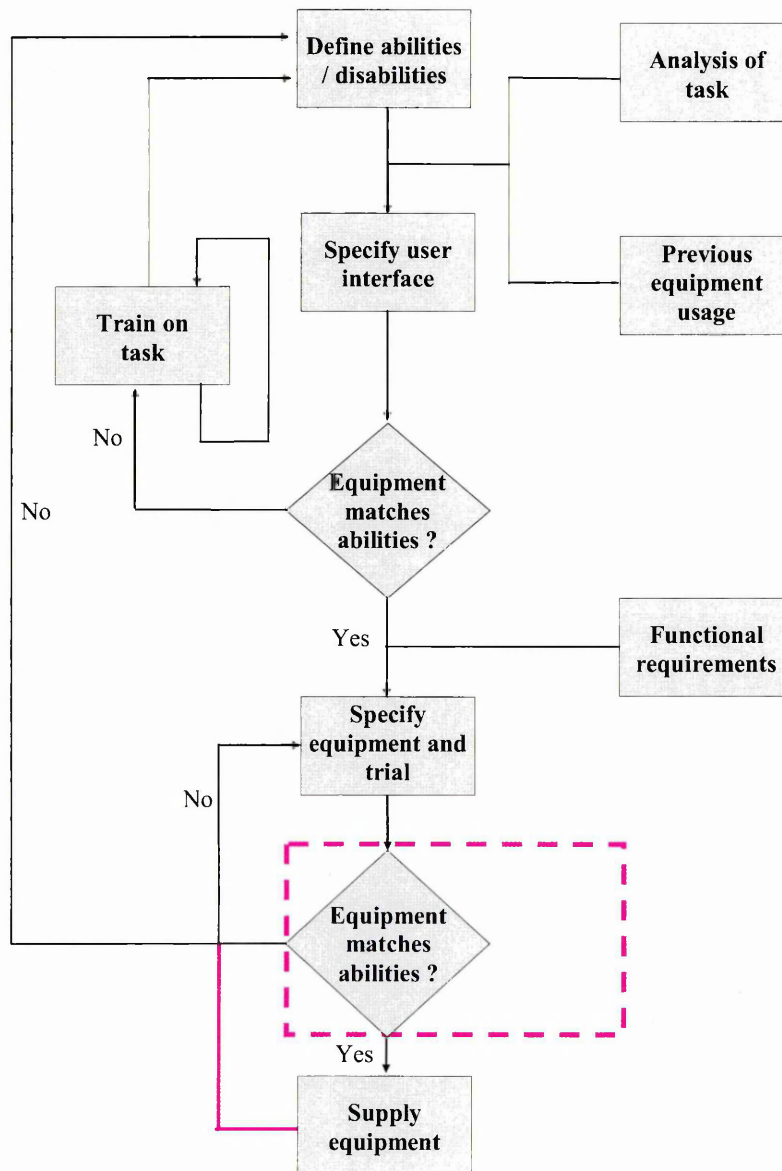
This part of the method was used to provide validation to the hypothesis from the field study. Therefore, the laboratory study was designed to ensure it would provide the answers. In addition, this study would provide a triangle of comparison with one of each of the three participants on a point, and each of them with their own distinctive characteristics. (See Chapter 7 'The Laboratory Experiments, section 7.2.3 'Participants' for more detail.)

5.3.3 Comparison of Field Results with Controlled Study Results

This section of the method, as already pointed out, enabled the PhD Research student to collate all findings and compare the results from both the field and Laboratory studies.

5.4 The Multi-Disciplinary Service Model

"A Client-Centred Multi-Disciplinary Service Model" is presented here, generated from the paper by (Hawley, (1995)). Within this diagrammatical representation (please see the following page) the PhD Research student included the methods described in '5.3.1 Field Study' of this Chapter, and this is represented by the pink dotted box. In addition, because the PhD Research student believes that in order to get the best out of the methods described, the method must be iterative. Therefore the PhD Research student has included this within the Hawley model by linking the 'Supply equipment' back to the 'Specify equipment and trial', to make this iterative loop.



**Figure 10 Client-Centred Multi-Disciplinary Service Model
with Data Logging Analysis Procedures Incorporated**

5.5 Chapter Summary

This Chapter started by providing the reader with an overview of the methodology used within the dissertation and provided a pictorial representation along with a textual description of each of its elements and how they interact. In addition, the next section described which of these elements link the model into the Hawley model.

The following part of the Chapter explained that a number of methods were investigated by the PhD Research student e.g., 'UserFit', but were found to be unsuitable as it was determined that a model which was created around the existing prescription model would be preferable and the reasons are given. The Chapter then described the method that was used during this research project of comparison of field and laboratory results and each of the components along with there sub-components were discussed in detail in the following sections of this Chapter.

The Chapter concluded by displaying a diagrammatical representation of the "Client-Centred Multi-Disciplinary Service Model" and also shows where the dissertation methodology, fits within that model.

Chapter 6. The Field Studies

Chapter Structure:

This Chapter describes the empirical field studies that were conducted over a number of years. It also explains the processes of analysis that were developed to answer questions from ATPs within the department of "Medical Physics and Clinical Engineering Services" at Barnsley Hospital.

In addition the analysis processes which are deemed to be useful within the process of the enhancement of the prescription are identified. This Chapter concludes with a number of hypotheses and descriptions of ATP's knowledge enhancements made during the field studies. The means by which they are to be further investigated are highlighted.

6.1 Introduction

This empirical study was conducted over a period of approximately six years observing and collecting the data from a subject as described in Chapter 2 'The Stakeholders', using the methods described in the previous Chapter, Chapter 5 'The Methodology'. The data logs were collected by the researcher periodically and the process of analysis was conducted as outlined in 6.4 'The Analysis Processes' to answer the questions previously stated by (Hawley *et al* (1999)) on the basic usage of the system as well as the objectives stated in Chapter 1 'Introduction'. Fundamentally, these questions were being asked by the ATP's at 'Barnsley District General Hospital NHS Trust' within the department of Medical Physics and Clinical Engineering Services (CES) in order to substantiate the time and resources required in the development of these systems and also to enhance the prescription of the system. This in turn was intended to enhance the user's quality of life.

It is important to note that due to the duration of the field studies the stakeholder went from being an eight year old girl to a fourteen year old teenager.

"Children must pass through several stages, or take specific steps, on their road to becoming adults. For most people, there are four or five such stages of growth where they learn certain things: infancy (birth to age two), early childhood (ages 3 to 8 years), later childhood (ages 9 to 12) and adolescence (ages 13 to 18). Persons 18 and over are considered adults in our society."

[ERIC Clearinghouse on Rural Education, 1998]

Our stakeholder falls within the third and fourth stages of development. It is acknowledged that many aspects of her self-esteem, behaviour and motivation changed over this period as with any child. In addition, our stakeholder also had the aspects of her disability to cope with, adding to the complexity of her development. Gerber and Okinow (1994) **assert that:**

“Adolescents with chronic illness or disability experience the same developmental transitions as their peers without disabilities, yet their illness or disability places them at risk for certain psycho-social problems as they move into adulthood. The risk is not solely in the medical complications of the illness or disability...rather risk is more often related to the degree of fit between the adolescent and his or her environment: family, school, peers, health care services, work, and societal attitude. The fit can lead to optimal integration and development, or it can result in isolation and low self-esteem”

[Gerber, (1994)]

The research into adolescence is vast and, in addition, the investigation into the effects of having a disability and going through this period is also of considerable size. It is beyond the scope of the research reported here to consider both instances of adolescence and coping with a disability in this period of life. However, the PhD Research student acknowledges here that these aspects must have exerted an influence on the results at particular points within this investigation.

6.2 The approach undertaken within the field study

The researcher would visit the subject periodically at home and school which were her two main places of occupation. Information and knowledge would be obtained during these visits in the following manner:

- Un-notified Observations
- Notified Observations
- General Discussion with Subject
- General Discussion with ¹³ Assistants
- Data Collection

¹³ Assistants include the following groups of individuals that interact with the subject, Parents, Siblings, Teachers, Carers and Peers etc.

During these visits time would be spent observing, with a view to obtaining some knowledge of the types of tasks she may be trying to accomplish.

“Some form of direct observation, whether formal or informal, is essential if the analyst is to get an understanding of the task situation. At the simplest level the analyst can simply spend time watching people and chatting, just to get the 'feel' of the task.”

[Dix *et al*, (1993), pp281]

These observations would initially be without the participant's knowledge but always ended with the disclosure of the PhD Research student's presence. It is important to note that the participant was aware that observations may be made in this manner and both she and her parents had given prior consent. These observations (without the participant's knowledge at the start) would often be dependent on other individuals around her not informing her of the PhD Research student's arrival. These are therefore classified within this document as 'Un-notified Observations' and would vary in duration, hence a possible increase in the information obtained. A 'General Discussion with the Subject' would be undertaken during the transfer of the data logs, due to the individual's communication difficulties. This would invariably be in the format of 'Yes' or 'No' responses to the researcher's questions which would mainly focus on comments made by the assistants to the researcher on his arrival about the system's performance and the subject's ability to use the system. Additionally these comments would often include information about the subject's daily tasks and provided information about lack of usage of the system on a particular day. For example, it was noted during one analysis that the subject did not use the system one particular afternoon; this could not be explained from the data alone. However, during a visit the researcher was informed that the subject went swimming in the afternoon of that day which fully explained this lack of usage.

"Continuity and stability of relationships with key players: This is important in building trust and commitment with all part takers and having access to critical information and resources only accessible through those key players."

[Bayeh, (1997)]

6.3 The Rationale

During the advancement of this research project a number of hypotheses became apparent; these were investigated within the lifetime of the field studies of the project and reported within its publications. In general these hypotheses fell within the following areas and were fully or partially answered within the publications:

- *Whole system information*
- *Functional level information*
- *Interface level information*

These levels are defined in more detail below:

- *“Whole system information* is concerned with obtaining an overall view of assistive technology utility and utilisation. Aggregates of technology use are used to ensure uptake, identify periods of familiarisation, learning and other possible trends in usage. For prescription activity, this level is significant at a basic level of ensuring the technology is adequate (Hawley *et. al.* (2001)). At a more sophisticated level whole system information is relevant in assessing trends and fluctuations in usage that may be indicative of changes in a user’s condition or environment. For instance, a change of physical accommodation may be reflected in a profile of overall usage time.
- *Functional level information* is concerned with the match between a user's assistive technology needs and the assistive applications and functionality provided. For example, in the case of the Barnsley Wheelchair Interface we could ask whether the eight distinct directions are those needed - both more directions and fewer directions are valid alternatives. Functional level analysis of logs is reliant upon abstracting over log events in order to map them to domain-orientated activities that are suitable for consideration by clinicians involved with prescription.
- *Interface level information* is focused upon the effectiveness with which required functions can be accessed. Therefore, the configuration of a device such as the scanning menu of the device (in terms of highlight order, pace, hold-down-time and release-time) will be the finest level determinant of whether the required assistive functions are accessed when they are needed by end users. In this case analysis is primarily focused upon the reliability of the log characteristics - that is, do log events correspond to actions intended by the user?”

[O'Neill *et al.*(2001)]

Although all of these hypotheses were comprehensively investigated and published, they did contain limitations which are indicative to field studies without comprehensive and prolonged observations. In some instances it became apparent that the lack of understanding of the 'task trying to be accomplished' and other characteristics of the environment and wheelchair were hindering the investigations.

It was therefore decided by the PhD Research student and his supervisory team that a laboratory experiment should be designed and undertaken to include all of the areas that still required further investigation. The laboratory experiment is outlined and reported in the following Chapters:

Chapter 7 'The Laboratory Experiments' explains the experiments procedures and design.

Results of the field studies and laboratory experiments are compared in the subsequent Chapter,

Chapter 8 'Comparison of the Field and Laboratory Studies'. There are eight hypotheses that are considered to require a fuller investigation with regard to the areas of 'task knowledge', 'stakeholder observations', 'electric wheelchair' and 'environment characteristics' before these results can be of use to the ATP's. These hypotheses are listed in section 6.5 'The Hypotheses' along with a given, 'Description of ATP's knowledge enhancement', which is intended to describe the usefulness of the possible results to the ATP's working in the field.

The hypotheses have the commonality of being able to present the ATP with an insight into the way in which the system is being used or not used as the case may be. This may highlight a possible cause of a particular difficulty and therefore a possible means of enhancing the system. This may increase the user's productivity and thus enhance their quality of life.

6.4 The Analysis Process

In order to answer the hypotheses presented towards the end of this Chapter (see section 6.5 'The Hypotheses') a process to prepare the data was created. This process is outlined in the following paragraph and was conducted manually.

The data log file was imported into an "Excel Worksheet" and visually viewed by the PhD Research student for any imperfections, for example, if the PC had been turned off without going through the Windows® close down procedure then the data log would terminate without a 'Termination' entry and this would require us to physically place an 'Abnormal Termination' record within the data log. With this visually looking for imperfections procedure completed a column was labelled 'Duration' and a formula was entered into the cells within this column. This formula then calculated the duration of the event in seconds, which was the finest granularity possible within these logs. The event could be the time spent doing a particular task, for example, talking or moving. When the data was taken from the BASE application information about which particular application was in focus was recorded. At this level, information with regard to the activity within the particular application is not recorded by BASE. However, an application such as the BWI could record the time spent driving in a particular direction and this could be analysed from the BWI data. With these basic processes completed the procedure to extract the required information was then undertaken. The different forms of information are listed below:

- Frequency of Selection
- Accumulated Frequency of Duration
- Average Frequency of Selections
- Average Duration of the Selections
- Frequency Duration per Selection
- Frequency of Consecutive Selection
- Erroneous Rate
- Scan Modelling
- Duration Moving and Scanning
- Normalisation of opposite Selection
- Path Profile

The procedures for extracting the above types of information are shown in more detail in Appendix C of this dissertation 'Methods of Formulating the Data Logs'. The comparison and analysis of the data was then examined visually and the hypotheses described in 6.5 'The Hypotheses' could be validated, invalidated, or in some instances require further investigation. The analysis conducted within the field study where further investigation was required was repeated again on the data generated within the laboratory studies (see Chapter 7 'The Laboratory Experiments'). The results from the laboratory study were then compared with the results from the field study in order to validate those findings which could not be validated from the field studies alone.

It is important to note that due to the lack of 'task knowledge', that is the 'task being undertaken' by the stakeholder while driving the electric wheelchair and subsequently reported within the published work, the research team made a number of assumptions with regard to the following areas:

- User's Characteristics
- System Characteristics
- Environment Characteristics

In addition, when comparing or looking through the data on rare occasions it would become apparent that the results were inferring a particular behaviour. For example viewing the data from the BWI with the overall iterative selections of the activity of 'Forward' then 'Forward Left' or 'Left', would draw (as suggested in the 'Path Profile') the graph below (Figure 11 Example of Stepping in the Path Profile):

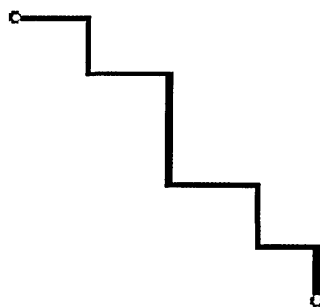


Figure 11 Example of Stepping in the Path Profile

In the example above, where the starting point is signified by the green dot and the end by the red dot, with the line making its way towards the left we would conclude that the electric wheelchair veered to the right. This veer would then fall within the 'System Characteristics' or 'Environment Characteristics', as this could be caused by the pile of a carpet and/or the fact that the two motors on the electric wheelchair ran at different speeds from each other. In the field studies this could only be confirmed by undertaking observations, whereas using the additional laboratory study results should confirm or refute this assumption as the outcomes from the field and laboratory studies can be compared to see if the results are comparable. In addition, the PhD Research student was aware of the 'task being undertaken' in the laboratory study. Therefore, with this 'task knowledge' he could determine if the line should be straight or slant to one side due to the participant driving down a straight corridor or turning a corner respectively.

6.5 The Hypotheses

The hypotheses listed below are a conglomerate of the hypotheses investigated within the published work (Hawley *et al* (1999)); O'Neill (2000)a; O'Neill *et al* (2000)b; O'Neill *et al* (2000)c; O'Neill *et al* (2000)d; O'Neill *et al* (2000)e; O'Neill *et al* (2001); Roast *et al* (2002). These hypotheses are those which were investigated within the literature published and referenced above, but could not adequately be validated due to the authors lack of 'task knowledge', 'stakeholder observations', 'electric wheelchair' and 'environment characteristics' due to the data being created and collected from the field.

Moreover, in order to understand to what extent, if any, the stakeholder's disability was influencing her usage of the system, a means of comparison was required. Therefore in Chapter 7 'The Laboratory Experiments' the inclusion of two additional participants was requested so that a foundation of 'without the disability' but 'with' and 'without the knowledge of wheelchair usage' could be included.

The hypotheses requiring deeper investigation are presented, along with a statement labelled 'Description of ATP's Knowledge enhancement' which is intended to give an outline as to the usefulness of this knowledge to the ATP's working within the field.

Hypothesis

“The disabled individual will make shorter selections than an able-bodied participant.”

Description of ATP's knowledge enhancement

1. The 'Expert Disabled System User' will have difficulty sustaining a switch closure.

Hypothesis

“The 'Expert Disabled System User' will make more errors than others due to her physical impairment.”

Description of ATP's knowledge enhancement

2. The Expert Disabled System User's spasms will be the cause of her errors.

Hypothesis

“The disabled person should make fewer selections and be quicker with negotiation, where the course is constrained.”

Description of ATP's knowledge enhancement

3. The Expert Disabled System User's expertise will become evident in confined spaces.

Hypothesis

“The BWI's scanning methods may influence the user's directional selections and not the environment (course being driven).”

Description of ATP's knowledge enhancement

4. All participants will turn more frequently in the direction that is bias scanned by the system.

Hypothesis

“The scanning methods, in conjunction with the characteristics of the electric wheelchair, are of greater influence than the environment (course being driven).”

Description of ATP's knowledge enhancement

5. The scanning method being opposite to the direction of the veer of the wheelchair is of greater influence than the environment's attributes.

Hypothesis

“Hypothetical times generated from the real time data logs of any scan method will be less than the real time of that scanning method, for both attributes of driving and scanning.”

Description of ATP's knowledge enhancement

6. Reality takes longer than the hypothetical model due to other influences.

Hypothesis

“The physical limitations of the disabled participant will be clearly evident when compared to the unlimited ability of the able-bodied participant despite the differences in the individual's expertise.”

Description of ATP's knowledge enhancement

7. The extent to which the physical disability plays a part will be clear when comparing a disabled and able-bodied user.

Hypothesis

“Involuntary selections may be causing an increase in selections by the disabled participant.”

Description of ATP's knowledge enhancement

8. Is it the spasms of the disabled user that are causing an increase in selection?

6.6 Chapter Summary

In the introduction was contained an explanation of an empirical study that had been conducted over six years in order to answer the questions presented by CES of Barnsley District General Hospital NHS Trust. The next section continued by describing the means by which this was undertaken and the ways the information and knowledge about the system's usage was obtained. The section went on to acknowledge that the stakeholder was going through adolescence and this, in conjunction with her disability would have made this particular period in her life more difficult. It is therefore assumed that adolescence and these physical difficulties will have influenced the findings at particular points. The next section contained definitions of the three distinctive categories. The type of information which would be encapsulated within these categories was also detailed.

The next section outlined the rationale and the PhD Research student explained that a considerable number of hypotheses were investigated within the lifetime of the project

and they seemed to fall into three distinctive categories. However, these hypotheses required investigating in a controlled environment such as a laboratory study. The Chapter continued with a brief description of the analysis processes that were conducted on the data logs and then listed these processes. This section also expressed the need for assumptions to be made with regard to the results from the field studies and that these assumptions fell within the characteristics of 'task knowledge', 'stakeholder observations', 'electric wheelchair' and 'environment characteristics'. In addition, this section of the Chapter explained that, with experience, the PhD Research student learnt to recognise behaviours within the data logs and what these behaviours were suggesting. The PhD Research student also recognised that due to the lack of 'task knowledge', 'stakeholder observations', 'electric wheelchair' and 'environment characteristics', it was not possible to validate the 'Hypotheses' and 'Description of ATP's knowledge enhancements' without additional field observations. However, this would not be the case within Chapter 7 'The Laboratory Experiments'. Finally, this Chapter concluded with a list of the hypotheses which are the outcomes from the numerous published works within the lifetime of the field study.

Chapter 7. The Laboratory Experiments

Chapter Structure:

This Chapter takes the hypotheses and descriptions of ATPs' knowledge enhancements from Chapter 6 and runs a series of experiments with users of differing abilities and knowledge of wheelchair and system usage.

7.1 Introduction

This Chapter contains a view of the approach taken to search for supporting evidence concerning the hypotheses described in the previous Chapter. This is achieved by conducting a laboratory experiment where the task being undertaken is not only known to the PhD Research student, but comprehensive observations could also be made. These comprehensive observations were conducted in the following ways:

- Data Log Collection
- Researcher Observation
- Video Recording

The laboratory study was designed to ensure that it would provide the information required, not only to answer the hypotheses but additionally to validate or invalidate the assumptions made whilst reaching the results already reported in the published work. A full description of the laboratory experiment is contained within section 7.2 'The Approach Taken'.

This Chapter then goes on to describe in brief detail the analysis processes undertaken on the data created from the laboratory study. The Chapter continues by outlining the results of this laboratory study and finally concludes by explaining that the results from the laboratory and field study are reviewed in Chapter 8 'Comparison of the Field and Laboratory Studies'.

7.2 The Approach Taken

7.2.1 Introduction

A number of tests were undertaken by the two able-bodied participants who are described in 7.2.3 'Participants' as the 'Novice' and 'Able-bodied' expert. A procedure was constructed for the familiarisation of these two participants. This is shown diagrammatically below 'Diagram 7.1':

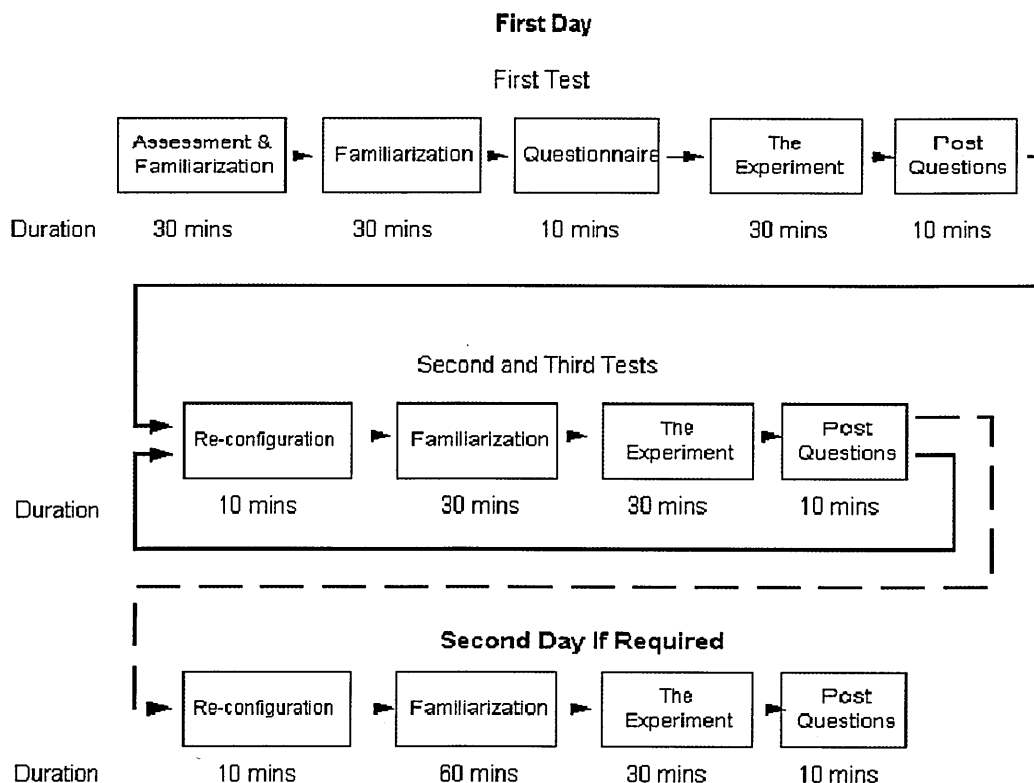


Figure 12 Overview of the Experimental Procedure undertaken by the 'Able-bodied Novice' and 'Able-bodied Expert' when undergoing the experiment with the BWI in different configurations

It is however important to note the Expert (see 7.2.3 'Participants') would only be required use the system to travel the course only once using in her everyday configuration due to the extensive physical effort required to accomplish this (please see DVD with the title "The Enhancement of the Prescription of Electronic Assistive Technology").

7.2.2 The Experiment Variables

This section of the thesis outlines the three main influencing factors within this experiment. These are listed below and then reviewed in more detail:

- Participants
- BWI configuration and Electric Wheelchair influences
- Environment (the course being driven)

7.2.3 Participants

A short description of each of the participants is provided below, along with substantiation of their expertise with regard to using both the Barnsley Wheelchair Interface (BWI) and an electric wheelchair.

Participant One (Novice)

The first participant was an able-bodied individual ('Novice') who was in his mid-twenties, with no physical limitations apart from that he required prescribed spectacles, which he used during the experiments. Thomas (1998) pp19 defines novice as an individual who does not use something regularly and has not done so in the past.

Participant Two (Able-bodied Expert)

The second participant was the PhD Research student who is physically disabled and uses an electric wheelchair in his everyday life. He has done so for over 40 years. He does not however have any physical limitation with regard to using the BWI interface. Therefore, this participant could be described as an 'Able-bodied Expert'. Thomas (1998) pp25 defines expert as an individual who has used something regularly and has done so for some time.

Participant Three (Expert)

The third participant was the 14 year old girl referred to in Chapter 2 'The Stakeholders' section 2.1.3. The Classification for this Dissertation, *Picture 2.1. Stakeholder using Barnsley Wheelchair Interface (BWI) through a head located switch* who has the disability of Athetoid Cerebral Palsy. She had been using this type of device for a considerable number of years and could therefore be considered an 'Expert'.

7.2.4 BWI Configuration and Participant's Participation

On each occasion the experiment was run with the Barnsley Wheelchair Interface in a different configuration or a different participant occupying the Electric Wheelchair. This is summarised on the table below (see Table 6). Additionally the full configuration of the Barnsley Wheelchair Interface is provided in Appendix D 'Barnsley Wheelchair Interface's Configuration during each of the Experimental Process'.

Experiment	Participant's Experience	Electric Wheelchair	BWI Configuration
Experiment 1	Novice	Department's	Chosen Fit
Experiment 2	Novice	Department's	ATP
Experiment 3	Novice	Department's	User's Chosen Fit
Experiment 4	Able-bodied Expert	Department's	User's Chosen Fit
Experiment 5	Expert	User's	Chosen Fit

Table 6 The experiment's Individual Characteristics

The 'BWI Configuration', 'Chosen Fit' is the configuration selected by the participant and deemed by her to be their personal preference. In this instance, where the 'BWI Configuration' has been specified as 'ATP', these were changes suggested by the ATP to the 'Novice's' 'Chosen Fit'. These small changes to the configuration were considered by the ATP as an enhancement to the prescription which minimised the time spent scanning during the experiment. The outcome of the Novice's 'Chosen Fit' and the 'ATP's' changes to that configuration are reported in this dissertation at Chapter 8 'Comparison of the Field and Laboratory Studies'.

It is important to note that the Expert (stakeholder) participant used an alternative electric wheelchair because using the same wheelchair was not possible for ethical and logistical reasons.

7.2.5 Environment (the course being driven)

The course that was travelled was divided into four sub-sections and each of these sub-sections had different characteristics. The first and third sections were carpeted; the remaining areas had a linoleum floor covering. Two diagrams appear below, one which shows the characteristics of the course and the other the scale and dimensions.

See Figure 13 'The Course's Physical Characteristics' and Figure 14 'The Course's Physical Dimensions'

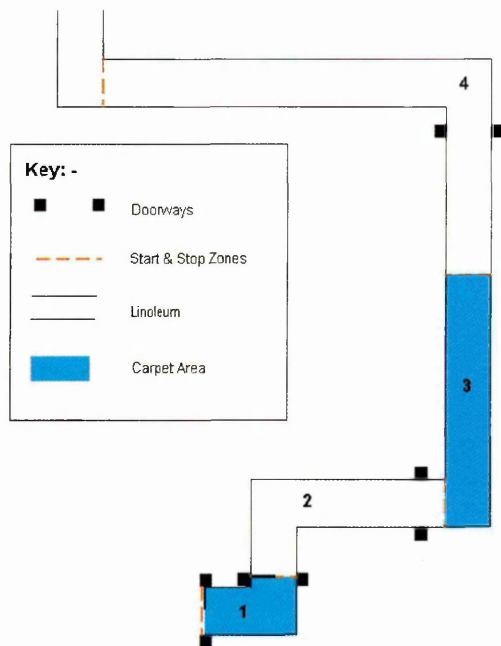


Figure 13 The Course's Physical Characteristics.

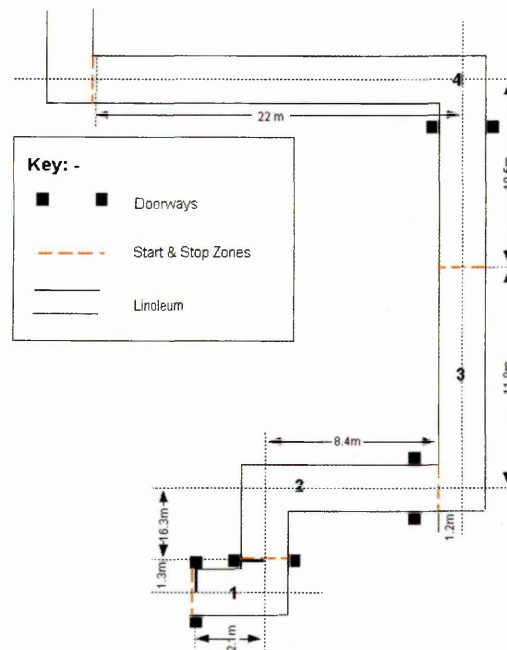


Figure 14 The Course's Physical Dimensions.

It is important to note that all of the participants drove the same course. Therefore no obvious differences were noted before the experiment took place - with the exception of other individuals using the corridor which the researcher could not have any control over.

7.2.6 Observational Methods

During the experimental procedure all parties were observed in the following ways:-

- Data Log Capture
- Video Recorded
- Human Observation by the researcher

The primary method of investigation would be the computation analysis of the data logs, which:

(c) Interact and record: Each user works with the system and you note the problems they have. The procedure is designed to help them to verbalize the, problems they experience through thinking aloud. What they say and do is noted. Ideally what they say should be audio recorded and what happens on the screen should be video recorded. Some kind of automatic system-generated log is a good alternative to a video record.

[Wright et al, (1989)]

This could be reinforced by viewing the video as described by (Yamagishi (1987); Laws and Barber, (1998)) and the observations made by the PhD Research student at the time of the experiment. This was with exception of when the PhD Research student was participating, and in this case, the video was viewed by the research PhD Research student at the termination of his experimental period.

The video camera was mounted onto the back of the electric wheelchair giving a panoramic view of the BWI interface and direction in which the chair is moving (Dix, Finlay et al. (1993)). In addition, a clock (showing '10:29AM' in the Figure 15 'Video View' shown below), was synchronised with the video and Personal Computer (PC). During the recording of each of the experiments the clock was clearly visible. In addition, the environment in which the experiment was taking place is also shown in the background.

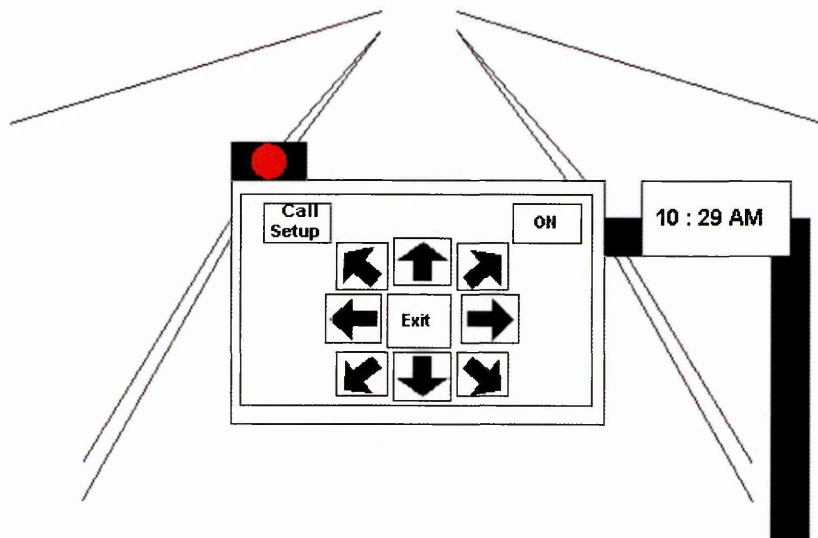


Figure 15 Video View

In Figure 15 'Video View' an LED is situated in the top left-hand corner of the interface. This LED lights up whenever the subject closes the switch even if the subject is unaware that they have done so. The LED which lights up was surrounded by a dark colour in order to ensure that it was clearly visible on the video.

Due to the considerable number of experiments that were undertaken it is quite clear that a considerable amount of video would be shot. However, on completion of the experiment the tape recorded was transferred to a PC for editing. During this process care was taken to ensure that important information relating to the experiments was included. This is reported by numerous researchers to be very time consuming and thus would be too costly for ATP's to undertake regularly as reported by Lyberg and Kasprzyk, (1991)). This edited video was then converted into a 'DVD' format with relevant menus to each of the experiments. The footage on the DVD presented the analyser with an accurate means of playing the recording time and time again, without the tape getting stretched and possibly reducing the quality of the image. In addition this offered more accurate functionality with regards to timing, as most 'DVD' players provide a accurate clock or information about the number of frames shown. The accuracy of the clock was extremely useful when comparing the video log with the data logs produced by the BWI. Hence the researcher's objectives here were to:

1. Remove un-required video footage
2. Convert video format to DVD and Add Menus
3. Store footage onto DVD

The statement '1. Remove un-required video footage', refers to video footage captured between the experiments and therefore ensuring analysis was only conducted on the video captured within the experiments in order to keep the time to the minimum as reported by Roberts (1985), Laws and Barber (1989) and numerous others who have conducted video analysis, the use of video analysis is highly time consuming and difficult. However, with the methods suggested above: synchronising the video with the clocks; data files having 'markers' placed; and the conversion of video to 'DVD' file, the time required to analyse the data should be minimal. The placement of the 'markers' will also be shown on the video so that the synchronisation between video and data log is maintained. This is explained in more detail in Hilbert and Redmiles (1999) and simply outlined here.

During the observed experiments, should an observation with regard to the Expert or Novice's performance be made by the observer then it can be noted on paper or an

audio signal can be made by the observer onto the video (see Hilbert and Redmiles (1999)). This audio signal can be searched for and the relevant BWI log can be examined closely using the time synchronisation of the two devices and the visible clock on the video. Unfortunately, marks within the BWI log during the running of the tests cannot be made without stopping the procedure and starting again. However, as already stated the time stamp on the video and BWI log will indicate the place of interest.

7.2.7 Conduction of the Studies

All participants were shown the diagram of the course (see Diagram 7.1 'The Course's Physical Characteristics') and at the same time were physically shown the route they were to take. As a result of this none of the participants veered from the required course during the experiments and all drove it without difficulty.

However with regard to the Able-bodied Expert during the experiment, no observation could be made by the PhD Research student, as they are the same person. Therefore, observations by the PhD Research student were made entirely from the video.

7.2.8 Cleaning Preparation of the Raw Data

The raw data for each of the experiments conducted and described within this Chapter can be found within Appendix E of this dissertation 'The Experimental Processes Raw Data Logs'. It is important to note that the data included with the Appendix is, as it states, raw. At this stage of the process, the complete data from the BWI logs of: Event, Session, Day, Month, Date, Time, Year, Application and Action are viewed by the PhD research student and the time line from the video evidence is used to select just the data from within the experiment process.

Due to the researcher's familiarity with the content BWI's data logs and the knowledge retained from observations during the experiment, even during this stage interesting events can be spotted. One example would be the novice being the only participant to select a backward direction and the successive selections of the same directions more intensively made by the 'Expert'. It is not until the data is processed as described in a

subsequent section of this Chapter that the data is manipulated for each of the analysis processes.

Additionally a DVD showing each of the experiments can be found at the end of the dissertation. As a considerable amount of time was taken between each of the experiments to prepare the BWI and the participants for the actual experiment itself, this DVD was edited to show only the experiments in progress

7.3 Analysis Processes

In total eleven processes were conducted on the raw data and these are listed below along with a brief description. Additionally, a table (see page 72) is provided, listing each of the 'Description of ATP's knowledge enhancement' along with the processes that will be used during the analysis which are reported in the following Chapter.

7.3.1 The Processes

1. Frequency of Selection

The number of occasions an event was selected.

2. Accumulated Frequency of Duration

The total time each event was selected.

3. Average Frequency of Selections

The number of occasions an event was selected in comparison to the number of total selections made.

4. Average Duration of the Selections

The total duration of each event in comparison to the total duration of all other events.

5. Frequency Duration per Selection

Count the number of occasions of each of the total durations, for each event.

6. Frequency of Consecutive Selection

Count the number of occasions an event was selected followed by another event.

7. Erroneous Rate

Count the number of occasions an event was selected under a particular duration. (In this instance, duration under a particular time was considered to be an error)

8. Scan Modelling

Using the directions selected from the data logs; predict the time spent scanning for each of the scan methods available.

9. Duration of Moving and Scanning

Calculate the total time spent moving and the total time spent scanning in real time from the logs.

10. Normalisation of Opposite Selection

Calculate the number of occasions the left and right bias directions are selected, then normalise them against each other e.g., take the frequency of each pair of left and right directions, divide each of them by two, then add them together. A pair is 'Forward-Left' and 'Forward-Right', 'Left' and 'Right' and 'Backward-Left' and 'Backward-Right'.

11. Path Profile

For each unit spent travelling in a particular direction, a line is drawn in a particular direction, with a unit of measurement to represent the number of unit/s spent travelling. This is shown in Figure 16 'Examples of the Path Profile When Plotted on Graph Paper' below - where green is the start point and red is the stop point):

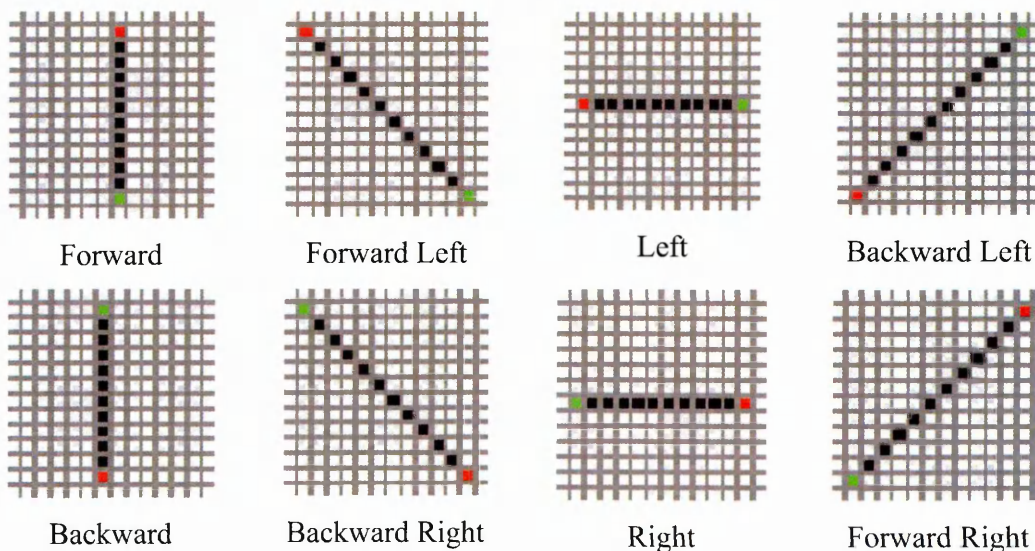


Figure 16 Examples of the Path Profile When Plotted on Graph Paper.

However before these processes could be carried out, the raw data was imported into a spreadsheet and an additional column was added. This calculated the time spent in any of the activities by using the date and time that the event occurred. In addition the data was visually inspected for any anomalies. In this instance with the data being from the experiment, and the PhD Research student observing all of the experiments, no examples of such anomalies were expected and none were found.

7.3.2 Description of ATP's knowledge enhancement: Processes and Their Relationship

In this section of the Chapter, a table is presented which shows a description of each of the ATP's knowledge enhancement from Chapter 6 'The Field Studies' and also which of the processes (see section 7.3.1 'The Processes') relate to each of them. This table therefore can be used by ATP's to suggest which of the processes should be used on the data logs to obtain information with regards to the particular knowledge they want about a users ability to use the system. For example, if the ATP wishes to know if the user as difficulty sustaining a switch closure they should use the following processes which should suggest if this is the case:

- Number of Selections
- Average Duration of Selection
- Frequency of Consecutive Selection

This is displayed in the table on the following page along with other knowledge and processes that may provide the evidence:

Description of ATP's knowledge enhancement	Number of Selections	Frequency of Section	Accumulated Frequency of Duration	Average Frequency of Selection	Average Duration of Selection	Frequency Duration per Selection	Frequency of Consecutive Selection	Scan Modelling	Duration of Moving and Scanning	Number of Selections fore & Again
The 'Expert Disabled System User' will have difficulty sustaining a switch closure	✓				✓		✓			
The Expert Disabled System User's spasms will be the cause of her errors						✓				
The Expert Disabled System User's expertise will become evident in confined spaces						✓			✓	
All participants will turn more frequently in the direction that is bias scanned by the system		✓		✓						
The scanning method being opposite to the direction of the veer of the wheelchair is of greater influence than the environment's attributes										✓
Reality takes longer than the hypothetical model, due to other influences								✓		
The extent to which the physical disability plays a part will be clear when comparing a disabled and able-bodied user			✓							
Is it the spasms of the disabled user that causes an increase in selection		✓	✓				✓			

Table 7: Processes used within the analysis of each Description of ATP's knowledge enhancement

7.4 Chapter Summary

This Chapter started with an introductory section explaining the purpose of conducting the laboratory experiment. It also explained the three methods that were used to obtain information about the usage during the laboratory study and why these methods were chosen. The Chapter then continued to explain the procedure undertaken by the 'Able-bodied Expert' and 'Novice' to ensure that these two participants did not enter the experiment completely blind, but that they did have time to become familiar with the characteristics of the electric wheelchair and the BWI different configuration possibilities.

The main experimental variables were then given along with the ways these variables would influence the experiment. These were, 'Participants', 'BWI configuration and Electric Wheelchair' and 'Environment (the course being driven)'. The next three sections of this Chapter reported on these three previously stated influencing factors in more detail. Then it focused on the methods that were used to collect data during the experiment and these are explained in more detail.

Having outlined all of the background information in the previous sections the next section explained the way the experiments were conducted in all instances. Please note any changes from the explained procedure are also articulated e.g. that the PhD Research student could not observe himself during the running of the experiment. It is therefore reported that he observed himself from the video recording once the experiment had concluded.

The next section of the Chapter gave an account of the cleaning procedure of the raw data logs generated during the experiments and how these data logs were tied by the three clocks, which synchronised the three individual media types. Finally, the Chapter concluded by giving a brief account of the eleven different analysis procedures that were conducted on the data logs and provided a brief description of the findings that were obtained from these procedures.

Chapter 8. Comparison of the Field and Laboratory Studies

Chapter Structure:

This Chapter compares and combines the results from Chapter 6 'the field studies' with those from Chapter 7 'laboratory study'.

8.1 Introduction

This Chapter of the dissertation reviewed the hypotheses (Description of ATP's knowledge enhancement) that are relevant to the mobility issues and to the use of the BWI, as outlined in Chapter 6 'The Field Studies'. This is achieved by looking at the assumptions made during the evaluation of those hypotheses and reported in the numerous papers created from the field studies as well as the work contained within the PhD Research student's published work. In addition, using the data analysis from the laboratory study, an attempt was made to validate or invalidate the previous findings and assumptions from those field studies that are relevant to the user's usage of the BWI by comparing the results of the laboratory study outlined in 'Chapter 7 The Laboratory Experiments'.

Although all of the analysis procedures were conducted on data from the data logs, only the analysis processors that are significant to validating or invalidating the hypothesis reviewed are reported here. In addition, the results are divided into two sections, those that are primary and those that are secondary. 'Primary' are those which provide results which the ATP would be able to obtain within the field alone, whereas 'secondary' results are those that cannot be achieved without the additional processes such as video or individual task orientation. A brief comparison of the results from the laboratory study follows, with the hypotheses from the field study and given general observations was made with regard to this comparison.

Due to the fact that the experiment concentrated on the BWI and user's mobility only the hypotheses that are concerned with these aspects are investigated. Other aspects concerned with the more general usage of the Assistive Technology System (ATS), for

example complete system usage and time spent in other functions are reviewed in section 8.3 'Other Processes And Computational Techniques', of this Chapter. The results from this Chapter will however still be applicable to an overall system and not just the mobility aspect of an ATS.

Finally, this Chapter brings together the findings and gives a brief comparative summary of the individual sections, plus an overall review of these findings.

8.2 Comparison of Field and Laboratory Study Results

In this section of the Chapter each of the hypotheses from the field studies are presented, along with any of the assumptions that were made in these field studies. A brief description or comparison of the laboratory results from the single or multiple participants is then given. Finally, the results from the laboratory study are discussed in respect of whether or not these results provide supporting evidence towards the field studies hypotheses.

It is important to note that, throughout this entire Chapter all attributes were the same for all of the participants with the exception of the electric wheelchair, which was the same for the 'Novice' and 'Able-bodied Expert', but the 'Disabled Expert' used her own electric wheelchair. No attempts were made for the 'Novice' and 'Able-bodied Expert' to use the 'Disabled Experts' electric wheelchair, or for the 'Disabled Expert' to use the chair used by the two other participants, due to ¹⁴ethical and ¹⁵logistical reasons. The PhD Research student strongly recommends that at this point you the DVD accompanying this thesis with the title "The Enhancement of the Prescription of Electronic Assistive Technology" is viewed. 'Experiment 3', 'Experiment 4' and 'Experiment 5' are recommended as they will assist you in understanding the results in the remainder of this Chapter.

¹⁴ Ethically it was considered not to be acceptable to take the electric wheelchair away from the Disabled Expert while the other two participants used it to undergo their experiments. Due to it leaving the Disabled Expert without the ability to speak or move for the duration.

¹⁵ Logistically it was not possible to put the Disabled Expert into the electric wheelchair to be used by the other two participants due to her required, seating arrangements.

8.2.1 Field Study Description of ATP's knowledge enhancement

The 'Expert Disabled System User' will have difficulty sustaining a switch closure.

8.2.1.1 Field Study Assumptions

Following a considerable amount of time being spent by the Researcher with the participant (Bayeh, 1997) it was believed that the following three assumptions could be the cause for the user's lack of prolonged selections. However there are clearly many more and this is not an exhaustive list. It may not even be any single one but a number of attributes may be the cause.

The assumption here was that due to the individual's lack of physical ability she would not be able to sustain a switch closure (prolong selection). Therefore this lack of continued physical coordination (involuntary movement) would result in shorter selections.

--- Or ---

The environment was constraining the 'Disabled Expert's' movement therefore resulting in shorter selections.

--- Or ---

The location of the switch was not suitable for the 'Disabled Expert' to make prolonged selections and observe her surroundings.

8.2.1.2 Laboratory Study Comparison

Below is a chart showing each of the participant's total number of selections made during their comparable experiment.

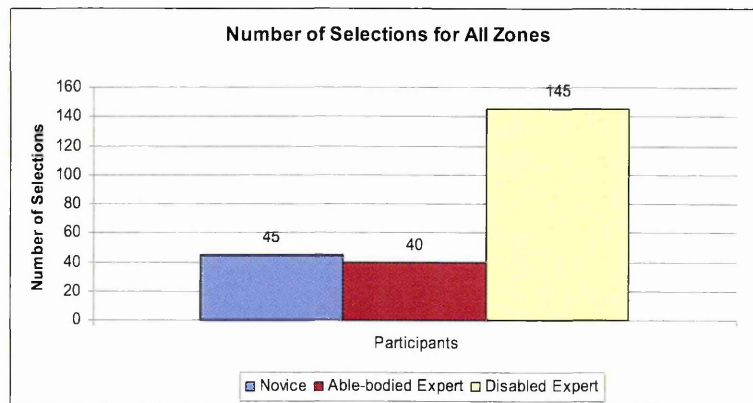


Figure 17 Comparison of Users Number of Selections.

The Figure 17 'Comparison of Users Number of Selections' clearly shows that the 'Disabled Expert' does make a considerably higher number of selections than those of the 'Novice' and 'Able-bodied Expert'. In addition, Figure 18 below shows 'Average Duration of Selection for each Participant in All Zones', which indicates that the 'Able-bodied Expert' and 'Novice' have an average duration very close to each other but the 'Disabled Expert' is nearly one second less than the average duration.

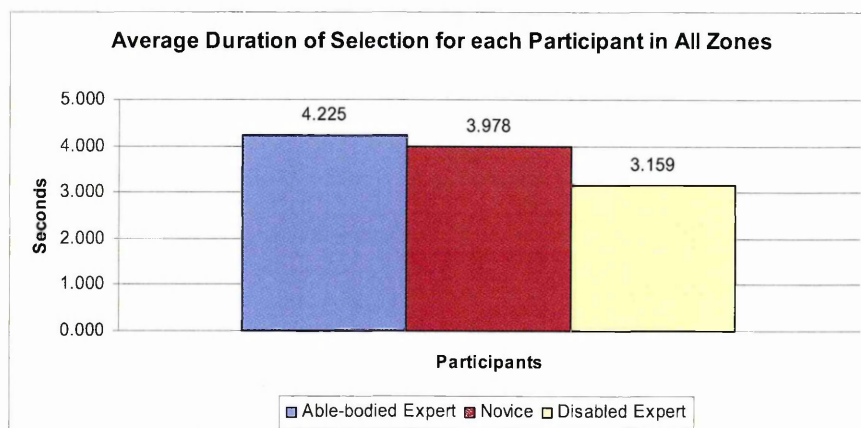


Figure 18 Average Duration of Selection for each Participant in All Zones.

However, when viewing the video and looking at the consecutive selections for each of the participants, as shown in the three tables, where 'F' = Forward, 'FR' = Forward Right, 'R' = Right, and so on below :

		First Selection							
		F	FR	R	BR	B	BL	L	FL
Second Selection	F	0	15	0	0	0	0	0	6
	FR	14	1	0	0	0	0	0	1
	R	0	0	0	0	0	0	0	0
	BR	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0
	BL	0	0	0	0	0	0	0	0
	L	0	0	0	0	0	0	0	0
	FL	6	0	0	0	0	0	0	0

Table 8 The Novice's Consecutive Selections

		First Selection							
		F	FR	R	BR	B	BL	L	FL
Second Selection	F	0	11	0	0	0	0	0	5
	FR	12	3	0	0	0	0	0	0
	R	1	0	0	0	0	0	0	0
	BR	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0
	BL	0	0	0	0	0	0	0	0
	L	0	0	0	0	0	0	0	0
	FL	5	0	0	0	0	0	0	1

Table 9 The Able-bodied Expert's Consecutive Selections

		First Selection							
		F	FR	R	BR	B	BL	L	FL
Second Selection	F	65	1	0	0	0	0	0	23
	FR	1	4	0	0	0	0	0	0
	R	0	0	0	0	0	0	0	0
	BR	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0
	BL	0	0	0	0	0	0	0	0
	L	0	0	0	0	0	0	0	0
	FL	23	0	0	0	0	0	0	26

Table 10 The Disabled Expert's Consecutive Selections

These results are primary results as they can be generated by the ATP by collecting the data from the field and then conducting analysis on that data. It can be clearly seen in the instances above that the 'Novice' and 'Able-bodied Expert', when totalled together, make only five selections of a direction followed by the same direction, as shown by the grey cells in the above tables. Whereas the 'Disabled Expert' makes in total 95 selections where the direction selected is followed by the same direction. This phenomenon could be associated with two attributes and these are switch location and user observation.

However, the secondary results require ATP's observations as well as in this case the use of the laboratory experiment and the video. On viewing the video it can be seen that for the 'Disabled Expert' the observation is difficult whilst selecting the direction to travel in (please see DVD with the title "The Enhancement of the Prescription of Electronic Assistive Technology", 'Experiment 5'). The location of the switch is discussed in more detail in the following section of this Chapter. From a clinical point of view the location of the switch, with regard to distance from the user and its location with regards to switch placement is very important. For example, ensuring that the user has the ability to observe their surrounding whilst still driving the electric wheelchair.

8.2.2 Field Study Description of ATP's knowledge enhancement

The Expert Disabled System User's spasms will be the cause of her errors.

8.2.2.1 Field Study Assumptions

The assumption was that due to the 'Disabled Expert's' spasms (unintentional physical body movements) she would unintentionally release or hit the switch. Therefore, these unintentional selections and releases could be considered as errors. In addition, it was considered that selections of up to one second could be included as within this time frame the electric wheelchair would not have responded.

8.2.2.2 Laboratory Study Comparison

To investigate this phenomenon the frequencies of durations of the selections were processed for each of the participants and are displayed below in Figure 19 'Frequencies of the Durations of Selections':

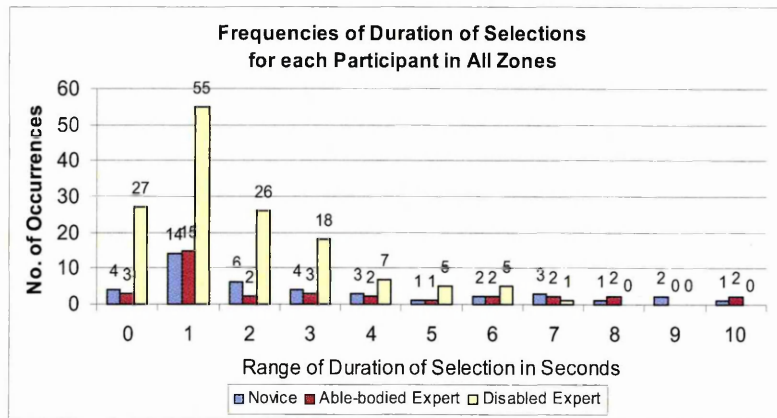


Figure 19 Frequencies of the Durations of Selections

It can clearly be seen that the 'Disabled Expert' does make a lot more selections of up to one second in duration and therefore these could be considered as errors. When viewing the video it is apparent that moving the switch closer would mean that it makes it possible for the 'Disabled Expert' to select the chosen direction for longer. However, this also means that it is easier for the 'Disabled Expert' to make unintentional selections, due to spasms and the fact that the switch is in the way for other activities. The spasm event became apparent while developing the Petri Net of the User (see Appendix F. 'Modelling Using Petri Nets') and it is extremely useful for the clinician to be aware of it when configuring and constructing such a system as 'hold down time' or switch location. This is paramount to the user being able to use the system with comfort and confidence, if the stakeholder is to use the system for prolonged periods and not report repetitive strain and muscle fatigue (Gilad, 1997; Olsen S, (2006)), which must be the aim of the ATP.

8.2.3 Field Study Description of ATP's knowledge enhancement

The Expert Disabled System User's expertise will become evident in confined spaces.

8.2.3.1 Field Study Assumptions

Due to the tight confinement of the environment the 'Disabled Expert' will not need to make prolonged selections. Therefore with her expertise and comprehensive knowledge of both the electric wheelchair and the system's characteristics she will make optimum selection and therefore less selections.

¹⁶ The 'Hold down time is the time that the switch must be closed before the system accept the switch closure as a genuine selection.

8.2.3.2 Laboratory Study Comparison

Interestingly it was believed that with the minimal requirement of physical ability to sustain a selection, and her comprehensive knowledge of the system and electric wheelchair's characteristics, the 'Disabled Expert' would, due to this zone's confined space, not only be the quickest participant through this zone, but she would also make fewer selections than the other participants. However as seen in the chart below Figure 20 'Frequencies of Duration of Selections for each Participant in Zone 1 Only Magnified by 5 for Direct Comparison with All Zones' it can be seen that in this instance, this is not the case.

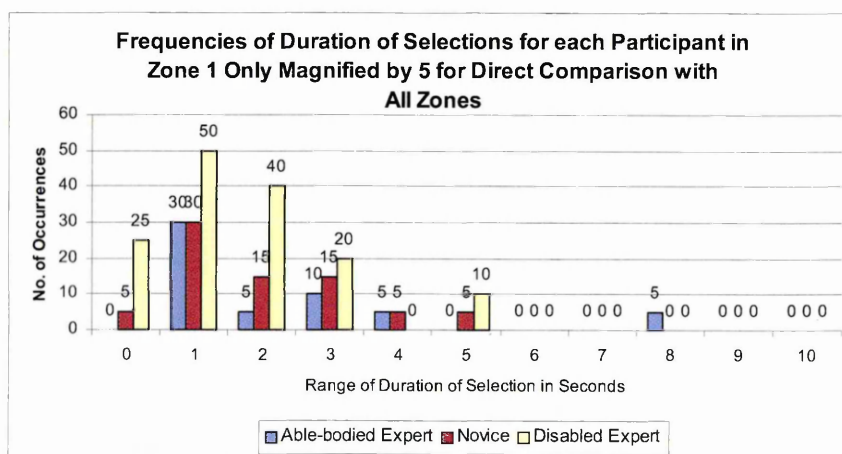


Figure 20 *Frequencies of Duration of Selections for each Participant in Zone 1 Only Magnified by 5 for Direct Comparison with All Zones.*

In addition the time taken to complete the Zone 1 took considerably longer then the other two participants, as can be seen in Figure 22 'Duration to Complete Zone 1 for each Participant Magnified by 5 for Direct Comparison with All Zones' below:

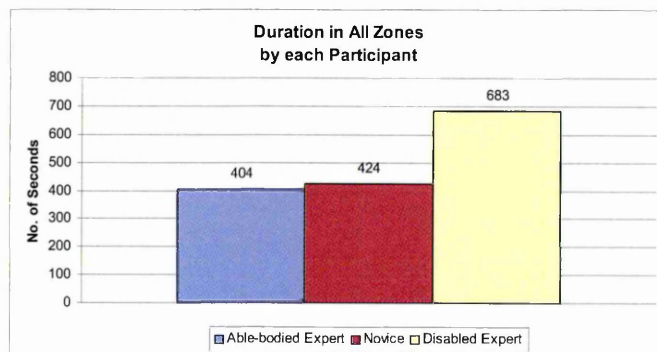


Figure 21 *Duration to Complete All Zones for each Participant*

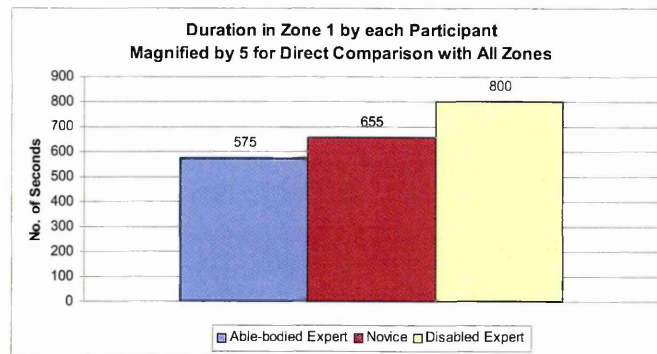


Figure 22 Duration to Complete Zone 1 for each Participant Magnified by 5 for Direct Comparison with All Zones

This would therefore suggest that her ability to hold the switch closed is not the primary influence but, from observation and viewing the video, she must release the switch in order to view her location. This means that the field hypothesis is not supported, as her observing her present location within the environment was overlooked. However, from a researchers and clinical point of view it does support the previous findings of the importance of switch placement.

8.2.4 Field Study Description of ATP's knowledge enhancement

All participants will turn more frequently in the direction that is bias scanned by the system.

8.2.4.1 Field Study Assumptions

The assumption here was that if you had to wait for eight items to be highlighted and the scan time was considerable, together with the user believing that it would take longer to scan each of the items than to select the opposite direction and to turn in the opposite direction until you faced the direction in which you wished to travel, that this would save you time. In order to save time the user may then select the opposite direction to what they wish to travel and turn 180° or above instead of waiting for the scan to reach the correct direction.

8.2.4.2 Field and Laboratory Study Comparison

If only the 'Disabled Expert' had undertaken the experiment then it would have been easy to come to the conclusion that the hypothesis was strong. However, for the hypothesis to remain strong, high levels of selections of 'FL' should apply to the 'Novice' and 'Able-bodied Expert' too, as already stated all participants were using the same scanning method.

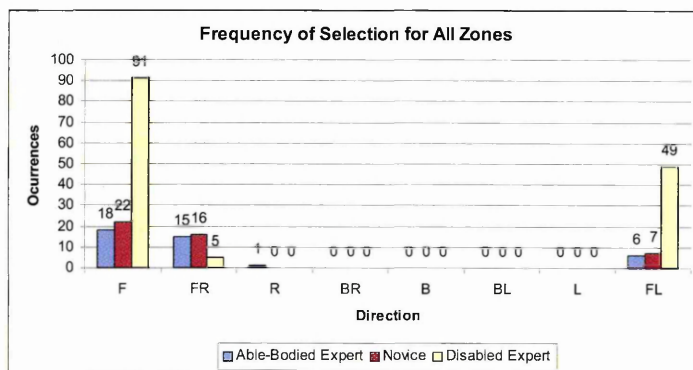


Figure 23 Frequency of Selection for All Zones for each Participant.

However, from the above chart, Figure 23 'Frequency of Selection for All Zones for each Participant' this is not the case and it can be said that it is highly unlikely that the scanning method influences the directions selected by the user. This is not to say that it does not matter which scanning method is used, as explained in subsequent sections of this Chapter, as other influences such as veer and environment could be a factor.

With this scanning method being 'Forward Bias' and the required waiting time for the opposite direction to be highlighted being only the scan duration (in this instance 2.2 seconds), the PhD Research student investigated other scanning methods where the scan time would be no greater than the time to turn up to 360° . The only instance where turning 360° in the opposite direction would be quicker is where the duration of five highlights is greater than the time to turn (the highest number of items requiring highlighting before one in the right direction is highlighted) and this is dependent on the speed of the electric wheelchair and the scan duration required by the stakeholder. Therefore, the PhD Research student would consider this to be highly unlikely due to the room required to make this type of turn (e.g., twice the length of the electric wheelchair, if the electric wheelchair is rear wheel drive, which invariably they are) as well as a long scan duration for each item highlighted.

From a clinician's point of view it is good to be aware that the scanning method does not lead to the user of the system selecting a direction they do not wish to travel, just because it is the most accessible direction for them to select, but that they are prepared to wait for the desired direction to be highlighted and then select it.

8.2.5 Field Study Description of ATP's knowledge enhancement

The scanning method being opposite to the direction of the veer of the wheelchair is of greater influence than the environment's attributes.

8.2.5.1 Field Study Assumptions

With the scanning method highly unlikely to influence the directions selected as previously stated, the assumption was that the environment and/or veer of the electric wheelchair may be influencing the selections made and as a consequence an investigation into these other two possible influences needed to be undertaken.

8.2.5.2 Field and Laboratory Study Comparison

The data of all three participants was used here to ensure that it was not just the differences in wheelchairs or participants, as two of the participants would be using the same electric wheelchair. Therefore if the results from the two participants using the same electric wheelchair were similar yet both different from the other participant using a different wheelchair, then it was felt that the evidence focussed on the differences between the electric wheelchairs and not the differences between the participants. Looking at, Figure 23. 'Frequency of Selection for All Zones for each Participant' in the previous section of this Chapter, it can clearly be seen that the 'Novice's' and 'Able-bodied Expert's' selection pattern is different to that of the 'Disabled Expert's'. With the exception of the 'F' (Forward) the next most selected item for the 'Disabled Expert' was FL (Forward Left), whereas 'FR' (Forward Right) was the next most selected item for the 'Novice' and 'Able-bodied Expert'. Due to the fact that the 'Novice' and Able-bodied Expert' drove the same electric wheelchair it is quite clear that it is not the participants but the electric wheelchair's veer that is the influencing factor. Therefore, the PhD Research student came to the conclusion that the

'Disabled Experts' electric wheelchair veered to the right and the electric wheelchair used by the 'Novice' and 'Able-bodied Expert' veered to the left. On viewing the video (please see DVD with the title "The Enhancement of the Prescription of Electronic Assistive Technology" and particularly 'Experiment 1' and 'Experiment 5' up to Zone 2 in both instances), it became apparent that the PhD Research student's conclusion was the case.

In addition it can be said that the environment does influence the driving of the electric wheelchair when the investigation takes the veers of the wheelchairs into consideration. Table 11 below shows 'Number of Selections For and Against the Veers for each of the Electric Wheelchairs for each Zone and each Participant'

Participant	Zone 1		Zone 2		Zone 3		Zone 4	
	Against	For	Against	For	Against	For	Against	For
Able-Bodied Expert	4	3	2	1	5	0	5	2
Novice	4	4	5	2	1	0	6	1
Disabled Expert	9	0	10	5	16	0	14	0

Table 11 Number of Selections Fore and Against the Veers for each of the Electric Wheelchairs for each Zone and each Participant.

This shows that the 'Disabled Expert' does make a higher number of selections of the opposite direction to the veer than the other two participants in Zone 2, and particularly Zone 3, which are comparable in length but with different floor surfaces. Therefore, this would imply that the carpet which is in Zone 3 is affecting the veer of the electric wheelchairs. On viewing the video of this Zone for each of the participants, it is clear that the carpet increases the veer of the 'Disabled Expert's' electric wheelchair, whereas it decreases the veer with respect to the other electric wheelchair

From a clinical point of view, this gives excellent guidance when choosing the configuration of a system when the system includes the driving functionality. It tells the clinician to be aware of which way the electric wheelchair veers and reminds them to ensure that the scanning method used is biased to the opposite of the veer direction. If it is at all possible to correct the veer this should be undertaken and can be achieved by two primary methods of exchanging motors until a matching pair is found. Alternatively, where tyres are pneumatic you can inflate or deflate the tyres in order to correct the veer. It is important to remember that should this latter solution be used,

then periodic visits to check tyre pressures should be undertaken. Furthermore with this additional knowledge, it is possible to provide this information to others who may be in charge of the environment around the user and therefore, making them aware of the importance of different floor surfaces, when any changes to these are required.

8.2.6 Field Study Description of ATP's' knowledge enhancement

Reality takes longer than the hypothetical model, due to other influences.

8.2.6.1 Field Study Assumptions

The assumption here was that environmental factors such as other individuals travelling the same course and obstructions etc., being left on the stakeholder's path could not be taken into account within the hypothetical model.

It is important to note that the hypothetical modelling assumes that the user will select the required item on the first occasion that it is highlighted.

8.2.6.2 Field and Laboratory Study Comparison

The hypothetical scan times give the clinician an excellent opportunity to see which of the scanning methods would best suit that individual's needs. For example, in the chart below, Figure 24. 'Hypothetical Generated Scan Duration from Real Usage Data Logs and the Real Scan Times it can be seen that the lowest scan time for the 'Disabled Expert' is 'Forward Bias Anti-clockwise', which is the actual scan method used by the 'Disabled Expert'. However, with the 'Able-bodied Expert' and 'Novice', the scan duration is 53 and 59 respectively, in 'Forward Bias Clockwise'. Again, the PhD Research student believed that the most efficient scanning method would be 'Forward Bias Clockwise' for the 'Able-bodied Expert' and 'Novice', as the electric wheelchair veered to the right and therefore 'Forward Bias Clockwise' being the opposite is the most efficient scanning method for that electric wheelchair. Therefore, from a clinical point of view, this tool is extremely useful in optimising the scan method for that system from the analysis of a small amount of data log.

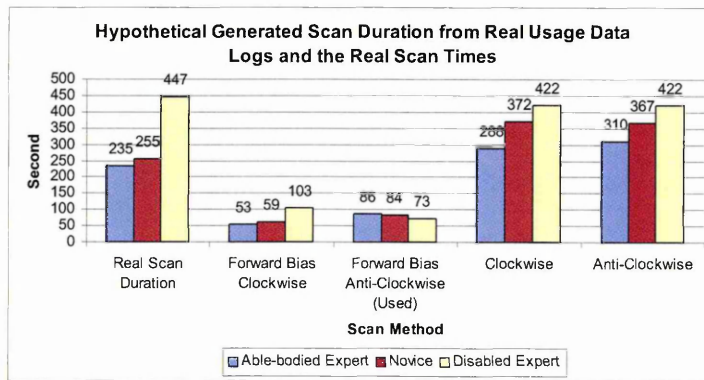


Figure 24 *Hypothetical Generated Scan Duration from Real Usage Data Logs and the Real Scan Times.*

In addition, the evidence from 8.2.4.2 'Field and Laboratory Study Comparison' also supports these findings.

8.2.7 Field Study Description of ATP's knowledge enhancement

The extent to which the physical disability plays a part will be clear when comparing a disabled and able-bodied user.

8.2.7.1 Field Study Assumptions

It was strongly believed that in this instance the user's physical disability would play a considerable role in her ability to use the system. The following attributes proved to be influences:

- Spasms (Involuntary Body Movement)
- Switch Distance from Body Site
- Switch Placement

In the following section of this dissertation each is briefly described.

8.2.7.2 Field and Laboratory Study Comparison

First, 'Spasms' became clearly evident when modelling the user's interaction with the system using Petri-Nets, as already explained within this thesis. The 'Distance from Body Site' and 'Switch Placement' had been understood by the ATP's for a considerable number of years. From previous analysis results already presented, it can

clearly be seen that the three main attributes from our assumptions all influence the user's ability to interact with the system. However, what is less clear is to what extent each of these attributes plays a part, and it is considered that these will be different for each user.

In the charts 8.2.7.2.1 'Accumulated Duration of Selections Able-Bodied Expert', 8.2.7.2.2 'Accumulated Duration of Selection Novice' and 8.2.7.2.3 'Accumulated Duration of Selection Disabled Expert', we can see three different profiles. From 8.2.7.2.3 'Accumulated Duration of Selection Disabled Expert' we can see that all four lines are very close to each other, showing that the user is very consistent. However the longest selections are around six seconds. Whereas, the other two charts '8.2.7.2.2 Accumulated Duration of Selection Novice' and '8.2.7.2.3 Accumulated Duration of Selection Disabled Expert', show selections of 15 and 18 seconds respectively are made but consistency is not as good for the 'Able-Bodied Expert' and are worst for the 'Novice' believed to be showing less experience.

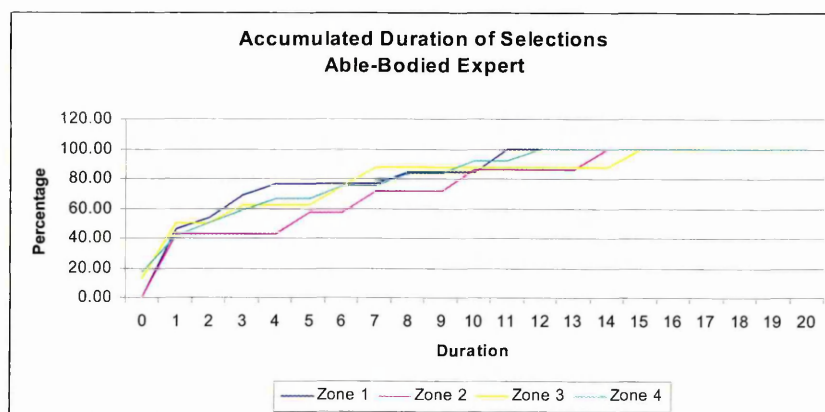


Figure 25 Accumulated Duration of Selections Able-Bodied Expert

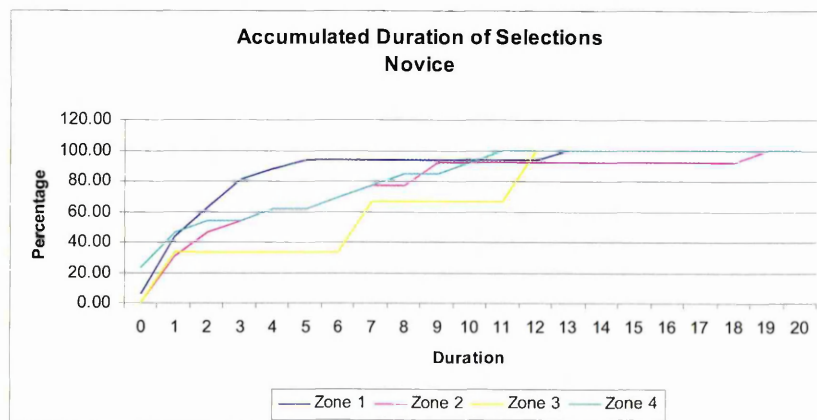


Figure 26 Accumulated Duration of Selections Novice

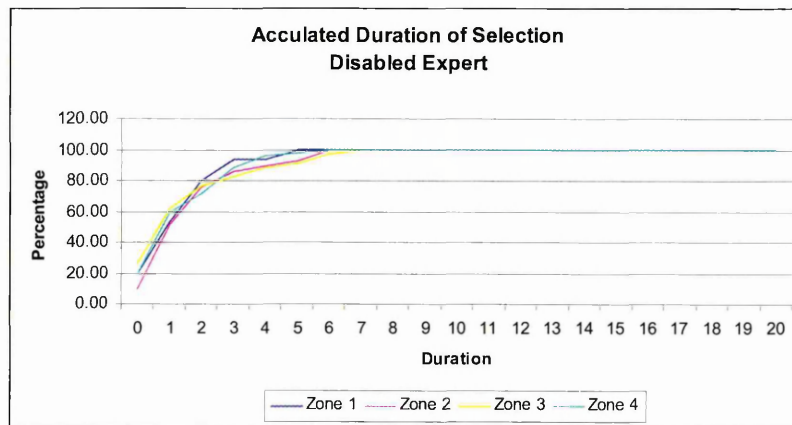


Figure 27 Accumulated Duration of Selections Disabled Expert.

However with the clinical knowledge of the attributes stated above, they can be used to focus the investigation and the manipulation of those attributes which can be changed e.g., switch site and location can be adjusted and then left with the user before analysis of the data logs is repeated to see if there is any marked improvement. Should it be necessary, the action of changing the system and leaving it with the user, then repeating the analysis and changing the system again, can become recursive. This procedure can therefore be conducted as many times as required in order to enhance the prescription.

8.2.8 Field Study Description of ATP's knowledge enhancement

Is it the spasms of the disabled user that causes an increase in selection?

8.2.8.1 Field Study Assumptions

The assumption was that the user catches the switch unintentionally due to the switch being sited too close to her body.

8.2.8.2 Field and Laboratory Study Comparison

On viewing Figure 23. 'Frequency of Selection for All Zones for each Participant', and Figure 27 'Accumulated Duration of Selections Disabled Expert' we can firstly observe that the 'Disabled Expert' does make a lot more selections than the other participants. In addition, from Figure 27 'Accumulated Duration of Selections Disabled Expert', we can also see that these selections are of a lot shorter in duration than for the other two

participants. However, the PhD Research student has already explained that he believes that not all of these short selections are due to spasms or unintentional selections, and that at least selections of the same direction, as shown on Table 10 'The Disabled Expert's Consecutive Selections' could be removed as these could result from the 'Disabled Expert' checking her location before continuing her movement. Removing these consecutive selections would reduce the number by 95 and make the number of selections made by the 'Disabled Expert' comparable with the other two participants.

Also' on viewing the video, the 'Disabled Expert' does not appear to catch the switch but does unintentionally release the switch due to spasms. As a result of this observation (which could be conducted by the ATP's over a number of visits) if the ATP was aware of this phenomenon it could be investigated with the possibility of the switch being moved closer before conducting further analysis on the data generated, to see if these changes had increased or decreased the user's ability to use the system.

8.3 Other Processes and Computational Techniques

It is important to note that not all processes and computational techniques described were used earlier within this Chapter as they were not required for these comparisons. However each of these processes brings additional information or supports other processes as can be seen in the publications produced during the undertaking of this research project. For example, earlier we did not use the 'Path Profile' technique. Had this been undertaken, the differences between the veers of the electric wheelchairs would have become evident because on a section of straight corridor it is suspected that the following would have been shown for the 'Disabled Expert' and 'Able Bodied' or 'Novice'.



Figure 28 Disabled Expert's Path Profile

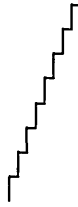


Figure 29 Able-Bodied or Novice's Path Profile

Had these path profiles been undertaken and had they been as shown above, then they would have supplemented the evidence already presented earlier within this Chapter. This supplementary evidence will be of more use when these processors are being used by the ATP's' in the field as they will not have access to the video as we had within the laboratory study. Therefore the supplementary evidence may be used as a replacement of the film to confirm the other findings.

8.4 Chapter Summary

This Chapter was comprised of comparisons of the results from the field study and those from the laboratory study. Each of the results from each of the methods relevant to the particular focus of interest of the attributes being investigated would be undertaken on that data. For example, if the investigation was to what extent the attribute of veer, made on the user's ability to get from one location to another, then data from the field and laboratory study would first be analysed and these results of that comparison were then reported within this Chapter.

Overall the Chapter reported that a number of the hypothesis suggested could be speculated to be correct and for those that are not so clear, an explanation is provided as to why, this may have been the case.

Chapter 9. Additional Tools to Aid the Prescription

Chapter Structure:

This Chapter describes the additional tools created as a result of this study to aid the prescription process as well as the ways in which these tools can be used within the multi-disciplinary approach to enhance the accuracy and speed that a prescription can be fulfilled.

9.1 Introduction

This Chapter focuses on the additional tools that were generated due to the PhD Research student's in depth knowledge of the domain. This knowledge of the domain as well as an understanding of the role of an ATP while prescribing an EAT system was brought together to create an application (the additional tools), to be used by the ATPs' during the prescription process.

The prototype version of this application, called 'Switch Environment Assessment Tool (SEAT)' is briefly described along with the suggested location the SEAT application should be used within the 'Multiple Disciplinary Service Model'. Finally, the Chapter concludes with a description of the commercial version of SEAT which is to be created by the PhD Research student's company - Madhouse Software Productions Ltd.

9.2 The Tools

The aim throughout this research project was, and still is, to enhance the prescription of Electronic Assistive Technology (EAT) in order that this enhancement will increase the user's productivity and the system's suitability for the user. This enhancement is achieved in two ways and these are:

- Changes to the ATP's methods and practices.
- Changes to the system with regards to functionality and Human Computer Interaction (HCI) for the given System User.

Often the changes to the ATP's methods and practices implemented throughout the prescription process would lead to the second element of the changes for the System

User. While reviewing the paper and being involved in the implementation of a prescription using 'A Client-Centred Multi-Disciplinary Service Model' the PhD Research student became aware of the importance of the ATP's knowledge of all the different aspects in respect of the prescription process. Of particular importance are the system settings with regard to the user's interaction. Although the published research provides settings for perception, cognition and motor cycle time (Horstmann *et al*, (1990)), invariably these system settings would usually be obtained using 'trial-and-error' techniques alongside ATP's previous knowledge. These 'trial-and-error' techniques would require the ATP to use the real system and change its configuration for each of the settings on numerous occasions for each of the attributes. The manipulation of this configuration would take some considerable time but consequently reduce the process time. It would however often increase the time taken to complete the prescription. It became apparent that some of the fundamental settings for the user's interaction with the system were largely based on the ATP's experience and 'trial and error', as previously stated. Consequently, if a system was prescribed by an ATP with little or no experience the prescription process would take much longer and rely more heavily on the 'trial and error' process to ensure that the settings matched the System User's needs.

Alternatively, if the ATP had a great deal of experience then the ATP may assume the required settings. In general, the settings are, at best, very subjective and the same system for the same person could be significantly different depending on the ATP that had prescribed it. By formulating these processes with a tool it should result in the same outcomes being reached, irrespective of the person's knowledge and therefore providing consistency in administering the tests. However before a tool could be developed it was felt that a deeper understanding of the interaction of the user and system were required. The means by which this was achieved is discussed in the following section of this Chapter.

9.2.1 Investigated Analysis Techniques

Although a number of analysis techniques were investigated none of those studied would permit the inclusion of timers and the parallel activity required to analyse both the user's and system's interaction. However, one analysis technique named Petri Nets, was brought to the PhD Research student's attention by Dr. Chris Roast. The PhD

Research student was subsequently introduced to 'Timed Petri Nets' (Palanque, P and Bastide, R (1996)), which proved to be one of the few modelling techniques that are appropriate for this problem domain. Specifically, the real-time and parallel characteristics of interaction with scanning menus cannot be accommodated within traditional techniques. Other modelling techniques for example concentrate on the delays waiting for the user to respond. However with scanning applications a number of delays have to be taken into consideration. For example:

- Waiting for the required item to be highlighted
- Waiting for the computer to accept the switch closure as a valid closure

The advantages obtained by the user domain using the Petri Nets modelling techniques are explained in more detail below.

9.2.2 Timed Petri Nets

The Petri Nets within this section provided the researcher with the ability to model both system and user. These two independent models of user and system are connected and ran in parallel to provide an overview of the complete interaction between the human and the system. Additionally, the Petri Nets provided the researcher with the ability to include time delays. These time delays can be used for the scanning activity of the system and cognitive perceptual and motor activities of the user (see Appendix F 'Modelling Using Petri Nets'). This time delay facility is not available in other modelling techniques.

Modelling the user in Petri Nets brought to the PhD student's attention that involuntary movements e.g., 'Spasms' had no perception or cognition time. The PhD student was previously aware of involuntary movement due to the number of presumed unintentional selections made, but, until the modelling, the lack of perception and cognition had not been recognised. The modelling highlighted these unintentional selections and the need for the 'Hold Down Time' within the applications. 'Hold Down Time' reduces the unintentional selections by requiring the user to close the switch for a predetermined period of time before any action will be taken. Of course there is also the inverse of this time, which is called 'Post Acceptance Delay'. This is the time that the switch must be open after a genuine closure before the next closure will be looked

at as a new closure. These values for the user's interaction were obtained from (Horstmann *et al*, (1990)), which incredibly were obtained from able-bodied users. Other values such as 'Scan Rate' were still obtained from ATP's previous knowledge (subjective) for the purpose of the modelling.

9.3 The Switch Environment Assessment Tool's Background

With this subjective behaviour of the prescription process in mind the PhD Research student used the knowledge gained from the investigation conducted within this research work to remove some of the subjectivity and the 'trial and error' process by developing an application called 'Switch Environment Assessment Tool' (SEAT). Although SEAT's primary aim was to produce settings for EAT systems a secondary outcome was that the application could also provide values that are useful within this research domain. These primary and secondary values are described in more detail in the next section of this Chapter.

9.3.1 SEAT Overview

The prototype Switch Environment Assessment Tool (SEAT) application was created to provide an estimate of the following settings for the System User:

Primary Values

Hold Down Time

This is the time that a switch must be closed before it is accepted as a genuine switch closure.

Post Acceptance Delay

This is the time that a switch must be open after a closure before it will be accepted as a genuine new switch closure.

Scan Rate

This is the time an item is available for selection by the user before the next item in the sequence is given focus.

Scan Type

This is the sequence that the obtainable items are available for selection by the user.

Secondary Values

Reaction

This is the time it takes the user to react to a visual stimulus.

Perception

This is the time required for visual stimulus to enter the brain. Please see (Horstman *et al*, ((1990)) for a comprehensive description.

Motor Cycle

This is the time required for the brain to request motor action and for this motor action to occur. Please see (Horstman *et al*, 1990)) for a comprehensive description.

Cognition Cycle

This is the time required by the brain to make a decision. Please see (Horstman *et al*, (1990)) for a comprehensive description.

Each of these values is obtained by the user undergoing a total of ten tests. Each one is designed to gain some knowledge about the user's ability to interact with a system. The commercial version of SEAT is discussed in Chapter 11 'Future Work and Conclusions' and is intended to be located within the model on the following page. In addition, it should be used in 'Specify user interface'; and the evaluation stage of 'Equipment matches abilities' as shown in Figure 30 'SEAT's Location Within The Client-Centred Multi-Disciplinary Service Model':

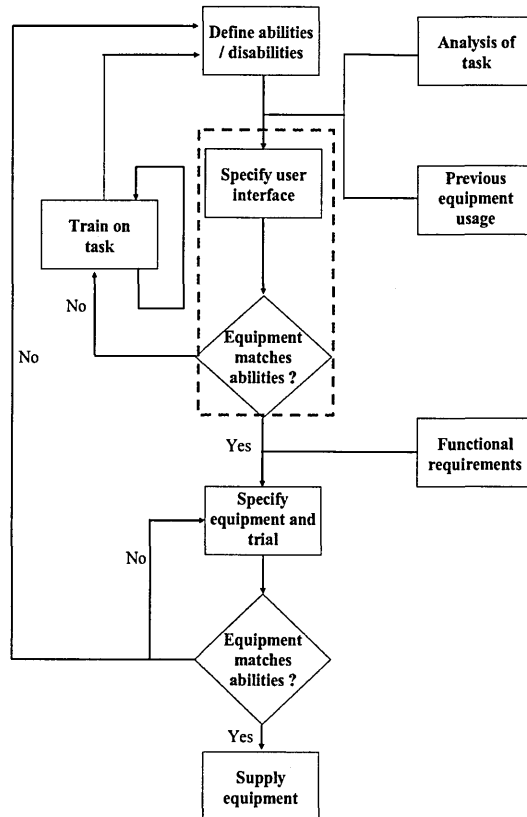


Figure 30 SEAT's Location Within The Client-Centred Multi-Disciplinary Service Model

Like the additional analysis using the data logs and place within the model in Chapter 5 'The Research Methodology', the SEAT application should also be used within the iterative procedure shown above, including the training element.

In addition, the SEAT application can be used to test the user's abilities when the switch is located at different sites. For example, some users prefer to use their forehead to the left, right or centre, others prefer to use their hands, feet or knees. Basically, by using the SEAT application, the ATP can let the user try any part of their body to undergo the tests. After the user has tried each area they may come back with two sites that they are particularly comfortable with. At this point the ATP may look at both of the tests to see which one provided the best scores and therefore would give the user their best potential productivity rate when using their system. Examples of the data output from SEAT can be found in Appendix I 'Switch Environment Assessment Tool's Data Output'. It is important to note that the SEAT prototype application was not validated and the information contained within this Appendix is an example of the output only.

However the SEAT application did include the following tests which are presented with a brief description of the suggested values for each of the attributes required:

Reaction

This, as its name suggests, recorded the time it took the individual to respond to a visual stimulus and thus obtained the suggested total 'Reaction Time'.

Moving Dot

This test was to obtain the suggested 'Perception Cycle'.

Scan Rate

This test recorded the suggested 'Scan Rate', when the interface is static.

Rapid Fire

This test obtained the suggested 'Motor Cycle'.

Target Scan Rate

This test recorded the suggested 'Scan Rate', when the interface is **NOT** static.

Hold Down

This test obtained the suggested 'Post Acceptance Delay Time' (see 9.3.1 'SEAT Overview' for a description).

Sizer

This test recorded the suggested minimum 'Item Dimensions' the user could see on the screen at a set distance.

Scan Type

This test suggested which 'Scan Type' may be used.

Building Block

This test was included to allow the user try the suggested settings from all of the other tests.

9.4. The Commercial Version of SEAT

The prototype version of the 'Switch Environment Assessment Tool' (SEAT) was not fully validated before the PhD Research student left the employment of Barnsley Hospital NHS Foundation Trust (BHNFT) to create his own company called '17Madhouse Software Productions Ltd.'. However, an ATP working within the Clinical Engineering Service (CES) at BHNFT conducted trials with users and the results of these trials are reported in Friday and O'Neill (2005). The conclusion of these trials indicated that the SEAT application was likely to provide assistance for the ATP and, with revision, it could be a useful tool to aid the prescription process.

Madhouse Software Productions Ltd. was contacted as a direct result of this ATP's knowledge of the PhD Research student's work on the development of SEAT. The company's Managing Director, (the PhD Research student) was invited to discuss possible further developments with the aim of making SEAT a commercial product. After much discussion an agreement between BHNFT and Madhouse Software Productions Ltd came to fruition. Additionally, SEAT would have some of its tests further developed. Other tests that had been included for academic purposes and user trial only would be removed completely. The following tests were included within the new SEAT application:

- Reaction
- Rapid Fire
- Scan Rate (renamed Scan Rate (Novice))
- Target Scan Rate (renamed Scan Rate (Expert))
- Hold Down
- Sizer
- Scan Type

The application would retain the title of 'Switch Environment Assessment Tool (SEAT)', but would have its version increased to 'version 2.0' to be available in the next six months.

¹⁷ Madhouse Software Productions Ltd., creates EAT systems for the disabled and elderly members of society. Visit www.madhousesoftware.co.uk

9.5 Chapter Summary

This Chapter commenced by explaining that the in depth knowledge obtained by the PhD Research student of the prescription process during his research made him aware that tools were not only required to evaluate the prescription, but also to assist with evaluating the Human Computer Interaction (HCI). It is reported that if this interaction was to occur efficiently then the EAT application needed to be configured to meet the users particular, physical, visual and functional needs. It is explained that at present these settings are obtain via previous knowledge of the ATP and 'trial and error'.

In the next section of the Chapter the PhD Research student explains that with his understanding of this trial-and-error process, led him to develop a prototype application called "Switch Environment Assessment Tool" (SEAT). In addition, is described one of the few modelling techniques that includes time delays called Petri-Nets and there usefulness within this development is described. A description of SEAT, which evaluates the user's switch access abilities, is also provided. The Chapter then goes on to described were the SEAT application should be used within the Hawley model.

The Chapter continues by explaining that the SEAT prototype application was evaluated by ATP's at Barnsley Hospital NHS Foundation Trust. Then the Chapter continues by describing the outcome from that evaluation. Finally it is reported that the PhD Research student's company is to develop a commercial version of the SEAT application.

Chapter 10. Contribution to Knowledge

Chapter Structure:

This Chapter defines the contribution to knowledge that this study has made ,together with the way that this knowledge could be used to enhance the system user's quality of life.

10.1 Evaluation Before Data Logs

Prior to this research being undertaken the evaluation of an 'Integrated Electronic Assistive Technology' (IEAT) prescription was fulfilled (if this evaluation was undertaken at all) in the following manner:

- With occasional field visits by the ATP.
- Requests for changes by Social Assistants.
- Requests for changes from the User where possible.

However this was with the exception of a child's prescription if it included an Augmentative and Alternative Communication (AAC) software application. This would invariably be constantly updated by the school's Speech & Language Therapist (S & LT) due to the child's continuing language development. Additionally, it is important to note at this point that the AAC software did include data logs, but the company retailing the AAC software application was not promoting this fact. These logs were not, to the best of the research PhD Research students' knowledge, being used by the S & LTs. Therefore, although one company was aware that data logs may be useful it did not have the conviction to push the possible advantages that using these logs may bring to the prescription process.

Often the enhancement process of a system - when the individual does not use the system for speech, or is an adult - was and still is conducted on an ad hoc basis, or often only undertaken when the system fails. Although the ATP's are aware of this lack of revision to the user's system they are caught between two forces each pulling them in different directions. For example, if the ATP spends time watching someone use the system in order to enhance it, then there is a possibility that another user is going without the equipment that they require as the ATP cannot be in two places at the same time.

At the beginning of this research data logs had been overlooked as a possible source of obtaining information in the areas listed below. Although this does not exclusively specify ways of obtaining information about the system usage from the data logs, it does highlight the main points:

- ATP's awareness with regard to possible system constraints.
- ATP's awareness with regard to user's physical ability.
- The ways these systems were being used, e.g., functional availability.
- Duration these systems were in use.
- Ways by which the system may be enhanced:
 - ¹⁸Hardware Location
 - Software Configuration

Interestingly, all of the above information, and possibly more, can be gained by the ATP with minimal visitation and with the creation of assessment tools which will conduct the analysis automatically with minimal time spent analysing the data logs.

10.2 The Contribution to knowledge (The Inclusion of Data Logs)

The PhD Research student's inclusion of data logs into the complete 'Integrated Electronic Assistive Technology' (IEAT) system had not been undertaken previously. Therefore, the information subsequently gained from these comprehensive data logs in respect of the user's usage of the system also included an element of knowledge that had not been previously available. It is therefore possible to make the following three claims:

1. The work reported has indicated that the usage of data logs for this particular user group is extremely practical (requiring little intervention from the ATP to obtain the information) and does not require any additional system user interaction (the user's usage of the system provides the information required).

¹⁸ Hardware Location is referring to the switch and PC's location in respect to the user.

2. The work reported has demonstrated that through the analysis of the data logs, the ATP can gain an insight into the system's usage in respect of the functionality made available e.g. Speaking, Writing, Computer Access and Movement. Configurationally it is possible to gain information from the analysis of the data logs which suggests changes to the system's configuration. These aspects of information in turn suggest possible changes to the system's configuration or/and physical location of hardware. This adds to the ATP's knowledge and can be used to enhance the prescription which in turn can lead to an enhancement of the user's quality of life.
3. The work reported indicates that with additional research, using data logs as the primary source of information, together with a larger population (in the short term at the very least) it is possible to create a framework of configurations in the knowledge that a particular configuration fits a particular user group, both configurationally and functionally. In the long term it is suggested that an inference engine may ask the system user a series of questions about the configuration of the system, in conjunction with the analysis of the data logs, and suggest configuration changes which the user can accept or reject, therefore letting the user configure the system for themselves.

The final point is, at present, speculation but should be an aim which all people working within this domain should be striving towards, i.e. a system that requires minimal intervention at the initial stage of the prescription process, that grows with the user and which the user controls. Once again, the above should be achievable with the minimal outside intervention.

10.3 The Future Focus

After the initial work undertaken on an IEAT system the study then focussed on the usage of the 'Barnsley Wheelchair Interface' (BWI) - the component and application responsible for the mobility aspect of the system.

Although many of the methods used to analyse the data logs are well known mathematical formulae, their usage within the assistive technology domain, to the best

of the PhD Research student's knowledge, had not previously been undertaken in a formal or informal way as reported in this study. This work provides the 'Evidence Based Practice' (EBP) often requested or researched by funding bodies, such as the Department of Health (DOH), which has an organisation set up within it to investigate evidence based purchasing, called PASA (see Purchasing And Supply Agency).

With the government forecasting an increase in the ageing population (see National Statistics) and that population having an increasing knowledge of assistive technology, more demand will be made on these organisations to provide the technology discussed within this dissertation. This in turn will require the ATP's to provide the EBP that these devices are providing what is actually required by the individual, and that these systems, together with the finance required to create them, is being used to its best potential. In addition, the ATP's working within this field will see an increase in requests for these systems and therefore an increase in the number of revisits required to enhance the systems being prescribed.

In order to sustain this demand tools such as those described within this dissertation must be used and enhanced to the automated stage. Creating systems that are automated as much as possible should serve both users and ATP's. Firstly, this will enable users to have the system they require, when they require it, and secondly, ATP's will be relieved of the demands of both providing the initial stage of the prescription and undertaking maintenance on those systems already prescribed.

10.4 Chapter Summary

The Chapter starts by providing an outline of the processes of evaluating an IEAT prescription before the introduction of data logging and how these processes placed a comprehensive amount of work on the ATP's and relied on third party information from the user's family members, Social Assistants and their peers. Then the Chapter continues by discussing that with an increased work load on an already pressured workforce this often led to evaluations not being undertaken. However, it does explain that this would not be the case, were a child or AAC software was included within the prescription, due to the child's development and that this is due to the S & LT constant reviews the child's communication development. This paragraph concludes by giving

the advantages of including and undertaking analysis on the data logs as a form of evaluating the system prescription.

In the next paragraph is explained that the inclusion of these data logs are partly the PhD Research student's contribution to knowledge and gives three areas where the data logs have assisted with our understanding.

In the final section the PhD Research student expresses the need for EBP as he speculates that this evidence will be required by the funding bodies in the future, particularly with the projected increase in aging of the population which is also reported and along with the increasing demand for IEAT which will be made by a more knowledgeable public.

Chapter 11. Future Work and Conclusions

Chapter Structure:

The final Chapter brings together the preceding Chapters and based on the evidence presented in this thesis, addresses the original research question. This Chapter also suggests other research areas and ways forward within this domain.

11.1 Motivation for Change

“Why should we change?” is a question that is often raised when the human race diverges into a new area of discovery, irrespective of the research domain. Like all other areas of research this question is also asked within the domain of Assistive Technology (AT) and Electronic Assistive Technology (EAT). The Assistive Technology Professional (ATP) as part of their function provides systems that are in many instances are essential to a user’s quality of life. It is at the very least their professional duty to ensure that they provide the best of what is available to match that user’s needs at the time of delivery. Invariably this requires ATP’s to seek, learn about and use the latest devices available, hence this instigates change.

In addition to using the latest technologies available in order to ensure the system is matching the user’s needs, and giving value for money with regards to the funding bodies, the ATP needs to be provided with feedback about the system’s usage. As already explained this is extremely difficult for many users due to the system user’s lack of ability to vocalise, particularly if the statements they require are not contained within their system (as stated earlier in this dissertation). Alternative methods for gaining this information must be therefore be used and the data logging utilised and evaluated within this dissertation is one of those methods that lends itself to this domain. Without the comprehensive information provided by the data logs and the tools, methods and procedures to extrapolate this information the ability and therefore the motivation to develop is seriously restricted.

11.2 Inhibitors of these Changes

In order for data logging to provide this information, assistive technology software applications and other devices need to include this functionality but, due to the ethical issues of invasion of privacy, companies and ATP's are reluctant to include this functionality. Madhouse Software Productions Ltd. have however satisfied this issue by including within the application the protocol 'That the system **MUST** contain an item to turn the data logger "On/Off" '. If this item is not available within the configuration then the application will automatically turn the data logger "Off". This means that should the system user require privacy they can attain it by turning the logger "Off" themselves. Other major inhibitors for the inclusion of this functionality are:

- Small population hence little commercial viability.
- Demand on Clinicians and Therapists time.
- Financial constraints on the ¹⁹NHS and ²⁰LEA's and other funding bodies.

Despite the reasons stated above the inclusion of this functionality is slowly being accepted as the norm in Augmentative and Alternative Communication (AAC). Companies who provide AAC in combination with EAT are also including the data logging functionality. For example, the Ultimate Switching Environment (USE) is an AAC which also includes EAT functionalities like emulating a keyboard, computer mouse and Environmental Control System (ECS) for controlling the user's television, radio and lights within their home. Chapter 11.5 'Development and Future Research refers.

11.3 Answers to the Original Research Questions

The original aims and objectives of this research project were: firstly to determine if data logs would and could provide useful information to the ATP's to enable them to enhance the prescription of an EAT. Secondly, to develop a set of tools which would facilitate the acquisition of this useful information and thus assist with the enhancement of the prescription processes. Clearly from the work reported within this dissertation both of the above objectives have been reached. An example is the inclusion of the

¹⁹NHS National Health Service.

²⁰ LEA's Local Education Authorities.

data logger module within the Barnsley Active Switch Environment (BASE) and the consequent analysis of those data logs created by the BASE application. Initially the information extrapolated related to the duration the system had been in use during a specific period of time. Subsequently this information about the duration of system utilisation was to become a milestone in the ATP's understanding of Assistive Technology usage data. With the enhancement of ATP's understanding of the use of AT systems through the analysis of data logs, then the inevitable followed and the inclusion of the data logger into the Barnsley Wheelchair Interface (BWI) was undertaken.

Use of the more extensive and comprehensive data logs from the mobility application e.g., BWI, resulted in methods and processes being created to obtain information about the user's usage of the system which could potentially facilitate the enhancement of the prescription. Again soon after the inclusion of the data logs it became evident that the user was waiting some considerable time for the interface to scan around each of the directions before returning to the forward direction as 'Forward Bias' (see Chapter 4 'The Available Systems', section 4.2.4.1.3 'Scanning Methods') this function had not been created as the PhD Research student did not identify a requirement for this scanning method until after the analysis of the data logs created by the BWI had been conducted. Following the design of these methods and processes over the years and the subsequent validation through the comparison of the field and laboratory studies, the required tools became available. However these tools needed refining into automated procedures in order to make them more accessible to ATP's working within the field. It is these points that are discussed in the following section of this dissertation.

11.4 Future Developments

During this research project the PhD Research student requested a year away from his commitment to the research work being undertaken in order to start up his own company called "Madhouse Software Productions Ltd." This company develops and retails EAT applications for this as well as the wider range of users than the participant included within the work discussed here. It was also intended that most of the future work described here would be undertaken by this named company in view of the work which had already been undertaken.

The remaining part of this Chapter will therefore be divided to cover the three segments of the project:

1. Work Already Undertaken and the Immediate Future Work
2. Work Up to Five Years Ahead
3. Work Five Years and Beyond

It is important to note that only a brief description is given. As additional research within this domain continues to be undertaken it may result in some areas requiring refocusing - dependent on those research outcomes.

11.4.1 Already Undertaken and the Immediate Future Work

11.4.1.1 Additional Interaction

During this research project the PhD Research student was looking for modelling methods which were suitable for modelling the user and system interaction. Following much investigation he was introduced to the work of Palanque & Bastide, (1996) and “Petri-Nets”. Consequently a Petri Net of the “User” and “System” was developed including the way in which these two models interact with each other. This diagram is contained in Appendix F of this thesis. During the development of this Petri-Net the PhD Research student became aware of an additional interaction that was not, to his knowledge, being used. This additional interaction is shown in Diagram 9.4.2.2.1 ‘User Model using a Petri-Net’ : detailed on the following page.

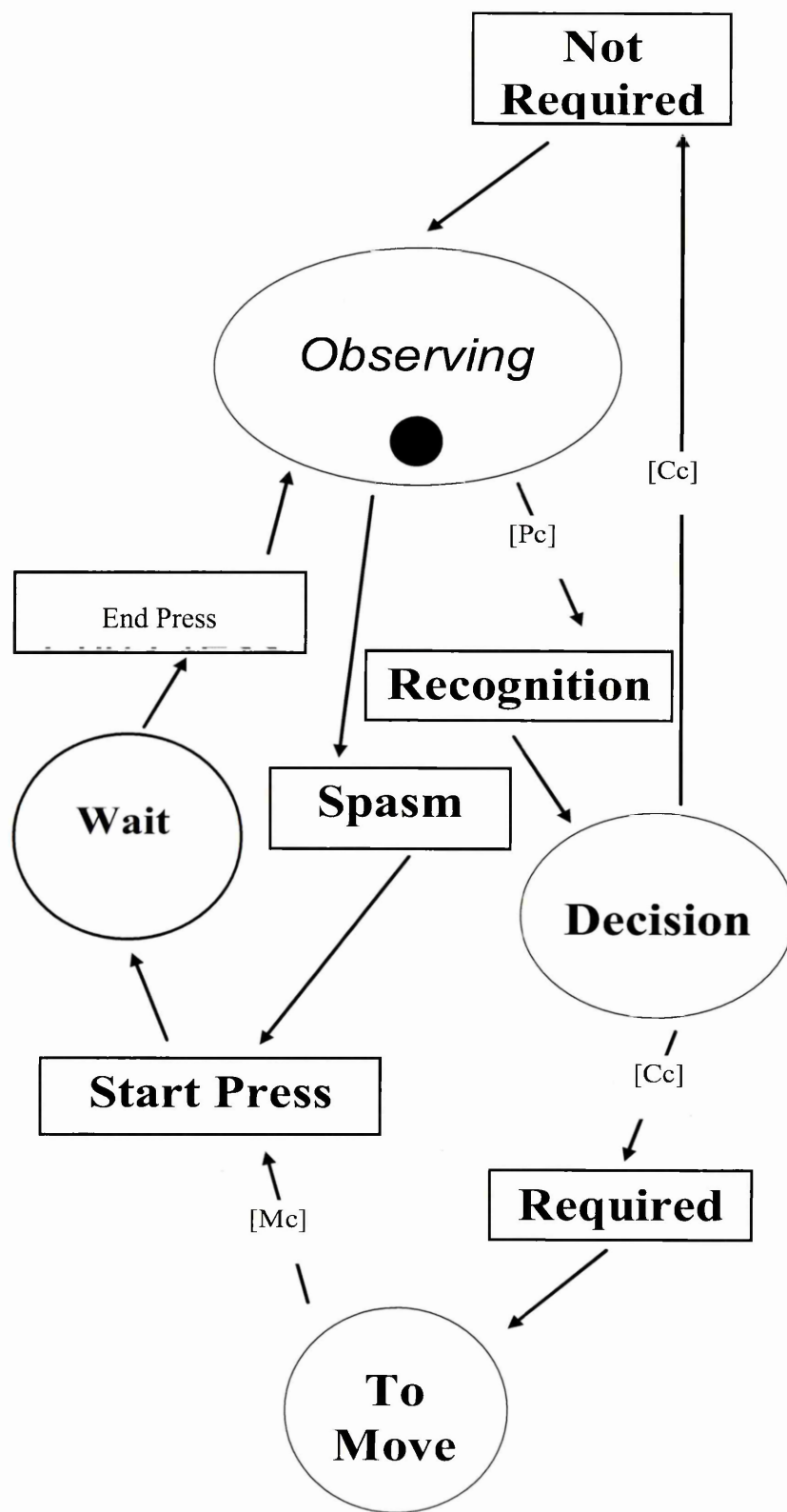


Figure 31 User Model using a Petri-Net

In this instance the component that is of particular interest and the element that had been missed or ignored was the “End Press”. It became apparent to the PhD Research student that a means by which this could be used to increase the user functionality and productivity was not obvious. However, the PhD Research student arranged to take a year away from the research to setup his own company called “²¹Madhouse Software Productions Ltd.” A method for utilising this additional input method was developed in this period.

During the year away from the research a method to utilise this additional input was investigated and the birth of layers was incorporated into the company’s main application “Ultimate Switching Environment” (USE). Layers in one switch mode uses the continuation of a switch closure and a timer to pace through the layers as shown here:

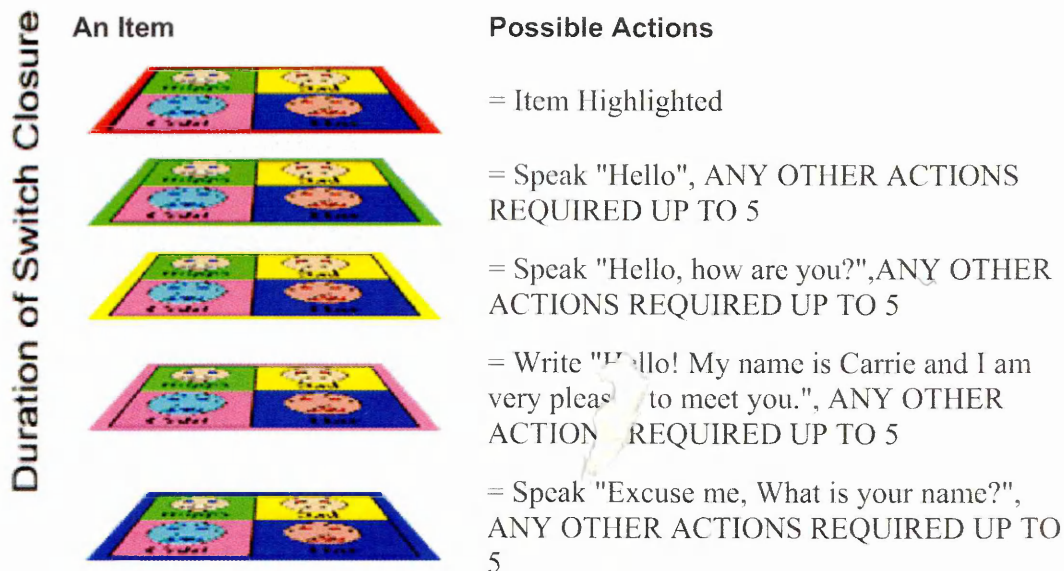


Figure 32 Multiple Layers per Item Within The ²²Ultimate Switching Environment (USE)

In addition to the five layers per item it is also possible to have five actions on each of the layers. This means that with a configuration of 100 items available to the user, a possible 2500 actions can be achieved, 500 of which are independently selectable.

²¹ www.madhousesoftware.co.uk

²² For more information on USE visit www.madhousesoftware.co.uk

It will become apparent that data logs are included with most of the products of “Madhouse Software Productions Ltd.”. However, in all instances the user must be given the ability to turn the data logging function “Off” and “On” or the system will automatically turn the logging “Off” to ensure that there is no infringement on the users civil liberties. Additionally, because of the PhD Research student’s awareness of the limitation caused by the one second granularity of the data logs within BASE and the BWI, the products of “Madhouse Software Productions Ltd.” introduced an additional attribute to the data logs of the ‘Number Of Clicks’ that is the number of clicks the processor has made since the beginning of the application. This means that it is generally possible to come down to a granularity of one thousandth of a second.

With the consent of Barnsley Hospital NHS Foundation Trust, Madhouse Software Productions Ltd. will develop the prototype version of the “Switch Environment Assessment Tool (SEAT) for commercial retail. This application will not contain some of the tests that were instigated for research purposes but will still provide the ATP’s with a tool which should assist in obtaining values for :-

- Scan Method
- Hold Down Time
- Post Acceptance Delay
- Scan Rate
- Minimum Item Size

It is essential that the above five attributes are set correctly in order to ensure that the device can be used by an individual switch user. Therefore use of the SEAT tool should reduce the time taken to obtain settings for a user and should also reduce the need for a ‘trial and error’ approach. In addition, and more importantly the SEAT application should remove a great deal of the subjectivity. This in turn will mean that it does not matter who prescribes the system, the attributes settings should be the same regardless of the ATP fulfilling the prescription.

11.4.2 Up to Five Years Ahead

With the company development of multiple interfaced applications, that is where a user may select an item and the interface will change thus presenting the user with a

different interface with different functions and not the static interface as described within this dissertation.

Adaptation of the analysis methods and processes described will be required, and these methods and processes then need to be created into software applications (external tools) which will automatically undertake the following activities:

1. Import the Data Logs.
2. Undertake the analysis processes described within this dissertation.
3. Present the outcomes from these analyses.

The creation of these external tools (as briefly described above), as well as new developments of present and future applications created by “Madhouse Software Productions Ltd.” shall run in tandem. It is the company’s intention to promote these tools and develop generic configurations that match a group of users needs which, once used for a while enable analysis to be carried out on the data logs and can subsequently be modified by the ATP to match that users needs as closely as possible. This should thus reduce the need for ATP’s intervention and reduce the time required by the ATP to prescribe these systems. In turn these generic configurations should mean that the user gets a more complete system from the outset as these generic configurations will have been developed through many hours of usage by others in similar circumstances. The analysis of their experience/s will enable tweaking of the system to match their particular requirements. (see Appendix H. ‘Transfers Document From MPhil To PhD, section 9. The Way Forward’)

11.4.3 Five Years and Beyond

With regard to the research conducted and reported within this dissertation and the external tools explained in the previous section of this Chapter, it is intended that these external tools will become integrated into the EAT with additional functions of:

1. Undertake Maintenance
 - i. Import Data Logs
 - ii. Conduct Analysis
 - iii. Save Analysis Outcomes

2. Conduct Interface and Functional Updates

- i. Review Analysis Outcomes
- ii. Using Inference Engine Construct Boolean Questions
- iii. Present Boolean Questions
- iv. Implement, If Requested By User

With the exception of 1.iii “Save Analysis Outcomes” this means for the application to store its results onto the hard drive of the computer. Other items from “1. “Undertake Maintenance” are explained in 11.4.2 ‘Up to Five Years Ahead’.

However, part 2: ‘Conduct Interface and Functional Updates’ have not yet been considered for investigation. Each of these processes will require further comprehensive investigation and may eventually lead to other academic work along with examination of the commercial viability of these processes.

Overall the intention is to set up a framework where the ATP would provide a system with the entire hardware requirement to meet the functional needs of the individual, leading to the installation of the configuration which matches the hardware and characteristics of the user. Attributes such as the timings ‘Scan Rate’, ‘Hold Down Time’ etc., will be obtained from SEAT and included within the configuration. Items within the configuration will give the user the ability to conduct maintenance and updates without the intervention of the ATP and the ATP’s role will hopefully become an initial provider and someone to deal with hardware failure, software conflicts etc and to assist those individuals who have a system but do not have the capability to undertake the updates alone.

11.5 Conclusions

Finally, all of the work undertaken and subsequently reported here and in the publications were conducted in isolation. At the current time this is also true for the developments made by “Madhouse Software Productions Ltd.”.

- Mobility
- Augmentative and Alternative Communication AAC (Speech Aids)
- Environmental Control Systems (ECSs)
- Computer Input Device Emulators

However, to ensure that all areas we call as a collection 'EAT' are to be prescribed to best fit the user then we must come to a mutual agreement on standards, particularly with regards to data logging if this is the means by which we are to assess future prescriptions.

Therefore the first requirement would be for all companies that create EAT applications to include the data logging functionality. This can clearly lead to ethical issues and, as already expressed within this dissertation, these can be satisfied by ensuring that the user is always given the ability to turn this function "OFF" as and when they choose to do so. AAC at present are the leaders within data logging and its analysis. It would therefore be suggested that other EAT applications should follow the format already constructed by the AAC application creators. Although the structures and timing granularity used within AAC are adequate for that functionality (due to the time it takes the system to speak) the study conducted here has found that this timing granularity is not fine enough for general EAT.

Additionally, the multiple layered interface which was the development introduced by "Madhouse Software Productions Ltd." requires additional information to be stored within the data logging e.g., which layer was selected. Despite the infancy of this work it has already become apparent that future development of these systems should include the storage of additional information. It is therefore suggested that with the exception of the general information e.g., Session, Selection, Date, Time, Activity Type and Function, content should not be rigid but there is a need for some agreement with regard to its format. This would assist with the development of automated analysis tools and thus encourage ATP's to refine the prescriptions already provided. This in turn should assist with increasing the user's productivity and hence, the user's quality of life.

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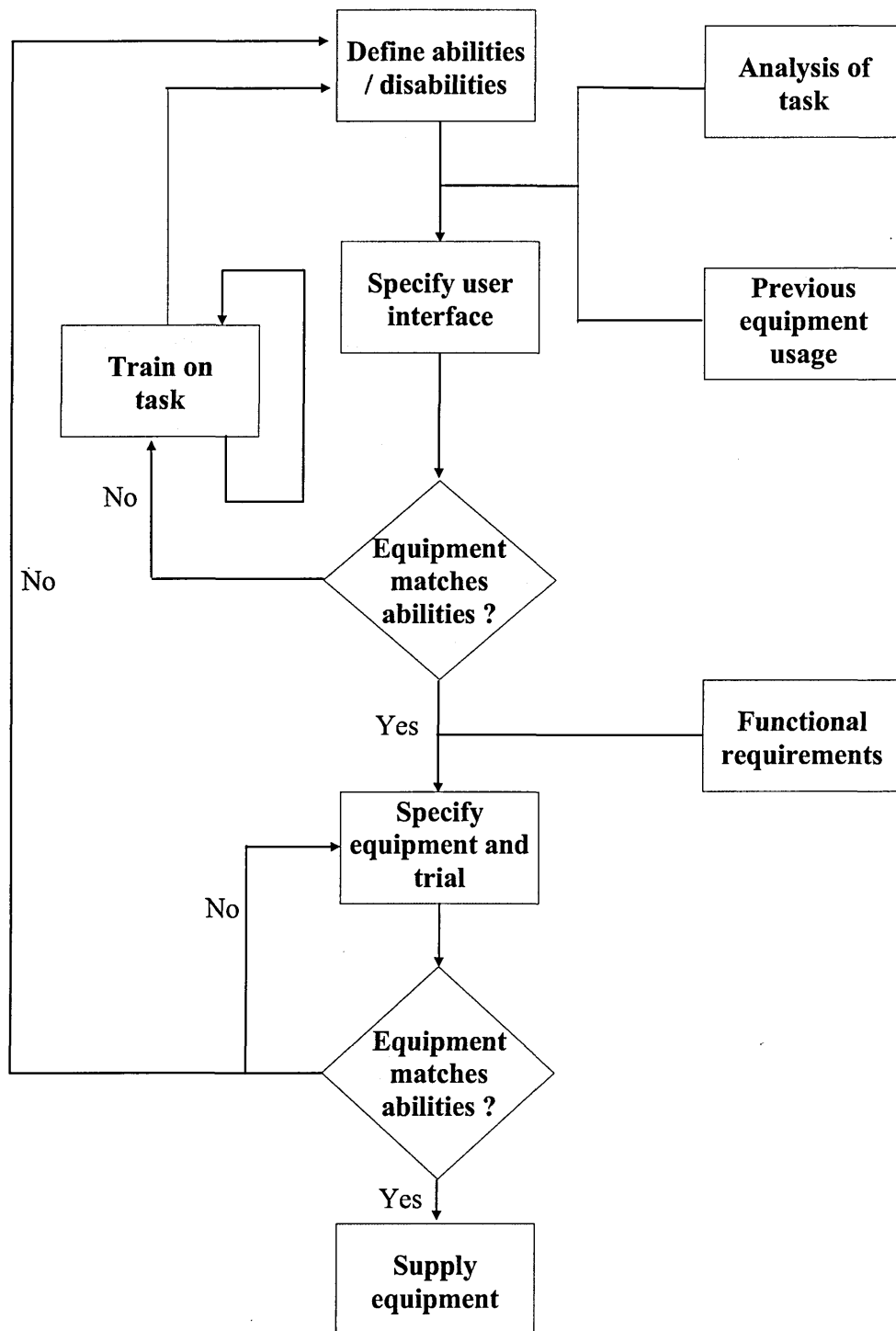
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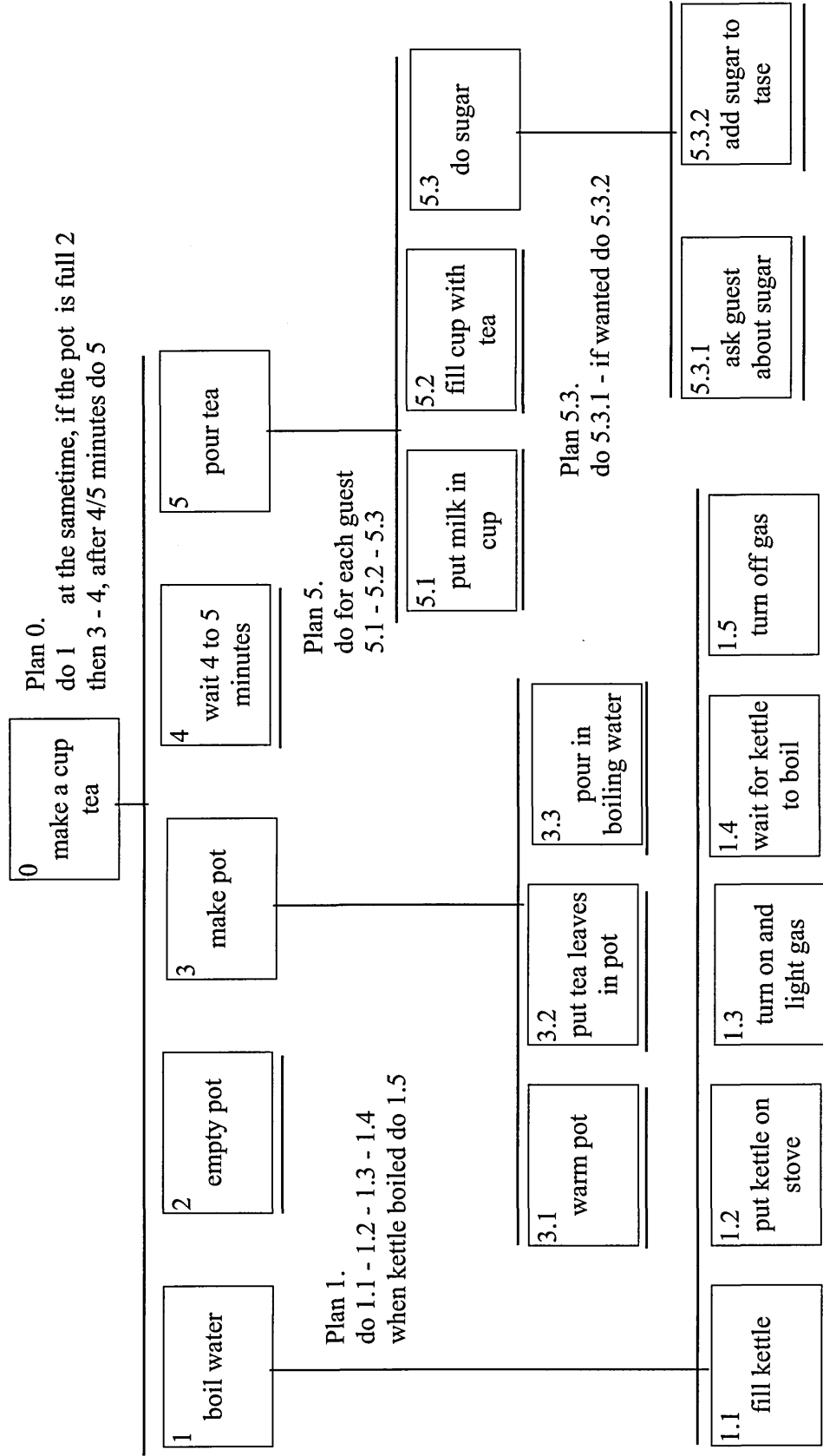
Appendix A

Service Model



Appendix B

Making a Cup of Tea



Appendix C

Methods for

Formulating the

Data Logs

The procedures for each of the methods that were used or created during this research project are described below. Because all of the procedures require the data logs created from the Assistive Technology, these initial processes are constructed of a number of steps which prepared the data logs for any of the methods which may be selected by the researcher.

Initial Processes

Step 1.

Load the data log file into a 2 dimensional array e.g., a spread sheet within “Excel”.

Step 2.

Label each of the columns starting in the top left, ‘Selection’, ‘Session’, ‘Date’, ‘Time’ and ‘Activity’.

Step 3.

Using the ‘Time’ column, calculate the number of seconds an activity was active, by subtracting the time of the present event from the previous event and label this column ‘Duration’.

(Please Note. Where the ‘Date’ changes e.g., ‘Time’ goes through midnight, make an adjustment to the number of seconds.)

Time	Duration
13:05:29	
13:05:35	6

For example the value in the blue cell is subtracted from the value in the red cell and the result placed in the purple cell

The Procedure for the Method Frequency of Selection

Step 1.

Create a list of all the available activities and label this column 'Action', then label the column to its right 'Occurrences'

Step 2.

Count the number of times an 'Action' in the yellow column occurs in the 'Activity' column (shown here in blue) and enter this value in the cell to the right of the respective 'Action' in the green column.

Activity

F
S
FR
S
F

Action Occurrences

F	2
FR	1
R	0
BR	0

The Procedure for the Method Accumulated Frequency of Duration

Before you can undertake this procedure you must prepare the data logs as described in the three steps of 'Initial Processes'

Step 4.

Create a list of all the available activities and label this column 'Action' (see yellow column), then label the columns to its right a range of values, which include the shortest to the longest value in the 'Duration' column (shown as light blue) in a linear increment.

		Range of Values										
Activity	Duration	Action	0	10	20	30	40	50	60	..	..	..
F	10	F		1	1							
S	30	FR		2								
FR	5	R										
S	3	BR										
F	11	B										
S	10	BL										
FR	7	L										

Step 5.

Count the number of instances a duration occurs in the 'Duration' column where the 'Activity' is the same as the 'Action' and the value from the duration is between the values at the top of the column (here in pink) and the value in the proceeding column (shown in orange).

Step 6.

Sum the number of times a duration occurs in the 'Range of Values', e.g., $10 = 3, 20 = 1$.

The Procedure for the Method Average Frequency of Selections

Before you can undertake this procedure you must prepare the data logs as described in the two steps of 'The Procedure for the Method Frequency of Selection'.

Step 3.

Create another list of all the available activities and label this column 'Action', then label the column to its right 'Average Frequency'

Step 4.

In the column labelled 'Average Frequency' (In purple) enter the, sum of all of the 'Occurrences' (values from the green column), divided by the value to the right of the 'Action' (yellow cell).

Activity		Action	Occurrences
F		F	2
S		FR	1
FR		R	0
S		BR	0
F			

Action	Average Frequency
F	1.5
FR	3
R	0
BR	0

Step 6.

Average Frequency = $\frac{\text{sum of the Occurrences}}{\text{Occurrences}}$

For example.

Add all of the values in the 'Occurrences' column (with green borders) and then divide this value by the value to the right of the 'Action' column (yellow column) and place the result in the 'Average Frequency' column in purple, to the right of the same 'Action'.

The Procedure for the Method Average Duration of the Selections

Before you can undertake this procedure you must prepare the data logs as described in the three steps of 'Initial Processes'.

Step 4.

Create a list of all the available activities and label this column 'Action' (see yellow column), then label the column to the right 'Total Duration', in this column add the values from the 'Duration' column here in light blue, where the 'Activity' (dark blue), is the same as the action in the yellow column labelled 'Action'.

Activity	Duration	Action	Action Duration
F	10	F	21
S	30	FR	12
FR	5	R	
S	3	BR	
F	11	B	
S	10	BL	
FR	7	L	

Step 5.

Create another list of all the available activities and label this column 'Action', then label the column to its right 'Average Duration'.

Action	Average Duration
F	1.571
FR	2.75
R	0
BR	0

Step 6.

Average Duration = $\frac{\text{sum of the Action Duration}}{\text{Action Duration}}$

For example.

Add all of the values in the 'Action Duration' column (with grey borders) and then divide this value by the value to the right of the 'Action' column (yellow column) and place the result in the 'Average Duration' column in purple, to the right of the same 'Action'.

The Procedure for the Method Frequency Duration per Selection

Before you can undertake this procedure you must prepare the data logs as described in the three steps of 'Initial Processes'

Step 4.

Create a list of all the available activities and label this column 'Action' (see yellow column). Then label the columns to the right of the 'Action' column, 'Range of Values', which include the shortest to the longest value from the 'Duration' column (shown as light blue). For example, shown here as the values 0, 10, 20, 30

Activity	Duration	Range of Values											
		Action	0	10	20	30	40	50	60	..	..	..	...
F	10	F		1	1								
S	30	FR		2									
FR	5	R											
S	3	BR											
F	11	B											
S	10	BL											
FR	7	L											

Step 5.

Count the number of instances a duration occurs in the 'Duration' column where the 'Activity' is the same as the 'Action' and the value from the duration is between the values at the top of the column (here with pink background) and the value in the proceeding column (shown with a orange background).

The Procedure of the Method Frequency of Consecutive Selection

Before you can undertake this procedure you must prepare the data logs as described in the three steps of 'Initial Processes'

Step 4,

Create a 2 dimensional array with each of the 'Action' going across the top of the array, label these 'First Selection' and down the left side labelling these 'Second Selection' and shown here with yellow borders:

Second Selection	First Selection								
	Action	F	FR	R	BR	B	BL	L	FL
	F								
	FR								
	R								
	BR								
	B								
	BL								
	L								
	FL								

Where F = Forward, FR = Forward Right, R = Right, BR = Backward Right and so on

...

Step 5.

Populate each of the cells with a pink background with the number of times where the 'First Selection' is followed by the 'Second Selection' of the 'Action', both shown with yellow borders, from the 'Activity' column, shown with blue borders.

In this instance 'S' = Scanning which is a passive function and not selected by the user. Therefore, the 'S' between each of the requested functions are ignored.

		First Selection							
Activity	Action	F	FR	R	BR	B	BL	L	FL
F	F		1						
S	FR	2							
FR	R								
S	BR								
F	B								
S	BL								
FR	L								
	FL								

The Procedure of the Method Erroneous Rate

Before you can undertake this procedure you must prepare the data logs as described in the three steps of 'Initial Processes'

Step 4,

Count the number of occurrences where the value in the 'Duration' column (in blue) is less than or equal to n .

Duration

10
30
5
3
11
10
7

Where 'n' is "the period of time" considered to be an error.

The Procedure of the Method Scan Modelling

Due to the complexity of this method it is necessary to conduct a number of processes before we generate the Scan Modelling method.

Step 1,

First, we must determine the number of highlights that will be required to get from any one of the first activities to any other one of the second activities including itself, for the particular scanning method. An example, in the form of a table is presented to demonstrate this process.

The Scanning Method of Clockwise

First Activities	Forward	Forward	Forward	Forward	Forward	....
Second Activities	Forward	Forward- Right	Right	Backward- Right	Backward	....
'H'	0	1	2	3	4	....

These values are on the assumption that the user selects the second activities the first time it is highlighted.

These values become '**H**' where '**H**' is the "number of Highlights" required in the equation shown later within this method.

Step 2,

Next we need to acquire the user's system attribute values for '**S_i**' where '**S_i**' is the "Scan Rate time" and '**P_i**' where '**P_i**' is the "Pause on Continue time" and finally, '**H_i**' where '**H_i**' is the "Hold down time".

Step 3,

Next we need to obtain the values with respect to the users characteristics with regards to:

$'P_c'$ = the individual's "Perception cycle"

$'C_c'$ = the individual's "Cognitive cycle"

$'M_c'$ = the individual's "Motor cycle"

[Due to these values not being available for our domain group, the values suggested by Horstmann and Levine (1990) have been used. Another way of obtaining $'P_c'$ and $'M_c'$ is from the users undertaking the tests within the Switch Environment Assessment Tool "SEAT", see Appendix I Switch Environment Assessment Tool]

Step 4,

In addition we must complete the procedure frequency of consecutive selection as explained in "The Procedure for the Method Frequency of Consecutive Selection" within this document. The value for each of the consecutive selections becomes the variable $'I'$ where $'I'$ is the number of "Instances" the activity took place.

Step 5,

Calculate the following equation on each of the consecutive selections.

$$T_i = \sum I (S_i H + H_i + P_i + P_c + C_c + M_c)$$

Step 6,

Finally add each of the instances of $'T_i'$ where $'T_i'$ is the "Total time" spent in the scanning activity for that scanning method.

Step 7,

Repeat these procedures for each of the scanning methods.

The Procedure for the Method Duration Moving and Scanning

Before you can undertake this procedure you must prepare the data logs as described in the three steps of 'Initial Processes'.

Step 4.

Create a list with the two actions of 'Moving' and 'Scanning' and label this column 'Action' (see yellow column), then label the column to the right 'Duration', in this column.

Activity	Duration	Action	Duration
F	10	Moving	21
S	30	Scanning	12
FR	5		
S	3		
F	11		
S	10		
FR	7		

Step 5.

In the 'Duration' column in red in the cell to the right of 'Moving' add the values from the 'Duration' column here in light blue, where the 'Activity' (dark blue), is one of the moving functions e.g., 'F', 'FR', 'R', 'BR' and 'B' etc..

Step 6.

In the 'Duration' column in red in the cell to the right of 'Scanning' add the values from the 'Duration' column here in light blue, where the 'Activity' (dark blue), is 'S'.

The Procedure for the Method Normalisation of opposite Selection

Step 1.

Create a list of all the available activities and label this column 'Action', then label the column to its right 'Occurrences'.

Step 2.

Count the number of times an 'Action' in the yellow column occurs in the 'Activity' column (shown here in blue) and enter this value in the cell to the right of the respective 'Action' in the green column.

Activity		Action	Occurrences
F		F	2
S		FR	1
FR		R	0
S		BR	0
F			

Step 2,

With regards to the 'Occurrences' of 'F' = "Forward" and 'B' = "Backward" these directions remain the same.

Step 3,

For each of the directions, which is on the left side take its opposite direction on the right side:

- "Forward-Left" and "Forward-Right"
- "Left" and "Right"
- "Backward-Left" and "Backward-Right",

then conduct 'Step 4' on each of the above pairs of directions.

Step 4,

In turn, take the 'Occurrences' of each pair of left and right directions, divide each of them by two, then add them together.

Step 5,

Conduct the same calculation as explained in 'Step 4', for each of the pairs listed in 'Step 3'.

The Procedure for the Method Path Profile

Step 1,

Take a large piece of graph paper and a pen or pencil. Locate the centre of the graph paper and place the nib in this location.

Step 2,

Reading directly from the data logs, look for the first movement and determine its duration.

Step 3,

On determining its direction and duration, draw a line the length determined by the duration e.g., if the movement was 15 seconds in duration then draw a line which includes 15 squares, to determine the direction of the line see the examples on the following page.

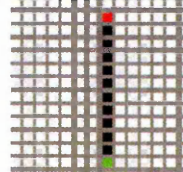
Step 4,

Repeat process 'Step 3' until the end of the data log file.

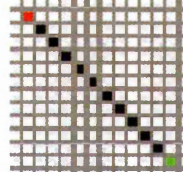
Logged Direction

Directions on Graph Paper
(Starting at Green and End at Red)

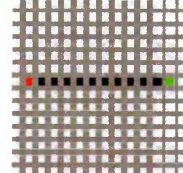
Forward



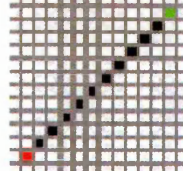
Forward Left



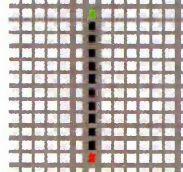
Left



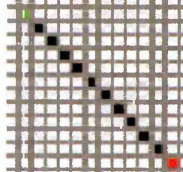
Backward Left



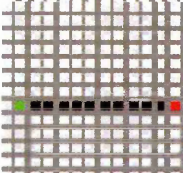
Backward



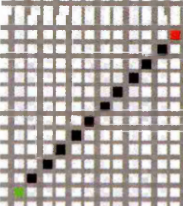
Backward Right



Right



Forward Right



Appendix D

Barnsley Wheelchair Interface's Configuration during each of the Experimental Process

Experiment 1

The Barnsley Wheelchair Interface Configuration.

[General]

DIRECTIONS = 4

ACTIVE_STYLE = both

SIZE = Large

START_ICON = uparrow

CLOCKWISE = yes

FORE_GROUND_COLOUR = 14

BACK_GROUND_COLOUR = 4

HIGHLIGHT_BOX_COLOUR = 10

CALLSETUP = no

SOUND = none

FORWARD_FIRST_SCANNING = yes

SWITCH_ERROR_TIME = 10000

RESPONSE_ERROR = 10

SAVE DATA = no

[Scanning]

NUMBER_OF_SWITCHES = 1

SLEEP_TIME = 2

SWITCH_HOLD_TIME = 0

SCAN_RATE = 700

PAUSE_ON_CONTINUE = 0

DISTANCE_TIME = 32000

OFF_SWITCH_HOLD_TIME = 300

[Communications]

SWITCH_PORT = 1016

Experiment 2

The Barnsley Wheelchair Interface Configuration.

[General]

DIRECTIONS = 8

ACTIVE_STYLE = both

SIZE = Large

START_ICON = uparrow

CLOCKWISE = no

FORE_GROUND_COLOUR = 14

BACK_GROUND_COLOUR = 4

HIGHLIGHT_BOX_COLOUR = 10

CALLSETUP = no

SOUND = none

FORWARD_FIRST_SCANNING = yes

SWITCH_ERROR_TIME = 10000

RESPONSE_ERROR = 10

SAVE DATA = yes

[Scanning]

NUMBER_OF_SWITCHES = 1

SLEEP_TIME = 2

SWITCH_HOLD_TIME = 0

SCAN_RATE = 700

PAUSE_ON_CONTINUE = 0

DISTANCE_TIME = 32000

OFF_SWITCH_HOLD_TIME = 300

[Communications]

SWITCH_PORT = 1016

Experiment 3

The Barnsley Wheelchair Interface Configuration.

[General]

DIRECTIONS = 8

ACTIVE_STYLE = box

SIZE = Large

START_ICON = centercell

CLOCKWISE = no

FORE_GROUND_COLOUR = 1

BACK_GROUND_COLOUR = 2

HIGHLIGHT_BOX_COLOUR = 12

CALLSETUP = yes

SOUND = none

FORWARD_FIRST_SCANNING = yes

SWITCH_ERROR_TIME = 10000

RESPONSE_ERROR = 10

SAVE DATA = yes

[Scanning]

NUMBER_OF_SWITCHES = 1

SLEEP_TIME = 3

SWITCH_HOLD_TIME = 200

SCAN_RATE = 2200

PAUSE_ON_CONTINUE = 500

DISTANCE_TIME = 5000

OFF_SWITCH_HOLD_TIME = 1000

[Communications]

SWITCH_PORT = 1016

Experiment 4

The Barnsley Wheelchair Interface Configuration.

[General]

DIRECTIONS = 8

ACTIVE_STYLE = box

SIZE = Large

START_ICON = centercell

CLOCKWISE = no

FORE_GROUND_COLOUR = 1

BACK_GROUND_COLOUR = 2

HIGHLIGHT_BOX_COLOUR = 12

CALLSETUP = yes

SOUND = none

FORWARD_FIRST_SCANNING = yes

SWITCH_ERROR_TIME = 10000

RESPONSE_ERROR = 10

SAVE DATA = yes

[Scanning]

NUMBER_OF_SWITCHES = 1

SLEEP_TIME = 3

SWITCH_HOLD_TIME = 200

SCAN_RATE = 2200

PAUSE_ON_CONTINUE = 500

DISTANCE_TIME = 5000

OFF_SWITCH_HOLD_TIME = 1000

[Communications]

SWITCH_PORT = 1016

Experiment 5

The Barnsley Wheelchair Interface Configuration.

[General]

DIRECTIONS = 8

ACTIVE_STYLE = box

SIZE = Large

START_ICON = centercell

CLOCKWISE = no

FORE_GROUND_COLOUR = 1

BACK_GROUND_COLOUR = 2

HIGHLIGHT_BOX_COLOUR = 12

CALLSETUP = yes

SOUND = none

FORWARD_FIRST_SCANNING = yes

SWITCH_ERROR_TIME = 10000

RESPONSE_ERROR = 10

SAVE DATA = yes

[Scanning]

NUMBER_OF_SWITCHES = 1

SLEEP_TIME = 3

SWITCH_HOLD_TIME = 200

SCAN_RATE = 2200

PAUSE_ON_CONTINUE = 500

DISTANCE_TIME = 5000

OFF_SWITCH_HOLD_TIME = 1000

[Communications]

SWITCH_PORT = 270

Appendix E

The Experimental Processes Raw Data Logs

Experiment 1

The Barnsley Wheelchair Interface generated raw Data Logs.

1,2,Tue,Jul,30,02:14:02,2002,drive.pif,DriverStarted
2,2,Tue,Jul,30,02:14:11,2002,drive.pif,SystemOff
3,2,Tue,Jul,30,02:14:12,2002,drive.pif,EndOfMovement
4,2,Tue,Jul,30,02:14:45,2002,drive.pif,SystemOn
5,2,Tue,Jul,30,02:14:47,2002,drive.pif,Forward
6,2,Tue,Jul,30,02:14:51,2002,drive.pif,EndOfMovement
7,2,Tue,Jul,30,02:14:54,2002,drive.pif,Left
8,2,Tue,Jul,30,02:14:56,2002,drive.pif,EndOfMovement
9,2,Tue,Jul,30,02:14:58,2002,drive.pif,Right
10,2,Tue,Jul,30,02:14:59,2002,drive.pif,EndOfMovement
11,2,Tue,Jul,30,02:15:01,2002,drive.pif,Forward
12,2,Tue,Jul,30,02:15:05,2002,drive.pif,EndOfMovement
13,2,Tue,Jul,30,02:15:08,2002,drive.pif,Right
14,2,Tue,Jul,30,02:15:09,2002,drive.pif,EndOfMovement
15,2,Tue,Jul,30,02:15:11,2002,drive.pif,Forward
16,2,Tue,Jul,30,02:15:11,2002,drive.pif,EndOfMovement
17,2,Tue,Jul,30,02:15:15,2002,drive.pif,Left
18,2,Tue,Jul,30,02:15:15,2002,drive.pif,EndOfMovement
19,2,Tue,Jul,30,02:15:17,2002,drive.pif,Backward
20,2,Tue,Jul,30,02:15:17,2002,drive.pif,EndOfMovement
21,2,Tue,Jul,30,02:15:21,2002,drive.pif,Left
22,2,Tue,Jul,30,02:15:21,2002,drive.pif,EndOfMovement
23,2,Tue,Jul,30,02:15:23,2002,drive.pif,Forward
24,2,Tue,Jul,30,02:15:24,2002,drive.pif,EndOfMovement
25,2,Tue,Jul,30,02:15:28,2002,drive.pif,Left
26,2,Tue,Jul,30,02:15:28,2002,drive.pif,EndOfMovement
27,2,Tue,Jul,30,02:15:30,2002,drive.pif,Forward
28,2,Tue,Jul,30,02:15:36,2002,drive.pif,EndOfMovement
29,2,Tue,Jul,30,02:15:39,2002,drive.pif,Right
30,2,Tue,Jul,30,02:15:40,2002,drive.pif,EndOfMovement
31,2,Tue,Jul,30,02:15:42,2002,drive.pif,Forward
32,2,Tue,Jul,30,02:15:46,2002,drive.pif,EndOfMovement
33,2,Tue,Jul,30,02:15:50,2002,drive.pif,Left
34,2,Tue,Jul,30,02:15:51,2002,drive.pif,EndOfMovement
35,2,Tue,Jul,30,02:15:52,2002,drive.pif,Forward
36,2,Tue,Jul,30,02:15:57,2002,drive.pif,EndOfMovement
37,2,Tue,Jul,30,02:16:00,2002,drive.pif,Right
38,2,Tue,Jul,30,02:16:01,2002,drive.pif,EndOfMovement
39,2,Tue,Jul,30,02:16:02,2002,drive.pif,Forward
40,2,Tue,Jul,30,02:16:08,2002,drive.pif,EndOfMovement
41,2,Tue,Jul,30,02:16:11,2002,drive.pif,Left
42,2,Tue,Jul,30,02:16:12,2002,drive.pif,EndOfMovement
43,2,Tue,Jul,30,02:16:14,2002,drive.pif,Forward
44,2,Tue,Jul,30,02:16:21,2002,drive.pif,EndOfMovement
45,2,Tue,Jul,30,02:16:23,2002,drive.pif,Right
46,2,Tue,Jul,30,02:16:24,2002,drive.pif,EndOfMovement

47,2,Tue,Jul,30,02:16:28,2002,drive.pif,DriverEnded

1,3,Tue,Jul,30,02:16:33,2002,drive.pif,DriverStarted
2,3,Tue,Jul,30,02:16:34,2002,drive.pif,Right
3,3,Tue,Jul,30,02:16:34,2002,drive.pif,EndOfMovement
4,3,Tue,Jul,30,02:16:37,2002,drive.pif,Right
5,3,Tue,Jul,30,02:16:37,2002,drive.pif,EndOfMovement
6,3,Tue,Jul,30,02:16:39,2002,drive.pif,Forward
7,3,Tue,Jul,30,02:16:44,2002,drive.pif,EndOfMovement
8,3,Tue,Jul,30,02:16:47,2002,drive.pif,Right
9,3,Tue,Jul,30,02:16:49,2002,drive.pif,EndOfMovement
10,3,Tue,Jul,30,02:16:51,2002,drive.pif,Forward
11,3,Tue,Jul,30,02:16:59,2002,drive.pif,EndOfMovement
12,3,Tue,Jul,30,02:17:00,2002,drive.pif,DriverEnded

1,4,Tue,Jul,30,02:17:05,2002,drive.pif,DriverStarted
2,4,Tue,Jul,30,02:17:11,2002,drive.pif,Right
3,4,Tue,Jul,30,02:17:12,2002,drive.pif,EndOfMovement
4,4,Tue,Jul,30,02:17:14,2002,drive.pif,Forward
5,4,Tue,Jul,30,02:17:16,2002,drive.pif,EndOfMovement
6,4,Tue,Jul,30,02:17:20,2002,drive.pif,Left
7,4,Tue,Jul,30,02:17:21,2002,drive.pif,EndOfMovement
8,4,Tue,Jul,30,02:17:23,2002,drive.pif,Forward
9,4,Tue,Jul,30,02:17:29,2002,drive.pif,EndOfMovement
10,4,Tue,Jul,30,02:17:30,2002,drive.pif,DriverEnded

1,5,Tue,Jul,30,02:17:33,2002,drive.pif,DriverStarted
2,5,Tue,Jul,30,02:17:36,2002,drive.pif,Left
3,5,Tue,Jul,30,02:17:37,2002,drive.pif,EndOfMovement
4,5,Tue,Jul,30,02:17:39,2002,drive.pif,Forward
5,5,Tue,Jul,30,02:17:57,2002,drive.pif,EndOfMovement
6,5,Tue,Jul,30,02:18:00,2002,drive.pif,Right
7,5,Tue,Jul,30,02:18:01,2002,drive.pif,EndOfMovement
8,5,Tue,Jul,30,02:18:03,2002,drive.pif,Forward
9,5,Tue,Jul,30,02:18:04,2002,drive.pif,EndOfMovement
10,5,Tue,Jul,30,02:18:10,2002,drive.pif,Forward
11,5,Tue,Jul,30,02:18:19,2002,drive.pif,EndOfMovement
12,5,Tue,Jul,30,02:18:21,2002,drive.pif,Right
13,5,Tue,Jul,30,02:18:22,2002,drive.pif,EndOfMovement
14,5,Tue,Jul,30,02:18:24,2002,drive.pif,Forward
15,5,Tue,Jul,30,02:18:35,2002,drive.pif,EndOfMovement
16,5,Tue,Jul,30,02:18:38,2002,drive.pif,Right
17,5,Tue,Jul,30,02:18:38,2002,drive.pif,EndOfMovement
18,5,Tue,Jul,30,02:18:40,2002,drive.pif,Forward
19,5,Tue,Jul,30,02:18:45,2002,drive.pif,EndOfMovement
20,5,Tue,Jul,30,02:18:48,2002,drive.pif,Right
21,5,Tue,Jul,30,02:18:49,2002,drive.pif,EndOfMovement
22,5,Tue,Jul,30,02:18:51,2002,drive.pif,Right
23,5,Tue,Jul,30,02:18:51,2002,drive.pif,EndOfMovement
24,5,Tue,Jul,30,02:18:53,2002,drive.pif,Forward
25,5,Tue,Jul,30,02:18:56,2002,drive.pif,EndOfMovement

26,5,Tue,Jul,30,02:19:00,2002,drive.pif,Left
27,5,Tue,Jul,30,02:19:01,2002,drive.pif,EndOfMovement
28,5,Tue,Jul,30,02:19:03,2002,drive.pif,Forward
29,5,Tue,Jul,30,02:19:05,2002,drive.pif,EndOfMovement
30,5,Tue,Jul,30,02:19:08,2002,drive.pif,Right
31,5,Tue,Jul,30,02:19:09,2002,drive.pif,EndOfMovement
32,5,Tue,Jul,30,02:19:11,2002,drive.pif,Forward
33,5,Tue,Jul,30,02:19:15,2002,drive.pif,EndOfMovement
34,5,Tue,Jul,30,02:19:21,2002,drive.pif,Forward
35,5,Tue,Jul,30,02:19:24,2002,drive.pif,EndOfMovement
36,5,Tue,Jul,30,02:19:28,2002,drive.pif,Backward
37,5,Tue,Jul,30,02:19:28,2002,drive.pif,EndOfMovement
38,5,Tue,Jul,30,02:19:32,2002,drive.pif,Left
39,5,Tue,Jul,30,02:19:33,2002,drive.pif,EndOfMovement
40,5,Tue,Jul,30,02:19:35,2002,drive.pif,Right
41,5,Tue,Jul,30,02:19:36,2002,drive.pif,EndOfMovement
42,5,Tue,Jul,30,02:19:38,2002,drive.pif,Forward
43,5,Tue,Jul,30,02:19:43,2002,drive.pif,EndOfMovement
44,5,Tue,Jul,30,02:19:46,2002,drive.pif,Right
45,5,Tue,Jul,30,02:19:47,2002,drive.pif,EndOfMovement
46,5,Tue,Jul,30,02:19:49,2002,drive.pif,Forward
47,5,Tue,Jul,30,02:19:55,2002,drive.pif,EndOfMovement
48,5,Tue,Jul,30,02:19:58,2002,drive.pif,Right
49,5,Tue,Jul,30,02:19:59,2002,drive.pif,EndOfMovement
50,5,Tue,Jul,30,02:20:01,2002,drive.pif,Forward
51,5,Tue,Jul,30,02:20:10,2002,drive.pif,EndOfMovement
52,5,Tue,Jul,30,02:20:13,2002,drive.pif,Right
53,5,Tue,Jul,30,02:20:14,2002,drive.pif,EndOfMovement
54,5,Tue,Jul,30,02:20:15,2002,drive.pif,Forward
55,5,Tue,Jul,30,02:20:18,2002,drive.pif,EndOfMovement
56,5,Tue,Jul,30,02:20:22,2002,drive.pif,Left
57,5,Tue,Jul,30,02:20:22,2002,drive.pif,EndOfMovement
58,5,Tue,Jul,30,02:20:24,2002,drive.pif,Forward
59,5,Tue,Jul,30,02:20:28,2002,drive.pif,EndOfMovement
60,5,Tue,Jul,30,02:20:31,2002,drive.pif,Right
61,5,Tue,Jul,30,02:20:32,2002,drive.pif,EndOfMovement
62,5,Tue,Jul,30,02:20:34,2002,drive.pif,Forward
63,5,Tue,Jul,30,02:20:42,2002,drive.pif,EndOfMovement
64,5,Tue,Jul,30,02:20:45,2002,drive.pif,Right
65,5,Tue,Jul,30,02:20:45,2002,drive.pif,EndOfMovement
66,5,Tue,Jul,30,02:20:47,2002,drive.pif,Forward
67,5,Tue,Jul,30,02:20:53,2002,drive.pif,EndOfMovement
68,5,Tue,Jul,30,02:20:56,2002,drive.pif,Right
69,5,Tue,Jul,30,02:20:59,2002,drive.pif,EndOfMovement
70,5,Tue,Jul,30,02:21:13,2002,drive.pif,SystemOff
71,5,Tue,Jul,30,02:23:23,2002,drive.pif,SystemOn
72,5,Tue,Jul,30,02:23:29,2002,drive.pif,Exit
73,5,Tue,Jul,30,02:23:29,2002,drive.pif,DriverEnded

Experiment 2

The Barnsley Wheelchair Interface generated raw Data Logs.

1,9,Tue,Jul,30,02:39:32,2002,drive.pif,DriverStarted
2,9,Tue,Jul,30,02:39:48,2002,drive.pif,SystemOff
3,9,Tue,Jul,30,02:39:49,2002,drive.pif,EndOfMovement
4,9,Tue,Jul,30,02:39:54,2002,drive.pif,SystemOn
5,9,Tue,Jul,30,02:39:57,2002,drive.pif,ForwardLeft
6,9,Tue,Jul,30,02:39:57,2002,drive.pif,EndOfMovement
7,9,Tue,Jul,30,02:39:59,2002,drive.pif,Forward
8,9,Tue,Jul,30,02:40:03,2002,drive.pif,EndOfMovement
9,9,Tue,Jul,30,02:40:06,2002,drive.pif,ForwardLeft
10,9,Tue,Jul,30,02:40:08,2002,drive.pif,EndOfMovement
11,9,Tue,Jul,30,02:40:10,2002,drive.pif,Forward
12,9,Tue,Jul,30,02:40:12,2002,drive.pif,EndOfMovement
13,9,Tue,Jul,30,02:40:15,2002,drive.pif,ForwardRight
14,9,Tue,Jul,30,02:40:16,2002,drive.pif,EndOfMovement
15,9,Tue,Jul,30,02:40:18,2002,drive.pif,Forward
16,9,Tue,Jul,30,02:40:18,2002,drive.pif,EndOfMovement
17,9,Tue,Jul,30,02:40:23,2002,drive.pif,ForwardLeft
18,9,Tue,Jul,30,02:40:24,2002,drive.pif,EndOfMovement
19,9,Tue,Jul,30,02:40:25,2002,drive.pif,Forward
20,9,Tue,Jul,30,02:40:28,2002,drive.pif,EndOfMovement
21,9,Tue,Jul,30,02:40:31,2002,drive.pif,ForwardLeft
22,9,Tue,Jul,30,02:40:31,2002,drive.pif,EndOfMovement
23,9,Tue,Jul,30,02:40:33,2002,drive.pif,Forward
24,9,Tue,Jul,30,02:40:34,2002,drive.pif,EndOfMovement
25,9,Tue,Jul,30,02:40:36,2002,drive.pif,ForwardLeft
26,9,Tue,Jul,30,02:40:36,2002,drive.pif,EndOfMovement
27,9,Tue,Jul,30,02:40:40,2002,drive.pif,ForwardRight
28,9,Tue,Jul,30,02:40:41,2002,drive.pif,EndOfMovement
29,9,Tue,Jul,30,02:40:42,2002,drive.pif,Forward
30,9,Tue,Jul,30,02:40:45,2002,drive.pif,EndOfMovement
31,9,Tue,Jul,30,02:40:49,2002,drive.pif,ForwardRight
32,9,Tue,Jul,30,02:40:49,2002,drive.pif,EndOfMovement
33,9,Tue,Jul,30,02:40:51,2002,drive.pif,Forward
34,9,Tue,Jul,30,02:40:57,2002,drive.pif,EndOfMovement
35,9,Tue,Jul,30,02:41:00,2002,drive.pif,ForwardRight
36,9,Tue,Jul,30,02:41:01,2002,drive.pif,EndOfMovement
37,9,Tue,Jul,30,02:41:03,2002,drive.pif,Forward
38,9,Tue,Jul,30,02:41:12,2002,drive.pif,EndOfMovement
39,9,Tue,Jul,30,02:41:16,2002,drive.pif,ForwardRight
40,9,Tue,Jul,30,02:41:17,2002,drive.pif,EndOfMovement
41,9,Tue,Jul,30,02:41:19,2002,drive.pif,Forward
42,9,Tue,Jul,30,02:41:30,2002,drive.pif,EndOfMovement
43,9,Tue,Jul,30,02:41:34,2002,drive.pif,ForwardRight
44,9,Tue,Jul,30,02:41:36,2002,drive.pif,EndOfMovement
45,9,Tue,Jul,30,02:41:38,2002,drive.pif,Forward
46,9,Tue,Jul,30,02:41:46,2002,drive.pif,EndOfMovement

47,9,Tue,Jul,30,02:41:50,2002,drive.pif,ForwardRight
48,9,Tue,Jul,30,02:41:51,2002,drive.pif,EndOfMovement
49,9,Tue,Jul,30,02:41:53,2002,drive.pif,Forward
50,9,Tue,Jul,30,02:41:57,2002,drive.pif,EndOfMovement
51,9,Tue,Jul,30,02:42:00,2002,drive.pif,ForwardLeft
52,9,Tue,Jul,30,02:42:01,2002,drive.pif,EndOfMovement
53,9,Tue,Jul,30,02:42:03,2002,drive.pif,Forward
54,9,Tue,Jul,30,02:42:07,2002,drive.pif,EndOfMovement
55,9,Tue,Jul,30,02:42:10,2002,drive.pif,ForwardLeft
56,9,Tue,Jul,30,02:42:11,2002,drive.pif,EndOfMovement
57,9,Tue,Jul,30,02:42:13,2002,drive.pif,Forward
58,9,Tue,Jul,30,02:42:17,2002,drive.pif,EndOfMovement
59,9,Tue,Jul,30,02:42:20,2002,drive.pif,ForwardRight
60,9,Tue,Jul,30,02:42:22,2002,drive.pif,EndOfMovement
61,9,Tue,Jul,30,02:42:24,2002,drive.pif,Forward
62,9,Tue,Jul,30,02:42:27,2002,drive.pif,EndOfMovement
63,9,Tue,Jul,30,02:42:30,2002,drive.pif,ForwardLeft
64,9,Tue,Jul,30,02:42:31,2002,drive.pif,EndOfMovement
65,9,Tue,Jul,30,02:42:33,2002,drive.pif,Forward
66,9,Tue,Jul,30,02:42:42,2002,drive.pif,EndOfMovement
67,9,Tue,Jul,30,02:42:46,2002,drive.pif,ForwardRight
68,9,Tue,Jul,30,02:42:47,2002,drive.pif,EndOfMovement
69,9,Tue,Jul,30,02:42:49,2002,drive.pif,Forward
70,9,Tue,Jul,30,02:43:00,2002,drive.pif,EndOfMovement
71,9,Tue,Jul,30,02:43:03,2002,drive.pif,ForwardRight
72,9,Tue,Jul,30,02:43:04,2002,drive.pif,EndOfMovement
73,9,Tue,Jul,30,02:43:06,2002,drive.pif,Forward
74,9,Tue,Jul,30,02:43:15,2002,drive.pif,EndOfMovement
75,9,Tue,Jul,30,02:43:18,2002,drive.pif,ForwardRight
76,9,Tue,Jul,30,02:43:19,2002,drive.pif,EndOfMovement
77,9,Tue,Jul,30,02:43:21,2002,drive.pif,Forward
78,9,Tue,Jul,30,02:43:22,2002,drive.pif,EndOfMovement
79,9,Tue,Jul,30,02:43:32,2002,drive.pif,ForwardLeft
80,9,Tue,Jul,30,02:43:33,2002,drive.pif,EndOfMovement
81,9,Tue,Jul,30,02:43:35,2002,drive.pif,Forward
82,9,Tue,Jul,30,02:43:38,2002,drive.pif,EndOfMovement
83,9,Tue,Jul,30,02:43:42,2002,drive.pif,ForwardRight
84,9,Tue,Jul,30,02:43:43,2002,drive.pif,EndOfMovement
85,9,Tue,Jul,30,02:43:45,2002,drive.pif,Forward
86,9,Tue,Jul,30,02:43:48,2002,drive.pif,EndOfMovement
87,9,Tue,Jul,30,02:43:51,2002,drive.pif,ForwardLeft
88,9,Tue,Jul,30,02:43:52,2002,drive.pif,EndOfMovement
89,9,Tue,Jul,30,02:43:53,2002,drive.pif,Forward
90,9,Tue,Jul,30,02:44:01,2002,drive.pif,EndOfMovement
91,9,Tue,Jul,30,02:44:05,2002,drive.pif,ForwardRight
92,9,Tue,Jul,30,02:44:06,2002,drive.pif,EndOfMovement
93,9,Tue,Jul,30,02:44:08,2002,drive.pif,Forward
94,9,Tue,Jul,30,02:44:11,2002,drive.pif,EndOfMovement
95,9,Tue,Jul,30,02:44:14,2002,drive.pif,ForwardLeft
96,9,Tue,Jul,30,02:44:16,2002,drive.pif,EndOfMovement
97,9,Tue,Jul,30,02:44:18,2002,drive.pif,Forward

98,9,Tue,Jul,30,02:44:19,2002,drive.pif,EndOfMovement
99,9,Tue,Jul,30,02:44:29,2002,drive.pif,Forward
100,9,Tue,Jul,30,02:44:34,2002,drive.pif,EndOfMovement
101,9,Tue,Jul,30,02:44:38,2002,drive.pif,ForwardRight
102,9,Tue,Jul,30,02:44:39,2002,drive.pif,EndOfMovement
103,9,Tue,Jul,30,02:44:41,2002,drive.pif,Forward
104,9,Tue,Jul,30,02:44:50,2002,drive.pif,EndOfMovement
105,9,Tue,Jul,30,02:44:54,2002,drive.pif,ForwardRight
106,9,Tue,Jul,30,02:44:54,2002,drive.pif,EndOfMovement
107,9,Tue,Jul,30,02:44:56,2002,drive.pif,Forward
108,9,Tue,Jul,30,02:45:02,2002,drive.pif,EndOfMovement
109,9,Tue,Jul,30,02:45:06,2002,drive.pif,ForwardRight
110,9,Tue,Jul,30,02:45:07,2002,drive.pif,EndOfMovement
111,9,Tue,Jul,30,02:45:09,2002,drive.pif,Forward
112,9,Tue,Jul,30,02:45:18,2002,drive.pif,EndOfMovement
113,9,Tue,Jul,30,02:45:22,2002,drive.pif,ForwardRight
114,9,Tue,Jul,30,02:45:22,2002,drive.pif,EndOfMovement
115,9,Tue,Jul,30,02:45:25,2002,drive.pif,ForwardLeft
116,9,Tue,Jul,30,02:45:25,2002,drive.pif,EndOfMovement
117,9,Tue,Jul,30,02:45:27,2002,drive.pif,Forward
118,9,Tue,Jul,30,02:45:36,2002,drive.pif,EndOfMovement
119,9,Tue,Jul,30,02:46:00,2002,drive.pif,SystemOff
120,9,Tue,Jul,30,02:51:43,2002,drive.pif,DriverEnded

Experiment 3

The Barnsley Wheelchair Interface generated raw Data Logs.

1,1,Tue,Jul,30,03:07:54,2002,drive.pif,DriverStarted
2,1,Tue,Jul,30,03:08:12,2002,drive.pif,SystemOff
3,1,Tue,Jul,30,03:08:13,2002,drive.pif,EndOfMovement
4,1,Tue,Jul,30,03:08:36,2002,drive.pif,SystemOn
5,1,Tue,Jul,30,03:08:38,2002,drive.pif,ForwardLeft
6,1,Tue,Jul,30,03:08:39,2002,drive.pif,EndOfMovement
7,1,Tue,Jul,30,03:08:41,2002,drive.pif,DriverEnded

1,2,Tue,Jul,30,03:08:44,2002,drive.pif,DriverStarted
2,2,Tue,Jul,30,03:08:46,2002,drive.pif,Forward
3,2,Tue,Jul,30,03:08:50,2002,drive.pif,EndOfMovement
4,2,Tue,Jul,30,03:08:53,2002,drive.pif,ForwardLeft
5,2,Tue,Jul,30,03:08:55,2002,drive.pif,EndOfMovement
6,2,Tue,Jul,30,03:09:06,2002,drive.pif,ForwardLeft
7,2,Tue,Jul,30,03:09:06,2002,drive.pif,EndOfMovement
8,2,Tue,Jul,30,03:09:10,2002,drive.pif,ForwardRight
9,2,Tue,Jul,30,03:09:11,2002,drive.pif,EndOfMovement
10,2,Tue,Jul,30,03:09:13,2002,drive.pif,Forward
11,2,Tue,Jul,30,03:09:15,2002,drive.pif,EndOfMovement
12,2,Tue,Jul,30,03:09:18,2002,drive.pif,ForwardLeft
13,2,Tue,Jul,30,03:09:18,2002,drive.pif,EndOfMovement
14,2,Tue,Jul,30,03:09:21,2002,drive.pif,Forward
15,2,Tue,Jul,30,03:09:29,2002,drive.pif,EndOfMovement
16,2,Tue,Jul,30,03:09:33,2002,drive.pif,ForwardRight
17,2,Tue,Jul,30,03:09:34,2002,drive.pif,EndOfMovement
18,2,Tue,Jul,30,03:09:36,2002,drive.pif,Forward
19,2,Tue,Jul,30,03:09:45,2002,drive.pif,EndOfMovement
20,2,Tue,Jul,30,03:09:49,2002,drive.pif,ForwardRight
21,2,Tue,Jul,30,03:09:49,2002,drive.pif,EndOfMovement
22,2,Tue,Jul,30,03:09:51,2002,drive.pif,Forward
23,2,Tue,Jul,30,03:10:00,2002,drive.pif,EndOfMovement
24,2,Tue,Jul,30,03:10:04,2002,drive.pif,ForwardRight
25,2,Tue,Jul,30,03:10:05,2002,drive.pif,EndOfMovement
26,2,Tue,Jul,30,03:10:08,2002,drive.pif,Forward
27,2,Tue,Jul,30,03:10:15,2002,drive.pif,EndOfMovement
28,2,Tue,Jul,30,03:10:18,2002,drive.pif,ForwardRight
29,2,Tue,Jul,30,03:10:21,2002,drive.pif,EndOfMovement
30,2,Tue,Jul,30,03:10:23,2002,drive.pif,Forward
31,2,Tue,Jul,30,03:10:29,2002,drive.pif,EndOfMovement
32,2,Tue,Jul,30,03:10:32,2002,drive.pif,ForwardLeft
33,2,Tue,Jul,30,03:10:33,2002,drive.pif,EndOfMovement
34,2,Tue,Jul,30,03:10:35,2002,drive.pif,Forward
35,2,Tue,Jul,30,03:10:40,2002,drive.pif,EndOfMovement
36,2,Tue,Jul,30,03:10:44,2002,drive.pif,ForwardRight
37,2,Tue,Jul,30,03:10:45,2002,drive.pif,EndOfMovement
38,2,Tue,Jul,30,03:10:47,2002,drive.pif,Forward

39,2,Tue,Jul,30,03:10:52,2002,drive.pif,EndOfMovement
40,2,Tue,Jul,30,03:10:55,2002,drive.pif,ForwardLeft
41,2,Tue,Jul,30,03:10:57,2002,drive.pif,EndOfMovement
42,2,Tue,Jul,30,03:10:58,2002,drive.pif,DriverEnded

1,3,Tue,Jul,30,03:11:01,2002,drive.pif,DriverStarted
2,3,Tue,Jul,30,03:11:03,2002,drive.pif,Forward
3,3,Tue,Jul,30,03:11:21,2002,drive.pif,EndOfMovement
4,3,Tue,Jul,30,03:11:25,2002,drive.pif,ForwardRight
5,3,Tue,Jul,30,03:11:26,2002,drive.pif,EndOfMovement
6,3,Tue,Jul,30,03:11:28,2002,drive.pif,Forward
7,3,Tue,Jul,30,03:11:41,2002,drive.pif,EndOfMovement
8,3,Tue,Jul,30,03:11:45,2002,drive.pif,ForwardRight
9,3,Tue,Jul,30,03:11:46,2002,drive.pif,EndOfMovement
10,3,Tue,Jul,30,03:11:48,2002,drive.pif,Forward
11,3,Tue,Jul,30,03:11:53,2002,drive.pif,EndOfMovement
12,3,Tue,Jul,30,03:11:56,2002,drive.pif,ForwardLeft
13,3,Tue,Jul,30,03:11:57,2002,drive.pif,EndOfMovement
14,3,Tue,Jul,30,03:11:59,2002,drive.pif,Forward
15,3,Tue,Jul,30,03:12:06,2002,drive.pif,EndOfMovement
16,3,Tue,Jul,30,03:12:10,2002,drive.pif,ForwardRight
17,3,Tue,Jul,30,03:12:11,2002,drive.pif,EndOfMovement
18,3,Tue,Jul,30,03:12:13,2002,drive.pif,Forward
19,3,Tue,Jul,30,03:12:23,2002,drive.pif,EndOfMovement
20,3,Tue,Jul,30,03:12:26,2002,drive.pif,ForwardLeft
21,3,Tue,Jul,30,03:12:27,2002,drive.pif,EndOfMovement
22,3,Tue,Jul,30,03:12:30,2002,drive.pif,Forward
23,3,Tue,Jul,30,03:12:44,2002,drive.pif,EndOfMovement
24,3,Tue,Jul,30,03:12:45,2002,drive.pif,DriverEnded

1,4,Tue,Jul,30,03:12:48,2002,drive.pif,DriverStarted
2,4,Tue,Jul,30,03:12:51,2002,drive.pif,ForwardRight
3,4,Tue,Jul,30,03:12:51,2002,drive.pif,EndOfMovement
4,4,Tue,Jul,30,03:12:54,2002,drive.pif,Forward
5,4,Tue,Jul,30,03:12:59,2002,drive.pif,EndOfMovement
6,4,Tue,Jul,30,03:13:03,2002,drive.pif,ForwardRight
7,4,Tue,Jul,30,03:13:04,2002,drive.pif,EndOfMovement
8,4,Tue,Jul,30,03:13:06,2002,drive.pif,Forward
9,4,Tue,Jul,30,03:13:16,2002,drive.pif,EndOfMovement
10,4,Tue,Jul,30,03:13:20,2002,drive.pif,ForwardRight
11,4,Tue,Jul,30,03:13:21,2002,drive.pif,EndOfMovement
12,4,Tue,Jul,30,03:13:23,2002,drive.pif,Forward
13,4,Tue,Jul,30,03:13:34,2002,drive.pif,EndOfMovement
14,4,Tue,Jul,30,03:13:38,2002,drive.pif,DriverEnded

Experiment 4

The Barnsley Wheelchair Interface generated raw Data Logs.

1,1,Tue,Sep,03,14:19:01,2002,drive.pif,DriverStarted
2,1,Tue,Sep,03,14:20:14,2002,drive.pif,SystemOff
3,1,Tue,Sep,03,14:20:17,2002,drive.pif,EndOfMovement
4,1,Tue,Sep,03,14:20:58,2002,drive.pif,SystemOn
5,1,Tue,Sep,03,14:21:01,2002,drive.pif,Forward
6,1,Tue,Sep,03,14:21:05,2002,drive.pif,EndOfMovement
7,1,Tue,Sep,03,14:21:11,2002,drive.pif,ForwardLeft
8,1,Tue,Sep,03,14:21:12,2002,drive.pif,EndOfMovement
9,1,Tue,Sep,03,14:21:16,2002,drive.pif,Forward
10,1,Tue,Sep,03,14:21:19,2002,drive.pif,EndOfMovement
11,1,Tue,Sep,03,14:21:28,2002,drive.pif,ForwardRight
12,1,Tue,Sep,03,14:21:29,2002,drive.pif,EndOfMovement
13,1,Tue,Sep,03,14:21:32,2002,drive.pif,Forward
14,1,Tue,Sep,03,14:21:34,2002,drive.pif,EndOfMovement
15,1,Tue,Sep,03,14:21:40,2002,drive.pif,ForwardLeft
16,1,Tue,Sep,03,14:21:41,2002,drive.pif,EndOfMovement
17,1,Tue,Sep,03,14:21:42,2002,drive.pif,ForwardLeft
18,1,Tue,Sep,03,14:21:43,2002,drive.pif,EndOfMovement
19,1,Tue,Sep,03,14:21:46,2002,drive.pif,Forward
20,1,Tue,Sep,03,14:21:54,2002,drive.pif,EndOfMovement
21,1,Tue,Sep,03,14:22:03,2002,drive.pif,ForwardRight
22,1,Tue,Sep,03,14:22:04,2002,drive.pif,EndOfMovement
23,1,Tue,Sep,03,14:22:07,2002,drive.pif,Forward
24,1,Tue,Sep,03,14:22:18,2002,drive.pif,EndOfMovement
25,1,Tue,Sep,03,14:22:27,2002,drive.pif,ForwardRight
26,1,Tue,Sep,03,14:22:28,2002,drive.pif,EndOfMovement
27,1,Tue,Sep,03,14:22:31,2002,drive.pif,Forward
28,1,Tue,Sep,03,14:22:42,2002,drive.pif,EndOfMovement
29,1,Tue,Sep,03,14:22:50,2002,drive.pif,ForwardRight
30,1,Tue,Sep,03,14:22:53,2002,drive.pif,EndOfMovement
31,1,Tue,Sep,03,14:22:56,2002,drive.pif,Forward
32,1,Tue,Sep,03,14:23:06,2002,drive.pif,EndOfMovement
33,1,Tue,Sep,03,14:23:14,2002,drive.pif,ForwardRight
34,1,Tue,Sep,03,14:23:15,2002,drive.pif,EndOfMovement
35,1,Tue,Sep,03,14:23:19,2002,drive.pif,Forward
36,1,Tue,Sep,03,14:23:26,2002,drive.pif,EndOfMovement
37,1,Tue,Sep,03,14:23:32,2002,drive.pif,ForwardLeft
38,1,Tue,Sep,03,14:23:33,2002,drive.pif,EndOfMovement
39,1,Tue,Sep,03,14:23:37,2002,drive.pif,Forward
40,1,Tue,Sep,03,14:23:42,2002,drive.pif,EndOfMovement
41,1,Tue,Sep,03,14:23:51,2002,drive.pif,ForwardRight
42,1,Tue,Sep,03,14:23:52,2002,drive.pif,EndOfMovement
43,1,Tue,Sep,03,14:23:55,2002,drive.pif,DriverEnded

1,2,Tue,Sep,03,14:24:00,2002,drive.pif,DriverStarted

2,2,Tue,Sep,03,14:24:02,2002,drive.pif,Forward
3,2,Tue,Sep,03,14:24:16,2002,drive.pif,EndOfMovement
4,2,Tue,Sep,03,14:24:24,2002,drive.pif,ForwardRight
5,2,Tue,Sep,03,14:24:25,2002,drive.pif,EndOfMovement
6,2,Tue,Sep,03,14:24:28,2002,drive.pif,Forward
7,2,Tue,Sep,03,14:24:34,2002,drive.pif,EndOfMovement
8,2,Tue,Sep,03,14:24:43,2002,drive.pif,ForwardRight
9,2,Tue,Sep,03,14:24:43,2002,drive.pif,EndOfMovement
10,2,Tue,Sep,03,14:24:48,2002,drive.pif,ForwardRight
11,2,Tue,Sep,03,14:25:01,2002,drive.pif,EndOfMovement
12,2,Tue,Sep,03,14:25:09,2002,drive.pif,ForwardRight
13,2,Tue,Sep,03,14:25:10,2002,drive.pif,EndOfMovement
14,2,Tue,Sep,03,14:25:14,2002,drive.pif,Forward
15,2,Tue,Sep,03,14:25:29,2002,drive.pif,EndOfMovement
16,2,Tue,Sep,03,14:25:37,2002,drive.pif,ForwardRight
17,2,Tue,Sep,03,14:25:38,2002,drive.pif,EndOfMovement
18,2,Tue,Sep,03,14:25:42,2002,drive.pif,Forward
19,2,Tue,Sep,03,14:25:49,2002,drive.pif,EndOfMovement
20,2,Tue,Sep,03,14:25:55,2002,drive.pif,ForwardLeft
21,2,Tue,Sep,03,14:25:56,2002,drive.pif,EndOfMovement
22,2,Tue,Sep,03,14:26:00,2002,drive.pif,Forward
23,2,Tue,Sep,03,14:26:12,2002,drive.pif,EndOfMovement
24,2,Tue,Sep,03,14:26:20,2002,drive.pif,ForwardRight
25,2,Tue,Sep,03,14:26:22,2002,drive.pif,EndOfMovement
26,2,Tue,Sep,03,14:26:25,2002,drive.pif,Forward
27,2,Tue,Sep,03,14:26:35,2002,drive.pif,EndOfMovement
28,2,Tue,Sep,03,14:26:44,2002,drive.pif,ForwardRight
29,2,Tue,Sep,03,14:26:44,2002,drive.pif,EndOfMovement
30,2,Tue,Sep,03,14:26:45,2002,drive.pif,ForwardRight
31,2,Tue,Sep,03,14:26:46,2002,drive.pif,EndOfMovement
32,2,Tue,Sep,03,14:26:49,2002,drive.pif,Forward
33,2,Tue,Sep,03,14:26:53,2002,drive.pif,EndOfMovement
34,2,Tue,Sep,03,14:26:59,2002,drive.pif,ForwardLeft
35,2,Tue,Sep,03,14:26:59,2002,drive.pif,EndOfMovement
36,2,Tue,Sep,03,14:27:03,2002,drive.pif,Forward
37,2,Tue,Sep,03,14:27:11,2002,drive.pif,EndOfMovement
38,2,Tue,Sep,03,14:27:20,2002,drive.pif,ForwardRight
39,2,Tue,Sep,03,14:27:21,2002,drive.pif,EndOfMovement
40,2,Tue,Sep,03,14:27:24,2002,drive.pif,Forward
41,2,Tue,Sep,03,14:27:30,2002,drive.pif,EndOfMovement
42,2,Tue,Sep,03,14:27:43,2002,drive.pif,Right
43,2,Tue,Sep,03,14:27:46,2002,drive.pif,EndOfMovement
44,2,Tue,Sep,03,14:27:50,2002,drive.pif,DriverEnded

Experiment 5

The Barnsley Wheelchair Interface generated raw Data Logs.

1,9,Mon,Aug,19,15:03:13,2002,drive.pif,DriverStarted
2,9,Mon,Aug,19,15:03:15,2002,drive.pif,Forward
3,9,Mon,Aug,19,15:03:15,2002,drive.pif,EndOfMovement
4,9,Mon,Aug,19,15:03:17,2002,drive.pif,Forward
5,9,Mon,Aug,19,15:03:18,2002,drive.pif,EndOfMovement
6,9,Mon,Aug,19,15:03:20,2002,drive.pif,Forward
7,9,Mon,Aug,19,15:03:21,2002,drive.pif,EndOfMovement
8,9,Mon,Aug,19,15:03:22,2002,drive.pif,Forward
9,9,Mon,Aug,19,15:03:25,2002,drive.pif,EndOfMovement
10,9,Mon,Aug,19,15:03:29,2002,drive.pif,Forward
11,9,Mon,Aug,19,15:03:30,2002,drive.pif,EndOfMovement
12,9,Mon,Aug,19,15:03:37,2002,drive.pif,ForwardLeft
13,9,Mon,Aug,19,15:03:39,2002,drive.pif,EndOfMovement
14,9,Mon,Aug,19,15:03:43,2002,drive.pif,Forward
15,9,Mon,Aug,19,15:03:46,2002,drive.pif,EndOfMovement
16,9,Mon,Aug,19,15:03:48,2002,drive.pif,Forward
17,9,Mon,Aug,19,15:03:48,2002,drive.pif,EndOfMovement
18,9,Mon,Aug,19,15:03:54,2002,drive.pif,ForwardLeft
19,9,Mon,Aug,19,15:03:54,2002,drive.pif,EndOfMovement
20,9,Mon,Aug,19,15:03:58,2002,drive.pif,ForwardLeft
21,9,Mon,Aug,19,15:03:58,2002,drive.pif,EndOfMovement
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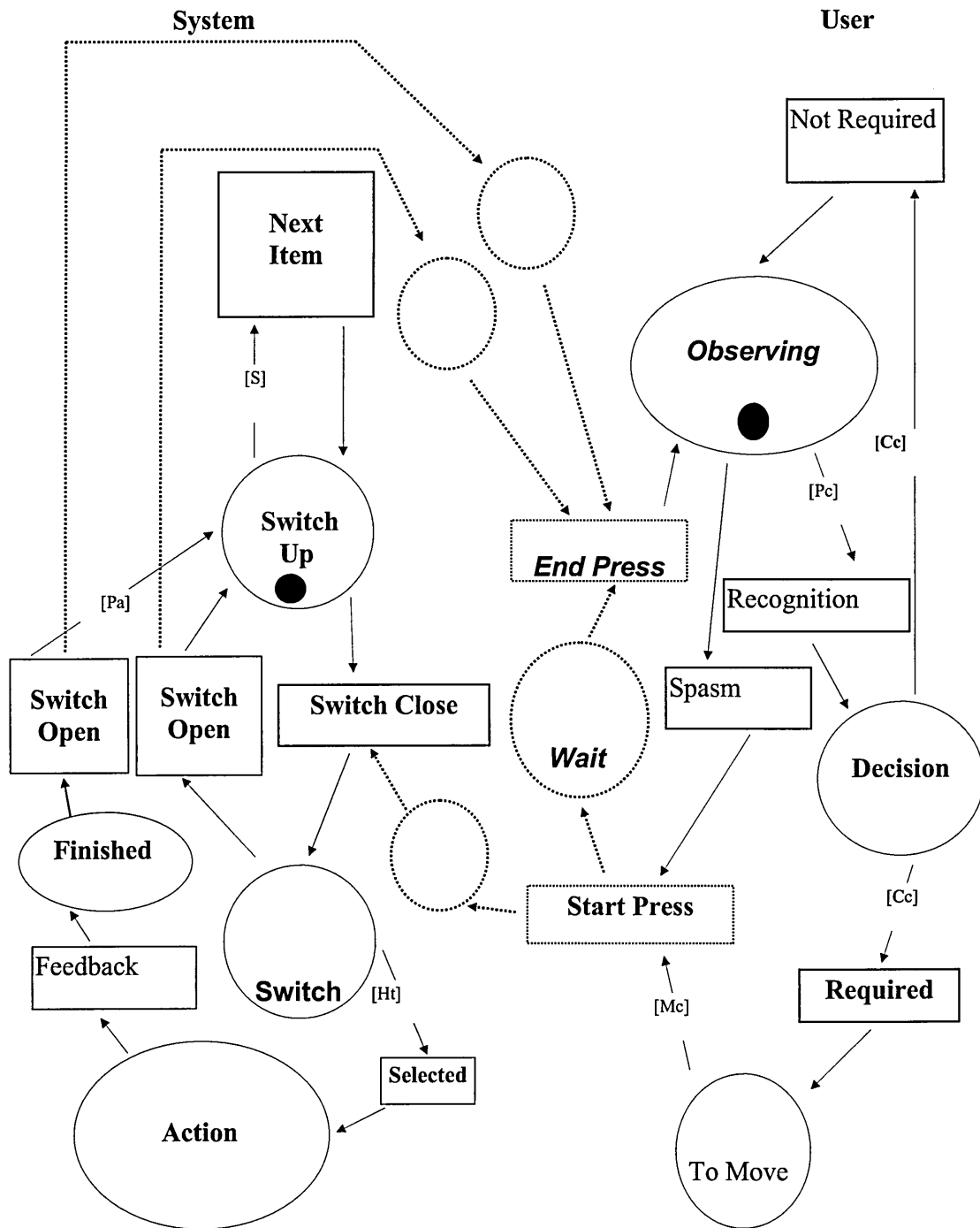
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Appendix F

Modelling Using Petri-Nets



A Model of User and System Interaction of a One Switch System

The tokens are moved around their respective systems on the opening and closure of the switch respecting the timing constraints (depicted in square braces). The attributes, Mc (Motor Cycle), Pc (Perception Cycle), Cc (Cognitive Cycle) are times suggested in [5], and the Ht (Hold Down Time), Pa (Post Acceptance time) and S (Scan duration) are attributes defined within the configuration of BASE.

Appendix G

Transfer Document From MPhil To PhD

Content

Section	Page
1. Motivation and Background of the Project	4
2. Context of the Research	5
3. Prior To The Initial Stages of the Project	6
3.1. Barnsley Active Switch Environment (BASE)	6
4. Initial Stages of the Project	7
4.1. Initial Literary Search	7
4.2. Deeper understanding of the domain	7
4.3. Research Proposal in the “RF 1”	8
5. Obtain information on the System Usage	9
5.1. Talking	10
5.2. Barnsley Wheelchair Interface (BWI) Driving Component	11
5.3. BWI, Enhancement into a Real-Time-Data logging tool	12
6. Investigated Analysis Techniques	13
6.1. Timed Petri Nets	13
6.1.1. Modelling the User and System	14
6.1.2. Analysis Purpose	14
6.2. GOMS Modelling	15
6.3. Erroneous Selections Modelling	16
6.4. Scan Method Modelling	17
7. Evaluation Tools and Utilities	19
7.1. Switch Environment Assessment Tool (SEAT)	19
7.2. BWI, Mapper	20

Section	Page
8. Presentations and Other Research Work	22
9. The Ways Forward	23
9.1. Process of Knowledge Formation and Use	23
9.1.1. Level 1	24
9.1.2. Level 2	25
9.2. The Knowledge Base System	25
9.2.1. Prescription of New Systems	26
9.2.2. Analysing Existing Systems	26
9.3. The Objective	28
10. Aspects felt to be at PhD Level	29
11. Plan of Remaining Project's Objectives	31
12. References	32

APPENDICES

Description	Page
A. Application to the Research Ethics Committee	35
B. Barnsley Wheelchair Interface Attributes	54
C. Switch Based Application Attributes	56
D. Switch Environment Assessment Tool Attributes	58

Figure Content

Description	Page
1. Pictorial Scanning Menu, BASE	6
2. An example of BASE usage data logs	10
3. The Barnsley Wheelchair Interface, (BWI) display	11
4. The BWI “Exit First, Clockwise Highlight Method”	11
5. The BWI “Forward Bias, Forward First, Anti-Clockwise Highlight Method”	12
6. An example extract of BWI data	12
7. Timed Petri Nets Modelling of the User and System Combined	14
8. State transition showing minimal times for erroneous free use	15
9. Accumulated Erroneous Selections going into Talk from BASE logs	16
10. Accumulated Erroneous Selections going into Drive from BASE logs	17
11. Theoretical time spent scanning	18
12. Time Ratio to Degree of Turn	20
13. The Knowledge Based Model	24
14. Prescribing a System	26
15. Analysing the Sets Performance	27

Table Content

Description	Page
1. Conventional and Suitability of Analysis Techniques for the Evaluation Methods, of people that have physical, sensory, visual, auditory disabilities	9
2. Percentage of erroneous selections made each month, over a six-month period	16
4. Possible visualisation patterns from BWI Mapper	20

1. Motivation and Background of the Project

The researcher is employed by the Clinical Engineering Service (CES) at Barnsley District General Hospital (BDGH). Part of the duties is to create and configure Integrated Electronic Assistive Technology (IEAT) for the severely physically disabled. The researcher became aware of the lack of basic knowledge in the following areas of the prescription and use of IEAT: -

- Were the systems being used by the users?
- Was the configuration optimised for the individual user?
- How much redundancy is there in the system?
- If there is redundancy, could it be used to provide useful functionality?

This report and the project aims, in the long term, is to provide tools and utilises to assist with answering these questions, with regards to prescribing, configuring and the use of IEAT. The following hypothesis was created in a report prior to the beginning of the project and this outlines the objectives of the investigation.

“The collection of ‘Real-Time-Data’, will increase the validation and verification of the functional needs of an individual within an integrated system. This will provide the professional bodies with an insight into the system’s day to day use, which will reduce the overall prescription time for that individual and others in the future.”

“By analysing the ‘Real-Time-Data’ the integrated system will over a prolonged period of time, be able to pre-empt the users day to day needs. It will also reduce the selection time and the need for professional bodies to reconfigure the system within its entirety.”

[O'Neill. P, “Enhancement of an Integrated System”, 1998, p42]

This hypothesis is discussed in detail in section “4.2. Deeper understanding of the domain”, of this report.

2. Context of the Research

The research is a collaborative venture between the CES at BDGH and the Computing Research Centre (CRC) at Sheffield Hallam University (SHU). It is to be carried out by the author of this document whom has been employed by CES for four years, creating and configuring Integrated Electronic Assistive Technology (IEAT). The research builds on the work of Prof. Mark Hawley and his team at CES, who assess the needs of people with severe and multiple physical and sensory disabilities. They have developed experience in meeting individual's prescriptions by customising and integrating currently available off the shelf Electronic Assistive Technology (EAT).

The IEAT discussed within this report to the best of the authors knowledge, is the first software base integrated system, both nationally and internationally. This provides CES and the author with a perfect opportunity to increase the professional body's knowledge. These gains in the knowledge of each of the single components that make up the IEAT and the IEAT as a whole should reduce the overall prescription time, plus enhance the individual's functionality.

Although, a large amount of research as been conducted in the area of HCI, very little of this research is related to people whom have severe and multiple physical and sensory disabilities. Therefore, this project intends to address this imbalance by providing tools and utilities to assist with the prescription of these systems.

The research is to analyse the ways in which IEAT is used, with the motivation to reduce the prescription time and improve the efficiency for the users of IEAT. This analysis is conducted by collecting information about the user's usage of the system; e.g., communications and actions selected by the user are recorded. Due to the collection of this information, an ethical issue arose and became a major feature of the research within the early stages of the project. To satisfy these ethical issues an application to the Barnsley District General Hospital NHS Trust Research Ethics Committee was constructed and submitted. (see Appendix A) With the approval of the Research Ethics Committee at Barnsley the project could commence. A number of usual constraints were placed on the project by the ethics committee: -

- Confidentiality of the subject's personal details.
- Confidentiality with regards to the logged information, which remains the property of the subject.
- The subjects have the right to remove themselves from the project.
- The subject has the right to remove their data logs.

It is also important to point out that the researcher undertaking this project is highly involved through his position in CES at BDGH in prescribing and maintaining the system for a twelve-year-old with athetoid cerebral palsy. This twelve-year-old is highly reliant upon the system for the individual's day to day living.

3. Prior To The Initial Stages of the Project

Prior to the commencement of the research project, a client of CES required the functionality of task swapping between speech and mobility applications, via a switch. With this need, came the birth of the Barnsley Active Switch Environment (BASE), a pictorial “Windows Task Manager” and a “Windows” based IEAT.

3.1. Barnsley Active Switch Environment (BASE)

The BASE application essentially enables severely disabled users who are only able to operate a single switch input device to swap between applications using a pictorial scanning menu. (For example, see Figure 1). Associated with each of the pictures is an application to enable the individual to perform a particular function e.g. Speak, Move, etc. With the particular item highlighted and the user input switch closed the application is started. BASE may be recalled with the termination of the active application or the continuation of a switch closure, for a predetermined period of time.

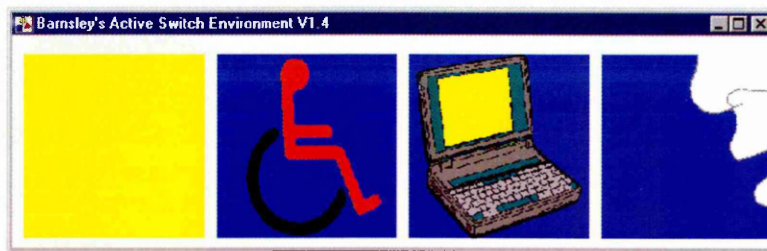


Figure 1. Pictorial Scanning Menu, BASE

The researcher while creating and testing the application for any errors within the code was made aware of how frustrating it must be for the users of BASE to live with on a day to day basis. This was partly due to the time spent waiting for the required item to be highlighted before making the desired selection. These delays were caused due to the clinician's lack of knowledge and awareness of the individuals required functionality and optimum settings for the attributes e.g. scan rate, hold down time etc.. The lack of knowledge, quantifiable information and tools to assist with the prescription process of IEAT became apparent due to the limited research that has been undertaken within the domain.

The researcher sees a need to give the clinician and therapist a better knowledge and understanding of this domain. After discussing these thoughts and feelings with colleagues, it was agreed that a research project should be undertaken to investigate the prescription and use of IEAT. It was at this point that the original hypothesis was written. (see section 1 of this document)

4. Initial Stages of the Project

4.1. Initial Literary Search

At the commencement of the project, colleagues presented the researcher with literature that had been published by themselves, (Hawley et al, 1992; Hawley et al, 1994; Cudd et al, 1995; Cherry et al, 1995). With the above literature and a comprehensive, search carried out by the researcher, it became apparent that several authors had highlighted the need for models and evaluation methods for IEAT when used in the field. (Rosen, Goodenough-Trepagnier, 1989; Hawley 1995; Cherry et al, 1996) Past and present methods of evaluation are mainly expert assessment with some field observation and trial and error. Each of these could benefit from the availability of more objective quantifiable information about IEAT use.

“Although the development of technology associated with integrated solutions is now well advanced, the development of service models specifically designed to facilitate the provision of such complex systems is lagging behind. This paper describes a service model which has been established in Barnsley UK for the development and provision of integrated assistive systems using a client-centred multi-disciplinary approach, involving the engineer in a key role. The client-centred approach to the provision of technology, as the name suggests, places the requirements of the client and not those of the providers or of the technology at the centre of the process. In order to deliver a client-centred service, multi-disciplinary input is required, the local teams consisting of physiotherapist, occupational therapist, speech and language therapist, clinical engineer, doctor, social worker and counsellor.”

[Hawley M S, 1995, p376]

After analysing the results of searches with the criteria of ‘assistive technology, modelling and evaluation’, a considerable number of publications on conventional methods became apparent. (Card et al, 1978; Manenica, 1987; Yamagishidi, 1987; Fairhurst, Stephanidis, 1988; Wright et al, 1989; Dix et al 1993; Treu, 1994; Stary, 1997) However, none of the literature obtained, focussed on modelling and evaluation of individuals whom have severe and multiple physical and sensory disabilities.

Again another literature search was carried out, using the keywords of ‘augmentative communication and modelling’; this again presented the researcher with numerous papers for investigation. (Kieras, 1988; Fairhurst, Stephanidis, 1989; Benyon, Green, 1995; Butterworth et al, 1998) Although some parts contained within the selected literature would have relevance to the research project, they did not investigate the domain in depth. These mainly focussed on the linguistics and overview of accessing this technology.

4.2. Deeper understanding of the domain

From the time of the original concept of the research project, to the writing of the “Technical Report for Supervisors” (O'Neill P. (1998)), the research had a slight change in direction. Once the initial literature searches had been conducted there was a change of direction. This was due to a deeper understanding of the domain and the acknowledgement of the scale of the original hypotheses. Therefore, the first statement shown below of the original hypotheses was considered the overview of the research project.

Statement 1.

“The collection of ‘Real-Time-Data’, will increase the validation and verification of the functional needs of an individual within an integrated system. This will provide the professional bodies with an insight into the system’s day to day use, which will reduce the overall prescription time for that individual and others in the future.”

[O’Neill. P, “Enhancement of an Integrated System”, 1998, p42]

The second statement should be considered as an enhancement outside the scope of the PhD programme.

Statement 2.

“By analysing the ‘Real-Time-Data’ the integrated system will over a prolonged period of time, be able to pre-empt the users day to day needs. It will also reduce the selection time and the need for professional bodies to reconfigure the system within its entirety.”

[O’Neill. P, “Enhancement of an Integrated System”, 1998, p42]

4.3. Research Proposal in the “RF 1”**Aims**

To develop a better understanding of the issues surrounding service prescription in integrated computerised systems for people with severe physical disabilities and to develop a toolset, to support the prescription of IEAT.

Objectives

- To develop a model of use and toolset to assist in improving usability requirements specification and reduce prescription time
- To develop a data collection tool which aims to provide information regarding usage of assistive technology devices
- To evaluate the model and toolset developed based upon the “real time” usage data

Subsequent sections within this document describe the work to fulfil these objectives.

5. Obtaining information on the System Usage

Other researchers have concerned themselves with mainstream evaluation methods such as Co-operative evaluation. These do not take in to consideration people that have physical, sensory, visual, auditory disabilities. The user group’s limitations are shown in table 1, in the section labelled “Method Suitable for User Group” : -

	Conventional Method Used					Method Suitability for User Group				
	User Notebook	Computer Logging	Video Recording	Audio Recording	Pencil and Paper	User Notebook	Computer Logging	Video Recording	Audio Recording	Pencil and Paper
Analysis Techniques										
Think Aloud	-	-	✓	✓	-	-	-	✗	✗	-
Post Walkthrough	✓	-	✓	✓	-	-	-	✗	✗	-
Query	✓	-	✓	✓	✓	✗	-	⚠	✗	✗
Questionnaire (Scaleable)	-	-	-	-	✓	-	-	-	-	⚠
Questionnaire (Multi-Choice)	-	-	-	-	✓	-	-	-	-	⚠
Questionnaire (Open ended)	-	-	-	-	✓	-	-	-	-	✗
Questionnaire (Ranked)	-	-	-	-	✓	-	-	-	-	⚠
Computer Data Logs	-	✓	-	-	-	-	✓	-	-	-

Table 1. Conventional and Suitability of Analysis Techniques for the Evaluation Methods, of people that have physical, sensory, visual, auditory disabilities.

Symbols Explanation:-

Where – is None Applicable, ✓ is Possible, ✗ is NOT Possible and ⚠ is With Difficulty.

It is important to note that the “With Difficulty”, symbol is highly dependent upon the design of the questionnaire or query. For example, the user must be presented with a question that only requires a Boolean response e.g., “Yes”, “No”, “True” or “False”. In the situation where a questionnaire gives the possibility of multiple responses e.g. “Multi-choice Questionnaires”, each possible choice would require the user to respond with yes or no.

Clearly shown on the table 1 above, there is only one possible evaluation method that presents itself for use with this user group. The other methods such as the questionnaires marked with the symbol “With Difficulty”, would be possible but particularly hard to apply with the user group for the following reasons. Comprehensive dialog between assessor and user is not always possible, as the system itself is often the user's main communication aid. This makes conversation highly time consuming and physically demanding on the user. Other assessment methods such as design experimentation can be highly interventionist for users who are highly reliant upon the IEAT and have acquired skills to work with particular configurations. Therefore, logging the systems usage is the chosen evaluation method. BASE was extended to include a data recorder, which would monitor the item being selected by the user. Each time a selection is made a log is created and stored, recording attributes, including: session number, date, time and the item selected (see Figure 2).

1,	1,	Sat,	Jun,	19,	10:18:16,	2001,	Start
2,	1,	Sat,	Jun,	19,	10:40:32,	2001,	Scanning
3,	1,	Sat,	Jun,	19,	10:40:33,	2001,	Drive
4,	1,	Sat,	Jun,	19,	10:42:09,	2001,	Scanning
5,	1,	Sat,	Jun,	19,	10:42:12,	2001,	Talk
6,	1,	Sat,	Jun,	19,	10:42:38,	2001,	Scanning
7,	1,	Sat,	Jun,	19,	10:42:41,	2001,	Drive
8,	1,	Sat,	Jun,	19,	10:42:45,	2001,	Scanning
9,	1,	Sat,	Jun,	19,	10:42:49,	2001,	Talk
10,	1,	Sat,,	Jun,	19,	10:45:52,	2001,	Scanning
11,	1,	Sat,	Jun,	19,	10:46:00,	2001,	Drive
12,	1,	Sat,	Jun,	19,	10:46:03,	2001,	Scanning
13,	1,	Sat,	Jun,	19,	10:59:30,	2001,	End

Figure 2. An example of BASE usage data logs.

The technique may be used to monitor and model usage of IEAT as explained in (O'Neill et al, (2000(b)). Course granularity provided by the above data logs answered the clinicians' initial question, “Is the system being used?” (stated in section “1. Motivation and Background of the Project”) and in the following statement from Hawley: -

“Two basic measurements have been chosen: how much BaSIS has been used; and the number of error the user makes in operation.”

[Hawley et al, “A provisional framework and software tools to aid the prescription of electronic assistive technology: results of a case study.” 1999, p729]

However, in order to enhance the system and obtain a deeper understanding of the user's requirements within each of the sub-applications e.g., Talking and Driving, the switch activity would be required.

5.1. Talking

A considerable amount of research has been conducted in modelling with relationship to augmentative communication; two such papers are (Vanderheiden, 1988; Damper, 1994). For this project, it was decided at this point not to investigate this component for the following reasons: -

- The volume of data that the application will produce would be overwhelming at this point within the research.
- Entering into the linguistics domain would be a complete research project within itself.

5.2. Barnsley Wheelchair Interface (BWI) Driving Component

With the Barnsley Wheelchair Interface (BWI) activated, the following interface is displayed (see Figure 3) and the commencement of continuous communication with the electric wheelchair controller is started. A communication protocol between the computer and wheelchair ensure the individuals safety. This communication continues until the termination of the application or should this communication get out of sequence, the BWI will terminate automatically.

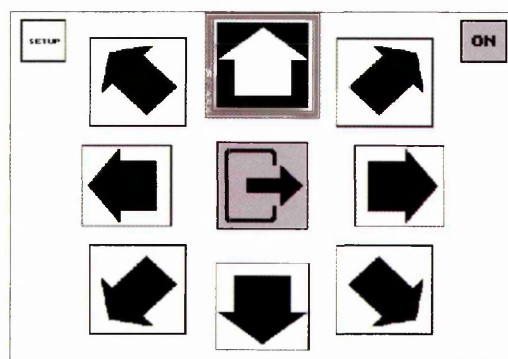


Figure 3. Barnsley Wheelchair Interface, (BWI) display

The BWI is configured by the therapist or clinician to meet the individual's perceived needs by changing the values of a predefined set of attributes (see Appendix B). For example, different highlight orders may be invoked depending on the user's needs and requirements. (see Figures 4 & 5) The BWI has a total of six highlight methods available; two of these highlight methods are shown below. The BWI highlights the direction in the numerical sequence shown. When configured in one switch mode each of the items is highlighted sequentially, at a set scan rate. When the desired direction is indicated on the user interface the user presses and holds the switch closed to move in the chosen direction.

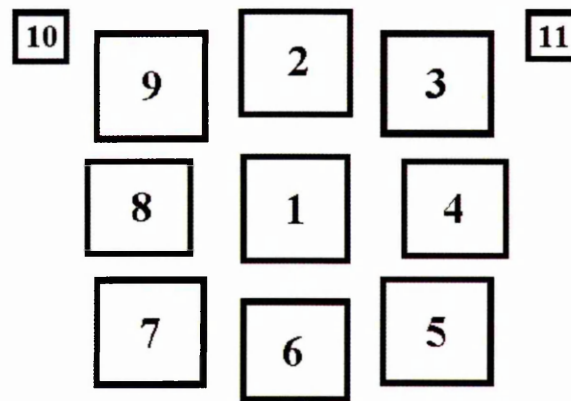


Figure 4. The BWI “Exit First, Clockwise Highlight Method”

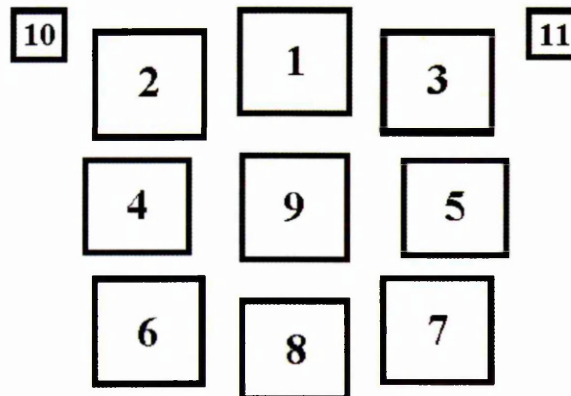


Figure 5. The BWI “Forward Bias, Forward First, Anti-Clockwise Highlight Method”

When the highlight method designates “Forward Bias”, this indicates that on the user selecting a desired direction the powered wheelchair moves in that direction. However, on releasing the switch, the powered wheelchair stops moving and the highlight returns to the “Forward” item, as shown in Figure 5 with the item labelled ‘1’. The scanning methods described as “Exit First” or “Forward First”, indicates that on initialisation of the BWI that one of these items are highlighted first. Finally, the remaining description e.g., “Anti-Clockwise” or “Clockwise”, indicates the direction the highlight method predominately adheres to.

5.2.1. BWI, Enhancement into a Real-Time-Data logging tool

In the BASE application, the BWI or speech component selected by the user is recorded. However, with the enhancement to the BWI, not only would the application selected be logged, but also the actions within that application.

The recorded attributes within the BWI are: selection number, session number, date, time, application and action, as shown in the BWI data logs below (see Figure 6).

1,	1,	Sat,	Jun,	19,	10:18:16,	2001,	Drive,	Start
2,	1,	Sat,	Jun,	19,	10:40:32,	2001,	Drive,	Scanning
3,	1,	Sat,	Jun,	19,	10:40:33,	2001,	Drive,	ForwardLeft
4,	1,	Sat,	Jun,	19,	10:42:09,	2001,	Drive,	Scanning
5,	1,	Sat,	Jun,	19,	10:42:12,	2001,	Drive,	Forward
6,	1,	Sat,	Jun,	19,	10:42:38,	2001,	Drive,	Scanning
7,	1,	Sat,	Jun,	19,	10:42:41,	2001,	Drive,	ForwardRight
8,	1,	Sat,	Jun,	19,	10:42:45,	2001,	Drive,	Scanning
9,	1,	Sat,	Jun,	19,	10:42:49,	2001,	Drive,	Backward
10,	1,	Sat,,	Jun,	19,	10:45:52,	2001,	Drive,	Scanning
11,	1,	Sat,	Jun,	19,	10:46:00,	2001,	Drive,	ForwardRight
12,	1,	Sat,	Jun,	19,	10:46:03,	2001,	Drive,	Scanning
13,	1,	Sat,	Jun,	19,	10:59:30,	2001,	Drive,	End

Figure 6. An example extract of BWI data

With this finer granularity, it is possible to investigate the individual components deeper e.g., Drive and Talk, and model the actions, generated by the user within these components.

6. Investigated Analysis Techniques

Other human computer interaction should be investigated to provide the researcher with an overview to the interaction between human and machine. It was at this point that the researcher was introduced to “Timed Petri Nets” (Palanque, Bastide, 1996), which is one of the few modelling techniques that is appropriate for this problem domain. In particular, the real-time and parallel characteristics of interaction with scanning menus cannot be accommodated within traditional techniques. For example, other modelling techniques concentrate on the delays waiting for the user to respond. However, with scanning applications a number of delays have to be taken into consideration: -

- Waiting for required item to be highlighted.
- Waiting for the computer to accept the switch closure as a valid closure.

The advantages with regards to the user domain using the petri nets modelling techniques are explained below in more detail.

6.1. Timed Petri Nets

The petri nets within this section provide the researcher with the ability to model both system and user. These two independent models of user and system are joined, ran in parallel to provide an overview of the complete interaction, between human and system. In addition, the petri nets provided the researcher with the ability to include time delays. These time delays can be used for the scanning activity of the system and cognitive perceptual and motor activities of the user. This time delay facility in other modelling techniques is not available.

By modelling the user in petri nets, it brought to the researchers attention that involuntary movements e.g., “Spasms” had no perception or cognition time. The researcher was aware of involuntary movement due to the number of presumed unintentional selections made. The modelling highlighted these unintentional selections and the need for the “Hold Down Time” within the applications. “Hold Down Time” reduces the unintentional selections by requiring the user to close the switch for a predetermined period of time before any action will be taken.

6.1.1. Modelling the User and System

The model provides the clinician with an overview of the system and user interaction that includes the inherent parallelism. Figure 7 illustrates a user and system combined model for an IEAT system where the user only has the ability to use a single switch.

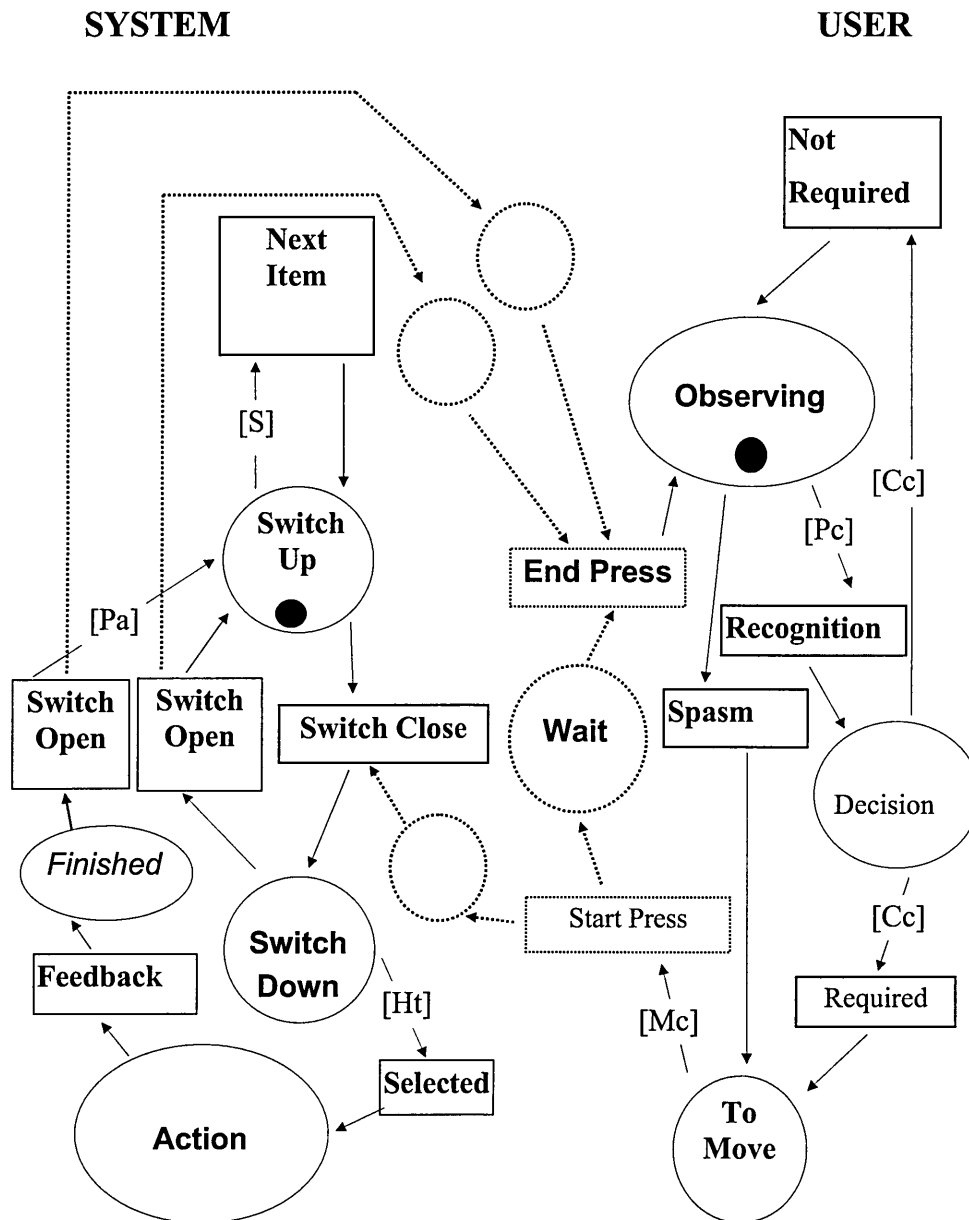


Figure 7. Timed Petri Nets Modelling of the User and System Combined

The tokens are moved around their respective systems on the opening, closing of the switch and scan duration time. Other time constraints are placed on the movement of the tokens (depicted in square braces). The attributes, Mc (Motor Cycle), Pc (Perception Cycle), Cc (Cognitive Cycle) are times suggested in (Horstmann, Levine, 1990), and the Ht (Hold Down Time), Pa (Post Acceptance time) and S (Scan duration) are attributes defined within the configuration of BASE, BWI and the Speech components.

6.1.2. Analysis Purpose

Within this model different timing constraints can be considered with initial values for user timing based on those of (Horstmann, Levine, 1990), and the settings from BASE chosen to optimise access and minimise erroneous selections. Currently the work is employing this model to interpret the activity of individual users, based upon BASE data logs as described earlier within this document. It appears that user timings based upon mainstream users as in (Horstmann, Levine, 1990) do not always reflect the abilities of the more severely physically disabled. It is for this reason and the requirements of the clinician's/therapists to have the ability to test user abilities with regards to switch access, that it is planned to develop a Switch Assessment Tool. Switch Environment Assessment Tool (SEAT), (see section 7.1) which is similar to the one described in (Rosen, Goodenough-Trepagnier, 1989) will obtain the value for Mc, Pc, Cc, Ht, Pa and S which are described in Appendix C.

However, it is important to note that until the SEAT application is created the researcher will continue to use the values provided by Horstmann and Levine.

The analysis technique of GOMS modelling was employed to extend the knowledge of the way, in which humans and computers interact and validate this against the system's real time usage logs. The GOMS modelling is described below.

6.2. GOMS Modelling

In analysing the data logs available from BASE, an important question is, "How can they be interpreted so as to inform clinicians about the use of IEAT by individuals". (see section 1. Motivation and Background of the Project)

Our initial interpretation of the data has been based upon adapting the use of the GOMS model presented in (Horstmann and Levine, 1990). The model is used to identify a minimal time for entering and exiting the applications using BASE. The minimal time is calculated based upon; the cognitive and perceptual operations involved; timing characteristics of the BASE scanning menu; and the applications available. Figure 6 shows the results for a specific BASE configuration.

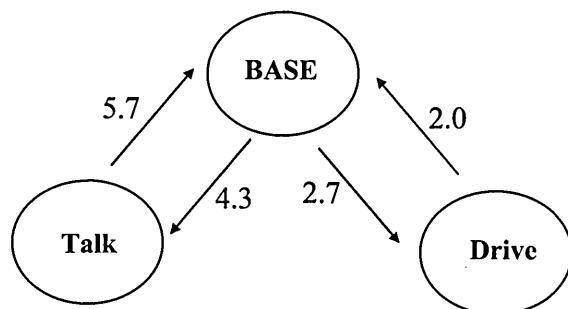


Figure 8. State transition showing minimal times for erroneous free use.

Using these Figures, erroneous selections were identified on the duration of application use that was lower than the minimal time for erroneous free use. Following a six-month period of use of a specific IEAT configuration, the usage of the two applications (Speak and Move) was analysed, presenting us with the following results. (see table 2)

% Erroneous	July	Aug	Sept	Oct	Nov	Dec
Talking (10 secs)	2.3	0.0	0.0	0.0	02.1	0.0
Moving	37.9	17.7	11.4	13.9	14.6	6.4

Table 2. Percentage of erroneous selections made each month, over a six-month period

The two important observations are; first, that percentage of erroneous selections made for Moving shows a strong downward trend; and secondly, many more selections that are erroneous are being made for Move, than are for Talk.

However, on viewing table 2, it soon became apparent that charts showing the accumulated frequency of duration in two activities e.g., Talk and Move would be useful. The researcher could draw a vertical line at the time erroneous selection would have been considered to have stopped, this would then show the number of times the selection had been made. Therefore 6.3. "Erroneous Selections Modelling." shows these values for duration of time spent in each of the activities in a chart format.

6.3. Erroneous Selections Modelling

The two charts below are erroneous frequency rates for six months, from July to December 1998, for erroneous selections going into drive and talk. It is possible to see the number of times the individual entered an application for the duration, shown on the X axis.

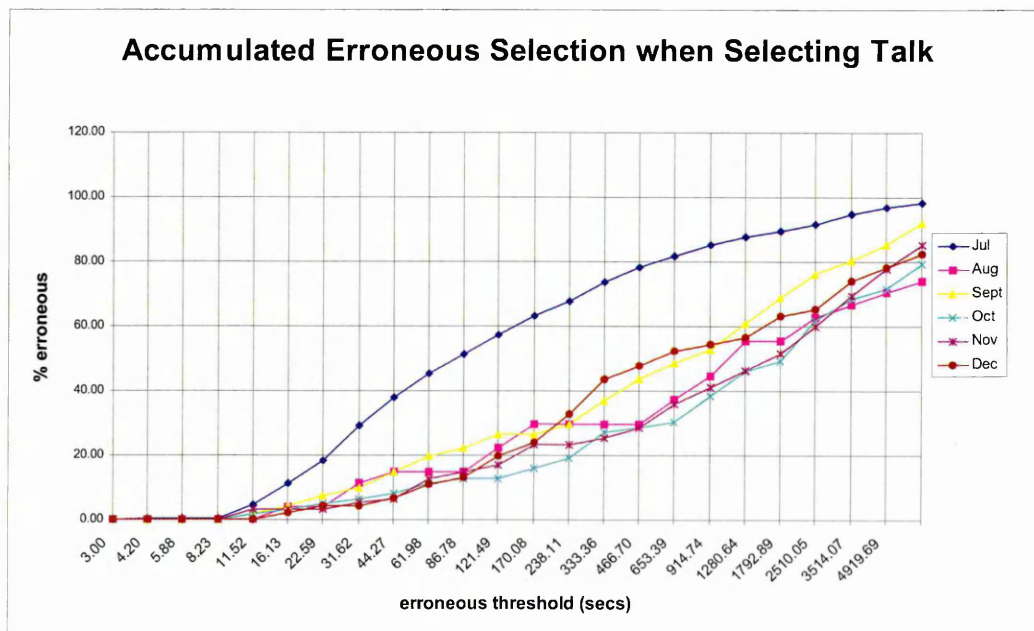


Figure 9. Accumulated Erroneous Selections going into Talk from BASE logs

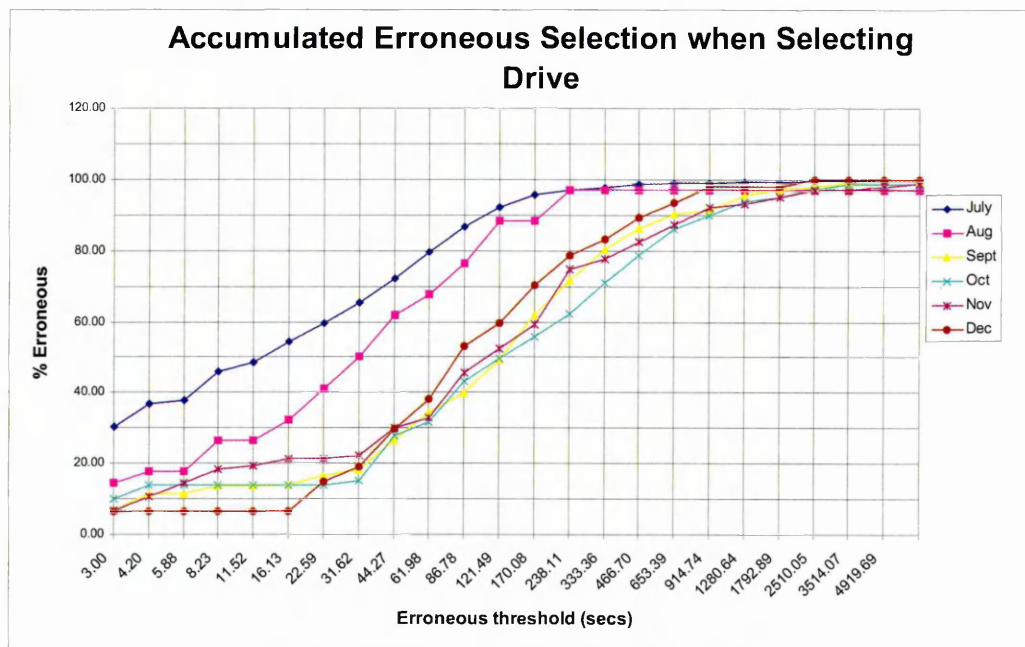


Figure 10. Accumulated Erroneous Selections going into Drive from BASE logs

It is quite clearly shown that more selections that are erroneous occur when going into the driver application (BWI). However, an explanation for this could be the nature of the application constantly communicating with the electric wheelchair controller for safety reasons as explained previously in section 5.2. “Barnsley Wheelchair Interface (BWI)”. This communication error may account for the considerable number of short duration’s spent in the BWI as shown above. However, at this point it is not possible to provide the number, without changing the data logger to report these occurrences.

The course granularity of the BASE real-time-data logs has been enhanced, to provide a deeper understanding of the activities taking place while the IEAT was in use. This enhancement took place with the conversion of the BWI into a real-time-data logging tool, described in section, “5.2.1. BWI, Enhancement into a Real-Time-Data logging tool.”

6.4. Scan Method Modelling

Scan method modelling uses the user attributes from (Horstman, Levine 1990) of perception, cognition and motor cycle times, of their GOMS model. These values will be replaced with more accurate values for perception, cognition and motor cycle times of people whom have severe and multiple physical and sensory disabilities once the SEAT application described (see section “7.1. Switch Environment Assessment Tool (SEAT)”) is created.

One of the models that had been employed to interpret the activity of individual users is based upon movement data logs as described above. These are generated from selections while in the Driver interface (Figure 2). The evaluation of the driver data logs, compares the theoretical times of four alternative scanning methods based upon a profile of use (see Figure 11). In contrast to earlier analyses of assistive technology at this level, the analysis is informed by the empirical assessment of performance characteristics of individuals.

Theoretical Time for Real-Time-Data Selections for each Scanning Method

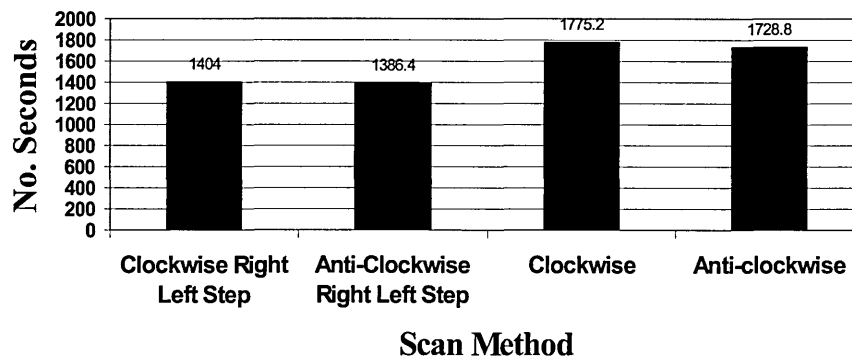


Figure 11. Theoretical time spent scanning

It is important to note that the method used during the creation of this data was “Anti-Clockwise Right Left Step”. Therefore, although it is possible to see that the scanning method selected was the most economical, this may have been influenced by this scanning method being used.

Due to the limited space available within this report, this one simple modelling technique is shown. However, a considerable number of other modelling techniques are and have been used upon the data logs generated by each of the components within the IEAT. This simple model described above provides the clinician with information not previously obtainable.

Other information such as the individuals ability to use a switch based interface and the attributes settings for that individual could not be obtained. The existing values for human computer interaction did not match with the modelling techniques findings. Evaluation tools and utilities to gain this information are presented below.

7. Evaluation Tools and Utilities

The values provided by (Horstman, Levine 1990), for perception, cognition and motor cycles time of ‘0.5’ of a second and the (Rosen, Goodenough-Trepagnier, 1989), MDM rate of ‘0.836’ of a second, when analysed with the data logs did not match with our findings. Therefore, an alternative means of obtaining these values was discussed with the supervisory team and the idea of the Switch Environment Assessment Tool (SEAT) application was born.

7.1. Switch Environment Assessment Tool (SEAT)

SEAT is an application that administers a set of tests, to assess the user’s ability to use a switch/es as a potential means of interfacing with a PC. The SEAT application’s aim is to provide the therapist and clinician with guidance values (see Appendix C) for a number of switch based applications.

The reason for creating such an application is based on research requested by (Cherry *et al.* 1996; Horstmann and Levine 1990; Hawley, 1995). These guidance values are also required for the modelling process, as shown in earlier sections on, Petri Nets (Palanque and Bastide 1996), GOMS Modelling (Horstmann and Levine, 1990) and Scan Method Modelling. If we are to have a deeper understanding of switch based interfaces, we will require values in the areas of: -

- Switch/es
- Items
- Selection Window
- Scan
- Sound

Each of the items listed above will have a number of tests associated with them, which will help in determining the foundation setting for that attribute and its respective parameter for that individual. The reasoning for having more than one test for the same parameter is so that the parameter values may be validated against each other. If two tests should suggest that the scan rate should be 0.8 and 2.0 seconds and all computer settings be equal, then clearly some other external attributes such as switch location or seating of the individual may have changed etc. The SEAT application is presently being constructed. Although SEAT is being constructed for CES, it will have a considerable influence on the BASE and BWI data logs by ensuring fundamental settings are as close to the optimum values in the applications. These values in turn will be used within the modelling tools and utilities, providing a higher degree of accuracy with regards to these models.

7.2. BWI, Mapper

The BWI mapper takes the data created by the user and draws lines, which represents the movement made. At present the Mapper does not have any constraints and draws a line north for forward, west for left, east for right and south for backward. For forward left a line is drawn north east and so on.

Below is some suggested visualisation patterns that the “BWI Mapper” should create when it becomes fully functional. The BWI Mapper should provide a good opportunity to quickly visualise the movement conducted by the individual and make it apparent if patterns of movement do occur.


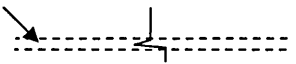
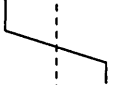
Pattern Description	What pattern would be found in the Data	BWI Drive Mapper application would show
‘Steps’	Repeated use of the forward direction, followed by a correction to the Left, Right or Forward left, Forward right.	
‘Over Shot’	When one or more movements are contradicted by each other. For example, turning left for n number of seconds, then turning right for n-n number of seconds.	Same time Slice 
‘Under Shot’	When more then one movement is made in the same direction. For example, Forward right for n seconds and then Forward right n seconds again.	End and Beginning of Selection 

Table 3. Possible visualisation patterns from BWI Mapper

During a supervisory session, it became apparent that an enhancement and alternate would be to have the mapper draw lines at different angles depending on the duration of the turn. (see Figure 12.)

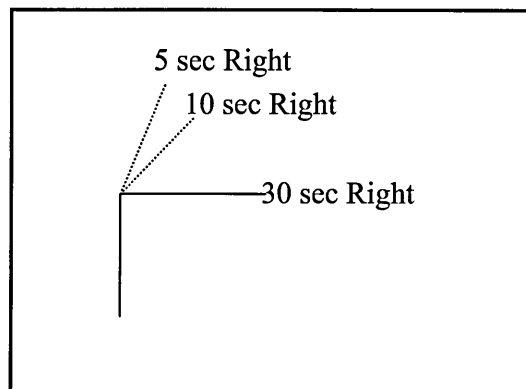


Figure 12. Time Ratio to Degree of Turn

It is intended that the BWI Mapper will have the ability to display a day, session, hour etc..

The BWI Mapper would instantly provide the clinician and/or therapist with a visual interpretation of the movement activities undertaken. This would be a quick and simple means of obtaining information about if the setting of the chair's speed, acceleration rate and turning rates etc., and if the present settings are suitable for that individual. For example, if the BWI Mapper continuously presents to the clinician and/or therapist the image of 'Over Shot' when turning (see table 3). Then the turning rate may be reduced or if 'Under Shot' is displayed then the turning rate could be increased.

8. Presentations and Other Research Work

In the 'RF1' particular importance was given to presenting the research and attending relevant courses at Sheffield Hallam University (SHU). During the initial stages of the research the author was asked to attend a library day in the Adsets building at SHU, where demonstrations and advice was given in all aspects of multi-media access of the internet, internal and external library catalogues, including 'BIDS', 'Ingenta', etc..

In May 2000 the researcher entered a poster competition at Leeds University, being run by the Yorkshire and Humberside Universities Associations (O'Neill, 2000a). The researcher was pleased to be awarded the best in section. Since then, the researcher has attended a three-day "MSc Research Methodology Course", at SHU in the School of Computing and Management Sciences. The researcher has presented the project to his peers at Barnsley District General Hospital NHS Trust in a 'Research Seminar' and presented the research in the Doctoral Consortium at the HCI 2000 Conference in September of last year. (O'Neill et al 2000a; O'Neill et al 2000b) In November of last year another paper was published in 'ASSETS 2000', Washington DC, USA, (O'Neill et al 2000d). On the creation of any papers for publication or otherwise, every precaution is taken to conceal the subjects identity which is the policy of the Research Ethics Committee at Barnsley District General Hospital. (see section 2. Context of the Research)

The collection of data sample from the subject/s is carried out approximately once a month; this consists of the data from the BASE, BWI and Talking Screen for Windows (Speech component) applications. Often the researcher on visiting the subject/s finds that he is also wearing the clinician's hat and he is maintaining the system at the same time. The analysis of the data from BASE and BWI is on going. However, at present the data from speech component (Talking Screen for Windows), is stored for future analysis for reasons explained within 5.1 Talking.

Throughout the duration of the project to this point, a number of changes have been made to the data collection section, within the BASE and BWI applications. One of the changes that were considered was to extend knowledge of the user's occupation of the wheelchair. For example, the BASE application would indicate if the individual was or was not in the wheelchair. However, suitable hardware to provide this information e.g., a switch placed in the seating area of the wheelchair, could not be obtained and the previous version of the BASE application was reinstalled.

Wishing to have a deeper understanding the elements within the research and the way in which these elements interact, the researcher constructed a model with a description of its different levels. The model and description is contained within the next section.

9. The Ways Forward

It is important to note at this point it is not the researcher's intention to try to fulfil all of the work suggested in this section. However, this section does show the placement of the tools and utilities within the model (see Figure 15). It also shows and explains a way in which these models may be used to test settings without disadvantaging the users of these systems.

9.1. Process of Knowledge Formation and Use

The Process of Knowledge Formation and Use model (see Figure 13 on following page) is divided into four levels. Levels 1 and 2 will be discussed in more detail below. Level 1 is the user, computer system and environmental attributes. That is the primary input to level 2 being the Knowledge based system itself. Level 3 is the Knowledge Based system's suggested page of items and configuration for that individual. Level 4, the real-time-data produced by IEAT, used by the user's in the real world, which is used in "Level 2, Previous Configuration and Real-Time-Data from User".

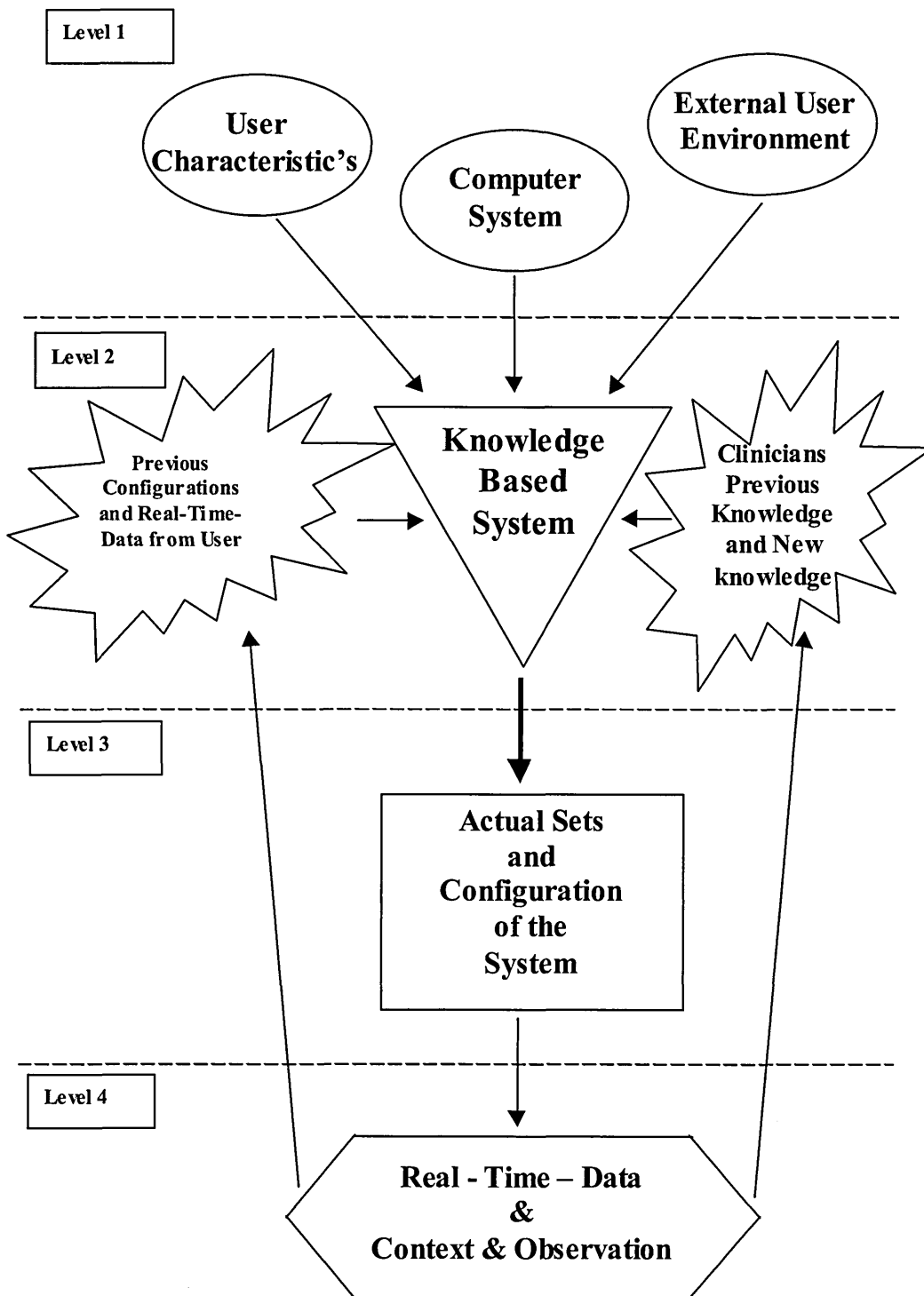


Figure 13. The Knowledge Based Model

9.1.1. Level 1.

Level 1 being the “User characteristics”, “Computer system” and “External user environment” attributes. These attributes will be obtained from the SEAT application and the user’s associates. Therefore, the SEAT application would need to collect the following information and other attributes may be added to the list shown below. Most of the information would be obtained from: -

- The User
- The Carers
- The Family members
- The User’s Friends
- The Clinicians
- The tasks undertaken by the user in the SEAT Application as explained earlier within this paper.

9.1.2. Level 2.

Level 2 is highly complex, consisting of three components, two of which feed the system. These feeders extend the existing knowledge and the bespoke pages of items already contained within the system. The last element in this level is the “Knowledge Based System” itself. Each of these components are explained in more detail below:

9.2. The Knowledge Based System

The “Knowledge Based System” is split into two, part one deals with the “Prescription of new systems”; and the second half deals with “Analysing existing systems”, which is provided with real-time-data logs from the BASE and BWI. First lets look at the section that deals with providing new systems. On the next page is a model showing this half of the system: -

9.2.1. Prescription of New Systems

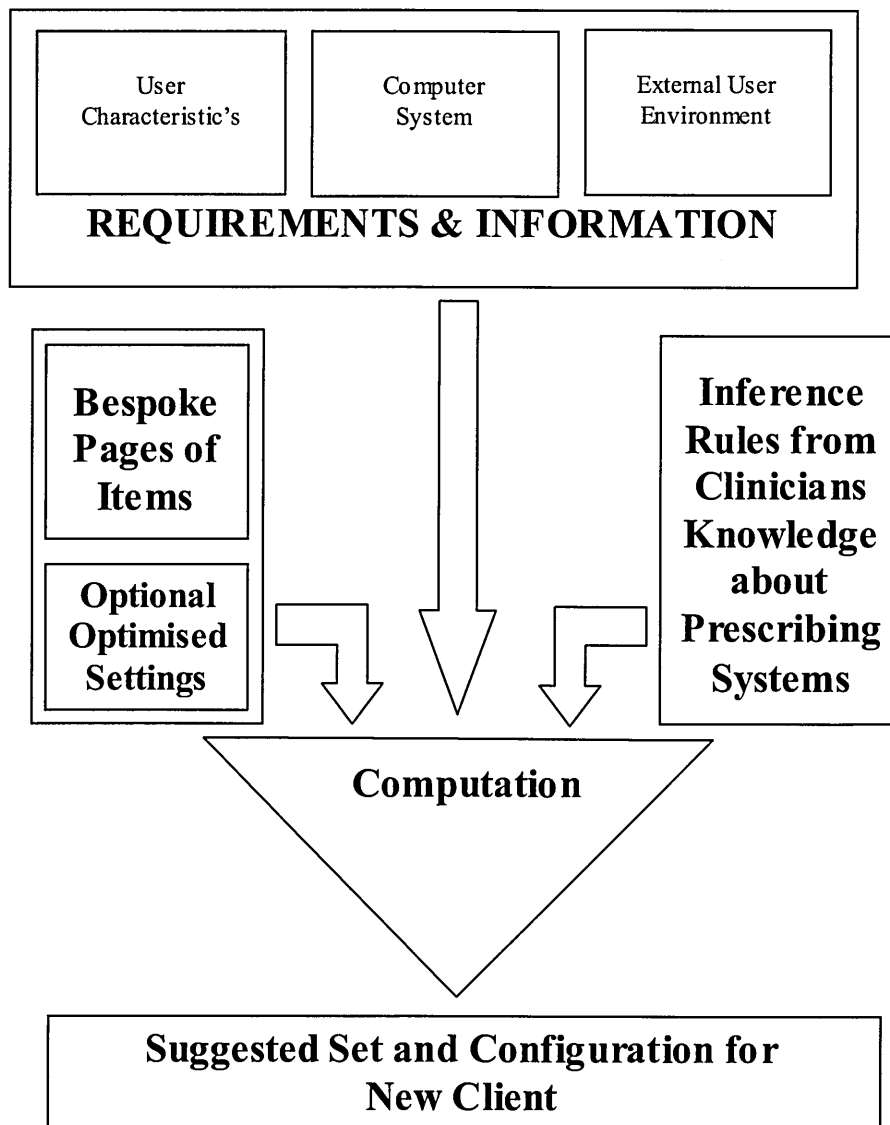


Figure 14. Prescribing a System.

When prescribing a new system, we would use inference rules based on the knowledge obtained from Clinicians Therapists and others, about the way a prescription is fulfilled. All of the elements, requirements, abilities, environment information, inference rules, bespoke pages of items with optional optimised settings, would go through computation based on the user's requirements. This would provide the suggested new pages of items, as shown in the above model.

9.2.2. Analysing Existing Systems

The modelling and analysis methods already undertaken may be utilised within this section. Of course, other methods, models yet to be found and personal creations, could also be used in optimising the pages of items. A model on the next page shows the elements that most probably will be used within this half of the "Knowledge Based System"

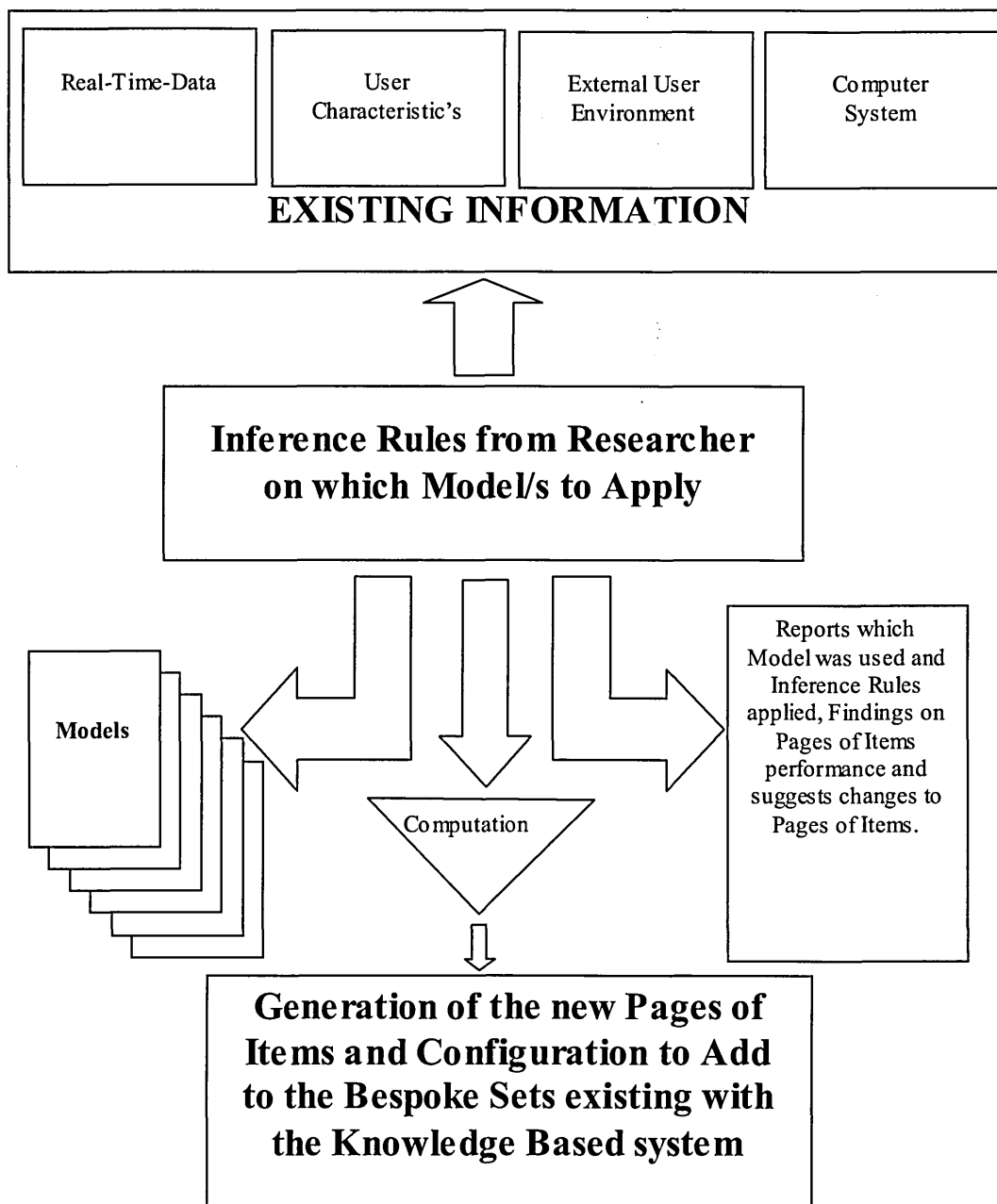


Figure 15. Analysing the Sets Performance.

This half of the “Knowledge Based System” enables the clinician to update the system with the most recent sets, new settings of attributes and possibly new rules. For example, suppose the knowledge based system twelve months ago suggested some sets and the configuration of a system for a Client. The Client has been using the system generated by the knowledge based system. However, the clinician or therapist did make one or two changes to the system e.g., made the Scan Rate 500 ms longer and changed one or two items within some of the pages. This new configuration could be analysed and then possibly added to the knowledge based system along with any changes to the user characteristics. This means that if another client should require a system and they have similar attributes within “Requirements & Information”. The knowledge based system will be able to suggest these pages given to it, for the new client. Alternatively, the system after applying the model/s may suggest changes to the pages of items. These changes could be made to the pages and then added to the knowledge based system but also applied to the user’s system immediately, if desired.

9.3. The Objective

The research is focused upon developing analytical assessment tools that can assist with the process of prescription for severely disabled people. Each of the modelling and analysis techniques described within this paper require deeper investigation or in a high number of cases, the completion of applying the techniques throughout all the variations of data available. However, the creation of charts and analysis of the data is highly time consuming. Therefore, once any form of analysis has been agreed upon with the supervisory team, it would be advisable to spend some considerable time creating macro's and templates to automate the processes. This process is already taking place and is providing an opportunity to analyse data logs generated by the different elements of IEAT e.g., BASE and BWI. This would provide several advantages: -

- Reduce the time to repeat the processes.
- Validity that the processes were carried out in the same manner.
- Use the analytical utility with a number of real-time-data logs

These models, analysis tools and utilities once perfected could be used in two ways. Firstly, integrated within a "Knowledge Based System" as explained earlier in this paper. Secondly, the models could be used as standalone utilities by clinicians/therapists to evaluate the system provided to the user and enhance their system.

10. Aspects felt to be at PhD Level

The method of using real-time-data logs, to capture information about the human computer interaction is not unique, as this method of data collection is well documented. (Bratton G. R., Newsted P.R., 1989; Treu S, 1994; Giese P et al 1995) However, this method is usually used in conjunction with analysis techniques, such as verbal walk through, video analysis, etc., often removing the individual from their normal environment into a laboratory situation. The first of which is not possible as the individuals main way of communicating is by means of using the system itself. This means that in many instances the individual can only respond with the phrases, words available on the system. Therefore, they are not able to express their true feelings or wishes. The other thing about the method is that it removes the individual from their normal environment. It is highly possible that the change in environment will make significant changes to the individual's behaviour and the way in which they use the system. The other alternative of observation within the field is highly time consuming for the Clinician and/or Therapist and not something that could be carried over a prolonged period. This way of obtaining information is one of the most useful means presently available, for the reasons stated below: -

- Due to its unobtrusive manner with regards to the user
- Minimal time required by Clinicians/Therapists to collect the required information
- By the quality and quantity of the information available

The aspects felt to be at PhD level, are not the methods and modelling techniques but the way these models and methods are used to make analytical sense of the IEAT; through the enhancement and prescription of these systems.

The essential elements that require completion are the extension and refinement to the model by (Hawley 1995). This refined model, methods, tools and utilities suggested within this document should enable the researcher, clinician and therapist to achieve the objectives stated in the "RF1", which are: -

- Increase in the knowledge, of the way in which the system is being used.
- Increase in the performance rate of the user.
- Reduction to prescription time.

The means by which these objectives will be achieved is contained within this document. For example, the statement, "Increase in the knowledge, of the way in which the system is being used", is being achieved by including the data logging functionality within the applications within the IEAT system. This is explained within section "4. Initial Stages of the Project" and "5.2.1. BWI, Enhancement into a Real-Time-Data logging tool".

With this extended knowledge from the data logs and tools such as "SEAT" and the "BWI Mapper" (see section "7. Evaluation Tools and Utilities") the item sets presented to the user should be configured to require the minimal time to select the desired action

- in conjunction with the knowledge of the users characteristics, the system timing attributes and item sets can be optimised.
- looking for similarities within the user characteristics, it may be possible to use the item sets used by one user with another.

By using the "SEAT" tool to obtain system timing attributes and bringing all of these elements together, this in turn will bring about a reduction to prescription time.

11. Plan of Remaining Project's Objectives

1. Complete Existing Work

Complete the existing modelling techniques for example:

- Petri Nets for switches two and three system
- Different scanning model
- Accumulated frequency of selection
- Others

6 Months

2. Design

Develop a toolset to enhance service prescription by:

- Locating which of the models above will be of most use in the context of service prescription and provision
- Determining requirements for the effective use of the model in service prescription and provision
- Developing a toolset based on the requirements
- Designing an interface for toolset based on "Design for All" principles

12 Months

3. Evaluation and Write up

- Evaluate the applicability of the model for service prescription with a range of rehabilitation centres, primarily at CES (BDGH)
- Thesis preparation

24 Months

12. References

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Appendix A

Application to The Research Ethics Committee

At

Barnsley District General Hospital NHS Trust.

Including: -

Research Proposal
Information Sheet
Consent Form

BARNSLEY RESEARCH ETHICS COMMITTEE

1 **TITLE OF PROJECT:**

Analysis of switch based Human Computer Interaction by people with disabilities and its application in Assistive Technology prescription and automatic configuration of interfaces

2 **INVESTIGATORS:**

- (a) Please list the name, position, and function in the proposed research, **of all** who will be responsible, and their qualifications.

Responsible Investigator	Position/ Employer	Function in Proposed Research	Relevant Qualifications
Name and Address for correspondence			
Dr. Mark S. Hawley	Principal Physicist BDGH NHS Trust	Supervisor	PhD
Other Investigators Name	Researcher		
Mr. Peter O'Neill	BDGH NHS Trust		BSc Software Engineering
	Senior Lecturer		PhD
Dr. Chris Roast	Sheffield Hallam University		
Prof Jawed Siddiqi	Professor Sheffield Hallam University		PhD
Dr. Lynda H. Webb	Research Fellow University of Sheffield. BDGH NHS Trust		PhD

- (b) **Please detail relevant research experience of investigators - if none please identify supervisor and arrangements for supervision.**

Dr Mark Hawley (Supervisor) has a PhD. in Medical Physics and Clinical Engineering. He has worked in the rehabilitation field for more than five years.

Mr Peter O'Neill has a BSc in Software Engineering. He has been researching in rehabilitation for two years.

Dr Chris Roast (Supervisor) and Prof Jawed Siddiqi, work in the Department of Computing and Management Sciences.

Dr. Lynda Webb has a PhD in the field of Disability and has been working in the field of disability for eleven years

- (c) **Is the proposed research part of a course of academic study?** Yes
- (d) **Is the investigator involved in any other research projects which will run concurrently with the proposed study - if yes give details**

Evaluation and Further Development of a Multi-media Information Package for Patients with Rheumatoid Arthritis.

- 3 **SPONSOR - Please give details of the company/organisation sponsoring or funding the research.**

Hawley Trust,
Remploy InterWork Leeds.
School of Computing and Management Sciences, Sheffield Hallam University

4 **THE RESEARCH:**

(I) **GENERAL**

Please provide an outline of the proposed research to include:

- (a) ***the purpose and objectives of the research***

To enhance prescription of electronic assistive technology to people with severe physical disabilities. To develop a data logging application of real time system usage. This will be used to evaluate the quality of the match of user to system and identify a 'best fit' scenario. To move towards an automatic configuration of devices based on usage data.

- (b) ***information about the drug(s)/appliance(s)/method(s) of treatment or diagnosis/question(s)/issues and/or Hypothesis(es) to be used and/or tested in the research***

The hypotheses are:

Information gained by electronic data logging of system usage can improve prescription of electronic assistive technology.

That a method can be developed to analyse and use logged data which will allow the automatic configuration of user interfaces for assistive technology.

- (c) ***the scientific background to the research including, previous research carried out in the field/on the drug(s)/appliance(s) or on the methods, question(s) or hypothesis(es) in question***

The assessment, prescription and provision of electronic assistive technology is mainly based on subjective judgements of the system provider.

The Lifespace Access Profile (Pattern and Stemach (1998)); The Client-Centred Multi-Disciplinary Service Model (Hawley (1995) and design methodologies such as USERfit (Poulson et al (1996)) recommend and use an iterative follow up process once assessment and prescription has taken place. The evaluation of the system usage is presently carried out by relying on qualitative reporting and observations. There is no method by which actual real time system usage can be monitored and logged.

- (d) *the value of and need for the research. If this project or similar research, has been carried out previously, please state the justification for and benefit of its repetition*

There is no method by which actual real time system usage of electronic assistive technology can be monitored and logged. A data log of system usage will give direct rather than secondary data for system analysis. The users of such systems can be unable to express directly their needs and requirements. The goals of this study will have long term benefits in assisting initial prescription and evaluation of systems in use.

- (e) *the design of the research and methodology to be adopted (ie randomised, placebo controlled, double blind etc*

Formative design following a standard developmental methodology. Subjects will act as their own controls. Observations and questionnaires will be administered before implementation of the system. The system will be prescribed, implemented and data logging started, observations and questionnaires will be repeated. Data logging will be analysed and modifications to the system made accordingly. The observation and questionnaires will be administered again post modification. Some questionnaires may be used on a daily basis, for gaining user opinions.

- (f) *the site(s) at which the research will be conducted and the facilities available*

The research will take place at the users own homes and or place of work or school. In addition some work may take place in the Medical Physics Department B.D.G.H.

- (g) *whether research is multi-centre and to how many and which other LREC(s) an application in relation to the research is to be/has been made. Please specify which is to be the "lead" site for the research*

Application for Ethical Approval only relevant in Barnsley at present

- (h) *the expected duration of the research/study/project -*

Four to five years

- (i) *how the data generated by the research will be analysed*

In the initial stages, descriptive data representation (Frequency, averages, standard deviation on Excel and SPSS), as required. Automatic data analysis software will be developed during the project.

(II) PROCEDURES**(a) Please state whether the project includes procedures which:
(Please tick as appropriate)**

- | | | |
|-------|--------------------------------------------------|--------------------------|
| (i) | are physically invasive | <input type="checkbox"/> |
| (ii) | involve the taking of bodily samples | <input type="checkbox"/> |
| (iii) | involve the administration of doses of radiation | <input type="checkbox"/> |

None of the above procedures are included in the project.

(b) Please outline the procedures involved. This outline must include details, as applicable, of:**(i) the dosage and route of administration of the drug(s) used in the research**

None

(ii) other substances and/or appliances to be administered/used, and the method of administration or use

Data logging software as part of electronic assistive technology hardware and software tools used by the subject.

(iii) measurements and samples to be taken

Record of actions taken using the assistive technology. Observations of subjects in using the system, these will take place in the individuals own home, school or place of work.

(iv) tests to be performed

Everyday use of system provides the data. There may be some sample testing of system usage, involving requested tasks of the user on their own or a modified system.

(v) the use of questionnaires, visual aids or the administration of psychological tests

Questionnaires will be developed as appropriate during the course of the study. They will investigate the satisfaction in use, reliability, ease of use, interaction with others and the environment relating to the use of the system.

(c) Please specify:**(i) which procedure(s) may cause pain, discomfort, distress or inconvenience to a subject and the likely extent of such pain, discomfort, distress or inconvenience**

The setting up of the system may take forty five minutes. The downloading of data from subjects systems, will take a maximum of thirty minutes. In addition where necessary observation of the system in use may take place with agreed consent of the user and others involved. The study will not result in any form of pain discomfort or distress.

- (ii) **any particular requirements or abstentions which will be imposed upon the participating subject, (eg multiple visits, abstention from alcohol, tobacco etc).**

None

- iii) **where samples will be taken from the subject, please state which samples, the amount and frequency of them and whether the sample would be taken as part of the normal patient care or specifically for the purposes of the research. If a sample would normally be taken as part of usual patient care - will the amount taken be any greater due to the participation of the subject in the research?**

None

- (d) **Where the research involves the use of radioactive isotopes, please confirm that the dosage proposed to be used in the research has been approved by ARSAC, and that the person(s) who will administer the dose is/are properly qualified and hold(s) the necessary certificates.**

None used.

- (e) **Where the research involves the testing of a medicinal product (or medical device), please state the regulatory status of the drug/device in question. Is the research being conducted under the terms of a product licence, CTC, CTX or DDX?**

N/A.

(III) RISKS AND HAZARDS

- (f) **Please:**

- (i) **describe the potential hazards or risks if any, for the subject associated with participation in the research and the precautions being taken to minimise and deal with them.**

Modification of the wheelchair driver for data logging could pose a potential risk if an error occurred that affected the control of the wheelchair. Therefore, testing of the wheelchair driver will take place before prescription and in a safe environment once prescribed. This is standard procedure presently used in the Medical Physics Department.

- (ii) **specify the probability and seriousness of the hazard/risk in each case**

Minimal risk as wheelchair driver used in an indoor safe environment.

- (g) **In cases of therapeutic research involving patients, describe the alternative/standard treatments (if any), normally given or available to the type(s) of patient(s) intended to be recruited to the research. Where a subject has been receiving such alternative or standard treatment prior to enrolment in the research, or would normally be prescribed such treatment, state whether that treatment will be temporarily suspended or withheld during the conduct of the research. Please state what the implications, if any, of such withholding or temporary suspension may be for the subject.**

There is no alternative or standard treatment. Subjects will either have no means of speech output, environmental control and self propulsion of the wheelchair. Those subjects who have their own systems will have data logging facilities added or additional control options where appropriate to the user.

(IV) Good Clinical Research Practice

- (h) **Please confirm that the research will be carried out in accordance with recognised standards of good clinical research practice - in particular, the Declaration of Helsinki and the Committee for Proprietary Medicinal Products Note for Guidance on Good Clinical Practice for Trials of Medicinal Products 1990. Please state to which UK Guidelines/Standards the investigators will adhere.**

Yes the research will be carried out in accordance with recognised standards of good clinical research practice.

- (i) **From whom have you had statistical and/or computing advice?:**

Dr. Chris Roast, Prof Jawed Siddiqi, Sheffield Hallam University

If none, why not?

N/A

- (j) **If drugs or treatments are being compared does the protocol include planned interim analyses of the results to enable early termination of the trial should one treatment prove to be dramatically superior or to have unexpected side effects?**

If not, why not?

N/A

If yes, will this be carried out independently of these investigators?

N/A

5 THE SUBJECTS

(I) General

- (a) **Please state the numbers of subjects to be recruited to the research stating, where more than one research centre will be involved, the total for the research as a whole as well as per investigational site.**

Initially, single case study. Subsequently, larger numbers, up to 30. This will be determined as the study progresses, as determined by the developmental methodology we have adopted

- (b) **Please describe the type/class of subject (eg under 60's, patients with specified disease, male/female etc) to be recruited to the research setting out the inclusions criteria and stating whether they are patients or healthy volunteers, the age group or range which will be recruited and from where/what source they will be recruited.**

The subject population will be drawn from people with severe physical disabilities, who require the use of assistive technology to enable them to control their environment, to talk, and to control their wheelchair. Subjects will be both children and adults with disabilities who are in good health.

- (c) **Please describe the type of subject and conditions which are to be contraindicated and excluded from the research. What measures will be taken to identify and exclude subjects who have recently or who are concurrently taking part in other research projects?**

N/A

- (d) **Please state whether any individual benefit to a subject's health (physical or mental) may be gained by participation in the research**

There may be social, self esteem and independence benefits in using the systems for the users, with concurrent benefits for carers.

- (e) **Please describe the means and methods of recruitment (eg advertising for subjects).**

They will be recruited via GP's, Medical Physics and therapy departments.

- (f) **Please indicate whether any payment is intended to be made to research subjects and, if so, the amounts in question**

N/A

- (g) **Please state the relationship, if any, which may/will exist between the investigator(s) and potential subjects: eg will any of the subjects be students, subordinates or colleagues of the investigator, or members of the Authority's or Investigator's staff**

No relationship of the sort described in (g) above exists between the investigators and the potential subjects.

- (h) **Please confirm the method and manner in which subject's consent to participation will be obtained, and where potential subjects will/may suffer from any difficulties of communication, the special methods to be employed both as to information and consent procedures to overcome those difficulties**

Taking into consideration the recommendations of the "Consent checklist for investigators, REF RECAPNT.405", an Information Sheet, and a Research Consent Form will be prepared for the subjects. In the former, the study will be fully explained to the subjects and carers in writing, and the subjects' and / or carers' permission will be obtained in writing (Research Consent Form). The Information Sheet and the Research Consent Forms, which are attached at the end of the document, make the subjects aware that they may choose to withdraw from the study at anytime.

- (i) **Please state:**

- (i) **whether the subject's GP will be informed of the subject's agreement to participate in the research prior to its commencement**

N/A

and

- (ii) **whether the subject's consent to contact being made and to information being supplied and obtained, will be a condition of participation. If not, why not?**

Yes the subjects consent to participation and collection and usage of information will be obtained before they will participate in the study.

- (j) **Please state what measures will be taken to protect the confidentiality of subjects' data (ie arising out of the research and contained in personal records). Who will have control of data generated by the research?**

Any use of visual data of the subjects (including photographs) in research presentations will require consent. Moreover, all subjects data recorded will be referred to by a code.

Only the investigators will have control of the data generated in the research.

(II) Special Groups

- (k) **Please state whether subjects belong to any of the following groups: (tick where appropriate)**

Children
Pregnant/nursing mothers
Women of child bearing age
The elderly
Mentally incompetent
emergencies/unconscious patients

- (l) Please state what special or additional arrangements, if any, will be applied particularly in information and consent procedures to safeguard the interests of such subjects**

Where children participate in the study consent of parent/guardian will be obtained. If the child shall reach the age of 16 years during the study then their consent will be requested to continue participation of the study.

Subjects who have unintelligible speech, literacy difficulties and who are unable to provide a signature will be asked for consent in the presence of a familiar communication partner to ensure clear communication.

- (m) Please explain why it is necessary to conduct the research in such subjects and whether the required data could be obtained by any other means**

Since the results of the study are only applicable to subjects of the described group, it would be inappropriate to use subjects who do not have such functional disabilities. Since children are also likely to benefit from this research it is important to include them so as to identify any key differences in the requirements between children and adults.

(III) Children - under 18 years

- (n) Please state whether, and if so how, participation in the proposed research may/will be of personal benefit to individual child subjects, (eg will the proposed subjects suffer from any condition which it is anticipated that the drug or technique under research has the potential to alleviate, treat or diagnose?)**

The proposed research should assist the individual subjects involved in increasing their independence and control of their environments.

- (o) If the proposed research is not intended to produce any direct benefit to the individual child subject, please describe and quantify the risks anticipated in relation to participation; please state whether it would be correct to describe such risks of harm as "negligible" (ie not greater than those ordinarily encountered in daily life or during the performance of routine physical or psychological examination or tests).**

N/A

- (p) Where the child subject is over 16, please confirm that consent to therapeutic research will be obtained from the child him/herself.**

Yes, consent to therapeutic research will be obtained from the child him/herself.

- (q) Where the child is under 16 and in the case of therapeutic research or under 18 in the case of non-therapeutic research, but is judged to have the maturity and capacity to understand the nature of the research, please confirm that his/her consent will be sought.**

Yes, his/her consent will be sought.

- (r) Where the child is not judged able adequately to appreciate the nature and implications of the research in order to consent in their own right, please confirm that the child's assent and co-operation (as opposed to consent) will nonetheless be sought.**

Yes, the child's assent and co-operation (as opposed to consent) will be sought.

- (s) Please state whether and how parental consent, or the consent of the legal guardian or the order/declaration of the Court, will be sought in relation to the participation of child subjects in the research.**

Yes, parental consent, or the consent of the legal guardian or the order/declaration of the Court, will be sought in relation to the participation of child subjects in the research. Once the investigators have identified potential subjects (consulting other appropriate health-care professionals), the subjects and their parents or legal carers will be approached. The study will be fully explained to the subjects and parents or legal carers verbally and in writing (Information Sheet) and their permission obtained in writing (Research Consent Form).

- (t) Please state the manner in which any apparent objection to participation by a child subject will be handled**

A child or any other person expressing any apparent objection to participation will have their views respected and will not be included in the study. However, they will be given the option to take part at a later date if they so wish, and if it falls within the duration of the study.

- (IV) MENTALLY INCOMPETENT ADULTS (IE THOSE NOT ABLE TO CONSENT IN THEIR OWN RIGHT)**

- (u) Please state whether the research proposed will relate to the/a condition suffered by the proposed subjects.**

N/A

- (v) Please state whether it is proposed to seek the prior approval of an informed independent adult or any other person or body to the inclusion of the subject in the research and what precise arrangements will be put in place.**

N/A

- (w) Please state whether:**

- (i) the participation of the subject in the research could be of potential benefit to the subject in the management of his condition or in any way in relation to the maintenance or improvement or his/her health and well being**
- (ii) the research is non-therapeutic but may contribute to the general knowledge and understanding of the subjects' condition or related conditions.**

N/A

- (x) **Please state the degree of risk involved to the subject and its nature. Please state whether it would be correct to describe such risks of harm as "negligible". (ie not greater than those ordinarily encountered in daily life or during the performance of routine physical or psychological examination or tests").**

N/A

Negligible risk as wheelchair driver used in an indoor safe environment.

- (y) **Please state the manner in which any apparent objection to participation by the subject will be handled.**

N/A

6 COMPENSATION FOR DEATH OR PERSONAL INJURY

- (i) **If the research is sponsored by a pharmaceutical company, has that company agreed to abide by:**

(a) the ABPI Clinical Trials Compensation Guidelines 1991 (patient studies) ☐ tick if appropriate
or

(b) the ABPI Guidelines for Medical Experiments in non-patient human volunteers 1988 (healthy volunteer studies). ☐ tick if appropriate

- (ii) **If the research is not sponsored by a pharmaceutical company, please state what arrangements or insurance are/is in place (if any) to compensate a subject in the event of personal injury or death arising out of participation in the research. If none, please say so.**

None

7 FINANCIAL AND OTHER ARRANGEMENTS

- (a) **Please state any financial or other interests the applicant, his department or employer has in relation to the conduct of this research. In the case of a hospital/university, please state what additional costs will be incurred through the conduct of the research to such institutions and how these are to be met.**

There is no financial interest by applicant, department, or employer. The staff costs of the project will be met jointly by Sheffield Hallam University, Hawley Trust and Remploy InterWork. Additional cost will be met from NHS research funds.

- (b) **Please confirm that the necessary arrangements have been, or will be, made to comply with the requirements of the Data Protection Act 1984 with regard to the computer storage and processing of subjects' personal information and generally, to ensure confidentiality of such data supplied and generated in the course of the research.**

Yes, the necessary arrangements will be, made to comply with the requirements of the Data Protection Act 1984 with regard to the computer storage and processing of subjects' personal information and generally, to ensure confidentiality of such data supplied and generated in the course of the research.

Signed _____

the Investigator

Signed _____

Supervising Head of Department/Consultant

Dated _____

Information Sheet:

Analysis of switch based Human Computer Interaction by People with Disabilities and its application in Assistive technology prescription and automatic configuration of interfaces

What is the purpose of this study?

The purpose of this study is to investigate the way in which people with physical disabilities use their control systems or communication aids. The aim is to find ways of changing how these systems are set up so that they will be more appropriate to the needs of the user. In the long term it is hoped to develop a system that will adjust itself automatically to user's abilities. Amongst other things the changes will aim to increase the speed of use of the system. This in turn, may improve user's mobility, environmental control and communication capabilities. It is worth noting that the goals of the study are, in general, of long term benefit.

What will be involved if I agree to take part in the study?

If you agree to take part in the study we will load a computer program into your computer. This program will record information about how you are using the computer, including the items that you have selected and the times and dates when you made the selections. This recorded information will be analysed and it is hoped that this information will enable us to make changes to the system, which will improve how the system works. You will also be asked to complete a number of questionnaires (support in doing so will be offered), and one of the researchers will request to observe you using your system or aid at home, in school or in your work place.

Can I withdraw from the study at any time?

Yes. You are free to refuse to join the study and may withdraw at any time, or you may choose not to answer certain questions.

Will the information in the study be confidential?

All data, and anything you say or disclose, will be treated in strict confidence. No names will be mentioned in any reports of the study, and care will be taken so that individuals cannot be identified from details in reports of the results of the study.

Will anyone else be told about my participation in the study?

No, no one, except for the researchers directly involved in the study, will be told of your participation in the study.

If you would like to take part in the study, we would be grateful if you could send back the enclosed "Consent Form" as soon as possible, so that appropriate preparations can be made. If you require any further information please don't hesitate to contact :-

Dr Mark Hawley, Dr. Lynda Webb or Peter O'Neill on 01226 777726.

Thank you!

RESEARCH CONSENT FORM

Analysis of switch based Human Computer Interaction by People with Disabilities and its application in Assistive technology prescription and automatic configuration of interfaces.

The patient/carer(s) should complete the whole of this sheet himself/herself (themselves)

Please indicate your selection with a ✓ or ✗

Have you read the attached "Information Sheet"

Yes ☐ No ☐

Have you have had an opportunity to ask questions and discuss the contents of the "Information Sheet"?

Yes ☐ No ☐

Have you received satisfactory answers to all of your questions?

Yes ☐ No ☐

Have you received enough information about the study described in the "Information Sheet"?

Yes ☐ No ☐

Do you understand that you are free to withdraw from the study

- at any time
- without having to give a reason for withdrawing
- and without affecting your future medical care

Yes ☐ No ☐

Are you taking part in other research projects?

Yes ☐ No ☐

Do you agree to take part in this study?

Yes ☐ No ☐

OR

Do you agree to your child taking part in this study?

Yes ☐ No ☐

Who have you spoken to Dr / Mr / Mrs / Miss / Ms.....

Signed

Date...../...../.....

(NAME IN BLOCK LETTERS)

Signature of Witness.....

Appendix B

Barnsley Wheelchair Interface (BWI) Attributes

Name	Definition
Scan Rate	The Scan Rate is the time an item is highlighted and can be selected by the user.
Hold Time	The time that a switch must be closed before the switch input is accepted as a valid request.
Action Time	The time it will take the selected action to occur e.g., if the individual selects a speech item. Then the Action Time will have to be added as no other selection may be made until the selected action occurs.
Number of Items	The number of items that are contained within a set.
Item X Location	The items location on the horizontal axis
Item Y Location	The items location on the vertical axis
Item Arrangement	Where items are placed within the set.
Post Acceptance Time	The Post Acceptance Time is the period of time that must elapse, once a selection has been made before any switch closures will be accepted as a valid input.
Comprehension Time	This is the time that should be added to the Scan Rate in the first instance of the GUI displaying a set and returning to the beginning of the set once a selection has been made.
Number of Switches	The number of switches that are connected to the system that the user can use for selection.
Scan Method	These include linear, row column, column row, 1 division - then row column, 2 division - then row column, binary division and group.

Appendix C

Switch Based Applications Attributes

Application Attribute	Attribute Description
DIRECTIONS = 8	The number of items eg. Directions, to displayed on the screen. (Available, 4 and 8)
ACTIVE_STYLE = both	The highlight style. (Available, Boxed, Negative and Both)
SIZE = Large	The size of the item. (Available, Small Medium and Large)
START_ICON = centercel	Which item will be initially highlighted on the execution of the application. (Available in BWI, Exit and Forward)
CLOCKWISE = yes	Highlight order will go Clockwise. (Available in BWI, Yes and No)
FORE_GROUND_COLOUR = 14	The items colour. (Available in BWI, Values 1 to 16)
BACK_GROUND_COLOUR = 4	The background colour. (Available in BWI, Values 1 to 16)
HIGHLIGHT_BOX_COLOUR = 10	The highlight box colour. (Available in BWI, Values 1 to 16)
CALLSETUP = no	Call Setup item is scanned. (Available in BWI, Yes and No)
SOUND = both	Only available in BWI
FORWARD_FIRST_SCANNING = yes	Only available in BWI
SWITCH_ERROR_TIME = 10000	Only available in BWI
RESPONSE_ERROR = 10	Only available in BWI
SAVE_DATA = yes	Available in BWI, on constantly in BASE
NUMBER_OF_SWITCHES = 1	Only available in BWI
SLEEP_TIME = 2	Only available in BWI
SWITCH_HOLD_TIME = 100	Time switch must be close before action occurs.
SCAN_RATE = 2000	Duration item is available for selection
PAUSE_ON_CONTINUE = 1000	Only available in BWI
DISTANCE_TIME = 32000	Only available in BWI
OFF_SWITCH_HOLD_TIME = 1000	Only available in BWI
SWITCH_PORT = 760	Communication Port that switch(es) are connected to.

Appendix D

Switch Environment Assessment Tool (SEAT) Attributes

User Characteristics

Below is the window that is displayed to enter the user's characteristics in the SEAT application. Please note, that not all of the characteristics are shown: -

Attribute List	Section describing the test/s to Acquire Value
Values Obtained from the Tests	
Perception & Cognition Cycle Time	(1) (3)
Motor Cycle Time	(1) (3)
Number of item in one set	(5) (6)
Style of highlight	(5) (2)
Size of each item	(1) (5)
Foreground colour	Individual Preference
Background colour	Individual Preference
Highlight colour	Individual Preference
Sound	(1) (2)
Scan type	(2) (6)
Number of switch/es	Set by the Administrator
Hold down time before action taken	(1) (2) (3) (6)
Scan rate	(1) (2) (3) (6)
Longest time can be held down	(2) (4)

1. Reaction Test

The 'Reaction Test', will assist in obtaining information about the individual's 'eye to hand co-ordination'. The test will ask the individual to depress or release the switch as quickly as possible, on seeing an object appear in the centre of the screen. A record of the time taken to react to the change will be stored, along with the configuration of the application during that assessment. The test will be repeated a number of times. At the end of that test period the application will evaluate the user's response time and display / store the optimum response time and configuration during that test.

2. Smiley Face Test

The "Smiley Face" test consists of four pictorial images placed across the screen that is scanned sequentially. The third image is a picture of a smiling face, which the user must select. The test begins with the scan rate set high, maximum scan period and decreases on a successful completion. When the user depresses the switch post the required item, S.E.A.T will increase the scan until such time that the user is constantly selecting the required item.

In this test the application is obtaining the desired scan rate for the individual, it can be assumed that if the individual is selecting the item after the desired item the scan rate requires a longer period. However, if the user over a predetermined number of tests is always selecting the correct item, there are two possibilities. First the scan rate is at the optimum setting and no further adjustments are required. Secondly that the scan rate is too slow and a reduction is required, this could then take place until such time that the user selects the item after the smiling face. At this point the scan rate could be reduced in smaller amounts until the user selects the required item repeatedly.

3. Rapid Fire Test

The "Rapid Fire" test is a means of obtaining the user's ability to depress the switch in rapid succession. While the switch is being depressed, the user interface will display images and present audio feedback to every single switch press. This test like all other tests will have the ability to have single or multiple switches, although the test may ask the user to depress individual switches in a set sequence. It is suggested that this test will ascertain, not only the ability of the user to depress a single switch but the individual's motor ability in moving from one switch to another. Factors that must be taken into consideration e.g., is the individual's ability to retain the order in which the switches are to be depressed.

4. Hold Down Test

The hold down test will be designed to present the user with feedback while ever the switch is closed. This test is a means of gathering information with regards to the individual's ability to make continuous motor action over a prolonged period of time. This test will be useful in obtaining, if the user has difficulty with continuous action but may also be used to gather information on response time to a visual or and audio instruction from the test to release the switch.

5. Sizer Test

This test is to obtain information with regards to the individual's visual ability by using size of a object displayed on the screen, along with the colours of the object and the background it is placed on. At the beginning of the test the object will appear as a small dot, which will grow in size over a period of time. Once the individual is able to see the image, they will be requested to depress the switch as confirmation. To ensure that the image they have perceived is the same as the one displayed, the user may be given a selection of images and they will be required to select the image they have seen. If the user identifies the incorrect image, they will be asked to confirm their selection. Regardless of the correct image, being selected a visual and auditory reward will be presented.

6. Jigsaw Test

The jigsaw test would be best described as a building block test, as down the right side of the screen a black and white image covered with a black grid is displayed. The grid divides the image into six equal elements, each of the elements are displayed on the left side of the screen. However, these elements are coloured and are displayed in the manner of a two row, three column selection grid. Each time the test is ran a different image is used but the items place within the selection grid and black and white image remain the same. For example, if the bottom right item on the black and white image is placed on the first row, third item from the left. Then even if the image changes on the next test the positions will remain relative. The purpose of the test is to get the user to build the image from the bottom up. Once the image is completed and in full colour the image enlarges to the full screen and video with fall audio action begins. This video with full audio becomes the reward for the individual and it is important that suitable video is chosen. During this test different scan methods, highlight methods may be evaluated e.g., single item, grouped items, boxed, negative and negative, boxed.

Appendix I

Switch Environment Assessment Tool's Data Output

**(It is important to note that the data included
within this Appendix was included as an example
for the results that are obtained)**

Personal Details

Name :- Simon Brownsell Gender :- Male Date of Birth :- XXXXXXXX
Address :- XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Post Code :- XXXXX Telephone :- XXXXXXXXXXXXXXXX

Other information

The individual as the reading age : Month/s 27 Year/s
Is the person on Medication : No Is the person on this Medication long term :
No Is the Medication due : No
Does the person wear Glasses : Yes Is the person colour blind : No
Is the person dyslexic : No
The individual is taking : None

Test Attributes

The instruction was presented in : Auditory
The location was : BHNFT
The start time was : 14:42:27 The end time was : 15:0:49 The date was : 8/5/02

Switch Information

The switch type was : Specs The switch colour was : Yellow The switch size was :
The switch was located at : Right hand

Visual Information

The monitor type was : SVGA (Colour) The monitor size was : 330
The distance from eyes to monitor was : 720

Personal Influence

Things about the individual that may have influenced the test :

Environmental Influence

Things about the environmental that may have influenced the test :

Reaction Test Results

Event No.	Shape Shown	Switch Closed	Reaction Time
1	254435	254625	190
2	256086	256265	179
3	258121	258305	184
4	260871	261091	220
5	264721	264905	184
6	269836	270040	204
7	271761	271970	209
8	274346	274560	214
9	278031	278251	220
10	282705	282905	200

The Shape Chosen was : Star

The number of none required switch closures was : 0

The number of times the shape was shown : 10

The total test in 1000th's of seconds took : 28470

The Average Reaction in 1000th's was : 200

Moving Dot Test Results

Event No. Extended Duration Dot

1	9
2	12
3	24

The Start highlight rate was : 200

The extended dwell rate was : 1000

The Average Extended Highlight rate was : 15

The suggested 'Pc', Perception Cycle value is : 15

Scan Rate Test Results

Event No.	Scan Rate	Which Item	Required Item Highlighted	Selection Made
1	1000	3	527786	525710
2	1000	3	000000	528125
3	100	2	537906	537315
4	100	2	000000	537985
5	910	3	545221	543365
6	910	3	000000	545830
7	180	4	552206	551560
8	180	4	000000	552271
9	840	3	557541	555795
10	840	3	000000	557965
11	240	4	562217	561405
12	240	4	000000	562240
13	780	3	573711	572075

14	780	3	000000	574060
15	290	3	580091	579445
16	290	3	000000	580345
17	740	3	585040	583515
18	740	3	000000	585385
19	250	3	592302	591765
20	250	3	000000	592440
21	700	3	602696	601280
22	700	3	000000	602950
23	210	4	613476	612775
24	210	4	000000	613560
25	660	3	620846	619485
26	660	3	000000	621115
27	250	1	000000	624215
28	250	1	000000	624340
29	620	3	642461	641155
30	620	3	000000	642755
31	280	3	651426	650780
32	280	3	000000	651670
33	590	3	662591	661395
34	590	3	000000	662875
35	250	4	674306	673495
36	250	4	000000	674325
37	560	3	684041	682845
38	560	3	000000	684360
39	280	3	692951	692305
40	280	3	000000	693235
41	540	3	704006	702865
42	540	3	000000	704395
43	260	3	715502	714965
44	260	3	000000	715605
45	520	3	722981	721895
46	520	3	000000	723295
47	240	3	732276	731740
48	240	3	000000	732350
49	500	3	743826	742740
50	500	3	000000	744135

Total Number of Selections made by the user was : 24

The Number of Correct Selections made by the user was : 18

The Number of Incorrect Selections made by the user was : 6

The Longest Duration for the Scan Rate should be : 500

The Shortest Duration for the Scan Rate should be : 220

The Difference between the Longest and Shortest Duration for the Scan Rate is : 280

The Suggested Duration for the Scan Rate in 1000th's is : 360

Rapid Fire Test Results

Switch Closed	Switch Opened
322285	322361
322430	322520
322581	322665
322700	322850
322920	322975
323040	323125
323175	323265
323320	323385
323430	323516
323575	323655

Average duration between Switch Closure was : 129

Average time the switch was held down for was : 86

The suggested 'Mc', Motor Cycle time is : 64

The suggested Hold Down Time is : 86

Target Scan Test Results

Event No.	Scan Rate	Which Item	Required Item	Highlighted	Selection
Made	Target Was				
1	1000	2	783151	782135	2
2	1000	2	000000	783510	2
3	100	2	793601	793010	3
4	100	2	000000	793625	3
5	910	1	000000	804230	2
6	910	1	000000	804975	2
7	180	4	823136	822490	4
8	180	4	000000	823215	4
9	980	4	831111	828100	4
10	980	4	000000	831405	4
11	100	5	836886	836405	4
12	100	1	000000	836997	4
13	900	4	842661	839870	4
14	900	4	000000	842992	4
15	180	4	854156	853510	3
16	180	4	000000	854185	3
17	830	3	859326	857580	3
18	830	3	000000	859605	3
19	240	3	864771	864235	3
20	240	3	000000	864810	3
21	780	1	000000	867480	2
22	780	1	000000	868185	2
23	190	4	885946	885300	3
24	190	4	000000	886001	3
25	830	4	898320	895695	4
26	830	4	000000	898675	4
27	250	3	909156	908620	2

28	250	3	000000	909425	2
29	780	3	917186	915550	3
30	780	3	000000	917455	3
31	300	3	921366	920720	4
32	300	3	000000	921696	4
33	740	3	928791	927265	3
34	740	3	000000	929070	3
35	340	4	933081	931940	4
36	340	4	000000	933380	4
37	700	3	945346	943930	3
38	700	3	000000	945665	3
39	310	4	957392	956415	4
40	310	4	000000	957675	4
41	670	3	965422	964005	3
42	670	3	000000	965755	3
43	280	3	969766	969120	3
44	280	3	000000	970045	3
45	640	4	980601	978635	4
46	640	4	000000	980901	4

Total Number of Selections made by the user was : 22

The Number of Correct Selections made by the user was : 14

The Number of Incorrect Selections made by the user was : 8

The Longest Duration for the Scan Rate should be : 640

The Shortest Duration for the Scan Rate should be : 250

The Difference between the Longest and Shortest Duration for the Scan Rate is : 390

The Suggested Duration for the Scan Rate in 1000th's is : 445

Hold Down Test Results

Switch Closed	Switch Opened
1009670	1029675

The time set of the individual to hold down the switch was : 20000

Average Switch Open Time was : 0

The number open Switch occurred was : 1

The longest duration the switch was closed for is : 20005

The suggested Post Acceptance Delay is : 0

Sizer Test Results

Item Height	Item Width	Correct Item	Item Shown
13	13	Yes	Smiling Face
13	13	Yes	Sad Face
15	15	Yes	Smiling Face

The total number of test undertaken was : 3

The scan rate of the two images was : 445

The speed at which the item was increase in size was : 300

The number of pixcels the item was increase in size was : 2

The suggested size for any of the item, when the individual is 720mm away from the screen is : 13

Scan Type Test Results

Scan Type Did Take	Item Selected	Item Location	Should Have Taken	Time It
Single Step	11	11	4450	5375
Single Step	13	13	5340	6214
Single Step	15	15	6230	7284
Single Step	7	7	2670	3319
Single Step	10	10	4005	4819
Row Column	11	11	2225	10729
Row Column	13	13	1780	2029
Row Column	15	15	2670	3310
Row Column	7	7	1780	2164
Row Column	1	10	2225	2689
Row Column	9	10	2225	1730
Row Column	10	10	2225	2349
Column Row	11	11	2225	2840
Column Row	13	13	1780	2304
Column Row	15	15	2670	3289
Column Row	7	7	1780	2399
Column Row	10	10	1780	2289

The Scan Rate used for these test was : 445

The Hold Down Time used for these test was : 86

The Post Acceptance Time used for these test was : 0

Out of the required 15 selections, the user made : 17

The suggestion Scan Type is that the user uses 'Column Row'

Building Block Test Results

Item Selected	Time It Did Take
5	3743
4	3799
2	4983
1	3499
3	2244
6	3145

The Scan Rate used for these test was : 445

The Hold Down Time used for these test was : 86

The Post Acceptance Time used for these test was : 0

The SEAT application makes the following suggested values for this individual

The suggested 'Pc', Perception Cycle value is : 15

The suggested 'Mc', Motor Cycle time is : 64

The suggested Hold Down Time is : 86

The suggested 'Scan Rate', value is : 445

The suggested 'Post Acceptance', value is : 0

The suggested 'Item Size', is : 13

The suggested 'Scan Method', is : The suggestion Scan Type is that the user uses
'Column Row'