A 3-DIMENSIONAL ASSESSMENT AND FEEDBACK SYSTEM FOR ANKYLOSING SPONDYLITIS

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Last but not least, I offer my thanks to all of those who supported me in any respect during the project.
Declaration

I hereby declare that this dissertation, submitted to the University of Salford for the degree of philosophy in the faculty of Health and Social Care, is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.
Abbreviations

ARTSI  Type 1 Tumour Necrosis Factor Receptor Shedding Aminopeptidase Regulator
AS     Ankylosing Spondylitis
ASAS   Assessment of SpondyloArthritis International Society
ASIF   Ankylosing Spondylitis International Federation
ASQoL  Ankylosing Spondylitis Quality of Life
ATLS   Advanced Trauma Life Support
BASDAI Bath Ankylosing Spondylitis Disease Activity Index
BASFI  Bath Ankylosing Spondylitis Functional Index
BASMI  Bath Ankylosing Spondylitis Metrology Index
CAVE   Cave Artificial Virtual Environment
DC-ART Disease-Controlling Anti-Rheumatic Therapy
DFI    Dougados Functional Index
HLA-B27 Human Leucocyte Antigen-B27
HMD    Head Mounted Display
ICD    International Classification of Diseases
IL23R  Interleukin 23 Receptor
MDT    Multi-Disciplinary Team
MMVR   Medicine Met Virtual Reality
NASS   National Ankylosing Spondylitis Society
NY Criteria New York Criteria for Diagnosis of AS
PCTs   Primary Care Trusts
PROMs  Patient Reported Outcome Measures
PTSD   Post Traumatic Stress Disorder
QTM    Qualisys Track Manager
RGEC   Research Governance and Ethic Sub-Committee
RLDQ   Revised Leeds Disability Questionnaire
SMARDs Symptom-Modifying Anti-Rheumatic Drugs
TNF    Tumour Necrosis Factor
VAS    Visual Analogue Scales
VEs    Virtual Environments
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
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<tbody>
<tr>
<td>VR</td>
<td>Virtual Reality</td>
</tr>
<tr>
<td>VRCPAT</td>
<td>Virtual Reality Cognitive Performance Assessment Test</td>
</tr>
<tr>
<td>VRET</td>
<td>Virtual Reality Exposure Therapy</td>
</tr>
<tr>
<td>WYSWYM</td>
<td>What You See Is What You Measured</td>
</tr>
<tr>
<td>YAWL</td>
<td>Yet Another Workflow Language</td>
</tr>
<tr>
<td>2-D</td>
<td>2-Dimensional</td>
</tr>
<tr>
<td>3-D</td>
<td>3-Dimensional</td>
</tr>
</tbody>
</table>
Abstract

This research aims to understand how 3-D visualisation can support the assessment of a chronic arthritic condition. The focus is on the assessment and associated feedback of information by the clinician.

The assessment of any chronic disease is an integral part of the treatment. In the case of Ankylosing Spondylitis (AS), it is particularly important as it helps to determine whether or not pharmaceutical and/or surgical interventions are required for a patient. The assessment process for a patient with AS is currently overseen by the physiotherapist. There is growing awareness that the current protocols and means of taking measurements are both inaccurate and inconsistent. Therefore, the objective of this research is to investigate whether utilising 3-D visualisation technology can enhance the current assessment and feedback process by augmenting assessment instruments and by visualizing the function of a subject in ways afforded by a 3-D visualisation tool.

From a consideration of the physical therapy process, a simplified assessment and feedback model is developed and used to understand where a new tool might add value. A 3-D visualisation research tool is prototyped, to include both subjective and objective aspects of current assessment instruments. The Bath Indices for AS were used to test the limits of the prototype as these are acknowledged as the gold standard of assessment for this condition.

To verify the prototype, experiments were carried out, collecting motion data and measurement data from a healthy adult in a laboratory environment. To validate the prototype, a qualitative evaluation was undertaken using a pilot study, focus group and individual interview methods. Participants are experts in this condition and comprised physiotherapists in both service and academia. The results of the evaluation suggested that 3-D visualisation and a prototype for evaluation, as developed in this research, would enhance assessment and feedback from the physiotherapist’s perspective. Furthermore, it would be beneficial to the treatment of AS with respect to obtaining subjective and objective measures, and supporting exercise activity.
Chapter 1

1 Introduction

This chapter provides an overview and introduction to the thesis. First, some background information is given, highlighting the motivation behind the research, focusing the choice of Ankylosing Spondylitis (AS) as an exemplar condition. Next, the aim and objectives of the thesis are explained, and the contribution of this research is given. Finally, the content of each chapter is outlined in order to provide a guide to the thesis.

1.1 Motivation

Patients and healthcare generate information. Information regarding treatment outcomes, which brings both together, is said to be critical to better care, better outcomes and reduced costs (Department of Health, 2010a). To support this claim, there has been evidence showing that involvement of patients in their care and treatment can enhance their satisfaction, increase their knowledge and understanding of their health status, and improve their compliance to the treatment (Stevenson et al., 2004). Specifically, there is evidence showing that such involvement can improve the management of long-term conditions (Heisler et al., 2002). Information tools, such as Patient Reported Outcome Measures (PROMS), patient experience data, and real-time feedback are important in this move to make the patient more active in their care. However, these tools are not yet widely used (Department of Health, 2010a). Furthermore many of these information tools are still paper-based and, perhaps, fail to take advantage of the opportunities afforded by computers.

Digital technology is often described as a solution looking for a problem. However, their potential always excites, Virtual Reality (VR), for example, is claimed to
offer enormous efficiency gains within the healthcare practice and services, particularly as part of tele-medicine and tele-health solutions. Here it can provide access to advice and support without the need to travel (providing advantages in terms of convenience, outcomes and cost), and the potential to deliver services directly and customize them for different individuals or groups (Department of Health, 2010b); it has been claimed that the potential benefits of VR to healthcare is revolutionary.

The outstanding characteristic of VR is its functionality to simulate a real world, making a virtual world which can make the impossible task possible by altering the user's sensations. VR met medicine in the late 1980s and early 1990s (Robb, 2001). Since then, a vast number of applications have been developed with respect to Medical Record, Diagnosis, Therapy, Education and Training (Satava and Jones, 1999). Specifically, there are near-term applications in the area of surgical planning. And the use of VR for therapy has made significant progress, especially in Neuro-Psycho-Physiology and Rehabilitation (Moline, 1997).

A major factor impeding integration of this new technology, however, is the high expense of the hardware and software. Full VR is not always required; the effect of VR is achieved via interactive 3-Dimensional (3-D) visualisation and it is regarded as the core technology of VR (Satava and Jones, 1999). Another problem is that most current VR applications are expensive to develop and are comparatively narrowly focused which limits their usefulness for widespread use with the NHS. To support chronic conditions with multiple symptoms requires that VR is part of a whole suite of systems or offers a framework that can integrate visualisation technologies in a seamless way. If this could be achieved the cost would fall and perhaps it could then be a part of the forthcoming NHS information revolution, which is expected to be cost effective and even to pay for itself. In this setting there are additional advantages for focusing on the core aspect of VR, 3-D visualisation, as it requires relatively low-tech, less expensive environments and, already a component; it makes it practical for potential integration and possible implementation in clinical settings that are complex. It also makes it feasible to consider applying it to multi-problem chronic conditions in which the patient has to actively be involved in their life-long treatment. Application to chronic conditions however has not been the focus of much research.

My interest in Ankylosing Spondylitis (AS) was in part because I had a mis-diagnosis of AS. Thankfully it was not the case but having looked at it I became aware it
was an area that cried out for better tools for clinician and patient alike. Furthermore on closer inspection it seemed very suitable for VR applications as AS is “visual” in a number of ways:

1 AS is part of the spondyloarthropathy (International Classification of Diseases (ICD)-10) conditions which are characterized by visible symptoms that are capable of being represented by visual means.

2 The assessment of symptoms currently relies on a 2-Dimensional (2-D) Visual Analogue Scale (VAS) assessment which is an early form of visualisation.

3 The recommended treatment of AS involves exercise as a treatment for mobility problems, and this too can be represented by visualisation techniques.

4 The current forms of assessment include multiple visual elements, but these are often separate and difficult to bring together in a coherent way. This is because AS has multiple symptoms, such as stiffness, pain, fatigue that all have to be measured by different types of instruments.

AS is a specific case of more general conditions related to arthritis and back pain and therefore advances in the treatment of this area are likely to be of wider benefit. If so then that is an added benefit to the current research. To the researcher’s knowledge, there is no VR applications targeted at AS; but it has considerable promise to improve the management of AS over a period of time via 3-D visualisation technology.

1.2 Thesis Aim and Objectives

The aim of this thesis is:

To investigate, from the perspective of the physiotherapist who has to assess AS clients, the perceived role and value of 3-D visualisation technology in the assessment and feedback activities.

The objectives are:

- To develop formalised assessment and feedback models for AS, which provide a context for researching and designing useful and usable tools;
- To develop a prototype using 3-D visualisation tools to deal with the assessment and feedback of AS in a more integrated way, which is particularly applied to physiotherapy exercises;
To evaluate the perceived value of the prototype and the proposed models to physiotherapists, with a view to extending their use to the patient and the wider therapeutic services.

1.3 Contribution of the Research

This work investigates the perceived value of a 3-D visualisation system to physiotherapists who work with AS clients to improve the assessment and feedback of AS.

A physical therapy model is summarized basing on the current literature and information from a variety of sources. This physical therapy model provides an overall view of the current therapy domain and becomes the basis towards a more comprehensive VR therapeutic environment. Within the facets identified in this model, i.e. patient literature, pain management, relaxation, exercise and evaluation, the evaluation tool is envisioned as a single conceptual tool which combines the patient literature facet with the evaluation facet. At the same time, the exercise facet is closely connected with the evaluation facet and integrated into a single visualisation tool as part of this thesis.

New formal assessment and feedback models for AS have been proposed and validated, as to the researcher’s knowledge no such models have been reported in the current literature. These models provide concepts which help to capture the information, arising from the assessment and feedback processes. Within these models’ scope, a prototype is designed and developed to study the perceived value of 3-D visualisation technology in augmenting assessment and feedback for AS. This is the first attempt to integrate several assessment instruments within a single visual scale.

The research focuses upon how the physiotherapist values the prototype and this is a necessary first step, providing the ground work for making such a prototype directly available to the client. To do this would require formal clinical trials and extensive time beyond the course of this current research. However, the current research results show that the prototype has the potential to become effective as a PROM. However, the prototype developed offers much more than just measurement capability and assessment functionality; it also offers the potential for immediate feedback enabling it to play a more active role in therapy.
1.4 Structure of the Thesis

There are seven chapters; each chapter's purpose and content are listed below to provide an overview and guide to the thesis.

Chapter 1 provides an overview of the research and this present guide.

Chapter 2 is a literature review of VR/3-D visualisation applications in healthcare, with emphasis on assessment and feedback of AS. The review of other work around VR/3-D applications in therapy ensures this work's originality and provides background information to assess the contribution of this work. Several research gaps were found in the literature. For example, none of the published work reviewed examined the possibility of integrating different tools to support the management of multiple problems related to the same condition. Nor did there appear to be an appreciation of how assessment/feedback of patient performance is an integral part of the tool set, rather than as something secondary or alien to it. It shows that 3-D visualisation is potentially appropriate and is likely to improve upon existing 2-D based assessment instruments and practice. In summary, it is worthwhile to test the feasibility of an integrated tool that specifically focuses on assessment/feedback to support the management of a complex condition like AS. It is based on the fact that treatment often requires the patient to undergo physical exercise, and that it is possible to provide the necessary contemporaneous assessment and feedback information over a period of time.

In Chapter 3, the research design is presented, with an explanation of each stage of the research process and the methods used. Towards a comprehensive VR therapeutic environment, a set of VR tools are envisioned for AS highlighting the evaluation tool (including assessment and feedback) as the focus. Then, assessment and feedback models for AS are proposed since none exists from the literature. The development of a prototype within its scope is explained in three stages: data collection, data process and data output. The output from this prototype was rendered as 3-D video. Qualitative evaluation methods were used to assess this system's perceived value. The participants and interviewees were experts in AS from both practice and academic environments. The content based thematic analysis was utilized to analyze the qualitative evaluation results.

Chapter 4 shows how a specific research prototype was designed to facilitate moving towards a comprehensive VR therapeutic environment for AS. The ultimate goal is to consider multiple symptoms in a holistic approach. The research is focused on the
VR evaluation tool (including assessment and feedback) that can integrate several instruments and may facilitate other relevant work in the future.

Chapter 5 provides a detailed description of the prototype. A proposal for assessment and feedback models for AS provides a foundation. The prototype places an emphasis on subjective assessment, objective assessment, exercise perception and meaningful feedback.

Chapter 6 describes the evaluation of the prototype and the formalised models. The evaluation involved participants from both practice and academia working through the same scenario of a typical hypothetical patient visiting a clinic. The detailed perceived values are concluded at the end of this chapter.

Chapter 7 provides a critical evaluation and conclusion of the thesis, in which the validity and generalizability of the work in terms of thesis aim and objectives are presented. Finally, the limitations and contributions of this thesis are given along with suggestions for future work.
Chapter 2

2 Literature Review

This chapter provides context information and more about the motivation to this thesis, its main goal is to ensure the originality of this research. First, the process and scope of the literature review are described; this identifies broad categories and more specific areas of interest which overlap. Next the broader categories are discussed further so as to provide the context before the specific overlap areas are described in detail. This chapter ends with the conclusions reached and a summary.

2.1 Process and Scope of this Review

The original examination covered VR in general including its possible applicability to health. This was very wide, then refined to the area of VR health applications, which focused upon existing work in the healthcare domain and so considerably reduced the scale of the literature to be reviewed. Further refinements were made such that the subject of VR was focused on 3-D visualisation. Health and healthcare were still too broad, given the interest of the researcher; an early decision was made to concentrate on such work applied to a chronic arthritic condition. The particular reasons as to why AS was chosen as the exemplar condition are considered as part of this review. The review of the literature in this area suggested that research is necessary concerning the assessment and feedback processes, which are key aspects of the treatment for conditions such as AS.
2.1.1 Process of refinement

Pictorially, Figure 1 shows this process of refinement. The process guided and informed both the review and subsequent research process, and although the literature presented here provides some wider discussion as a part of the context, the focus becomes the actual thesis.

The bottom row in Figure 1 is considered in more detail, but for convenience it is simplified by conceptualising the whole study into three main areas i.e. VR/3-D visualisation health applications, AS, and assessment and feedback of AS, with respect to the published literature. VR health applications and 3-D visualisation were initially combined but the focus was on the latter as it can be seen that it is integral to the broader VR; indeed VR cannot really work without the 3-D visualisation element. On the other hand, AS is treated as a major area in its own right as it provides the main condition and therefore the context for the overall work and furthermore it establishes a baseline from which it can be shown how the research might be capable of being generalised to other areas. Assessment and feedback of AS comprise the third area. In part because this is the application focus for the present research, but also because these functions are common to many other healthcare therapeutic processes and are increasingly relevant to the area of pervasive healthcare.

\[\text{Initial Ideas}\]

\[\text{Technology} \quad \text{Applied to} \quad \text{Area of Need}\]

\[\text{Virtual Reality} \quad \rightarrow \quad \text{Health}\]

\[\text{Focus}\]

\[\text{Virtual Reality/3-D Visualisation Health Applications} \quad \rightarrow \quad \text{Ankylosing Spondylitis}\]

\[\text{Specific}\]

\[\text{3-D Visualisation} \quad \rightarrow \quad \text{AS Assessment and Feedback}\]

Figure 1 The process of refining the research proposal and the focus upon a specific area of study
2.1.2 **Scope of this review**

The Venn diagram in Figure 2 illustrates the overlaps and distinguishes each part and thereby visualises the scope of the presented literature.

In addition to clarifying concepts and terms used through the whole thesis, this chapter will discuss the broad categories of AS, assessment and feedback, and the VR/3-D visualisation applications, shown in the diagram.

---

**Key:**
- VR/3-D HA: Virtual Reality/3-D Visualisation Health Applications
- AS: Ankylosing Spondylitis
- A&F: Assessment and Feedback
- I: VR/3-D visualisation application for AS
- II: A&F in AS
- III: VR/3-D visualisation health application for A&F
- IV: VR/3-D visualisation A&F for AS

---

**Figure 2** Consideration of research areas from the literature review

The overlap areas therefore become the main foci (labelled I, II, III and IV in the figure) as these are particularly relevant to this thesis. However, literature found within area IV would be of greatest significance to this research, as it defines the extent to which this thesis is original and describes the detailed context of this research.

As displayed in Figure 2, both broad categories and overlapping areas will be discussed clockwise in the following sections:

- 2.2 VR/3-D Visualisation Health Applications
- 2.3 AS
- 2.4 Assessment and Feedback
- 2.5 VR/3-D Visualisation Application for AS
- 2.6 Assessment and Feedback in AS
- 2.7 VR/3-D Visualisation Health Application for Assessment and Feedback
- 2.8 VR/3-D Visualisation Assessment and Feedback for AS
2.2 VR/3-D Visualisation Health Applications

VR is not a new term. The idea of immersion within an artificial environment has been around in many fields: e.g. the computer industry, the military, NASA, science fiction, the arts and counterculture (Chesher, 1993). In 1989, the idea was first announced as a new technology called "Virtual Reality" by the software company Autodesk and the computer company VPL. The developers and promoters described VR as "a work of art, and as unlimited and harmless as a dream" (Rheingold, 1991). They claimed that "VR opens up a new continent of ideas and possibilities" (Rheingold, 1991). Thereafter, the VR industry was born and began to penetrate into many areas.

2.2.1 Introduction to VR

VR definitions

There is more than one way to explain what VR is, though the essence is similar. The American Heritage® Dictionary of the English Language describes VR as "a computer simulation of a real or imaginary system that enables a user to perform operations on the simulated system and shows the effects in real time" (2000). VR is also called Virtual Environments (VEs) by Bryson (Bryson, 1996). The content of VEs is very similar to VR. Moline defined VEs as "interactive, virtual image displays enhanced by special processing and by non-visual display modalities, such as auditory and haptic, to convince users that they are immersed in a synthetic space" (Moline, 1997). The most extraordinary characteristic of VR is its capability of simulation of a real or imaginary world. It does this by altering the users’ sensations in the 3-D world, which then can make what might be an impossible mission in the real world possible with VR.

It is claimed that VR needs a completely new way of thinking compared with 2-D interfaces and certainly requires very high performance systems to deliver. There are three principal components of a VR system that have been identified; a head-tracked, usually stereoscopic, display; a high-performance computer graphics system; and 3-D input devices.

3-D visualisation and related technologies

The effect of VR is achieved via interactive 3-D visualisation and it is regarded as the core technology of VR (Satava and Jones, 1999). Other aspects of VR relate to the technologies used; for example, whether or not the experience is immersive, or augmented may depend on the display be it a Head Mounted Display (HMD), a 3-D
video monitor, or a room-sized Cave Automatic Virtual Environment (CAVE). This thesis' focus is refined on 3-D visualisation. Again the experience may change depending upon whether the system is on a local computer or distributed over the Internet, but either way similar peripherals can be used to customize the VR applications to best suit the users. A list of VR terms is given in Table 1, most are technical terms that are provided by authors of VR handbooks; almost none of those definitions have been universally adopted by any standards organization (Stanney, 2002), and so the definitions which are provided here reflect popularity and current usage.

Table 1 Virtual reality technologies

<table>
<thead>
<tr>
<th>Name</th>
<th>Technology</th>
</tr>
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<tbody>
<tr>
<td>HMD</td>
<td>Abbreviation for head-mounted display. Helmet usually fitted with wide-angle display and stereophonic speakers, so the wearer can see and hear what is generated by the computer. Most HMDs not only include a visual display, but also a position tracking to locate the orientation of the head. (Moline, 1997, Stanney, 2002)</td>
</tr>
<tr>
<td>3-D Glasses, Helmet</td>
<td>The wearer of these Glasses can not only look at the screens in the helmet but also can peer at real objects by looking down. (Moline, 1997)</td>
</tr>
<tr>
<td>CAVE</td>
<td>Abbreviation for Cave Automatic Virtual Environment. Images are displayed on three surrounding walls, floor and even ceiling using stereoscopic video projectors. Usually, a principle client's head position is tracked, and other clients can come along. (Moline, 1997, Stanney, 2002)</td>
</tr>
<tr>
<td>DataGlove™</td>
<td>An input device (a glove that works like a joystick) developed by VPL Research, Inc. It appears as a hand in the virtual world. It can track hand position and orientation, as well as the finger flexure. Therefore, the user can pick up and manipulate objects by making grasping motion with the glove in the virtual environment. (Moline, 1997, Stanney, 2002)</td>
</tr>
</tbody>
</table>

In the specific area of healthcare, many types of tools which will facilitate the use of VR have been under development. As Moline (Moline, 1997) summarized in a survey: a facial input tool intended to provide greater control for disabled people had been developed by David Warner at the Human Performance Institute of Loma Linda University Medical Center; Keller et al. had developed a chemical vapour sensing system to incorporate sense of smell in virtual environments; and a virtual perambulator had been under development by Hiroo Iwata of the Institute of Engineering Mechanics at the
University of Tsukuba in which bodily movement was coordinated with visual images tools and etc.

2.2.2 VR health applications - an overview

When medicine met VR

Medicine met VR in the very late 1980s and early 1990s (Robb, 2001) and the benefits of VR to healthcare has been claimed to be “revolutionary” (Satava and Jones, 1999). Satava (Satava, 1993) has identified five elements that affect the realism of a virtual environment for medical applications; these are:

- Fidelity -- high-resolution graphics
- Display of organ properties -- such as deformation from morphing or kinematics of joints
- Display of organ reactions -- such as bleeding from an artery or bile from the gall bladder
- Interactivity -- between objects such as surgical instruments and organs
- Sensory feedback -- tactile and force feedback

Taxonomy of VR health applications

A vast number of VR health applications have been developed and there are many different ways to classify them. Satava suggested a method for the classification which originated from the practice of medicine. In this schema, the key components are: Medical Record, Diagnosis, Therapy, Education and Training. Details follow:

- Medical Records, visualisation and the ‘medical avatar’
- Diagnosis
  - Virtual endoscopy
  - Pre-operative planning
- Therapy
  - Telesurgery
  - Interoperative navigation and image guided surgery
  - Psychiatry and rehabilitation
  - Empathy network
- Education and Training
  - Surgical simulators
  - ATLS course and educational content
Helene Hoffman and VR curriculum (Satava and Jones, 1999)

Satava emphasized that the implementation of these applications should be totally integrated and that the full spectrum of healthcare should be incorporated. Later, his schema was amplified by Judi Moline. In Moline’s classification, the terminology and categories are:

- Surgical procedures
  - Remote surgery or telepresence
  - Augmented (or enhanced) reality surgery
  - Planning and simulation of procedures before surgery
- Medical therapy
- Preventive medicine and patient education
- Medical education and training
- Visualisation of massive medical databases
- Skill enhancement and rehabilitation
- Architectural design for health-care facilities (Moline, 1997)

In contrast with Satava’s schema, there are several significant changes made by Moline. First, surgery is regarded as an important category independent from therapy because surgery is one of the most developed areas in VR applications in medicine. Then, two subcategories are added into the schema: “patient education” and “architectural design for healthcare facilities”, though the latter “architectural design for healthcare facilities” broadens the scope beyond what is thought of as typical VR health applications. However, the important application, “medical record” is missing from the new classification though there is a category for “visualisation of massive medical databases”.

In both schemas, 3-D visualisation is emphasized as an important category. It is believed that the 3-D visualisation of massive medical databases and the “medical avatar” that can integrate these seemingly distinct schemas.

**VR health applications overview**

VR has been applied in medicine decades of years ago. Most of the activity is still primarily research based, extremely localized and often remote from routine practice. It has been noted that: “there are long periods of discovery, testing and evaluation before the Age begins the accelerated growth. This phenomenon is painfully obvious to all researchers as they try to move their discoveries from laboratory to commercial success” (Satava, 2001). However, it is encouraging to know that diverse approaches have been
made not only in research but also in practice. As Robb notes, "as the decades have marched on, more and more reports on practical applications and careful evaluations of VR methods and devices in medicine have penetrated the series. This author believes this has been a good thing, rendering Medicine Meets Virtual Reality (MMVR) more inclusive of clinicians - an important original goal that had become marginalized" (Robb, 2001).

There are near-term applications in the area of surgical planning: interoperative navigation and surgical simulations (Satava and Jones, 1998). The promise of the immediate future is held in diagnosis, for example, the virtual endoscopy may replace standard endoscopic procedures for diagnostic screening. It is also claimed that computerised 3-D atlases of human anatomy, physiology, and pathology are about to revolutionise the teaching of these subjects (Satava and Jones, 1999).

The use of VR for therapy has made significant progress, especially in Neuro-Psycho-Physiology and Rehabilitation (Moline, 1997). A number of VR systems have been developed and tested for the physical or mental rehabilitation of patients, and to support mental health therapy (Moline, 1997). In addition to modifying eating disorders and stroke disorders, treating acrophobia and therapy for Iraq War Military Personnel with Post Traumatic Stress Disorder (PTSD) (Pair et al., 2006), VR is also applied in relieving pain and helping exercises, including distracting dental patients from work being done, diminishing psycho-ontological symptoms in cancer patients, relieving back pain or pain from burn or injury (Das et al., 2005), and helping exercise for cerebral palsy patients (Moline, 1997).

One example in particular, the fMRI image of the brain taken by Hoffman et al, showed that VR was not just changing the way patients interpret incoming pain signals; the programs actually reduced the amount of pain-related brain activity (Hoffman et al., 2004). Another preliminary study by Karen Grimmer et al. reported that immersion in a virtual world of monsters and aliens helped children feel less pain during the treatment of severe injuries such as burns (Das et al., 2005). Researchers at Emory University School of Medicine and Virtually Better (Inc.) have been testing the use of VR therapy in helping people with lower back pain to learn how to relax, to breathe properly, and to manage their pain.

The VR application in the patient's record is believed to be the thread that ties these seemingly unrelated applications together (Satava and Jones, 1998). The patient's
record, or more generally, the individual's record, is a particular research focus of Health Informatics and is also one of the more popular VR applications that seeks to capture the "digital me". A number of visualisation tools have been developed to process the massive scale of medical data. However, research on how to link the image with the text content is less researched (Moline, 1997, Märkle et al., 2001). The lack of research on record standards is still the main difficulty to integrating these techniques into the patient's record. Research on visualisation of clinical knowledge found within the record is rare.

Moreover, the majority of studies examine single applications, rather than taking a more holistic approach that might employ a range of related applications. A major factor impeding integration is the high expense of the hardware and software, but also the lack of a framework for integrating the technologies in a seamless way with the healthcare processes.

2.2.3 VR health applications in therapy

Though the overlapping areas in Figure 2 are of particular interest to this thesis, there is a limited literature found. So a decision was made to conduct a broad review of VR health applications to establish a base-line for therapeutic applications (Li and Kay, 2008). This review provides a comprehensive overview of the field, and considers the shortcomings of the approaches presented in the literature.

Method

Papers for the review were identified by means of a comprehensive search strategy utilising the following 7 bibliographic databases: MEDLINE, CINAHL, PEDro, Cochrane Library Issue, PsycINFO, Science Direct and Ingenta Connect. The following specific subject headings [MeSH] and free text words were used to identify relevant papers: virtual reality, virtual visualisation, user-computer interface, three-dimensional visualisation, imaging three-dimensional, computer simulation, medical informatics applications, therapy and therapeutics. Papers also had to meet the following additional criteria: they had to be written in English, published between 2002--2007, and were to be full text, peer reviewed journal articles. Surgery applications were deliberately excluded as the interest is on therapy related to non-medical, chronic conditions. Finally, after removing duplications, the number of papers found that meet the inclusion criteria is 159. A need to organise the content of the papers for subsequent analysis leads to the development of a taxonomy.
A taxonomy of VR therapy applications (Li and Kay, 2008)

The VR technology has been shown to successfully improve the therapy quality due to its simulation capability, which can alter people’s perceptions in an imaginary environment. As noted in a more general survey (Moline, 1997), several VR systems have been developed and tested for the physical rehabilitation of patients and for supporting mental health therapy. However, since then more has been developed. A new review and taxonomy of VR therapy applications was required. The following taxonomy (Figure 3) is specifically meant to describe the domain with respect to the VR applications within it. Although explicitly carried out to make sense of the review, the taxonomy has helped to assess the amount of independent work being published; it illustrates an organisation of the subject matter and identifies where papers are published from the same project, so as to understand the true extent of the work being currently undertaken.

The taxonomy of VR applications in Therapy that has so far been developed is shown in Figure 3. The therapies identified or targeted by these applications provide an initial structure for the taxonomy, forming the first level of headings:

1. Anaesthesia and Analgesia
2. Assessment and Feedback
3. Exercise Movement Techniques
4. Exposure Therapy
5. Rehabilitation
6. Summary and Reviews
7. Treatment of Disorder

The category (2) “Assessment and Feedback” is applicable across the other categories, but as the purpose of the taxonomy is to highlight different types of research activity in this area and to see the degree to which evaluation is the focus of the work, it was included separately. The category (6) “Summary and Reviews” is included separately as well. The headings are simply organized by alphabetic order. The second level scopes the conditions included in the parent category. The third level provides a subcategory of the specific condition. There are often further relationships between second level items that can be identified, e.g., PTSD is associated with the category (7) “Treatment of Disorder” but here it is classified into (4) “Exposure Therapy” according to its therapeutic method; the mapping is not displayed in the figure to avoid clutter and to make the map easier to view at this stage of the development.
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Figure 3 VR applications and papers in therapy domain
A more sophisticated ontology may be developed as a later part of future work.

In Figure 3, the pair of numbers displayed within square brackets indicate the number of applications (i.e. individual projects), followed by the number of associated papers. The two numbers are not equal as some papers relate to more than one application and some applications have published more than once, albeit from different aspects, e.g., Sik et al (Sik et al., 2004) mentioned several VR applications in one paper, including applications for travelling, claustrophobia, autistic children, stroke, intellectual disabilities and amblyopia. The aggregated sum of the lower counts is provided at the higher level.

Figure 3 shows that the specific phobia category is one of the most common application areas for VR, referring to agoraphobia (Choi et al., 2005), (Vincelli F, 2003), (Viaud-Delmon et al., 2006), acrophobia (Krijn et al., 2004), (Krijn et al., 2007b), (Emmelkamp et al., 2002), claustrophobia (Garcia-Palacios et al., 2007), cockroach phobia (Juan et al., 2004), driving phobia (Barkley et al., 2007), (Mühlberger et al., 2007a), flight phobia (Wallach and Bar-Zvi, 2007), public speaking phobia (Sandra et al., 2002), social phobia (Klinger et al., 2005), (Roy et al., 2003), spider phobia (Garcia-Palacios et al., 2002) and travelling phobia (Dong et al., 2000). The review shows that “Stroke” within the “Rehabilitation” category is the most published application area for VR. Figure 3 provides a snapshot of VR application in Therapy; the reasons claimed in the literature for the widespread use are to do with the effectiveness of VR, which is said to be at least as good as the vivo or other ways of imagining the therapeutic situations. This is especially the case for “exposure therapy” (Krijn et al., 2007a).

VR tools have also been researched in relation to pain, and with impressive results due to its immersion and distraction functions (Das et al., 2005), (Hoffman et al., 2004), (Steele et al., 2003), (Mühlberger et al., 2007b), (Windich-Biermeier et al., 2007), (Patterson et al., 2006). Comparatively, VR applications which support exercise have not been widely studied and research on feedback or assessment in VR environments is clearly lacking. Assessment/feedback as a VR application is discussed in (Kim et al., 2004) and (Broeren et al., 2007, Di Diodato et al., 2007).

The literature on this topic is diverse and growing, and the reported applications are scattered across many areas. The diversity of the applications reflect in part the nature of the therapeutic domain, but the multiple papers from single projects can provide a misleading impression as to the extent of the work being carried out. As discussed in the
previous sections, this review focused on journal papers published between years 2002 to 2007. The close correspondence between projects and the selected publications means that the review reflects the actual spread of research being undertaken. However, more papers from same projects maybe found, i.e. papers published on conferences. Summary and reviews were carried out reporting the values and limitations of applications in this field, including virtual environments for motor rehabilitation (Holden, 2005), stroke rehabilitation (Henderson et al, 2007), assessment and treatment of specific phobias (Grös and Antony, 2006), exposure therapy of anxiety disorders (Krijn etal, 2004). In order to evaluate the value and side effects and move the applications from the lab to the routine practice, more evaluations are desired.

2.3 Ankylosing Spondylitis (AS)

The basic facts of AS, such as definition, cause, symptoms and treatment approaches etc. will be introduced in this section to provide an introduction to this condition.

2.3.1 Introduction to AS

AS is a painful progressive rheumatic disease that affects mainly the spine. It can also affect other joints (such as hips, knees, ankles and shoulders etc), tendons and ligaments and other areas, such as the heart, lung, skin and eye (Calin, 2006, Walker, 2006). Definitions from the Encyclopaedia of Alternative Medicine, Encyclopaedia of Medicine, and an AS expert respectively are:

- “AS is a systemic disorder that refers to inflammation of the joints in the spine. AS is the primary disease in an entire group of conditions known as seronegative spondylarthropathies. It is also known as rheumatoid spondylitis or Marie–Strümpell disease (among other names). AS is an autoimmune disease, as are most forms of arthritis. By definition, other joints, in addition to the spine, can also be affected, including the shoulders, hips, knees, and feet. Tissues in the eye can also be affected.” (Encyclopaedia of Alternative Medicine) (2007a)

- “AS refers to inflammation of the joints in the spine. AS is also known as rheumatoid spondylitis or Marie-Strümpell disease (among other names).” (Encyclopaedia of Medicine) (2007b)
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- "AS is an inflammatory rheumatic disorder, primarily of the axial skeleton (sacroiliac joints and spine), but can affect hip and shoulder joints and infrequently the peripheral joints." (Khan, 2002)

AS is characterized by chronic inflammation, and causes pain and stiffness of the back, and progressively affects the chest and neck. Eventually, the whole back may become curved and inflexible if the bones fuse (this is known as "bamboo spine"). The disease spectrum is wide; in fact, any body system may be affected. It is a systemic disorder that may involve multiple organs, such as the: eye (causing an inflammation of the iris, or iritis); heart (causing aortic valve disease); lungs; skin (causing a scaly skin condition, or psoriasis); gastrointestinal tract (causing inflammation within the small intestine, called ileitis, or inflammation of the large intestine, called colitis).

Approximately one in 200 males and one in 500 females in the U.K., according to the statistic from the National AS Society (NASS), are suffering from this disease (NASS, 2009). The impact on the AS sufferer however, is very different from patient to patient. Some signs and symptoms are mild; some are moderate; others may be severe and even lead to death. However, it is currently unknown why some patients do better than others.

The actual cause of AS is not clear. Unfortunately, there is no known cure at this point in time; consequently attention falls to the use of therapy and the forms of managing the condition. It is believed that AS is associated with the gene Human Leucocyte Antigen B27 (HLA-B27), which presents in 40-95% of cases (Calin, 2006). Although this gene is present in about 8% of the British population, most individuals will not have the condition. Only 10-15% of those who inherit the gene develop the disease. The usefulness of testing for HLA-B27 and its subtypes\(^1\) differs among ethnic and racial groups. However the advent of HLA-B27 associated with the MRI test may help the early diagnosis of AS. The occurrence of AS around the world roughly follows the distribution of the HLA-B27 gene. Together with the genetic variant HLA-B27, and the recently discovered type 1 tumour necrosis factor receptor shedding aminopeptidase regulator (ARTS1, a tumour suppressor gene), and Interleukin 23 Receptor (IL23R, a gene encoding for the interleukin-23 regulator) (Cardon et al., 2007), it takes the number of genes definitely known to be involved in the disease to three.

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\(^1\) HLA-B27 is now recognized to include at least 23 subtypes, B*2701–B*2723; some types are protective against AS and some types are involved in causing AS.
2.3.2 Symptoms and treatment approaches

The main symptoms of AS are pain, stiffness and fatigue. Pain and lack of mobility are the most common complaints of individuals with AS (Calin, 2006), which are also the main symptoms treated. However, fatigue has also been considered to be a core symptom; indeed in studies fatigue has been reported as one of the main symptoms by up to 65% of patients (Jones et al., 1996a, Wolfe et al., 2004). Long-standing pain and fatigue may give rise to depression.

Current treatments for AS include pharmacological approaches, surgical management and other approaches. The medicines used in pharmacological approaches can be classified as: anti-inflammatory painkillers; ordinary painkillers; and other medicines (including Sulfasalazine, Methotrexate, Anti-TNF (Tumour Necrosis Factor), and Glucosamine sulphate) (Calin, 2006, Walker, 2006). However, pharmacological approaches bring with them the risk of potential side-effects. Surgical intervention is used most often in patients with an advanced hip problem. Rarely, and in extreme cases, spinal osteotomy is undertaken in those patients with severe spinal curvature (Calin, 2006).

Other approaches to treatment include encouragement of a healthy life style (not smoking; discouragement of splints, braces and corsets; good posture), complementary therapies (acupuncture, aromatherapy, reflexology and homeopathy) and exercise (Walker, 2006). Regular exercise is the keystone of this alternative non-pharmacological, non-surgical approach. The initial symptoms can be prevented and relieved by regular movement of the areas involved. If this is not done, the formation of new bone can lead to increased stiffness, and to deformity with stooping posture in the spine. Eventually the stiffness and deformity become irreversible.

A typical physiotherapy treatment process is summarized in Figure 4. During managing the various problems of AS, exercise is an essential element in this process. Therefore, it becomes an integral part of the assessment and feedback that whether or not the patient exercises are appropriately. A brief summary of current physical treatments for AS that derived from this process will be discussed in Chapter 4, which comprises Patient literature, Relaxation, Pain management, Exercises and Evaluation.

There is a paradox in the management of AS. AS sufferers need to participate in routine exercise in order to retain mobility and prevent pain, stiffness and irreversible
Physiotherapy Treatment Process

2.4 Assessment and Feedback

2.4.1 Assessment

Terms such as “assessment” are deceptively simple; they are frequently used by clinicians but the meaning is often subtly different even in the same professions; consequently the semantics are variable.

The most often used similar term is “measurement”. Stevens, one of the founders of modern measurement theory, said, “in its broadest sense, measurement is the assignment of numerals to objects or events according to rules” (Domholdt, 1993). Another broad definition of “measurement” is that, it is “the process by which things are differentiated” (Rothstein, 1985). As to “assessment”, the term has not been defined well in healthcare, though it has been defined as “the act of judging or forming an opinion about somebody or something” by online advanced language dictionary (OALD) (www.oup.com).
Although overlaps in meaning do exist between the definitions of “measurement” and “assessment”, it is difficult to form an overall clear meaning for the term “assessment”. In this thesis, it is mainly used to refer to the whole process and therefore broader than “measurement”. A simplified assessment model is given in Chapter 5.

2.4.2 Feedback

“Feedback” can be an integral part of the assessment process. However, “feedback” is also a term that is rarely defined in the literature. It is more widely used in educational fields where assessment is usually accompanied with feedback to the candidate or as an engineering term used to describe a mechanism. Like “assessment” it is a common practice, very little attention is paid to the term in the healthcare literature. Feedback is likely to be given at anytime in the process, depending on the preferences and behaviour of the attending clinician. A simplified but more formal feedback model is given in Chapter 5, and complements an assessment model.

2.5 VR/3-D Visualisation Application for AS

The literature on VR therapy application is diverse and growing, and the reported applications are scattered across many areas. The review shows that disease specific VR/3-D visualisation applications range from treating eating disorder, to acrophobia and rehabilitation etc. However, to the author’s knowledge AS has not been targeted as a specific application. For any potential implementation within VR environments, the assessment of any benefit/dis-benefit (including usability) is a key factor, as is the need to minimise costs.

As regards “cost”, many research efforts in the literature were laboratory based or needed the support of expensive VR hardware. This is one of the main criticisms directed at VR applications. To meet practitioner requirements for lower cost and portability, the impact on presence of porting a Virtual Reality Exposure Therapy (VRET) program onto desktop environments was reported (Tichon and Banks, 2006). Results show that the VRET program successfully made users feel they were “present” in both platforms. Subjective reports of experiences in the environments should be considered in future research, and together with technical advances, have clear potential for VR in home care programmes and Tele-rehabilitation.
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The side effect of cyber sickness symptoms related to VR immersion is one concern that is often discussed, but there has been little research on this topic in past years. Some work, which looks at cyber sickness symptoms as evaluation content, has been done: the evaluation of the intervention of VR distraction for chemotherapy indicated that patients believed the head-mounted device are easy to use, that they experienced no cyber-sickness, and found that 82% would use VR again (Schneider and Hood, 2007).

Condition-specific VR/3-D visualisation applications include those dealing with relieving pain from burn or injury, improving exercise in patients with cerebral palsy. However, these have tended to focus on a single aspect of the condition, whereas something like AS has multiple facets. Therapy therefore needs to take a more holistic view, as does evaluation.

2.6 Assessment and Feedback in AS

A set of instruments have been developed for AS assessment. These typically take the form of a number of related questions; e.g., indices from Bath. The questions range over a number of areas including main symptoms (pain, stiffness and fatigue), disease activity, functional activity, quality of life, and sleep amongst others. The current measurements taken try to encompass the multidimensional impact of AS. Generally, five core domains were recommended by the Assessment of SpondyloArthritis International Society (ASAS; www.asas-group.org). These five are single item scales except functional ability. They include pain (intensity; measured by a VAS), spinal stiffness/inflammation (morning stiffness duration; VAS), functional ability (measured by Bath Ankylosing Spondylitis Functional Index (BASFI) (Calin et al., 1994) or Dougados Functional Index (DFI) (Dougados et al., 1988)), patient global assessment of health status (VAS) and spinal mobility (van der Heijde et al., 1997, van der Heijde et al., 1999). Significant progress in the field has been made since the initial ASAS recommendations, which acknowledged that they could change in the light of new research evidence.

In the UK, a typical assessment includes interview and form completion capturing the demographic details and, amongst others, measurements provided by BASFI (for “function”), Bath Ankylosing Spondylitis Disease Activity Index (ASDAI, for pain and fatigue), Bath Ankylosing Spondylitis – Global (BAS-G for global well-being). Bath Ankylosing Spondylitis Metrology Index (BASMI, for range of movement) and Bath
Ankylosing Spondylitis Radiology Index-spine (BASRI-s) that provides a radiologic scoring system. These mainly utilise 10 cm VAS that are essentially the subjective patient self-assessments (albeit with clinicians deriving numeric scores). For example, each question in BASFI is presented as a VAS with endpoints of “easy” and “impossible”. The patient marks the line, the physiotherapist turns it into a number and by simple arithmetic returns an overall score for the BASFI. BASMI on the other hand requires clinicians to use various types of measuring device (such as tape measures and, rulers and, specialist measuring apparatus) to obtain “objective” measures. BASRI-s provides radiology measurement scales to classify the patient, and is therefore potentially the most objective of the indices.

The extensive specific instruments for AS assessment are classified into two categories here: Bath AS indices and other instruments. The former have been widely used in practice and translated into many other languages and consequently became the main focus for the review.

2.6.1 Bath AS indices

The Bath indices are mainly patient reported outcome measures (i.e. PROMs), and make heavy use of the VAS, a form of assessment which is of particular interest to this study.

2.6.1.1 PROMs

It is widely accepted now both by the academic and the practitioner that the patients’ perception of disease impact and the outcomes delivered by healthcare should be included as part of an evaluation on effectiveness. PROMs provide a means of gaining an insight into the way patients perceive their health and track the impact that the treatments or adjustments to lifestyle have on their quality of life (PROM Group, 2006). Patient-assessed health instruments usually use questionnaires containing multiple items to reflect the broad nature of health status, disease or injury (Garratt et al., 2002, Fitzpatrick et al., 1998). These instruments can be completed by patients themselves, or by others on their behalf. The application of patient-assessed health instruments has become increasingly important within the assessment of healthcare and specifically within rheumatology. However, the white paper from Department of Health (UK) has pointed out that PROMs, and other outcome measures etc are not used widely enough (Department of Health, 2010a). And there is an intension to expand their validity,
collection and use to extend PROMs across the NHS wherever practicable (Department of Health, 2010a).

Bath AS indices are mainly PROMs. The fact that they are subjective doesn’t diminish their value in assessment of health status from the patient’s point of view. Patients’ experience of treatment and care is treated as a major indicator of quality and there has been a huge expansion in the development and application of questionnaires, interview schedules and rating scales that measure states of health and illness from the patient’s perspective. In the case of Bath AS indices, VAS is utilised as a measurement means.

### 2.6.1.2 VAS

VAS is defined as “a measurement instrument that tries to measure a characteristic or attitude that is believed to range across a continuum of values and cannot easily be directly measured” (Crichton, 2001). Operationally a VAS is usually a 10 cm long, horizontal line, anchored by word descriptors at both ends. The patient is asked to mark on the line the point that they feel represents their perception of their current state. The VAS score is decided by measuring in millimetres from the left hand end of the line to the point that the patient marks. Occasionally, VAS is presented as vertical lines or lines with extra descriptors.

VAS was first used in clinical and research settings back to the 1920’s; the VAS began to appear in the literature with increasing frequency in the 1960’s (Wewers and Lowe, 1990). Although originally used as a method for the evaluation of individuals by raters, the use of VAS has been extended to the rating of subjective phenomena by individuals experiencing the phenomena of interest. VAS are widely utilised as subjective assessment tools, including Bath AS indices. It has been reported that VAS as a convenient, easy and rapidly administered measurement is useful in clinical and research settings to measure a number of subjective phenomena (Wewers and Lowe, 1990).

Although the VAS is described as being independent of language once instruction has been given, problems have been reported with the subject’s ability to conceptually understand the method itself. The patient sometimes has difficulty in conceiving the unit of the line as a representation of a personal perception of an abstract concept.

For example, Figure 5 depicts a “conversation” between a patient and a doctor who is supposed to be responsible for the pain treatment.
“Every day I must ask patients how they rate their pain. It seems stupid and patients are frequently stumped.

ME: Where is your pain on a scale from zero to ten with ten being the worst pain you've ever experienced and zero being no pain?
THEM: It hurts.
ME: I know, but can you put it on that scale?
THEM: It freaking hurts a lot.
ME: So like an 8?
THEM: Whatever. Can you fix it?”

Dr. Brett K., DC, General Medicine Community, Rochester, New York

Figure 5 A blog of a conversation between a doctor and a patient

Clearly, this patient has difficulty conceiving a unit of number as his personal pain score. Although this is not a direct example of VAS, by inductive reasoning, patients do have similar difficulty conceiving a conceptualized unit of either number or line as personal score of interest. Therefore, the researcher must provide very clear instruction.

Other pragmatic concerns of VAS include accurate reproduction of the instrument itself because caution is required when photocopying the scale as this can lead to significant changes in its length (Wewers and Lowe, 1990). Beyond these relatively obvious concerns, other major issues include there is an unsolved conceptual dilemma lack of experiential grounding for the maximal descriptor (Wewers and Lowe, 1990). For example, the definition of endpoint of “impossible” in BASFI is still confusing. As VAS is highly subjective, these scales are of most value when looking at change within individuals, and are of less value for comparing across a group of individuals at one time point.

2.6.1.3 Development of Bath AS indices

The Bath indices try to capture how the disease and treatment affect health both from the patient’s perspective and the clinician’s perspective, which is important to provide the most effective management in the care of individuals with AS. In this section, the full range of Bath AS indices is discussed with regard to their development process.

(1) Development of BASFI
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BASFI was designed by a team of clinical professionals with input from patients, and consists of 8 specific questions as to function in AS and 2 overall questions of the patient’s ability to cope with everyday life (Calin et al., 1994). Each question is answered on a 10 cm horizontal VAS, the mean of which gives the BASFI score (0-10) (for full details see Appendix A). For its developments, the questionnaire was completed 257 times in total. Although the BASFI researchers incorporated the opinion of healthcare professionals and patients, the patient’s precise role and level of involvement is not made explicit (Haywood et al., 2005).

(2) Development of BASDAI

BASDAI was developed as a new approach to defining disease activity in patients with AS, which was designed by a multidisciplinary team in conjunction with patients, and consists of six specific questions regarding severity of fatigue, spinal and peripheral joint pain, localized tenderness and morning stiffness (both qualitative and quantitative) (Garrett et al., 1994). Each question is answered on a 10 cm horizontal VAS, and the final BASDAI score has a range of 0 to 10. The higher the score, the more severe the patient’s disability is (for further details see Appendix B). The index was distributed to a cross section of patients, including inpatients and hospital outpatients. In its development BASDAI was completed by a total of 154 patients. Again the role of patient’s is not made explicit (Haywood et al., 2005).

(3) Development of BASMI

BASMI was designed to determine the most appropriate clinical measurements for the assessment of AS to develop the new metrology index (Jenkinson et al., 1994). One hundred and ninety-three individuals with AS were studied, who reflected the entire spectrum of cases of AS. Metrology was performed on 327 occasions. Finally, 5 simple clinical measurements were defined which most accurately reflect axial status: cervical rotation, tragus to wall distance, lateral flexion, modified Schober’s, and intermalleolar distance. The original BASMI scoring table has been modified to increase BASMI’s sensitivity to change and to alter the scoring system so that it reflects a similar approach to that for BASDAI and BASFI. Further details of BASMI are in Appendix C.

(4) Development of BAS-G

BAS-G was designed to reflect the effect of AS on the patient’s well-being (Jones et al., 1996b). A pilot study was performed to select the most appropriate wording for BAS-G. With two items (for details see Appendix D), BAS-G is the shortest among
specific instruments for AS, but a single item is often reported. Although it is quick to complete, single item may be a poor substitute for a patient's perception of disease impact as important information may be lost which hinders data interpretation and usefulness to clinical decision-making (Fitzpatrick et al., 1998, Streiner and Norman, 2003).

(5) Development of BASRI-s

BASRI-s was designed as a reproducible and simple radiologic scoring system especially for the spine in patients with AS (MacKay et al., 1998). Radiographs of 470 patients with AS were scored using the New York criteria (NY Criteria) (Moll and Wright, 1973) for the sacroiliac joints, lumbar and cervical spine on a scale of 0-4 (for normal, suspicious, mild, moderate, and severe). These 3 scores were added together to generate the BASRI-s score (scored 2-12) (for details see Appendix E).

A summary of Bath AS indices is listed in Table 2.

<table>
<thead>
<tr>
<th>Name</th>
<th>Purpose</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASFI (Calin et al., 1994)</td>
<td>To define and monitor functional ability in persons with AS.</td>
<td>Items ask the respondents about their perception of their functional ability and how well they are able to function in everyday life.</td>
</tr>
<tr>
<td>BASDAI (Garrett et al., 1994)</td>
<td>To define disease activity and status in the person with AS</td>
<td>Consists of six 10 cm horizontal VAS to measure severity of fatigue, spinal and peripheral joint pain, localized tenderness, and morning stiffness (both qualitative and quantitative).</td>
</tr>
<tr>
<td>BASMI (Jenkinson et al., 1994)</td>
<td>To assess the axial status (cervical, dorsal and lumbar spine, hips, and pelvic soft tissue) of individuals with AS and derive a metrology index to define clinically significant changes in spinal movement.</td>
<td>Five clinical measures used to assess the status of the axial skeleton including cervical rotation, tragus to wall distance, lumbar side flexion, lumbar flexion, and intermalleolar distance.</td>
</tr>
<tr>
<td>BAS-G (Jones et al., 1996b)</td>
<td>To make a global assessment of the well-being of the person with AS over a given period of time.</td>
<td>Questions asking the patient to mark on a VAS of 10 cm the effect of AS on their well-being over the last week/6 months.</td>
</tr>
<tr>
<td>BASRI-s (MacKay et al., 1998)</td>
<td>To develop a reproducible and simple radiologic scoring system for the spine in patients with AS.</td>
<td>Five scores (0-4) used to grade the radiology status of spine including the lumbar and the cervical spine.</td>
</tr>
</tbody>
</table>
2.6.1.4  Review of Bath AS indices

Widely used Bath AS Indices are mainly PROMs, except BASMI and BASRI-s that are objective measurements. BASMI and BASRI-s are more objectively measurements and therefore are exceptions as to measurement properties review and BASFI, BASDAI and BAS-G keep as main subjects as they are mainly subjective instruments.

Patient-assessed health instruments are intended to provide an accurate assessment of disease impact and healthcare from the patient’s perspective (Garratt et al., 2002). Evidence as to the measurement properties for patient-assessed health instrument in patients with AS includes criteria: validity, reliability and responsiveness:

- Validity assesses if an instrument measures what is intended (Fitzpatrick et al., 1998). Usually content validity and face validity are assessed, through an appraisal of item content for the former and evidence for the source of instrument items for the latter.
- Reliability means “repeatability” or “consistency” (Fitzpatrick et al., 1998). Usually test-retest reliability and internal consistency reliability are used to assess the consistency of a measure from one time to another and the consistency of results across items within a test respectively.
- Responsiveness is described as the ability of an instrument to measure clinically important change over time when change is present (Fitzpatrick et al., 1998).

However, populations, settings and interventions can affect instrument measurement properties that are context-specific attributes (Beaton et al., 2001, Liang et al., 2002, Terwee et al., 2003). Three treatment settings have been indentified by ASAS for evaluation of instrument measurement properties, and they are disease-controlling anti-rheumatic therapy (DC-ART), symptom-modifying anti-rheumatic drugs (SMARDs) and physical therapy, and clinical record keeping (van der Heijde et al., 1997, van der Heijde et al., 1999).

BASFI and BASDAI have been subjected to extensive trials (Haywood et al., 2005). It has been shown that BASFI and BASDAI had the greatest amount of evidence for reliability, validity and responsiveness across a range of settings (Haywood et al., 2005). There was evidence that supported the internal construct validity of BASDAI and BASFI. There was extensive evidence of responsiveness following both drug therapy and physical therapy for BASDAI and BASFI (Haywood et al., 2005). Larger score changes
have been reported for the single BAS-G items following drug therapy evaluation than following physical therapy.

Although widely accepted in clinical trials, currently, there is little evidence to support the effectiveness of including patient-assessed health instruments in routine practice and clinical record keeping (Greenhalgh and Meadows, 1999). Group-level estimates of instrument performance and score change have been provided by the majority of studies; the interpretation of these estimates may be difficult for clinicians wishing to use patient-assessed instrument to inform clinical decision-making at the individual level (Beaton et al., 2001). Further exploration of the acceptability, feasibility and interpretation of including patient-assessed health instrument in clinical practice and clinical record keeping and of the benefit to be gained is required.

BASFI has been compared with the Revised Leeds Disability Questionnaire (RLDQ) and found that, while BASFI exhibits a ceiling effect in measuring of functional ability in AS, RLDQ shows a floor effect (Eyres et al., 2002). Haywood has pointed it out that although the BASFI remains one of the instruments of choice for the assessment of functional disability; consensus is still required for the recommendation of a single instrument (Haywood et al., 2005). BASDAI has acceptable measurement properties as a measure of disease activity, but there are issues relating to item content and appropriateness of response formats (Haywood et al., 2005). The relationship between disease activity, disease progression and its functional consequences remain tenuous.

Patients often experience difficulty in completing VAS, the format of BASDAI, BASFI and BAS-G. A comparative evaluation of response formats by patients with AS supported a preference for categorical rating scales (49%), followed by numerical rating scales (38%) and VAS (9%) (van Tubergen et al., 2002).

Several core assessment domains (pain, stiffness, fatigue or global health) are inadequately assessed by Bath AS-specific, multi-item patient-assessed health instruments. Where assessed these domains are largely measured by single-item scales – they may provide a limited view of these important domains. In addition, as to objective measurements, limited literature was found relating to the results of BASRI-s when it was first used in the New York criteria – this has now been modified (van der Linden et al., 1984), and progression of structural damage is a relatively slow process, and should only be repeated at the large intervals (e.g. 2 years).
2.6.2 "Quality of Life" as an AS instrument

As the AS disease spectrum is wide, any part of the body can be affected. The spectrum of assessment is therefore extensive as well. Ankylosing Spondylitis Quality of Life (ASQoL) (Doward et al., 2003) was developed to assess the impact of AS on the quality of life, consisting of 18 items asking a "yes" or "no" response to questions regarding the impact of pain on sleep, mood, motivation, ability to cope, activities of daily living, independence, relationships, and social life (for details see Appendix F). Although ASQoL purports to measure AS-related quality of life, some of the 10 most important and frequently mentioned patient concerns was missing (Haywood et al., 2003). It has been reported that ASQoL has some evidence of validity, and good evidence of responsiveness following drug therapy, but small to moderate levels following physical therapy (van Tubergen et al., 2003).

2.6.3 Role of the physiotherapist

The AS patient is seen by a multi-disciplinary team (MDT) from the onset of their condition. The MDT oversees the different aspects of the condition, attempting to provide a comprehensive approach to care. As physical therapy is seen as a substantive, relatively safe treatment, the physiotherapist is a key member of the team. With any treatment, a physiotherapist is required to make an adequate assessment of the patient's physical condition, in order that suitable treatment can be prescribed, and a base-line can be established so that progress or deterioration of the condition can be determined.

There is an ongoing debate regarding what is the rightful role of the physiotherapist (Rothstein, 1985). Changing times and changing roles necessarily result in a re-examination of traditional patterns of practice and professional preparation. Central to this process must be a consideration of how to assess patients, not only their initial status but also how patients are affected by treatment. Older models of practice persist in that therapists apply various modalities, i.e. exercise, because authorities, e.g. consultants, have requested specific treatment (Rothstein, 1985). Rothstein (Rothstein, 1985) argued that if therapists can not break out of this "technician" role, measurement and assessment is irrelevant, and so is professional status.

As more and more therapists have adopted the role of assessors and treatment planners, as well as treatment givers, it is ironic that they have not been more concerned with the validity of the measurements that justify this role.
2.7 VR/3-D Visualisation Health Application for Assessment and Feedback

It has been reported that evaluation, including assessment and feedback, when carried out in a different environment from the activity being evaluated is not very rewarding (Horwitz, 2004). Although it is not as extensive as for VEs, research of VR as an assessment/feedback tool has covered, among other things, cognitive performance assessment, psychophysiological assessment of phobic fear, assessing clinician’s skills through a simulator, and haptic force feedback, etc.

Conventionally, cognitive function has been assessed by a paper-based neuropsychological evaluation. However these test environments are different from everyday life. Parsons et al. developed a VE-based neuropsychological cognitive performance assessment test: Virtual Reality Cognitive Performance Assessment Test (VRCPAT). Findings have been reported that the VRCPAT measures a capacity consistent with that of traditional neurocognitive measures; and is inconsistent with potential confounds (Parsons et al., 2008). Experiments have been conducted with a sample of 30 healthy adults for initial validation for assessment of memory functioning (Parsons and Rizzo, 2008). These suggest that VRCPAT correlates significantly with traditional neuropsychological tests that assess similar target constructs.

A preliminary study of VR based cognitive assessment in people with stroke was conducted utilising a virtual shopping simulation (Kang et al., 2008). People who had undergone a stroke and control participants were compared in an immersive VR program that used a HMD. User satisfaction with the tests, complications, and the user interface were evaluated. The results suggest that this computer-generated VR-based cognitive test shows promise in assessing cognitive function in patients with stroke. However, more refinements are needed in the user interface and the projection methods.

Another field where VR has potential impact is on assessment of professional skills. Time-efficient laparoscopic skills were assessed using an augmented-reality simulator by Oostema et al. (Oostema et al., 2008). In this study, medical students (3rd year), surgical residents (postgraduate years 1-5), and attending surgeons were invited to perform four different tasks three times in a hybrid laparoscopic trainer. The computer-derived metrics measured by the hybrid trainer correlated with laparoscopic experience, and these metrics could be automatically calculated and stored. This may make skills assessment and training a more time-efficient endeavour for instructors and trainees alike.
Further study is necessary to determine whether specific metrics are better indicators of actual skill.

Another VR simulator of screw and plate fixation of hip fractures was used to assess technical skill of novices and trainee surgeons (Blyth et al., 2008). Three groups (medical students, basic trainees, and advanced trainees) performed six virtual operations. Measurements included: reduction position, incision length, misplaced drill-holes, final screw placement, X-rays taken, surgical time as well as computer and operative experience. The study shows that accuracy, number of X-rays and speed are significantly different between novices and trainee surgeons.

A prototype force feedback device for VR-fMRI has been developed. Experiments validated device performance in terms of force output, interaction bandwidth, transmission delay, and fMRI-compatibility (Di Diodato et al., 2007). It is claimed that this device may facilitate further experiments to clarify the effect of haptics in VR, and may be adapted for characterizing brain function and behaviour associated with stroke-related hand paresis (Di Diodato et al., 2007).

Feedback is an important way in information transmission in motor function output. Though attention has been paid to haptic feedback, other form of feedback that is transmitted by movement-related information such as proprioceptive, visual and/or audial information output is lacking.

2.8 VR/3-D Visualisation Assessment and Feedback for AS

Literature found within this area would be very relevant to the current research, as it would define the extent to which this thesis is original and would describe the detailed context of this research. However, no literature was found in the bibliographic sources used, with exception of papers previously generated from the project itself. There appears to be a lack of research activity in this area. And this is reassuring as to the direction of the research and is both an incentive and a challenge.

It has been found that none of the published work in VR/3-D visualisation looked at a diverse spectrum of applications with a view of integrating different tools to support the management of multiple problems condition. Nor did there seem to be an appreciation of how evaluation of performance is required to be an integral part of the tool set, rather than something that is alien to it. More evaluation is required both with
respect to the application and its likely implementation context. Specifically, condition-specific VR/3-D visualisation applications include those dealing with relieving pain from burn or injury, improving exercise in patients with cerebral palsy, VR applications to support exercise have not been widely investigated, nor have VR applications been targeted specifically at AS, which is not that surprising as AS is not that well researched in relation to these technologies. Therefore, it could be argued that AS is a sensible exemplar condition that has multiple symptoms and requires evaluation (including assessment and feedback) as an integral part of its ongoing treatment process.

As regards to assessment and feedback in AS, it has been noticed that although Bath indices have been widely adopted, Bath indices, for example BASFI remain one of the instruments of choice for the assessment of functional disability; consensus is still required for the recommendation of a single instrument (Haywood et al., 2005). Where assessed these domains are largely measured by single-item scales – they may provide a limited view of these important domains. Moreover, VAS as the main method that Bath indices utilised, problems of which have been reported with the subject's ability to conceptually understand the method itself. In addition, the objective assessment, i.e. BASMI, has been reported that inconsistency exists in practice.

The transition of current assessment and feedback methods to a VR method of measuring is believed to be promising. It provides a conversion from subjective assessment to objective measurement by adding more objectivity into the measuring. The shift from verbal assessment to visual assessment method is showed to be beneficial. As discussed in (Horwitz, 2004), the use of different assessment techniques in dance/movement therapy in fibromyalgia patients most likely has affected the treatment outcome. The results showed that the video interpretation technique and self-figure drawings captured treatment effects that were not evident from verbal scales or reflected in hormone levels. It suggests that this work considers how AS is evaluated with respect to subjective assessment (i.e. BASFI), objective assessment (i.e. BASMI) and their applicability to exercise, and whether 3-D visualisation is a suitable technology to supply the bigger picture.

This work however will focus less on immersion and imagination but more on the element of 3-D visualisation, which is arguably the core technology of VR. It is important in this respect to note that AS, both as condition and in its treatment is almost defined by visual aspects. This in itself raised the question of whether or not these could
be represented and augmented by 3-D technologies. Furthermore, 3-D visualisation provides the means of integrating data and information that traditionally has been kept separate. A further advantage of this approach could stem from the attractiveness of the technology. The AS sufferer is often diagnosed during their early adulthood. It is often claimed that the young are more techno-savvy than the older persons but whether or not this is actually the case, it is true that VR technologies in general and 3-D visualization in particular are engaging for the users, and this may offer another way of managing this condition, as an alternative to the existing scales and 2-D forms of representation.

Thus, the goal of this work is to study 3-D visualisation technology's perceived value in supporting the clinical professionals', i.e. physiotherapists' task of assessment and feedback and its potential value in helping the patients to self-manage as seen from the clinical professional's point of view. The physiotherapists are designed to be involved in the qualitative evaluation of this research, as it is believed that it is beneficial to justify the quality of this work from the physiotherapist's perspective of view. The broader research interest is ultimately concerned both with respect to the application and its likely implementation context. However, many of these in-practice issues can only be followed up once the basic research has been undertaken.

2.9 Summary

The aim of this chapter is to define the scope of this research and to ensure its originality.

Process and scope of this review was provided in section 2.1, which showed the refinement process of this research and scoped the literature review. In section 2.2, background information about VR/3-D visualisation technology was introduced, followed by an overview of VR health applications, in the end of section 2.2, a review of VR health applications in therapy was undertaken to establish a base-line for therapeutic applications. Introduction information and treatment approaches for AS were discussed in section 2.3 to provide an overview of this condition. In section 2.4, terms such as "assessment" and "feedback" were discussed, specifying the meaning of terms used through this thesis. Although limited literature found in section 2.5, benefit and dis-benefit of VR/3-D visualisation applications that may minimise the cost of application for AS were discussed. Issues regarding assessment and feedback for AS were investigated in section 2.6, and Bath AS indices' role and its limitations were indentified. In section 2.7, VR being an assessment and feedback tool was discussed, suggesting that
application applied to assessment was weak and visual form of feedback information was rare. In section 2.8, the motivation for this work was summarized, specifying a research opportunity identified.

2.10 Conclusions

Although the literature on the more general topic of VR/3-D visualisation applications in healthcare was found to be extensive, it was noticeable that many of the applications described were still laboratory based and had yet to find their way into routine service. Furthermore, the diversity of the approaches taken has resulted in many of the developments being stand-alone, both in terms of the technology deployed and in terms of the lack of consideration of a more holistic application. There is a requirement to integrate distinct VR tools to support the management of a chronic condition such as AS and that evaluation provides the context for examining benefits for the clinician and, eventually for the patient.

VR/3-D visualisation tools have been heavily researched in relation to pain, and with impressive results. However, VR applications to support exercise have not been widely investigated. VR being an assessment/feedback tool has paid attention to cognitive performance assessment, psychophysiological assessment of phobic fear, assessing clinician’s skills through a simulator, and haptic force feedback. However, none VR application has specifically targeted AS, nor visual forms of feedback information.

AS is selected as the specific test condition for the research, not only because it is a chronic arthritic condition that need physical exercise as therapy method but also because it is a multi-faceted condition. The existing paper-based instruments for AS have been helpful to clinicians and represent the present state of knowledge in encapsulated form (Haywood et al., 2005). Undoubtedly a debt is owed to those who have introduced measurement where none has previously existed. However, it is also clear that the current gold standards can be improved upon in ways that previously have not been possible. The current means of assessment for the patient’s condition rely heavily on the use of VAS. Bath AS indices and other specific measurement instruments have limitations as discussed previously.

In summary, it is worthwhile to test the feasibility and perceived value of a tool that specifically focus on evaluation (including assessment and feedback) to support the
management of AS that requires the patient to undergo physical exercise from the clinical professionals’ view, and assessment and feedback information can be provided in the same time. In the next chapter, the research design and research methods will be introduced.
Chapter 3

3 Research Design and Methods

The literature review was discussed in the last chapter, and was instrumental in identifying the research opportunity. The aim of this chapter is to discuss the research design and methods used, including development of therapeutic VR models, proposal of assessment and feedback models, development of prototype and the qualitative evaluation.

3.1 Research Design

This section describes the research design and in particular specifies the research process undertaken.

From the literature review, the aim of this research focused on the perceived value of 3-D visualisation technology in assessment and feedback for AS from the physiotherapist’s view. Research interest was stimulated by the multi-faceted nature of AS, and the existing treatment processes. For example, this research makes a distinct feature of “feedback” although it is recognised that it is an integral part of the assessment process. Therefore, they were considered as being two distinct but complementary parts of the client/condition “evaluation”. Evaluation too is required not only with respect to the client’s condition but also to prototype’s application and its likely implementation.

Consequently, “evaluation” is a key concept. If a comprehensive VR therapeutic environment is to be established, then this research explores the possibility of developing a set of VR tools for AS. It is envisioned, that the design will be of an “evaluation tool”, one that includes both assessment and feedback functions, and one that will eventually be capable of integrating other tools for the purpose of serving the therapeutic.
It has been found that the descriptions of both the term and process of both "assessment" and "feedback" are lacking in the literature. As part of this research, distinct assessment and feedback models were proposed to provide a foundation for the development of the research prototype. To create the models, existing processes and tools were searched, in which the models were implicit but not described explicitly. Then it was begun by examining the types of measurements, provided by instruments such as BASFI and BASMI, and their application to exercise.

A road map of the research design is shown in Figure 6. The work starts at step 1 with a research aim derived from the research opportunity identified. Then at step 2, the development of therapeutic VR models towards a complex therapeutic VR environment is investigated. At step 3, the assessment and feedback models that are lacking from the literature are proposed. Step 4 specifies the development of the prototype, classified into data collection, data process and data output. Step 5 describes qualitative evaluation sessions, ethical issues, the recruitment of participants and pilot study etc are also considered to complement the process. Each step will be discussed in the sections given in parentheses in Figure 6.

![Figure 6 Roadmap of research design explaining the research process](image)

*Figure 6 Roadmap of research design explaining the research process*
3.2 Development of Therapeutic VR Models

AS was selected as the exemplar condition and its characteristics lent itself to using visual tools as a focus. For example, its visible symptoms are suitable for 3-D representation, and its recommended treatment involves exercise which also can be represented by 3-D visualisation techniques. A physiotherapy model (see Chapter 4) for AS was developed according to information generated from sources such as the AS International Federation (ASIF); the UK NASS etc. and so called grey literature such as patient information leaflets. The summarized elements within this model are regarded as facets for the model and prototype. This model forms the basis for proposing a set of VR tools that can be applied to each facet. Then it becomes necessary to consider how to design an application for integration and for likely implementation environment. In the context of limitation of time and resource, it is not feasible to construct a complete environment that treats each symptom. However, a VR evaluation tool related to AS does provide a means of integration as it must address the various systems to deliver a holistic view of the condition. Such an evaluation tool can integrate but also provide a basis for the design of other tools which contribute to the assessment and feedback. This is especially true for the exercise facet and this facet is prioritised in the development of the research prototype. Full detail will be discussed in Chapter 4.

3.3 Proposal of Assessment and Feedback Models

The terms "assessment" and "feedback" describe common practice activity and practitioners assume they know what they mean. They are often surprised when their "version" or understanding of the terms is subtly different from that of their colleagues. Although ambiguity and lack of attention to term boundaries is managed seamlessly by people in their daily routines, it is a poor basis on which to construct a meaningful computer-based prototype. It therefore became necessary to make the term descriptions more rigorous and to remove ambiguity by formalising the assessment and feedback processes. These models attempt to capture accurately what is done in practice; these then become the basis for development of the research prototype. The development of the assessment and feedback models are discussed in Chapter 5, and the validation of these models becomes part of the qualitative sessions.
3.4 Development of Prototype

The assessment and feedback models made it clear that the full profile was involved in the assessment and feedback processes. By contrast some of the measures deployed in current practice were simplistic and were not extendable to cover multiple facets. VAS has the advantage of being deemed "simple" and straightforward to use but is often misunderstood by clinician and patient alike. To overcome the limitations of the 2-D, linear scales used for representing the functional ability of complex entities, a 3-D virtual person is envisaged as being a major component of the tool. To be useful, the virtual person has 3-D motion data mapped to it which required pipe-lining outputs from a set of software tools including:

1) Qualisys®, a motion capture system, captures the motions of a healthy adult via markers as they completed a set of predetermined tasks. The outputs are exported as c3d files, which is the format required for the next stage;

2) Autodesk® MotionBuilder®, is where the previously captured motion data are mapped to a 3-D virtual person called "actor" within the scene, then the "actor" is borrowed from the scene as representation of this prototype. Output in avi or mov video format, which are common video formats that can be compatible with most media players, can be rendered here as well. As in Chapter 5, a neutral and simple actor will be showed as the assist of output and display to fit the video output purpose for present.

Figure 7 shows the process in detail of production workflow of the virtual person and 3-D data workflow.

For the moment this pipeline workflow production needs a healthy adult experiment the selected actions wearing the markers on. The process begins with the possibility of "creation" of a 3-D model, and followed by "characterization" into Motionbuilder®. They have been referred in the figure to show the potential of implementation into other environments. Since the "creation" and "characterization" of 3-D model fell off the research focus, it is only introduced here. A simplified 3-D "actor" was utilised to be the representation assist rather than a complicated 3-D model. And file format "FBX" could be the bridge between different software because it is the format that compatible to a range of 3-D modelling environment, such as 3ds Max®.

Here, a structure of the whole process of data collection, data process and data output is explained in sequence. The full details of the prototype are given in Chapter 5.
3.4.1 Data collection

This section discusses how 3-D data was collected in a laboratory environment by means of monitoring a healthy adult. The issues that arise with this approach, such as equipment set up and calibration of a marker set will be explained in this section.

Equipment and calibration

The optical motion capture system Qualisys®, consisting of 6 or 12 Oqus™ cameras and controlled by windows-based data acquisition software QTM, was utilised to collect motion data from a healthy adult. The data was collected in a laboratory environment, and two sets of Qualisys® systems were used. One system consists of 12 Oqus™ cameras in the organisation’s gait lab; the other system used 6 Oqus™ cameras in the usability lab. As will be discussed in detail in Chapter 5, subjective assessment activities and physiotherapy exercises were performed in the gait lab, and objective assessment activities were collected in the usability room reflecting the different space requirements and accessibility. The more constrained of the usability lab tested the possibility that a future development might be to collect objective assessment data in a relatively limited space like a client’s home.

Qualisys® is a marker based technology to track the movement trajectories of retroreflective markers that are attached to the healthy adult, which makes it precise and can deliver high quality 3-D data. Moreover, compatibility of data output format was
considered as well for future process. Prior to each data collection session, the cameras were calibrated using a T-shaped wand and an L-shaped reference structure in order to avoid measurement errors and incorrect integration of all measurement systems into the same timeframe.

**Marker set**

The data collection was conducted on a healthy adult. Therefore, there was to be no comparison between individuals. Whole body marker sets, including both single marker and marker clusters, were determined to use as it was compatible with the following process and it could provide rich information. Based on a whole body marker placement system that is used in the gait lab, two modified whole body marker sets (marker set A and marker set B) were used for data collection.

Marker set A (as shown in Figure 8) is for subjective assessment and exercise activity, and marker set model B (as shown in Figure 9) is for objective assessment.

**Figure 8** Images of whole body marker set model A (front and back)

The aim of this work is not to compare efficiency between marker sets or focus on a kinematic and kinetic study. Therefore, the marker was set under an experienced engineer’s supervision according to future process requirements, and a simple rule was followed i.e., to capture efficient information without affecting the healthy adult’s
movements. Marker set model A was shared across subjective assessment and NASS exercises; the detail of marker position, type and number is shown in Table 3. Marker set model A includes single markers on the joints, i.e. wrist, elbow, shoulder, knee, ankle etc., and marker clusters on various segments, i.e. forearm, upper arm, thigh, leg, pelvis etc.

![Image of whole body marker set model B](image)

**Figure 9** Image of whole body marker set model B

Marker set model B was shared across objective assessment. Compared to model A, a smaller number of markers was used, as shown in Table 4, as only single markers were set up. This slight change was made to fit the measurement purpose without sacrificing the data quality. In this research, the impact of different marker set models on data capture is deliberately skipped, and the quality of the data within Qualisys® manager was accurate.

The healthy adult was asked to complete the selected activities step by step, and the full spectrum of selected activities is explained in Chapter 5. And then 3-D motion data were captured and processed within QTM. Once the data were deemed satisfactory, they were stored in the c3d file and were ready for output to next step.
## Table 3 Whole body marker set model A

<table>
<thead>
<tr>
<th>Position</th>
<th>Single marker</th>
<th>Marker cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T/F*</td>
<td>number</td>
</tr>
<tr>
<td>Head</td>
<td>T</td>
<td>5</td>
</tr>
<tr>
<td>Face (L&amp;R)</td>
<td>T</td>
<td>2 (1×2)</td>
</tr>
<tr>
<td>Shoulder (L&amp;R)</td>
<td>T</td>
<td>2 (1×2)</td>
</tr>
<tr>
<td>Chest</td>
<td>T</td>
<td>1</td>
</tr>
<tr>
<td>Neck</td>
<td>T</td>
<td>1</td>
</tr>
<tr>
<td>Upper arm (L&amp;R)</td>
<td>F</td>
<td>N/A</td>
</tr>
<tr>
<td>Elbow (L&amp;R)</td>
<td>T</td>
<td>4 (2×2)</td>
</tr>
<tr>
<td>Fore arm (L&amp;R)</td>
<td>F</td>
<td>N/A</td>
</tr>
<tr>
<td>Wrist (L&amp;R)</td>
<td>T</td>
<td>4 (2×2)</td>
</tr>
<tr>
<td>Hand (L&amp;R)</td>
<td>T</td>
<td>8 (4×2)</td>
</tr>
<tr>
<td>Pelvis (L&amp;R)</td>
<td>T</td>
<td>2 (1×2)</td>
</tr>
<tr>
<td>Pelvis set</td>
<td>F</td>
<td>N/A</td>
</tr>
<tr>
<td>G troc (L&amp;R)</td>
<td>T</td>
<td>2 (1×2)</td>
</tr>
<tr>
<td>Thigh (L&amp;R)</td>
<td>F</td>
<td>N/A</td>
</tr>
<tr>
<td>Knee (L&amp;R)</td>
<td>T</td>
<td>4 (2×2)</td>
</tr>
<tr>
<td>Leg (L&amp;R)</td>
<td>F</td>
<td>N/A</td>
</tr>
<tr>
<td>Malleolus (L&amp;R)</td>
<td>T</td>
<td>4 (2×2)</td>
</tr>
<tr>
<td>Heel (L&amp;R)</td>
<td>T</td>
<td>2 (1×2)</td>
</tr>
<tr>
<td>Foot (L&amp;R)</td>
<td>T</td>
<td>6 (3×2)</td>
</tr>
<tr>
<td>Subtotal</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>83 (47+36)</td>
<td></td>
</tr>
</tbody>
</table>

*T/F means true or false; L means left and R means right.

## Table 4 Whole body marker set model B

<table>
<thead>
<tr>
<th>Position</th>
<th>Marker number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forehead</td>
<td>1</td>
</tr>
<tr>
<td>Face (L&amp;R)</td>
<td>2 (1×2)</td>
</tr>
<tr>
<td>Tragus (L&amp;R)</td>
<td>2 (1×2)</td>
</tr>
<tr>
<td>Shoulder (L&amp;R)</td>
<td>4 (2×2)</td>
</tr>
<tr>
<td>Upper arm (L&amp;R)</td>
<td>2 (1×2)</td>
</tr>
<tr>
<td>Elbow (L&amp;R)</td>
<td>2 (1×2)</td>
</tr>
<tr>
<td>Wrist (L&amp;R)</td>
<td>4 (2×2)</td>
</tr>
<tr>
<td>Back of hand (L&amp;R)</td>
<td>4 (2×2)</td>
</tr>
<tr>
<td>Middle finger tip (L&amp;R)</td>
<td>2 (1×2)</td>
</tr>
<tr>
<td>Chest</td>
<td>1</td>
</tr>
<tr>
<td>Abdomen</td>
<td>3</td>
</tr>
<tr>
<td>Pelvis (L&amp;R)</td>
<td>2 (1×2)</td>
</tr>
<tr>
<td>Knee (L&amp;R)</td>
<td>4 (2×2)</td>
</tr>
<tr>
<td>Malleolus (L&amp;R)</td>
<td>4 (2×2)</td>
</tr>
<tr>
<td>Foot (L&amp;R)</td>
<td>6 (3×2)</td>
</tr>
<tr>
<td>Total</td>
<td>43</td>
</tr>
</tbody>
</table>

*L means left and R means right.
3.4.2 Data process

Previously captured 3-D motion data were imported to Autodesk® MotionBuilder® pro for further processing. MotionBuilder® is a professional package designed for 3-D data acquisition, manipulation, and visualisation. MotionBuilder® has been selected for data processing not only because of its own characteristics, but also because of compatibility of both the import and export data format and ease of use.

Detailed data workflow within Motionbuilder® pro is provided in Figure 7. It was straightforward to create an actor within the scene and then import the 3-D motion data afterwards. The 3-D motion data were mapped on to the actor via the corresponding marker sets. While loading the markers into the scene, it was required that the markers should be in a T-stance facing the positive Z-axis. Therefore, while capturing data, each activity should start and end with the performer in a T-stance, and the calibration should set the performer to face positive Z-axis. Figure 10 is a screenshot of the creation of a marker set in Motionbuilder®.

The optical marker was dragged into the appropriate body part cell of the actor representation. Because each cell can have a maximum of five markers, the marker set models explained previously can provide enough data at this stage. The body cells
specified in the figure includes head cell, shoulder cell (left and right), upper arm cell (left and right), fore arm cell (left and right), hand cell (left and right), chest cell, abdomen cell, knee cell (left and right), ankle cell (left and right), foot cell (left and right) and foot toes cell (left and right). Imported motion data were matched into appropriate body cell one by one to provide an accurate representation of the healthy adult’s activities, for example, there were five markers assigned to the head cell.

It provides an environment where the imported data could be processed and used to drive the 3-D actor, therefore representing the activities of the healthy adult. Both subjective assessment data and objective assessment data in c3d format were imported, and mapped to a 3-D actor one by one, with files stored in FBX available for future output. Compatibility of 3-D data format and conversion between different environments is necessarily to be taken into consideration especially when data format and transmission standard are lacking.

### 3.4.3 Data output

3-D video of a virtual person was determined as the data output format. The rendering process is shown in **Figure 11**.

![Figure 11 Screenshot of rendering settings](image)

3-D video of a virtual person was chosen as the priority data output format, because it was possible for visualisation to use low tech equipment, i.e. a standard pc, also because it provides more complete information as opposed to separate images, scales
and charts that were not connected. The 3-D video of the virtual person is directly output from Motionbuilder® into “avi” or “mov” files. The rendering settings are shown in Figure 11. This figure shows that the picture format is 640×480, and with start time and stop time selected. The virtual actor is utilised due to its neutral appearance which is regarded as easy to view and convenient to compile. Screenshots taken from Motionbuilder® and video files are displayed and explained in Chapter 5.

3.5 Qualitative Evaluation

3.5.1 Ethical approval and access

This section discusses the ethical approval issues and recruitment of participants.

3.5.1.1 Ethical issues

Ethical approval for this research was needed prior to starting the study since human subjects were involved in the qualitative evaluation process. This is not just necessary in the case for patients, who were not directly evaluated here, but also for the clinicians, i.e., the physiotherapists, who were involved in this work. Ethical approval was granted by the Research Governance and Ethics Sub-Committee (RGEC) of the Research Committee at University of Salford in 2009, with reference number RGEC08/057. The University in particular is guided by specific basic ethical principles, which are generally accepted in the main national and international cultural traditions and have particular, but not exclusive, relevance to research involving human participants.

An information sheet was made available to the participants prior to start the study, which included the purpose of the study, whether any risk to the subjects, protection of subjects’ information confidentiality, protection of identity of subjects etc. (see Appendix G). Moreover, a consent form was provided for the subject to sign prior to the study, stating the subjects’ willingness to participate, and right to withdraw at any time without giving any reasons etc. (see Appendix H).

3.5.1.2 Recruiting participants

The participants were recruited from two major groups of interested parties (the “panels”). In practice these overlap, i.e. individuals could be said to have experience in both panels. Therefore, for the most part, the data from each panel was not analyzed separately.
Panel A: Practitioners. This panel includes those from northwest NHS trusts, including primary care trusts (PCTs), who routinely conduct assessment and feedback to AS patients. Such individuals need to know how to assess the patient and how to interpret and feedback assessment results to the patient and other stakeholders.

Panel B: Academia. This panel includes those who have publications within the area of AS management. Such individuals are closely involved in the training and assessment of student physiotherapists yet also understand patients’ requirements.

Individuals were contacted by email or phone with an outline of the nature of the project. The changing role of physiotherapists has been discussed in Chapter 2 revealing the importance of their involvement in the qualitative evaluation.

3.5.2 Qualitative evaluation design

Focus groups are a form of group interview that capitalises on communication between research participants in order to generate data (Mays and Pope, 1996). Use of focus group in the social sciences and health professions has become popular since the growth of qualitative research methods in the 1980s (Holloway and Wheeler, 2002). As described by Holloway and Wheeler (Holloway and Wheeler, 2002), “a focus group in health care research usually involves a number of people often with common experiences or characteristics who are interviewed by a researcher (or moderator) for the purpose of eliciting ideas, thoughts and perceptions about a specific topic or certain issues linked to an area of interest”.

Qualitative evaluation methods were used to evaluate the efficiency and deficiency of the prototype developed. Focus group was selected as the main method partly because of its characteristic of reliance on the researcher’s focus, but also because the group’s interaction could produce direct data on exact issues of this research. A number of “rules of thumb” have evolved to capture the most common choices that researchers have made regarding to each of these decisions (Morgan, 1992). According to these rules of thumb, focus group projects most often a) use homogeneous strangers as participants; b) rely on a relatively structured interview with high moderator involvement; c) have 6 to 10 participants per group; d) have a total of three to five groups per project. In reality, most projects have some elements that require special attention, and it may be relatively rare for a project to match all four of these criteria (Morgan, 1997). Design of focus group for this research is discussed according to above rules of thumb.
There were three focus groups. The first group was also used for a pilot study. However, due to reasons of availability and timing, the last group was abandoned and the single participant was interviewed. This section provides discussion on key factors that were involved in the design of the focus groups, including participants’ purposive selection, interview design, sample size and analysis.

1) Participants recruitment

In order to minimize sample bias, participants were purposively recruited from a number of sources, such as different NHS trust organizations, rather than from a single source. The goal was to represent a full spectrum of experiences and opinions. The participants were all expertise in AS. It was this homogeneity that not only allowed for more free-flowing conversations among participants within groups but also facilitated analyses that examined differences in perspective between groups. And the groups were mixed rather than segmented by sex, race or age because neither of the factors has been seen affecting the participants’ comfort in the discussion or the analyst’ ability to make useful comparisons. The rule of thumb (Morgan, 1992) favours strangers because acquaintances can rely on the kind of taken-for-granted assumptions that are exactly what the researcher is trying to investigate, though the notion that focus groups must consist of strangers is a myth. Participants recruited from different NHS sites had met occasionally on a Physiotherapy Networking Meeting. They were asked however not to talk to each other about the topic prior to the meetings.

2) Interview process design

The group meetings were held in the usability lab in the University. The groups were moderated by an experienced moderator and an assistant also attended the whole process. An interview guide was used. Morgan (Morgan, 1992) pointed out that an interview guide had at least as much influence on the content of the group discussion as did the moderator. Also the concept of the guide was not taken quite literally in order to avoid the tendency to follow a predetermined order of topics in a rigid fashion. Therefore, the interview process was organized in order that all the groups were discussing issues in a relatively comparable fashion. Each group lasted no longer than two hours and was recorded for analysis purposes. The agenda of the evaluation sessions is seen in Appendix I. The full details of the interview format are given in Chapter 6.

In addition, a higher level of moderator involvement was adapted to keep the discussion concentrated on the topics that interested the researchers rather than
extraneous issues. On the other hand, more structured approaches may narrow the questions and may produce limited data. So the “funnel strategy” was conducted for the research to design a compromise between the two, which meant each group began with a less structured approach that emphasized free discussion and then moved towards a more structured discussion of specific questions.

3) Sample size

Ten AS specialists agreed to participate in the groups; thereafter three groups were held. Only one participant attended the third group due to reasons beyond control. Small groups can produce more detailed data from each participant. However, it works best when the participants are likely to be both interested in the topic and respectful of each other. In addition, small groups are more useful when the researcher desires a clear sense of each participant’s reaction to a topic simply because they give each participant more time to talk. Patton has noted that “the validity, meaningfulness, and insights generated from qualitative inquiry have more to do with the information-richness of the cases selected and the observational/analytical capabilities of the researcher than with sample size” (Patton, 2002). There are reasons to believe that a smaller number of groups are still valid. Thereafter, the qualitative evaluation is composed of two focus groups; with the first one was conducted as pilot study, and one interview.

4) Analysis

One concern is that of contamination of data. This may arise from either where data from the pilot study are included in the main results or where pilot participants are included in the main study, but new data are collected from these people (van Teijlingen and Hundley, 2001). It is believed that contamination is less of a concern in qualitative research, where researchers often use some or all of their pilot data as part of the main study. Some have therefore argued that in qualitative approaches separate pilot studies are not necessary (Holloway, 1997). Frankland and Bloor (Frankland and Bloor, 1999) argue that piloting provides the qualitative researcher with a “clear definition of the focus of the study” which in turn helps the researcher to concentrate data collection on a narrow spectrum of projected analytical topics. Therefore, pilot study data were included in the overall analysis.

The data generated from the three sessions, including from the pilot study, the focus group and the interview, were transcribed using Transana® 2.22 and analyzed using Nvivo® 8.0. The interpretation and analysis of the data employed content based thematic
analysis which involved classifying and coding the content into themes. A full discussion of the analysis process, along with findings and conclusions are discussed in Chapter 6.

3.5.3 Pilot study

The first focus group was also conducted as a pilot study, which included two AS experts, one is from academic environment, and the other is from clinical environment. A pilot is a small scale preliminary study conducted before the main study in order to check the feasibility or to improve the design of the study (Polit and Beck, 2004). It can reveal deficiencies in the design of a proposed study or procedure and these can then be addressed before time and resources are expended on large scale studies.

The questions to pilot subjects were in the same order and same way as it will be administered in the main study. As part of the research strategy the following factors were resolved in advance:

- Check the correct operation of equipment (e.g. camera recording system);
- Check that the instructions given to the subjects are comprehensible;
- Check the questions, e.g. the wording and the order of the questions;
- Check that moderator is sufficiently in the procedures;
- Detect a floor or ceiling effect, e.g. if a question is too difficult or too easy;
- Assess whether the level of intervention is appropriate, e.g. the level of intervention from the moderator. (Peat et al., 2002)

Questions that were not answered as expected were re-worded or re-scaled; time that taken to complete the session was recorded to decide whether it is reasonable; ambiguities in questions were identified and clarified.

3.5.4 Advantages and disadvantages

In this section, advantages and disadvantages of using focus groups are discussed.

The main advantage of focus groups results directly from their two defining features: the reliance on the researcher’s focus and the group’s interaction (Morgan, 1997). The strength of relying on the researcher’s focus is the ability to produce concentrated amounts of data on precisely the topic of interest. It can increase the sample size of qualitative studies by interviewing more people at one time. Thereafter, it is relatively low cost and provides quick results (Krueger, 1988). Krueger also pointed out that, this method was socially oriented, studying participants in a natural, real-life
atmosphere rather than artificial experiment, therefore, the results had high face validity (Krueger, 1988).

Another broad source of strength for focus groups is their reliance on interaction in the group to produce the data, which can provide insights into participants’ opinions and experiences. It has been assumed that an individual’s attitudes and beliefs do not form in a vacuum; people often need to listen to others’ opinions and understandings in order to form their own (Krueger, 1988). Furthermore, group discussions provide direct evidence about similarities and differences in the participants’ opinions and experiences as opposed to reaching such conclusions from analyses of separate statements from each interviewee (Morgan, 1997). The format allows the moderator to explore flexibly unanticipated issues as they arise in the discussion.

Also the data may be difficult to analyze because context is essential to understanding the participants’ comments. The use of special room arrangements and highly trained moderators are required (Marshall and Rossman, 1999). A real concern is the dilemma situation for the moderator/researcher. On one hand, it has been argued that in the name of maintaining the interview’s focus, the moderator will influence the group’s interactions (Morgan, 1997). However, on the other hand, less control of the interviewer may result in lost time while dead-end or irrelevant issues are discussed (Marshall and Rossman, 1999). This problem is hardly unique to focus groups because the researcher influences all qualitative research methods. In reality, there is no hard evidence that the focus group moderator’s impact on the data is any greater than the researcher’s impact in other qualitative methods. The researcher’s influence on the data, however, is an issue in almost all qualitative research, and those who rely on focus groups must attend to it because it does affect the quality of the data. This means that focus groups require greater attention to the role of the researcher/moderator and need to provide more depth and detail about the opinions and experiences of any given participant at the same time.

The different value attached to the advantages and disadvantages of the method will depend on the research topic itself, the background and interests of the researcher, and the nature of the ultimate audience for the research. The respective weaknesses of other qualitative techniques, however, allow focus groups to operate appropriately.
3.6 **Summary**

This chapter has presented the whole research cycle with a process map comprising: development of VR therapeutic models, proposal of assessment and feedback models, development of prototype and qualitative evaluation. Methods for developing the prototype were explained in the process of data collection, data process and data output. A 3-D virtual person is envisaged to be a major component of the prototype and has 3-D motion data mapped to it. The next chapter will discuss the investigation towards a comprehensive VR therapeutic environment.
Chapter 4

4 Towards a Comprehensive VR Therapeutic Environment

The last chapter summarized the research design and methods used. The aim of this chapter is to show how a specific research tool can be designed such that it moves towards a comprehensive VR therapeutic environment for AS. First of all, a physical therapy model is proposed for AS, summarizing the treatment methods for each symptom. The ultimate goal will be to provide a holistic approach, and to that end an integrated VR tool set is envisioned. However, the pragmatic constraints of this PhD mean that the focus becomes a conceptual tool of evaluation that is applied primarily to exercise, assessment and feedback. These latter two key steps are relevant for “exercise” and the mobility of the patient and these are showcased and implemented in the prototype tool.

4.1 Complex Condition

This section will investigate the physiotherapy treatment for AS and for each of its symptoms.

4.1.1 Physiotherapy treatment for AS and for each symptom

As introduced in Chapter 2, the main symptoms of AS are pain, stiffness and fatigue. Current treatments for AS include pharmacological approaches, surgical management and other approaches, which have been detailed in Chapter 2. Physiotherapy treatment for AS, especially regular exercise, is the keystone of this alternative non-pharmacological, non-surgical approach. A summarizing picture of a treatment regime has been built up from the literature, which can be represented as follows:
- Patient Information
- Therapeutic Method
  - Relaxation
  - Pain management
  - Exercise
- Evaluation

To this end, a physical therapy model (see Figure 12) has been developed according to information generated from sources such as ASIF; UK NASS etc. along with grey literature such as patient information leaflets. This is called a "Physical Therapy" model, and five elements within this model: Patient Literature, Relaxation, Pain Management, Exercise and Evaluation are regarded as "facets". The previously mentioned "treatment paradox", discussed in Chapter 2, and the "fatigue symptom" are discussed separately as these emerge as a result of the therapy and are therefore not shown in the model. This thesis will not directly deal with the social or psychological aspects of the condition. Instead the attention is being paid to investigate the usability and flexibility of a specific research tool. Each element of this model will be discussed in the next section in detail, and a tool will be envisioned for each facet.

<table>
<thead>
<tr>
<th>CONCEPT</th>
<th>TYPE</th>
<th>GENERAL EXAMPLE</th>
<th>SPECIFIC EXAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient Literature</td>
<td>Type of Info</td>
<td>Introduction Info</td>
<td>FAQ</td>
</tr>
<tr>
<td>Relaxation</td>
<td>Type of Relaxation</td>
<td>Breathe</td>
<td>Stage I</td>
</tr>
<tr>
<td>Pain Management</td>
<td>Techniques</td>
<td>Muscle</td>
<td>Stage II</td>
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<tr>
<td>Exercise</td>
<td>Process</td>
<td>Distraction</td>
<td>Stage III</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Subject</td>
<td>Focus on the Pain</td>
<td>Back</td>
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<tr>
<td></td>
<td></td>
<td>Step-by-Step</td>
<td>Other Joints</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part-by-Part</td>
<td>Bath Indices</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Process</td>
<td>ASAS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Patient</td>
<td>Others</td>
</tr>
</tbody>
</table>

Figure 12 A physical therapy model
4.1.2 Envision a VR tool for each facet

There are 5 core elements of the physiotherapy model (Figure 12), i.e. Patient Information, Relaxation, Pain Management, Exercise and Evaluation that have been identified, which were termed "facets".

Facet 1 Patient Information is a supportive element for patients to understand AS and its treatment. Both the Introduction information and FAQ are available.

Facet 2 Relaxation, facet 3 Pain Management and facet 4 Exercise are the main therapeutic methods. Relaxation and Pain Management have been specified as two supportive functions for the main therapy method Exercise. Relaxation includes breathing relaxation and muscle relaxation (Bernstein and Borkovec, 1973, Pasero et al., 1997), which has three stages (www.asresearch.co.uk) to relieve the tension of the body. Pain management consists of distraction from the pain and focus on the pain relief techniques (Raj, 2000). Exercise provides information on keeping the involved part of the body active and exercised. The exercise programmes are composed of step-by-step exercise and part-by-part exercise, with respect to the patient's options to the specific involved part of the body. In conjunction with anti-inflammatory drugs, these exercises will help AS sufferers manage AS more easily. They should become part of the sufferers' normal daily routine. Details of exercise activity can be found from the UK NASS website and a list of those exercises is also seen in Appendix J.

Facet 5 Evaluation includes review of the evaluation process and instruments to be used to evaluate the patient's status.

The possibility of implementing a VR tool for each facet is envisioned in the next section. Among those five facets, facet 1, i.e. Patient Information, can be provided by simple means and does not necessarily require VR. However, arguably it is relevant to all the core therapeutic methods and therefore ways of presenting that information become critical and so it is worthwhile to examine whether VR can enhance its use or not. Therefore, it is treated as part of the evaluation facet, and in particular, it becomes important when considering "feedback" as part of the overall "evaluation". Then there are four facets, i.e. Relaxation, Pain Management, Exercise and Evaluation, to consider and think how VR tools might be built to implement each. A holistic approach for all facets and VR tools will be investigated in the next section.
4.2 Holistic Approach for VR Tools

In this section, an integrated VR tool set is envisioned comprising the four key facets, out of which the Patient Information facet is brought together with the Evaluation facet to create the evaluation tool and becomes the focus of the research.

4.2.1 Understanding how integration might work

A complete VR implementation that provides an effective holistic approach at this time is not possible. However, it is worthwhile to consider a “hybrid” strategy for the four identified key facets in the previous model (Figure 12). VR tools and components along side non-VR activity are introduced.

As the facets are interdependent and the treatment paradox and fatigue depend on how the facets are implemented, an overall VR therapy model (Figure 13) has been constructed to help think how it might be designed. Full detail of this model will be discussed in the following sections.

As shown in Figure 13, the evaluation tool is at a different conceptual level to the other three therapeutic elements. It can support and illuminate one, or potentially all, of these elements. Although full integration will be eventually possible, it is not feasible to produce all the required tools. “Evaluation” becomes a proxy for such integration as it will have to draw together the various outcomes from different facets if the ultimate goal of holistic therapy is to be achieved. Furthermore, particular focus is placed on the evaluation tool’s application to the “exercise” facet. This is for several reasons. First it is a key form of treatment given the chronic and incurable nature of the condition. Secondly
the motion from exercising is particularly suitable to visualisation techniques, even though there seems to be an insufficiency of VR application for it at the present. Thirdly it offers a form of integration both by using the same evaluation tool for both assessment and treatment.

### 4.2.2 Model of VR therapeutic process

In order to further understand the possibility of these four VR tools as an integrated tool set and the fundamental role of Evaluation tool, a schematic physical therapy process map has been drawn in Figure 14.

This figure utilises symbols that are used in YAWL (Yet Another Workflow Language) (Verbeek et al., 2007); their meanings are listed just below the figure for clarification and easy reading purpose. Concepts such as atomic task, multiple instances, XOR-join task and XOR-split task are fairly standard and straightforward. For example, XOR represents explicit alternative routing. However, OR-join represents letting the system decide whether it needs to synchronize or not; the decision to wait or not is on parts of the model that may lead to future triggers.

Within this process, four areas are highlighted corresponding to four associated envisioned VR tools. There is added flexibility with choice of function in each tool. Regarding user scenarios, the user, e.g. the patient, may choose one VR tool at a time according to the clinical professional’s guidance (Relaxation or Pain Management or Exercise) or they may choose to use the tools in sequence combination (Relaxation--Pain Management--Exercise, Pain Management—Relaxation--Exercise, Relaxation--Exercise, or Pain Management--Exercise, or Relaxation--Pain Management etc.). Information from therapeutic tools becomes information input to Evaluation tool. In this process map, assessment and feedback are highlighted as two key steps by integrating 3-D view of performance and assessment results.

Thus Evaluation tool not only can provide assessment results from, e.g. Exercise tool, but also can provide feedback information, e.g. viewing of performance in 3-D status to the user including the clinical professionals and the patient. The final goal of implementation is for the patient self-care in a low tech environment, such as at home etc. Thus a Patient Literature presentation is necessarily displayed along with VR tools.
Figure 14 A physical therapy process


4.2.3 Envision an integrated VR tool set

This section takes a holistic point of view of the envisioned VR tool set. Each facet of physical model (Figure 12) can be envisioned as a VR tool, i.e. Relaxation tool, Pain Management tool, Exercise tool and Evaluation tool, and Evaluation tool is combined with Patient Literature as a conceptual tool, as shown in Figure 13. Its scope has been presented in (Li et al., 2007), and a preliminary model for AS therapy has been identified as well. As specified, Relaxation, Pain Management and Exercise are the main therapeutic methods, and VR tools already contribute to each individually; the Evaluation is new, it can include instruments to be used to evaluate both the model and the patient’s status. The latter is the focus of this thesis.

For possible future implementation, four VR tools are described briefly in an informative manner for completeness:

(1) Relaxation tool. Either existing VEs could be borrowed or new comfortable VEs, such as virtual beach side, or virtual forest etc., could be created for this tool. Within the VEs, the user is able to simulate relaxation activity, i.e. sitting on a chair, with the option of listening to soothing music. Two relaxation programs are possible though future investigation of validity is required; one is to support relaxation through breathing, and the other is to support muscle relaxation. By immersing in a VE, this Relaxation tool would seek to help the user feel comfortable and relaxed.

(2) Pain Management tool. Two methods of pain relief are possible within VEs. One method is to distract sufferers by immersing them in VEs, which has been widely researched and could be borrowed. The other is to allow sufferers to focus on their pain, viewing and manipulating it as a simulated image in order to influence the real experience of pain. This is a new attempt and future research is required for validity and usability.

(3) Exercise tool. This tool should be designed to promote exercise through the use of dynamic 3-D models. Using this tool, users' movements (captured via the Evaluation tool) will be made viewable in the form of a dynamic 3-D model, thereby allowing users to track their progress and build their confidence.

(4) Evaluation tool. This evaluation tool is at a different conceptual level to the other three therapeutic tools. It can support and illuminate one, or potentially all of these tools. Although it has been shown that integration is possible, a particular focus is on the
tool's application to the "exercise" facet. This Evaluation tool envisioned as a single conceptual tool which combines the Patient Literature facet with the Evaluation facet. At the same time, the exercise facet is closely connected with the Evaluation facet and integrated into a single visualisation tool as part of this thesis. The rationale for considering an evaluation tool as an integral part of the environment emerges from the review; it has been shown that evaluation carried out by a completely different means of assessment from the activity being undertaken is not as rewarding (Horwitz, 2004). The development of a prototype of this evaluation tool will be discussed in full detail in the following Chapter 5.

Figure 13 in conjunction with Figure 14 shows the four tools along with their associated facets integrated together. It also suggests the potential means of carrying out the various functions: immersing in a VR environment with relaxation music, comfortable view and even imagination scenarios. The interaction between the four tools is critical. Each tool focuses on an aspect of the whole therapeutic process, but each tool supports other parts of the process. For example, the Relaxation tool supports the Pain Management tool and the Exercise tool; the Relaxation tool and the Pain Management tool together support the Exercise tool. The Evaluation tool seeks to reflect and improve the usability and efficiency of the other three tools.

4.3 Usable As Well As Useful

4.3.1 Solution will evolve and be incremental

The work described within this thesis has adopted an incremental approach to development ways of managing pain or relaxing that may be done by conventional means and/or may form other future research topics.

The concept of "pervasive health" (Department of Health, 2010a) suggests that PROMs activity will increase and that on-going treatment/therapy will occur in home settings. In the discussion of future work considerations of these possibilities and what technological advances mean for the idea of a useful VR therapeutic environment, the potential impact upon healthcare services should be taken into account. Integrating the evaluation and exercise tools may make the "solution" more usable and may be more effective, which has to be left to future trials. However, the fact that three of the five identified core elements have the potential to be integrated suggested that this should be the tool that is prioritised.
4.3.2 Prioritise and prototype components within overall process

Amongst the four VR tools proposed for AS, the evaluation tool is the focus of this thesis and will be discussed in detail in the following chapters. However, rather than focusing on evaluation of both the view of the clinical professionals and the usability of the other VR tools, the refined research focus is on the clinical professionals view of the assessment and feedback tool.

This prioritisation should be viewed within a wider and longer term vision of the whole research pathway. As shown in Figure 15, an illustration of the entire research pathway that can deliver the final and total solution to the AS problem defined is specified. Although the final goal is to augment the patient’s self-management of disease, this work was determined to contribute to investigating the benefit of 3-D visualisation for practice and even for the patient from the clinical professional’s point of view. This decision was made due to constraints in time and resources, e.g. it may take a longer period of time, such as 10 years or more to accomplish the final goal. And clinical professionals, i.e. physiotherapists were involved with all the system and models proposed since they are indispensable especially in the treatment process. As shown in Figure 15, the shadowed part indicates that this work will include the development of a prototype for the problem identified, and seek clinical experts’ opinion to evaluate the system proposed and refinement options.

Moreover, this tool is applied to a number of different measures in an assessment process which comprise a physiotherapist’s assessment and feedback. “Assessment” and “feedback” in this phased process model have been highlighted as two key steps that are relevant for “exercise” and these are showcased and implemented in the prototype. And this prototype tries to augment and even transform the assessment process itself by

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**Figure 15** Overview of the entire research pathway
providing a new form of feedback. If successful it can ultimately move the therapeutic environment to the home settings that will better suit the patients' need and lifestyle.

4.4 Summary

Physiotherapy treatment for AS and each symptom have been synthesised into a physical therapy model for AS, as shown in Figure 12. Each element within this model is viewed as a facet, and VR tools are envisioned for each facet. A holistic point of view of integration of different VR tools is envisioned by proposing an integrated tool set. The Patient Literature facet has been brought together with the Evaluation facet to make a single conceptual tool, which is called the Evaluation tool. It can support and illuminate one, or potentially all of these elements. Although it has been shown that integration is possible, a particular focus of this thesis is the Evaluation tool's application to the Exercise facet. This Evaluation tool is applied to a number of different measures in an assessment process which comprises a physiotherapist’s assessment and feedback. In this phased process model, “assessment” and “feedback” are highlighted as two key steps that are relevant for “exercise” and these are showcased and implemented in the prototype. Finally, a specific research prototype for AS has been identified, which is applied to the “exercise” facet, highlighting “assessment” and “feedback” as two key steps. The reason of involving clinical professionals, i.e. in the evaluation process is explained out of the whole research pathway. Full detailed information of construction of this prototype is given in the following Chapter 5.
Chapter 5

5 A 3-D Assessment and Feedback Visualisation Tool for AS

The previous chapter describes how the development of a research prototype is possible towards a comprehensive VR therapeutic environment for AS. This chapter discusses the development of the prototype, i.e. a 3-D assessment and feedback visualisation tool for AS. First, the simplified assessment and feedback models are constructed to highlight key AS areas used to focus the research. Then, the reasons for the choice of instruments are given, the intention being to provide a foundation for what might be a fully augmented treatment environment in the future. A 3-D virtual person is utilised to present this prototype and its facets. It enables different aspects of the assessment process to be visualised. The integration capability and the ways of providing meaningful feedback are added to this prototype.

5.1 An Assessment and Feedback Model

As discussed in the literature review, the basic model of assessment and feedback for AS is lacking. Therefore, it is essential to propose simplified models of assessment and feedback of AS being foundation for the development of the prototype. This section investigates the proposal of assessment and feedback models for AS.
5.1.1 An assessment model

To clarify what it means by the term "assessment" and to avoid potential misunderstanding, a simple model has been constructed (Li et al., 2009), as shown in Figure 16.

The simplified assessment model presents what is essentially a simple computational model of assessment with input (discover), process (learn), and output (perform) phases. The discover phase involves obtaining subjective and objective detail pertaining to the person’s condition, and this phase typically includes different types of assessment being undertaken either by the patient or the clinician, usually the physiotherapist. It is worth noting here that the subjective part is often related to information presented by the patient whereas the "objective" material is usually discovered by the use of tests or measurements performed by the clinician. The learn phase includes recording or documenting findings, making sense of the inputs, making clinical judgments and planning accordingly. Although presented serially, these steps are often interdependent and iterative. It is called the learn phase, because either the assessment is of a new patient, or if the patient has been previously seen then there is now new information to compare their current status with what is already known. The perform phase is the one where any feedback is given to the patient about their current status, recommendations or reports are passed to other clinicians and treatment is either explained or, in the case of exercises within the AS domain, shown and these “outputs” then become the criteria used for measuring progress at the next assessment.

![Figure 16 A simplified assessment model](image)

The model in Figure 16 has been shown and accepted by those physiotherapists attending a physiotherapist networking meeting (Northwest UK). Consequently, this
affirmation of its accuracy has driven how to think about assessment. The terms used within the model were deliberately chosen so that they did not conflict with current practice. The prototype under development has within its scope all three phases of this assessment model but not all of the steps. In particular, the prototype will not automatically make sense of the inputs, make clinical decisions nor determine plans autonomously; nevertheless the aim is that it should support the relevant user in these actions.

5.1.2 A feedback model

Although feedback can be given simultaneously throughout the whole assessment process, here it is artificially separated and presented in a simple model as in Figure 17. It can be envisioned as an extension of previous assessment model.

Subjective and Objective facts/results including:
- Bath indices scores
- Exercise prescription
- Etc.

Physiotherapist as assessor

MDT colleague

Patient

Figure 17 A simplified feedback model with the physiotherapist as the central actor

In this model, both the feedback content and communication route are of interest. Feedback information can be generated through all the steps during each phase of the assessment model. The feedback information ranges from VAS scores, measurement results, exercise compliance, report of treatment plan, to education and summary information. Different output from those steps depending on different environment will be given to different people within the MDT and eventually to the patient. The prototype under development tries to add more meaningful feedback information and to augment the communication process.

5.2 Scope of the Prototype

The prototype supports the scope of all the phases of the assessment and feedback model but not all of the steps. In particular the subjective assessment via the BASFI instrument and the objective assessment via the BASMI are addressed as part of the assessment, and
the potential for 3-D visualisation "feedback" to both clinician and patient of the same is considered for the feedback model. Although the intention is to develop the research to make the prototype appropriate for patients within their homes, and thereby remove many of the process problems of delays and infrequent assessment, it will be some time before this becomes feasible, and the present prototype is laboratory based. Also, the physiotherapy exercises are extended from the subjective assessment index in order to appreciate the full profile for this application. In the following sections, the scope of the prototype is described in full, including the selection of subjective assessment, physiotherapy exercises and objective assessment and questions selection within them.

5.2.1 Selection of subjective assessment

Although a consensus is still required for recommendation of a single instrument for subjective assessment for AS, in practice, the BASFI remains one of the instruments of choice for functional assessment (Haywood et al., 2005). In BASFI, selected domains within functional activity, including various physiotherapy exercises, are assessed by a single VAS separately. Thus, BASFI is selected to be included in the prototype.

There are ten questions in the BASFI, the first eight of which are related to movement, and the last two pertain to everyday life questions. Each question is presented as a 10 cm VAS with endpoints of "easy" and "impossible". The patient marks the line, the physiotherapist turns it into a number and by simple arithmetic returns an overall score for the BASFI. The concern is not primarily to critique the scale or to determine its value as an aggregated score, but rather to see whether each question within the index can be represented by the proposed prototype and to see if it has potential to augment the assessment and feedback.

In order to specify each question within BASFI, a set of exclusion criteria was set up prior to the experiment.

- Firstly, functional activities are the research focus. BASFI's 10 questions are therefore potentially valid.
- Secondly, Q. 6, i.e. "standing unsupported for 10 minutes without discomfort" was de-selected because of the unreasonable demand on a subject of study and the unmanageable size of the file from a ten minute recording.
- Thirdly, for technical and safety reasons, Q. 1 and Q. 5, i.e. "putting on your socks or tights without help or aids (e.g. sock aid)" and "getting up off the floor
without any help from lying on your back” were also ruled out. The first question posed problems for sensor placement and the second had the potential for causing the patient problems in the targeted home situation. 

• Fourthly, due to limitations of the gait laboratories, Q. 3 and Q. 7, i.e. “reaching up to a high shelf without help or aids (e.g. helping hand)” and “climbing up 12-15 steps without using a handrail or walking aid (one foot on each step)”, were excluded.

• Finally, Q. 10, i.e. “doing a full day activities whether it be at home or work”, was ruled out because it was impractical to track/monitor in the laboratory setting.

After exclusions, the following questions in BASFI were selected and included in the experiment, which are:

• Q. 2 “bending forward from the waist to pick up a pen from the floor without an aid”
• Q. 4 “getting up out of an armless chair without using your hands or any other help”
• Q. 8 “looking over your shoulder without turning your body”
• Q. 9 “please indicate your ability in doing physically demanding activities (e.g. physio exercises, gardening, sport)”

Q. 9 is considered regarding to physiotherapy exercise and will be discussed in the following section.

5.2.2 Selection of physiotherapy exercises

The scope of the prototype is extended to include physiotherapy exercises as they are of interest to this research and have been redeemed especially valuable for AS patient.

Q. 9 of BASFI “please indicate your ability in doing physically demanding activities (e.g. physio exercises, gardening, sport)”, relates to a broad range of activities related to gardening, sport and physiotherapy exercises etc. but does not distinguish between their relative merits. Therefore, Q. 9 is considered related to physiotherapy exercises as its original range is lack of precise and physiotherapy exercise are seen as being particularly valuable to AS patients and emphasizes the importance of the physiotherapist’s role. A set of physiotherapy exercises is recommended to AS patients at the NASS website (for a full list of NASS recommended exercises see Appendix J).
However, there is little evidence around priority among the various exercises. Then a group of exercises are selected being the research start point as those exercises, mainly upper body involvement ones, are suitable to complete within limited space which most based on a chair.

The set of AS approved exercises were selected according to resources constraints etc., which are:

- I. "Spinal side flexion"
- II. "Spinal rotation"
- III. "Neck rotation"
- IV. "Hamstring stretch"

### 5.2.3 Selection of objective assessment

A more objective assessment, via BASMI was included to test the feasibility of this prototype for this different type of assessment. It is common for a physiotherapist to record both objective and subjective measures and to integrate both types. While physiotherapists rely heavily on BASMI, it has been noted that physiotherapists are inconsistent in how they measure and the same physiotherapist might change the measurement according to the individual patient’s characteristics. Therefore the measurements are not rigorous. This section describes the objective assessment selection.

There are five measurements in BASMI, which are designed to obtain objective measurement by the clinicians. The patient should be comfortable and suitably dressed within all these measurements, and normally will be measured with rulers or tape measures or other specialist tools. This will often depend on what the physiotherapist is used to or what is available to them at their clinic. BASMI presents a table with predefined degrees for the results; full detail is given in Appendix C. For BASMI, two out of the five measurements were picked up and tested due to the laboratory limitations. They are:

- I. "Lumbar side flexion"
- II. "Tragus to wall distance” measurement

### 5.3 Presentation of the Prototype

The prototype presents a 3-D virtual person. In part this is done as a means to assess the applicability of VR for AS, but also because the current forms of representation and
measurement are unsatisfactory, and the use of a 3-D virtual person presents an alternative. This has clear advantages over 2-D forms of assessment such as the simple VAS for 3-D functionality, but it also permits dynamic recreation and representation of functional and exercise-related activities in a realistic fashion, with assessments being completed automatically during the capture of activity.

Three types of output are available at this stage of the prototype’s development: an unadorned 3-D virtual person, called avatar; a 3-D avatar with markers on; and video, as shown in Figure 18. 3-D video represents the main output method for the prototype at present and more detailed information regarding its 3-D functionalities, i.e. 3-D visualisation of subjective and objective assessment, its integration capability and meaningful feedback, etc. will be discussed in the following sections.

![Figure 18 Snapshots of BASFI Q. 2 in sequence](image)

Note:
A: beginning position with markers on
B, C and D: positions afterwards without markers on
E: 3-D video output

### 5.4 Visualisation of the Prototype

This section investigates this prototype’s 3-D functionality of 3-D visualisation and representation of functional and exercise-related activity and metrology activity. 3-D visualisation for a range of activities is discussed in the following order in this section: assessment activities, physiotherapy exercise activities and objective measurements, which have been discussed in (Li and Kay, 2009).
CHAPTER 5 A 3-D ASSESSMENT AND FEEDBACK VISUALISATION TOOL FOR AS

5.4.1 Assessment activities visualisation

The full range of selected questions in BASFI is explained in the following. The selected questions from BASFI have been successfully transferred to the 3-D avatar. For example, Q. 2, "please indicate your ability with bending forward from the waist to pick up a pen from the floor without an aid", was presented by the avatar shown in Figure 19, Figure 20 and Figure 21. It is possible to run the complete action and simply pause it at the point which the avatar corresponds to the patient's own performance to obviate the use of an intermediate analogue scale. This does not require the use of the marker sensors, the movement tracking software or the specialist cameras other than when the initial set of training actions were produced.

Q. 2 (BASFI) "please indicate your level of ability with bending forward from the waist to pick up a pen from the floor without an aid". Figure 19 presents the T-stance position, which is the start of the whole sequence from the technical perspective; Figure 20 presents the actual start position of being standing still prior to the assessment activity. The healthy adult was not actually asked to bend forward to pick up a pen, instead, to bend forward as far as possible towards the floor without bending their knees. Six directions and a 360° view of the person can be available. In Figure 19 and Figure 20, the upper two photos are perspective and back/front view of avatars with markers lighting on; while the lower two are top and left view of avatars. Figure 21 presents the overall trend of Q. 2 by showing several snapshots in sequence.

Q. 4 (BASFI) "please indicate your level of ability with getting out of an armless dining chair without using your hands or any help". Each activity starts from the same T-stance due to the technical requirements. Thereafter, all the activity captured share the same T-stance start position as shown in Figure 19. The start position of sitting on an armless chair for Q. 4 is showed in Figure 22. Again 6 directions and a 360° view can be displayed. In Figure 22, the first two photos are avatar and marker images, and the lower two are avatar only. Figure 23 presents the sequences of view for Q. 4.

Q. 8 (BASFI) "please indicate your level of ability with looking over your shoulder without turning your body". Again 6 directions and a 360° of view can be available. Figure 20 shows the start position of being standing still: the first two are avatar and marker images, and the lower two are avatar only. Figure 24 is the sequences view for Q. 8.
5.4.2 Physiotherapy exercises visualisation

The presentation and replay ability of avatar on exercises are examined in the research. Q. 9 of BASFI is considered related to physiotherapy exercises as its original range is lack...
of precise and physiotherapy exercises have been redeemed especially valuable for AS patient. A set of approved AS exercises has been accurately transferred to the avatar. And it is possible to run the play and pause it at the point when necessary. The results of four selected exercises are listed as following.

Q. 9 (BASFI) "please indicate your ability in doing physically demanding activities (e.g. physio exercises, gardening, sport)". And the selected exercises are presented as following:

I. Spinal side flexion. The start position of sitting on a chair is shared by the first three exercises, an overall view of which is presented in Figure 22. The healthy adult was asked to sit on a stable chair with feet on the floor, hands by their sides, and to bend sideways as far as possible, trying to reach the right hand towards floor without bending forwards, then to repeat on the opposite side. Instead of hooking around legs of the chair and holding the back of the chair, the healthy adult was asked to put legs by side of the chair. The reason of simulation of this activity is to capture good quality data without reducing the nature of the exercise itself. Snapshots of the sequences view of this activity is shown in Figure 25.

II. Spinal rotation. The healthy adult was asked to sit on a stable chair with feet on floor, hands in front of chest at almost shoulder level, turn the upper body as far as possible, then repeat on the opposite side. There are two compromises in this activity to capture good quality of data. The healthy adult did not hook legs on the chair, nor did clasp hands on forearms. Instead, the healthy adult put legs besides the chair and kept forearms being paralleled to each other. Figure 26 shows the sequences view of this exercise.

III. Neck rotation. The healthy adult was asked to sit on a stable chair with feet on floor, and to turn the head to the right as far as possible without letting the shoulders turn, then repeat on the opposite side. Figure 27 shows the sequences view of this exercise.

IV. Hamstring stretch. Figure 28 shows the start position for this activity, with one foot on a chair. The first upper two images show avatar and marker presentation; the lower two are avatar only. Figure 29 is the sequences view for this exercise. The healthy adult was asked to stand facing a chair, placing the right heel on the seat, keeping the knee straight, and reaching forwards as far as possible with both hands towards the foot, then repeat for the other leg.
Figure 25 Q. 9 I sequences view of “spinal side flexion”

Figure 26 Q. 9 II sequences view of “spinal rotation”

Figure 27 Q. 9 III sequences view of “neck rotation”

Figure 28 Q. 9 IV overall view of start position of “hamstring stretch”

Figure 29 Q. 9 IV sequences view of “hamstring stretch”
5.4.3 Objective assessment visualisation

BASMI comprises five objective measurements ranging from “lumbar side flexion”, “tragus to wall”, “lumbar flexion (modified Schober’s)”, “intermalleolar distance” and “cervical rotation”. All of these are completed by the clinician. Some of them need the patient to be dressed appropriately, i.e. lumbar flexion (modified Schober’s); some are less comfortable than others, i.e. intermalleolar distance. Consequently, two measurements in BASMI, i.e. lumbar side flexion and tragus to wall distance, have been selected for testing the objective assessment task and precisely presented by the avatar.

1. Lumbar side flexion. Conventionally, the clinician need to measure twice from the tip of the middle finger to floor for one side. The first measurement happens at the standing position, the other at the far end of side flexing. The difference between two measurements represents the amount of side flexion. Then repeat on the other side. The final result is the mean of both sides. During the experiment, the healthy adult was asked to carry out the same instructions: stand in bare feet; back to wall with knees straight; scapulae, buttocks, heels against wall; shoulders level; feet parallel with outer edges 30 cm apart. Figure 30 shows the start position for “lumbar side flexion”. The upper two snapshots are avatar and marker presentation; the lower two are avatars only. Figure 31 and Figure 32 are left “lumbar side flexion” and right “lumbar side flexion” respectively. Left-hand images are the upright position and the right-hand images are the far end point position.
The final result can be generated simultaneously by automatic calculation. As the three axes value \((X, Y, Z)\) of the marker on the middle finger tip are available through the cameras. Then the average lumbar side flexion distance is simplified calculated as:

\[
\text{Mean} = \frac{|Y_L - Y_L'| + |Y_R - Y_R'|}{2},
\]

Where \(Y\) is the vertical distance of the marker on middle finger tip to the calibration zero of the axis, \(Y_L\) means the original \(Y\) value of marker on left middle finger tip and \(Y_L\) means \(Y\) value at the far end. \(Y_R\) means original \(Y\) value of marker on right middle finger tip and \(Y_R\) means \(Y\) value at the far end. It is possible to remove the hitherto manual measurement and calculation from the treatment steps, and multiple tests can be completed by a single one via this automatic capture and calculation.

II. Tragus to wall. With the traditional method, the examiner needs to measure the distance between the tragus of the ear and the wall, using a rigid ruler. And then repeat on the other side. The final mean is the value for the degree. During the experiment, the healthy adult was asked with the same instructions to hold the head in as neutral a position (anatomical alignment) as possible, and to draw their chin in as far as possible (retraction) with both eyes open and side of face against the wall. This task shares the same starting position as in the previous measurement, as shown in Figure 30. Figure 33 and Figure 34 are snapshots of the left and right views of “tragus to wall” distance respectively.
Within the prototype, if the calibrated zero is located on the wall, there would be no further measurement required. The mean of left and right tragus to wall distance is calculated as follows:

$$\text{Mean} = (|Z_L| + |Z_R|)/2,$$

Where $Z$ is the horizontal distance of the marker on the tragus to zero, $Z_L$ means the $Z$ value of the marker on the left tragus and $Z_R$ means the $Z$ value of the marker on the right tragus. The results can be generated instantly.

![Figure 33 Tragus to wall (left)](image)

![Figure 34 Tragus to wall (right)](image)

### 5.5 Meaningful Feedback

Meaningful feedback to clients, including clinicians and patients is available via various approaches. Examples of videos that may be made available to them are shown in Figure 35.

BASFI is considered to be an example of PROMs. And it is likely that more research will be commissioned in creating such constructs as their importance increases (PROM Group, 2006). However, like many PROMs the information is uni-directional, i.e., flowing from the patient to the clinician, and often the end result/score is relatively abstract or perhaps requires too much clinical knowledge to have accessible meaning for the patient. Nevertheless, the objective measurement BASMI is completely executed by clinician and is mainly for the clinician as shown in the previous feedback model Figure 17.

However, it is possible in the foreseeable future to envisage, with the avatar within this prototype being driven by movement data taken directly from patients, that what you see is what you measure (what is termed, WYSWYM). Rather than depending on patients’ understanding of a scale and score, or their recall of their activities since the
last assessment, the actual action is part of a visual diary captured and stored for future analysis, replay, reflection and comparisons. The avatar’s performance is a faithful VAS that accurately shows the extent of the patient’s progress, as well as the capability of presenting other facets of the condition at that time.

A big advantage of this approach is that the means of collecting the individual’s AS health status, is precisely the same one that can provide meaningful feedback directly to the patient with minimal mediation. For example, Q. 2 in BASFI, asks “please indicate your ability with bending forward from the waist to pick up a pen from the floor without an aid”. Leaving to one side whether or not this is a good thing to do without bending the knees, it is much easier and more natural for an assessor if the avatar enacts the function enabling direct assessment by simple comparison, rather than by transferring the degree of difficulty to a 2-D scale. Furthermore, this prototype adds objectivity to the measurement by removing inconsistencies that arise due to differences in subjective reporting, imprecise protocols and differences in the use of measurement devices. So awkward questions regarding the current BASFI score system such as, “Does a reduction of 20% from 8 to 6 in BASFI have as much significance as a reduction of two points from 6 to 4, or 4 to 2?” (Calin, 2001) are left for arcane study.

Figure 35 Summary of snapshots for selected actions. First two images (A and B) are from a side view; the others (C, D, E, F, G and H) are from a perspective view.
5.6 Integration Capability

The prototype looks at not only subjective assessment and physiotherapy exercise activity but also involves objective assessment and patient information. The integration and possibility of integration of other facet (i.e., pain management, relaxation etc) has been taken into consideration, for example, the possibility of capturing aspects of pain such as its location and severity are also displayed.

With respect to setting up the markers, subjective assessment and physiotherapy exercises share the same single model, as shown in Table 3. It includes single markers on the joints and marker clusters on the body. The healthy adult can complete all these tasks at one time without any changes. Objective assessments share a second single model of markers which is shown in Table 4. Comparing to Table 3, smaller number of markers were needed because only single markers on the joint were set up. As the aim of the research was not to explore different marker set models per se, the model was selected in order to capture as much motion data as possible without affecting the healthy adult’s activity. Nevertheless, it is possible for the healthy adult to complete the objective assessment with minimum changes of the marker set.

Although activities have been placed into three categories, the T-stance start position (Figure 19) is shared by all activities during the data collection process. BASFI Q. 2 and Q. 8 share the same actual start position of being standing still (Figure 20); BASFI Q. 4 and Q. 9 (I, II and III) share the same actual activity start position of being sitting on an armless chair (Figure 22). This enables the consistency and fluency of the healthy adult’s movement.

For the listed reasons of similar marker set model sharing and assessment activity consistency that capable of being represented by a 3-D avatar, integration of subjective assessment, physiotherapy exercise and objective assessment can be realistic and durable. For example, Q. 2 in BASFI, asks “please indicate your ability with bending forward from the waist to pick up a pen from the floor without an aid”. During the activity data capture, measurement in BASMI i.e. “tragus to wall” can be measured automatically without interrupting the activity by standing against the wall for just a second.

At this stage, the menu interface, as shown in Figure 36, may be displayed as two videos running from the beginning to the end, providing other options of vision as therapy, presentation of condition development trend and remote supervision, etc. For example, replay mode of BASFI Q. 2 might be displayed at two simulated time point of
“today” and “two weeks ago”, as simulated in Figure 36, for comparison and analysis purposes. This prototype also provides the potential capability of integrating other facets, such as pain from different indices, i.e. BASDAI into the same prototype. A red spot is attached to the avatar integrating the cause and location of pain. A Good day/Bad day indicator, also shown in the mocked up interface, might capture data in BASDAI, and represented by the Likert scales.

![Figure 36 Integration of interface](image)

**5.7 Summary**

An integral part of the current assessment of AS is the measurements taken of a number of subjective and objective factors that affect the patient’s health status. There is growing awareness that the protocols and means of taking the measurements are both inaccurate and inconsistent. This chapter addressed how such assessments may be augmented by utilizing 3-D visualisation technology to collect and present data of the multifaceted condition in a more unified way. The final goal of the research is to provide a relevant tool for AS that can be used in both clinical and home settings. It was designed to directly support the therapeutic regime, to enhance assessment, to provide meaningful feedback to both AS sufferers and clinicians alike and to facilitate collection of more
objective evidence regarding the condition. The initial operation of the prototype does not require the patient to be fully "marked", which would currently be infeasible, but rather uses the healthy adult as an indicator, which the patient can relate to. The long term would see technology that maps the patient completely without the need of special markers and the avatar would then directly correlate to the patient, their unique characteristics and with the progression of their condition.

The assessment model given in section 5.1 recognises the importance of assessment in the process but also recognises that assessment as a whole comprises much more. Currently the physiotherapist is being asked to collect the data and to conduct the measurements in ways that are disproportionate in time and effort with respect to the other steps and arguably at the expense of more important clinical functions that only they can perform. This prototype developed has the potential to augment and improve the current assessment of AS and to give meaningful feedback to the long suffering patient.

A 3-D virtual person called avatar has been chosen as the principle representation, onto which motion data and measurement data is mapped. The selected assessment instruments BASFI and BASMI, and physiotherapy exercises activity have been successfully presented by the 3-D avatar, including:

- **BASFI (subjective)**
  - Q. 2 “bending forward from the waist to pick up a pen from the floor without an aid”
  - Q. 4 “getting out of an armless dining chair without using your hands or any help”
  - Q. 8 “looking over your shoulder without turning your body”

- **Recommended NASS exercises considered for BASFI Q. 9 “please indicate your ability in doing physically demanding activities (e.g. physio exercises, gardening, sport)”**.
  - I. “Spinal side flexion”
  - II. “Spinal rotation”
  - III. “Neck rotation”
  - IV. “Hamstring stretch”

- **BASMI (Objective)**
  - I. “Lumbar side flexion”
  - II. “Tragus to wall” distance measurement
The 3-D avatar is intended to be a faithful visual scale for the client. There are three types of output available at this stage of the prototype’s development: an unadorned 3-D avatar; a 3-D avatar with markers on; and a video. The current visualisation software is used in a laboratory setting with the 3-D avatar simulating selected questions from BASFI, NASS exercises and BASMI.

This prototype can provide the following main functionalities at this stage: firstly, it provides 3-D visualisation for a range of activities including assessment activities, physiotherapy exercise activities and objective assessments; secondly, integration capability of several measurements such as subjective assessment and objective assessment and physiotherapy exercises is possible; and meaningful feedback to clients is available by means of different types of output methods; last but not least it has the potential benefit of integrating other facets, i.e. pain from BASDAI. Evaluation of the prototype is followed in the next chapter.
Chapter 6

6 Evaluation

Chapter 5 discussed the research prototype. In this chapter, the qualitative evaluation results are discussed in detail. First, the evaluation goal is explained, which is to test the formalised models and to assess the prototype’s contribution. Then the evaluation process is introduced in order to provide an overall view of the whole process. The useful factors extracted from the evaluation results are categorized regarding primary research interests with respect to assessment, feedback, exercise activity and criticism of current instruments.

6.1 Evaluation Goals

An evaluation goal was to test the “formalised models”, i.e. assessment and feedback models discussed in Chapter 5 as shown in Figure 16 and Figure 17. This was done by the physiotherapists who used the models via simulation to see whether they were sufficient for the intended purpose. A further goal was to test the research prototype that was built upon the models to see whether it provided a potential alternative to the current paper based instruments used in the current situation.

The initial evaluation began as soon as the research idea was formulated. The literature was scanned to assess what was being done and what were the gaps in current assessment and feedback actions in relation to the treatment of AS. There seems to be three, almost contradictory findings. The first was that AS seemed to be well researched with a number of “gold standards” being developed to measure the affects of the condition. These indices, many from Bath, were published in the early 1990’s, and subsequent studies seemed to support the efficacy and validity of these instruments in different countries. The second finding was not specific to AS, but related to human
factors research which found that VAS were less than ideal as a way of capturing perception. And in this context, it failed to capture a complete picture of pain and of functionality. It was difficult too to use as a comparison tool as the perceptions were from an individual perspective. As the VAS instrument was used both for measuring functionality and pain in AS, it cast some doubts over the usability and usefulness of the instrument as a key part of AS assessment. The final finding was essentially not found from the literature but from discussions with practitioners and academics in physiotherapy. There was unease on the professional level that the current means of assessment were falling short for a variety of reasons, and more formalised and consistent ways of assessing and treating a patient with AS were required. Furthermore it was impossible to find any published, explicit models of assessment and feedback in the healthcare domain. Therefore, it is difficult to understand what was meant by such terms in practice, e.g., their scope and what data was collected/presented at each point. And it is difficult to understand the contribution made by the VAS to the patient’s treatment and their understanding of what was recorded.

Based on these preliminary findings, it was decided to see whether the 3-D visualisation capabilities of VR, not the whole VR functionality, could be used to provide an alternative way of presenting aspects of the symptoms and treatment by creating a prototype that could be evaluated. A prototype, as discussed in Chapter 5, was constructed and developed based on models and narratives, and then evaluated by scenarios in qualitative test sessions.

6.2 Evaluation Process

As discussed in Chapter 3, the evaluation utilised two focus groups, including one pilot study, and one interview comprising clinical and academic professionals who are experts in AS. The format for the evaluation, data analysis process and generation of themes and categories are discussed in this section.

6.2.1 Format for the evaluation

The agenda for each session is given in the Appendix I. Each evaluation session shared the same format and the questions are asked in the same order. Apart from that, the purpose of the pilot study was also to ensure meaningful evaluation sessions. As part of the study, formal models of assessment and feedback (Figure 16 and Figure 17) were
presented and discussed. The device of considering a hypothetical patient at various stages in the assessment and feedback processes was used to design how the prototype could be used and as a framework to elicit comment and create a focus for the discussion.

The hypothetical patient (or persona) was selected as being a typical AS stereotype of a young person, who first knew about the condition in her late 20’s, early 30s. The scenarios start from the first assessment at the onset of the condition and then the focus moves to later assessments made throughout the course of her life with the disease. Four scenarios were created, applicable to both assessment and feedback, and designed to be used in the evaluation process (as shown below).

**Persona:** Angie Stone; Female; 30 years old; Accountant

**Assessment Scenarios**

**Assessment Scenario 1:** 1st assessment by the physiotherapist
Ms Stone is confirmed with AS and is referred to the physiotherapist. This is the first attendance, which is introductory in nature and sets a base-line.

**Assessment Scenario 2:** nth assessment by the physiotherapist
Ms Stone revisits the clinic and sees same or maybe a different physiotherapist at the scheduled time. This scenario is about the subsequent visits by the patient for assessment as these differ from the very first. Subsequent assessments have one or more previous assessments to compare.

**Assessment Scenario 3:** prescribes exercises by the physiotherapist
A physiotherapist prescribes exercises to Ms Stone on the 1st visit or nth.

**Assessment Scenario 4:** documenting by the physiotherapist
After or during assessment of Ms Stone, a physiotherapist writes up her record on the 1st visit or nth.

**Feedback Scenarios**

**Feedback Scenario 1:** 1st assessment by the physiotherapist
Ms Stone visits the clinic for the first time, the assessment has been done, feedback information.

**Feedback Scenario 2:** nth assessment by the physiotherapist
Ms Stone revisits the clinic, the new assessment is done, feedback information again.

**Feedback Scenario 3:** previous and future exercises given by the physiotherapist
Ms Stone is asked about the exercises given to her.

**Feedback Scenario 4**: the different aspects of AS from the physiotherapist

Ms Stone visits/revisits the clinic; several assessments have been done, feedback information on all aspects of the condition and treatment.

The persona and scenarios were approved in the pilot study. Also, a number of logistical issues were raised during the pilot, and these were addressed in order to improve the validity of the evaluation. In order to improve comparison and support the analysis process, the participants were asked to go through all the scenarios twice: first time was to collect narratives of procedures in current practice; the second time was for narratives of assessment and feedback with the prototype.

### 6.2.2 Data analysis process

It has been decided that the data collected from the pilot study should be included in the overall data analysis, because it can add more insight and there is no risk of contamination (Holloway, 1997). All data were recorded and transcribed, and the transcriptions have been cross checked by another researcher prior to the analysis.

The qualitative data analysis package NVivo® 8.0 was used for the initial stages of coding. This tool allows to: index segments of the text to particular themes, carry out complex search and retrieval operations, and link notes to coding. King has pointed out that, software is only an aid to the organization of the material and is not an interpretive device (King, 2004). Nevertheless, computerisation does allow working with large amounts of text efficiently, coding complex schemes, facilitating in depth and sophisticated analysis.

The interpretation and analysis of the data are content based thematic analysis (Clifford, 1997). The basic procedure in content analysis is to design categories that are relevant to the research purpose and to sort all occurrences of relevant words or other recording units into these categories (Tesch, 1990). And the analysis also deals with creation and application of “codes” to data. Categories and themes are both generated from research emphasis and emerge from the data.

### 6.2.3 Generation of categories and themes

A snapshot of Nvivo® 8.0’s interface with data is shown in Figure 37. Both free nodes and tree nodes are utilised in the coding process. “Free nodes” can be understood as
containers for both the research material collected and notes on this material. This type of node is represented as ideas about the text, in essence capturing general themes. “Tree nodes” are particularly useful while they allow splitting up these broad categories through the use of interlinking “children”. These “children” serve as sub-categories under the broad headings. Decisions about what counts as a category come from all kinds of places – theory, literature, research experience and the data itself. The transcripts were coded into broad themes based on the research objectives and questions. Each broad theme was then subjected to a more detailed manual analysis, which led to the formation of more specific categories within each theme. The framework of four scenarios for both assessment and feedback were used to elicit comment and create discussion for the evaluation. These became the general context of the evaluation that provides the environments of generating data and establishing themes.

Figure 37 Snapshot of the Nvivo® 8.0 working interface with data

Throughout the evaluation, attention has been paid to identifying issues in the areas of interest rather than drawing conclusions about generalizability. The themes directly address the initial research objectives. Together they provide a comprehensive overview of the interpretations of the participants’ perceptions in terms of current practice context and for this prototype. For primary research interest and a clearer path,
these paralleled themes are gathered with respect to the limitations of current instruments (section 6.3), perceptions in the proposed models (section 6.4) and in the prototype (section 6.5). The sections following focus on the participants’ views of:

- The perceptions of current instruments’ limitations for AS (section 6.3)
- The perceptions of the proposed assessment and feedback models for AS (section 6.4)
- The perceived credibility on assessment for AS (section 6.5)
- The perceived credibility on feedback for AS (section 6.5)
- The perceptions regarding physiotherapy exercise for AS (section 6.5)
- Discussions and concerns of this prototype (section 6.5)

These broad themes and their associated categories are covered in the following sections. The physiotherapists and academics involved are referred to as “participants” in the focus group or the interview throughout the text. Each individual is presented here by a letter, ranging from “A” to “F”, indicating the quote source while avoiding identity being revealed. Any quotes are written in italics to indicate that this is not the authors’ wording but the words of the participants. And certain words that complete the participants’ words, where these are not known or that provide contextual information, are given in square brackets.

In each of the following sections, a summary of the data within each theme is presented followed with detailed discussion. The implications of the analysis are presented in relation to the key objectives in the summary, and the contribution is concluded in the end.

6.3 The Perceptions of Current Instruments’ Limitations

This is a critical issue within the overall research and therefore specific questions were asked regarding what did the physiotherapists feel concerning the limitations of current instruments used for AS.

The data are organized into four main categories:

- Limitations of the Bath indices
- Limitations of VAS
- Inconsistent measurement
- Desire for computerised documentation
6.3.1 Limitations of the Bath indices

The development of the Bath indices, specifically BASFI, BASMI, and BASDAI has been discussed in detail in Chapter 2. They are currently widely used in practice, and play an important role in the treatment of AS. Nevertheless, there seems to be growing criticism. Some physiotherapists don’t like the Bath indices because they are more subjective and there is risk of bias. Some physiotherapists believe it is time for a review since the Bath indices were developed in 1990s. Therefore, in the discussions of the participants, attention has been paid to the limitations of the Bath indices in general, and especially BASFI. In contrast to their widely acceptance and usefulness in practice, concerns of less sensitivity and likely bias are still common perceptions from the evaluation sessions. Since the Bath indices were developed in 1990s, a thorough review would seem necessary at this point of time, but that is beyond the scope of the present research.

“They are trying to change it. There are new equations, sort of things, coming. They are coming from the European leagues and something like that. And people understand that it is not good. What they are trying to do is to work with what we’ve got, and try to make it a bit more sensitive. I don’t understand what they are up to at this present time. But it is just crying out [for a solution]. It is 1994 [when they were developed].” (Participant B, Pilot)

“... BASFI and BASDAI are far more subjective than BASMI... That is why I didn’t like them. That could be an over strong statement? Yes, I think, you know, there could be a potential bias, isn’t it?” (Participant, Interview)

Specifically, regarding question 2 in BASFI, “please indicate your level of ability with bending forward from the waist to pick up a pen from the floor without an aid”, one of the physiotherapists has pointed out that it is no longer considered functional or even safe. And they won’t suggest it since it may put the patient in danger or pragmatically the patient simply won’t obey because they can’t do it.

“And I think probably ‘bending forward’ is actually not functional unless you pertain picking the pen off the floor, because ‘bending forward’ is not a functional movement. Why [would] you [be] bending forward for no reasons? And they don’t because they can’t. That is not functional any more. You ask them to bend forward, and they don’t do these days.” (Participant A, Focus Group)
6.3.2 Limitations of VAS

As discussed in Chapter 2, limitations of VAS have been explored in general and here as the main visual interface to a member of the Bath indices. The participants reflect again that patients have difficulty in using the VAS utilised in the indices. The patients have problems in conceptualising the VAS; instead, they express their understanding by writing an essay or drawing two lines etc. Consequently, it can consume more physiotherapy time in explanation and redoing. The patient’s response to the VAS is said to vary a great deal.

“But on the first visit, I don’t send out the forms. The first visit would be done there, and you sit with them and explain it, because it is very difficult sometimes [for the first time] ... Sometimes they do a scale, which goes to 10 to 12 [the maximum score is 10].” (Participant A, Focus Group)

“I think some people got VAS score quite quickly, but some people struggle with the concept, don’t they?” (Participant A, Focus Group)

“They write an essay on it rather than drawing one line.” (Participant D, Focus Group)

“Sometimes two lines, one is number 6; one is number 7 [for the same question].” (Participant E, Focus Group)

6.3.3 Inconsistent measurement

The participants have realized that the ways of carrying out objective measurement, i.e. BASMI, are also problematic. They have found that it was inconsistent and varied from individual to individual. For example, they found the way they measured “Schober’s flexion” varied between different physiotherapists due to the tools used or the procedure followed. In their networking meetings, measuring in a consistent way was the focus for discussion.

“Because we found in this group [physiotherapy network meeting], the way we measure ‘Schober’s flexion’, for instance, varied quite greatly between different physiotherapists. Then for the ‘neck rotation’ as well. If the tool [the prototype] did the assessment, then you can compare between the different MDT measures.” (Participant, Interview)
There is also a varied time span between each visit due to different requirements from and constraints on NHS trusts. In general, the first follow-up visit will be relatively quick, with subsequent visits further apart in their frequency. Given that AS symptoms can flare-up and the last week prior to an assessment is not necessarily representative of the whole period between assessments, it can be difficult to understand what the scores mean. Furthermore, the wholly subjective questionnaires are thought to vary in accuracy, according to whether they capture the patient's feelings on a bad day or a good day. This is another difficulty that distorts the object of measuring consistently.

"If you are on a bad day, you decide it [the answer to the question] is nearly impossible with these tasks. And that is how the subjective measurement actually performed." (Participant, Interview)

6.3.4 Desire for computerized documentation

While the resistance to IT remains a major concern, the possibility of computerised documentation of Bath scores and other relevant information has been raised in practice by some of the participants. One participant had requested their NHS Trust to sort out a computerized documenting of the Bath scores; the aim was to chart the scores over time. It is believed that such computerized documentation can help in feeding back information to the patients as well as reflecting disease trend over years.

"If you are to ask in 6 months time, I have a better answer. We currently got a request going through with the computer guys to sort out a computerized documenting of all the Bath scores. Like you might do for a patient's blood results, you can put on the computer, you have a graphic showing this is the trend available in the last 6 years. And you can see how this has gone up and down. That is what we hope to do with Bath scores in 6 months time. But, that is not happening. At the moment, I suppose the feedback is fairly informal; just here are three assessments sheets, measures, and scores over a course of time." (Participant, Interview)

6.4 The Perceptions of the Proposed Models for AS

As part of the study, more formal models of assessment and feedback (as shown in Figure 16 and Figure 17) were generated and presented at the Physiotherapy Network Meetings and at the evaluation sessions. The participants unanimously agreed that these
models captured the actual processes in simplified form. Although simple, it was the first time that they had seen such formal representations of what they did in practice.

Regarding the evaluation of the prototype, both the persona and scenarios were first used to capture data in procedures of current practice. Although feedback can be given along with the assessment process, in the model it is artificially separated from the assessment as it is a significant area for the current research. It therefore has its own place in the four distinct scenarios.

A summary of narratives from the participants going through those scenarios is presented as in Figure 38. This figure shows generally an overall view of current practice process though it may be various regarding to the input and output depending on different sites and professionals. The process and content in Figure 38 are within the scope of proposed models as in Figure 16 and Figure 17. The assessment activity follows the three phases: input (discover), process (learn), and output (perform). Both objective and subjective facts/results are fed back from the clinician to patients along with the process. Note the timing and frequency of the visits varied from Trust to Trust. Generally, the patient’s first visit is to meet the physiotherapist, build the base-line from which the physiotherapy will manage the treatment. The 2nd or 3rd visit is a follow up and these happen within a relatively short time. Thereafter, regular visits will be scheduled but the time between visits will usually be longer than the earlier ones. These differences pose potential problems for tracking the progress of the condition in the individual and for comparing results across all AS patients.

Bath indices, including BASFI, BASMI and BASDAI, are mainly used for the assessment process. Exercise remains a key therapy, however, NASS exercises are recommended in all participants’ Trusts except one, where there is a specific department generating exercise leaflet. There are some guide-lines but what exercises are done depends on the patient but also the experience of the physiotherapist. Agreement as to which should be used and to the value of each exercise is not yet fully evidence-based.

What is shown in Figure 38 was sent back to the participants as part of an evaluation report has and was created from the participant discussions. Findings and the possible value that this prototype might contribute are categorized and explained in the following sections.
Physiotherapy (Assessment/Feedback)
Timeline Model

Baseline
1st visit (45 minutes –1 hour)
- Demographics - Communication
- Subjective assessment - Disease history
- Objective assessment

Feedback
- Education - Referral result
- BASMI explain - Exercise guide
- Questionnaire score - Alternative treatment

2-6 weeks
2nd/3rd visit (20–30 minutes)
- Disease changes
- Life changes
- Coping with exercise

Feedback
- Assurance - Disease changes
- Modified exercise guide

Every 3/6 months thereafter
Nth visit (20–30 minutes). n≥3
- Review disease - Subjective assessment
- Review exercise - Other measures
- Changes comparison

Feedback
- Assurance - Score comparison
- Measurements - Disease changes
- Exercise guide (modified) - Referral results

Figure 38 Summary of current physiotherapy process
6.5 The Perceptions of the Prototype

The perceptions of the prototype in various ways with respect to assessment, feedback and physiotherapy exercise are discussed in this section.

6.5.1 The perceived credibility on assessment for AS

This section explores the objective of how this prototype is perceived with respect to assessment for AS. This theme encompasses perceptions of the credibility of this prototype and its status within the academic and practitioner communities on assessment for AS. It is identified in various ways in which credibility has been defined by the participants. And the implications that these different categories have for this prototype are discussed in the following sections:

- Credibility coming from visualizing movements in 3-D
- Potential credibility coming from visualizing pain in 3-D
- Credibility of encouraging multi-disciplinary working

6.5.1.1 Credibility coming from visualizing movements in 3-D

The participants believed that the prototype could be helpful in various ways by visualizing the movements in 3-D. First, they said it was possible to see how it would improve the assessment of movements with this prototype. The evidence is currently lacking as to what the patient is exactly doing in their daily life in response to the physiotherapist’s instructions from an assessment visit. Currently the physiotherapist has to ask the patient to show what exercises they have been doing at their home (i.e. when they are not being observed). If this prototype not only captured the immediate movement but also had a database tracking the movements between visits then it would be possible to replay the patients’ movements and therefore provide much more information to the clinician.

Furthermore, they felt that the tool made it possible to improve the understanding between the patient and the clinician. No matter how well the exercise is described by the patient, it is agreed that it would be hard to convey the movement in any accurate way without visualizing it. Again, if the patient’s performance could be monitored more effectively then the clinician could also assess risks of self harm through inconvenient or dangerous exercises. By visualizing movements in 3-D, explanation and understanding in an accurate way is more possible. Finally, the comparison of movement between each
visit can be performed by the computer, supporting the physiotherapist and the patient with data on improvement or the lack of improvement. Visual evidence can be made available for explanation of clinical terms, providing accurate measurement to statements such as “2cm’s difference”. Thus, the capability of visualizing the movements in 3-D is deemed potentially useful.

“You have to watch them to do it first. You know, probably let them show me, ‘how are you doing it’ Very often, that is what happened, they don’t do it. I think that is the first thing; you should make sure they understood it initially. And then if it is not helping for them, then you have to re-adapt it for them really, say, ‘you need to work on this bit, you need to work this way or try this way, or do something differently.

It would be easier to show them visually, what score means, rather than ‘cm’ For example, 2-cm’s difference, they might score a 2-cm or whatever, so of course you could show them ‘last week’ or ‘last month’ you’ve got, ‘You felt you could get this far, and obvious this time, for some reason, you feel you are not going this far.’ And that for them ‘watch’ for sure is easier.” (Participant A, Focus Group)

6.5.1.2 Potential credibility coming from visualizing pain in 3-D

Pain is one of the symptoms that is difficult to measure and describe. The capability of this prototype of integrating multiple measures, such as subjective assessment, objective measurement and pain assessment, etc, provides an opportunity to consider the multi-symptoms condition in an integrated way. The participants believed that there is a potential from visualizing pain in 3-D, which is thought to be a sensible representation of pain. Since the participants believe that the pain body chart used currently is liked by their patients, this prototype is seen to have potential. Visualizing pain in 3-D is an area for further research; the current prototype only illustrates the possibility.

“... So, it is a traditional questioning of the condition. Then we do a body chart, looking at areas where she is getting her pain. To that pain, what aggregates it, what eases it? We look at sleeping effect.” (Participant, Interview)

“... I’ve seen some patients filling pain chart, you know, since they like it. They got pain on the side of their body, images like that. I mean psychologically, you pick that up beautifully by doing that.” (Participant B, Pilot)
6.5.1.3 Credibility of encouraging multi-disciplinary working

AS usually involves a MDT in the treatment process which oversees different aspects of the disease. The physiotherapist is an important member of the MDT, although the group discussions revealed that they often had different roles and rights. For example, there were different ways to access the case note or patient note if not in a shared record and this depended on different hospital rules. After the first visit, documenting of the different output from the meeting sessions usually depended more on the particular work environment, whether it is an AS clinic or some other environment. There are differences in what the physiotherapist needs and so the physiotherapist will write different things to different people of the team. Another issue mentioned is that there is some repetition of information on the same assessment. The nurses sometimes will re-assess the patient on the next meeting day since they have not got the results yet from the physiotherapist. So it was felt that the prototype may facilitate the communication among the MDT by easily accessing and sharing information within one single environment. It is possible to believe that making such a prototype assist the record keeping and communication for all in the MDT has the potential to save time and resources. However this would be a useful “side effect” but is beyond the present scope of the research; the current prototype is focussed on the assessment and feedback of the physiotherapist-client relationship.

"I've got a letter to go to the consultant; it is that all of the scores I've taken on that day would be sent to the consultant, and put in the medical note. And also we had a database of the anti-TNFs, and all of their scores have to go in there as well."

(Participant F, Focus Group)

"We have physiotherapy notes, so we don't have access to patient notes."

(Participant A, Focus Group)

"I think previously would be like: here is your referral, do what you like to assess them, how you like. We will monitor them, educate them, and report back to the doctor. These days we intend to get more assessment, say, 'please could you perform the Bath scores with this patient and feedback?' So MDT kind of communication with this tool would be a kind of idea. It gives you importance. There isn't MDT communication between assessments, because we have patients to be assessed by us on a Thursday day, and the next Tuesday, they went to the nurses and the nurses would repeat the assessment. The patient is going like, 'this is done, and you've not got the information from the physios.' Maybe it is a more novel tool and MDT use would be encouraged."

(Participant, Interview)
6.5.2 The perceived credibility on feedback for AS

This theme is concerned with perceptions of this prototype with regard to feedback for AS. As such it is closely linked to the objective of understanding how it is evaluated and what makes it useful or not with respect to feedback. This section is divided into three categories:

- Credibility related to educating the patient
- Credibility from capturing disease trend and status
- Credibility of feedback information flow changes

6.5.2.1 Credibility related to educating the patient

AS is a progressive chronic disease; patient education is of importance in the treatment process and patient self management. Like any chronic arthritic condition, self-care plays a key role in the condition management. Therefore, patient education is vital for AS sufferers. It is also believed that “education in physiotherapy” may be of more importance than education of the disease for AS sufferers. Feeding back physiotherapy information to the patient with this prototype is believed to be promising in a number of ways. The fact that this prototype helps to show movements in 3-D provides the opportunity to educate the patient about what the physiotherapy requires of them. So the participants thought it might be helpful in feedback by explaining physiotherapy information in 3-D and possibly avoiding misunderstanding during the treatment.

“... Possibly, ‘education’ of that disease, perhaps is less important; ‘education in physiotherapy’, would be more important.” (Participant, Interview)

“... Again, the set is dynamic, isn’t it? If you look at a set of ‘rotations’, it is a very difficult concept for somebody. It is trouble here, because we know too much. You know about your estimation of what you are looking for, which is what you got to try to teach the patient. Because they might be doing the treatment, not moving the bit that you actually ask them to move. That is the fact that would be really helpful.” (Participant B, Pilot)

6.5.2.2 Credibility from capturing disease trend and status

There is a desire for computerized documentation of Bath indices in order to overview the scores over a period of time in a concise way. This prototype can represent the disease trend in actually showing the patient’s movements in 3-D over a period of time
which is more direct than a set of derived numbers, particularly if there are concerns over
the meaning of these numbers. A more continuous form of monitoring, say once a day,
means that fluctuation and flare-ups can be more easily assessed. Note some of the
participants emphasize the use of “markers”. It has been envisaged that any future
application would minimise the need for such constraints, particularly if it is to be used
on a routine basis at home. The capability of store and compare function and disease
status is thought to be useful with this prototype, as it can reflect the overall trend of the
disease over the years for a particular person.

"... yes, if we did have the markers on the patient, let’s say on both settings, it was
there before the movement, that would be easy to compare, depending on you’ve got the
software in front of you. And good feedback to the patient on how they perform,
comparing to [previous visits].” (Participant, Interview)

“I think that would be very useful if you had those markers on them. You could
actually see. I could show people things from my computer, ‘this is what you actually did
with your markers on last time’ You could actually have them superimposed. That is how
I would think it is marvellous. They could actually see, but that means the markers on,
that is all the spending time sticking markers on.” (Participant D, Focus Group)

“One thing comes into my mind is that, it might help in that. You know we said
this is a fluctuated disease which depends on which bit of the day you catch them on. If
the patient could somehow take average [measurements] over a week, do measurement
everyday for a week. And then they come to see the physiotherapists, and say, ‘look, this
is what I got’; downloading something into the physiotherapists’ computer, that would
give them indications.” (Participant C, Pilot)

6.5.2.3 Credibility of feedback information flow changes

The feedback model as shown in Figure 17 was accepted by the participants as a way of
representing what they did in practice, albeit in a simplified form. That model showed the
clinician as the centre in its simplified form. With this prototype, the feedback process
can be modified as shown in Figure 39. The patient now becomes the centre actor within
this modified model. And the information flow is not uni-directional any more, i.e.
flowing from the patient to the clinician; rather the prototype permits a two way
partnership. The previously clinician-oriented result/scores are a by-product whereas the
movement is much less abstract and requires less clinical knowledge for the patient to
understand their progress. The new information flow also allows more open interaction
during the treatment process between members of the MDT. This model therefore
supports the previous requirements for better communications throughout the evaluation process concerning both assessment and feedback.

Figure 39 A modified feedback model

6.5.3 The perceptions regarding physiotherapy exercises for AS

As well as providing some context to the general issue of physiotherapy exercise, this theme casts some light on the objective of exploring how the physiotherapist is prescribing exercises and what is the prototype’s value in exercise activity. To perceive the impact of this prototype on exercise activity is an important objective of this research. The questions therefore focused particularly on how participants recognise prescribing physiotherapy exercise, how participants anticipate the patient’s compliance, what is this prototype’s value in exercise activity due to the engaging of technology and how this prototype can facilitate the management of AS.

Three broad categories relating to physiotherapy exercise activity are presented:

- Physiotherapist prescribing exercises
- Participants’ anticipation of patients’ compliance
- Patient transforming exercises

6.5.3.1 Physiotherapist prescribing exercises

Physiotherapists usually prescribe exercises as a key therapy method to the patient in current practice. Although experience plays an important role in decision making, the fact is that evidence is poor regarding which exercise is better, and whether the patient complies to them or not. There have been previous attempts at trying to standardise exercise prescription through the Physiotherapy Networking Meetings. Currently, personal favourites and choice will continue to play an important role, e.g. breathing exercise is deemed as one of the most important and is therefore being pushed.
"... Oh, I see, because I know they won't do that. They only do [the ones that] fit in a few minutes. So I try to go for the BASMI, and emphasize the ones I think that are most important, and say, 'you can do any of these, but these are the ones that are musts for you'.

Sometimes, they come in and say, 'I haven't done your exercises'. And actually you are trying to give something. I always push the 'breathing' ones. I say, 'if you do nothing else, you can't live without breathing. So you do need to do these with the exercises'." (Participant D, Focus Group)

In contrast, another physiotherapist is happy with the patient initiating the exercise. In those circumstance, guidance works rather than instruction. It seems an enough compromise to provide the patient with the opportunity to initiate the exercise, providing guidance and continuous monitoring.

"I think we will guide them. But they had chosen them [exercises], because they [exercises] are similar, you know. There are three or four different exercises for 'lumbar spine rotation'. I think the patient can look at the booklet, and choose which one they want to do. So they would rather do one set on the chair because they can do at work rather than the one they have to go to bed to do it. And you know, by the time they go to bed in the evening to do the exercises, they tend to just fall asleep rather than doing it. So I think if it is a chronic condition, and long term exercise treatment is needed, I am happy the patient has initiated how they are going to perform their exercises." (Participant, Interview)

In fact, the physiotherapists try to customize the exercise for the patient in order to increase the possibility of compliance, while it is in conflict with the intention to standardize the exercise prescription. The link between the outcome and the exercise being done is still weak.

6.5.3.2 Participants' anticipation of patients' compliance

It is a complicated issue as to whether the patient is compliant or not with respect to the exercise prescription. It has been noticed in other researcher's work (Porter, 2010) that patients transform the prescribed exercise sometimes, others will not comply at all, and some will obey the exercise prescription strictly.

"An interesting one again, the physiotherapist would say to a patient, 'are you doing your exercises?' That was 'yes'. When I come to an interview, they say, 'actually, I don't, I didn't like to admit it at the time, when I don't need to do it.'

..."
Again, it is quite complicated. In a group of 100 AS patients, you will have a few that will do that. One guy I interviewed he set 15 minutes every day of his life to do the exercises, and pushed it quite hard. And I said to him, 'why did you do these, you know, because you are working, you got your family, why did you do them?' The answer was, 'the physiotherapist told me to do it.' He was the only one. But he was at one end of the spectrum, and then you got the other end of the spectrum, AS suffers go to be measured anyway. But don't think about it. And you've got to say, 'and why you go to be measured anyway?' 'It is sort of waiting for a miracle to appear'; or 'it is nice to know I am not getting any worse.' You heard that a lot. Sometimes it is like confidence building. The fact that they can have a figure put on it. 'oh, yes, I know I am not getting any worse'. You do get worse. You've got an answer for it.” (Participant C, Pilot)

It seems relatively difficult to monitor the patient’s exercise activity at home. Although exercise diary provides an opportunity for monitoring, there are doubts from the clinicians in these diaries.

“You get someone to do exercise diaries. They won't do it, they will just lie. And get them to do full diaries and exercise diaries for a week, and they just lie at the end of the week.” (Participant B, Pilot)

“The problem is, we are doing this diary, we are taking scores, and we are building these tools based on lies, aren't we?” (Participant C, Pilot)

Another general perception, either reflecting the practitioners' views or accredited to others, i.e. the researchers, is to understand what exercise the patients are actually doing. Instead of basing it on patients’ diary or physiotherapists’ anticipation, audit of compliance can be built in this prototype to help the monitoring of the patient, i.e. do they exercise on their own/more than others? The characteristic of engaging in technology brings the promise of improvement of exercise compliance since this prototype could take intervention into consideration. This potential has to be left for further investigation.

6.5.3.3 Patient transforming exercises

Besides compliance, the issues of defining and transforming “exercise” are found to be very complicated. Physiotherapist and patient may well have a different understanding of what “exercise” is. While the communication between the clinician and the patient may be clear, the content that is the “exercise” may be quite different. Nevertheless, transforming the prescribed exercise has been found a quite common issue by the participants. The complicated issue of transforming exercise may have something to do
with the unusual way of thinking with this condition. Unlike the common sense notion that pain is telling you not to do something, it seems essential with this condition to go through the pain barrier and to get the exercises done.

"I think as well as what it is asked, how to ask is important. Because another thing I found is that you may say to a patient, 'are you doing your exercises?' They will have a very specific idea of what they think the 'exercise' is, whether inside or outside that [definition]. They might say to the physiotherapist, 'yes, I am doing it.' But what they mean by 'doing exercises' is not what you understand. So I think it is important to think about how to ask, and how we define exercises." (Participant C, Pilot)

"I think, patients with AS, they have to understand it would involve a little hurt. But that is very difficult to say [that] the one [i.e. exercise] that hurts is the most, is the one you should be doing." (Participant A, Focus Group)

"Getting over that idea; most people realise pain is telling you not to do something, you may feel really good and go through that pain barrier, but pain is really telling you not to do something. But you have to change the way of thinking with this condition. Actually when it is painful, that is telling: you are doing well, you got to keep doing the same, it is the right exercise, you should push them more. And that is not what common sense tells you." (Participant D, Focus Group)

The participants thought that if this prototype could be used at home by the patient and the exercise activity could be captured, then it could be possible to start to build evidence for exercise selection and exercise prescription.

"So the other way round. They come back, and traditionally you know, made their Bath scores much improved. Let me see your exercises ... That is not in the booklet, but if that is what they have been doing, it is a better way forward. Then yes, we could change the exercise prescription you might use. Equally, if they picked x, y, z, rather than a, b, and c: x, y, z still achieved maintenance of improvement one year down the line. Then, that is fine." (Participant, Interview)

6.5.4 Discussions and concerns about this prototype

This section investigates the discussions and concerns of this prototype in the current context of work. It picks up on the objective of exploring this prototype's full profile. Some of the issues relate to health informatics in general, however, they may be particularly significant when it comes to 3-D visualisation technology.

Categories identified here and described below are:

- Discussions on the form of this prototype
• Concerns regarding cost
• Concerns of communication changes

6.5.4.1 Discussions on the form of this prototype

Certain design issues were discussed to investigate the prototype’s full functionality and interface. The participants liked the neutral appearance of the figure that represents the virtual patient and believed it provided a new platform for data management. From a clinical or care perspective, the participants felt that the neutral appearance of the figure was appropriate because they felt people would rather see an avatar than see themselves, especially when deformation to posture is happening. The avatar was felt to be much more appropriate than simple video.

"I was going to ask that, I think it is the ‘figure’, because someone don’t want to watch themselves." (Participant F, Focus Group)

"Some people are horrified when they look at family videos and wedding videos and things, and realizing what people are seeing, because they don’t feel what people will see.” (Participant D, Focus Group)

Although the prototype was clearly experimental and “rough”, the participants felt that the current form of the prototype needed to be simplified before it could be taken up and introduced in routine use. It is common to mistake “prototypes” for the “real” thing and expecting it to be closer to product than it actually is. Participants felt that an alarm might be added into the prototype that would be automatically triggered when there was a danger of over assessing the patient; this clearly requires a much more “intelligent” system than the visualisation tool shown. Even so, more sophisticated algorithms for calculation of the score and data processing were desired.

"I suppose, if you are looking at the BASMI score, let’s say the ‘lumbar side flexion’ score is 5. And they decide, like somebody playing on the Wii, we don’t like that age being 42 or whatever else. I am going to give myself a 4, whether I kill myself or not. I am going to have a 4 by the end of this week. And I am going to reassess myself daily. Then yes, it could be dangerous repeating what is an essentially 6 month assessment as an exercise ... I see this is the exercise they’ve been doing rather than the BASFI. BASMI. So, yes, you haven’t done the exercises for 3-6 months; you need to come to see the physiotherapist at this point.” (Participant, Interview)
The question of how this prototype can be used with the current instruments has been raised regarding service application. Whether it intends to combine with current instruments or replace current ones completely is an open question. However the goal of this research was to augment rather than replace. Since the current paper-based instruments for AS were developed back in 1990s, and they have been used in practice for decades of years, it was predictable that there would be resistance from the clinicians with respect to introduction of a new tool. As stated, the purpose of the research includes using this prototype to review current instruments and to seek opinions for the form of this prototype. There are several opportunities for the prototype: the first is to critique current instruments; the second is to combine with current instruments; and the third is to replace current instruments.

"... They are telling you how difficult they think it is, aren't they? ... What I am saying is how they perceive the degree of difficulty, whether they feel they could do it: could be pain, could be speed, could be whether they could do it or not, whether they avoid doing it." (Participant D, Focus Group)

"Are you going through exactly as what is done in the BASFI? Or you interpret it slightly into moving differently? Because, BASFI, obviously we didn't devise it, but we presume in brains of people of Bath who did, the first one is bending down to pick up a pen from the floor, isn't it? That is on to them, it is the way of saying to them 'how far can you bend forward to touch the toe', isn't it? 'Can you pick up from the floor?' It is not the way of bending knees." (Participant A, Focus Group)

### 6.5.4.2 Concerns regarding cost

As other technology enters healthcare, there are concerns and resistance from practice for this prototype. The cost of setting up the equipment is still one main concern. And there is further concern about how much clinical time may be needed for learning and setting up the prototype. It is hoped that costs will reduce, perhaps through the use of relatively inexpensive gaming technology, such as Wii®. The promise can be seen as the evolution of technology and dramatically decrease of the expense of the hardware. On the other hand, the engaging of the technology, especially this condition tends to affect the young people, holds the possibility for future home-based care.

"If you come to a scenario, you are just, perhaps, doing like the 'neck rotation'. You actually could show the patient how far they could turn, rather than somebody saying, 'when I put this [physio's specific tool] on your head, you could go that far.' And
then you get feedback from that. You have to put the trousers on, stuff like that. Clinically, I don't see we have enough time to do that. It should be like a top that can wear. I mean obviously we are at the very start here with the prototype.” (Participant B, Pilot)

“I think the people are getting much more computer intelligent, and much more into interaction, and, you know, the virtual world, and the 3-D stuff. I think it is time, bearing in mind that AS does tend to affect the younger people anyway. It is going to be a hit with people who will swallow this sort of things. I would imagine that.” (Participant C, Pilot)

6.5.4.3 Concerns of communication change

The integration of objective assessments, which can possibly generate automatic measurements, is seen as removing some responsibilities from the physiotherapist. “De-skilling” is one of the concerns, and this may in turn affect communication between the patient and the physiotherapist. Also, the quality of measurements may be affected. This argument has to be left for future research.

“I think if you got somebody who wasn't a physio to measure it; they would just measure it, and not make any judgement on the measuring.” (Participant E, Focus Group)

6.6 Conclusions

The evaluation sessions were carried out and the overall view of the work was positive. The results from the evaluation indicate that the research was well founded and the direction of travel was given assent.

First of all, there was agreement from the participants on the limitations of current instruments. The participants perceived that inconsistent measurement existed in the practice due to the varied measurement between individuals; the problems of the patient conceptualising VAS were confirmed according to their experience; and there was a desire from clinicians for computerised documenting of AS treatment process that the prototype would support and surpass.

Secondly, the proposed assessment and feedback models were accepted by the participants as the assessment basis, which captured what they did in practice.

Thirdly, the participants perceived the prototype positively. The prototype was convincing. It has been perceived as novel and helpful in the visualisation capability of movements and even pain in 3-D figure. This prototype was also perceived as beneficial
in educating patient and capturing disease status and trend. And the information flow has been augmented within this prototype by placing the patient as the central actor within the process. Moreover, if this prototype could be used in practice, it may be possibly beneficial to standardise the objective assessment resulting in increased reliability and trust. Now exercise is used as a key physiotherapeutic tool but it is lacking evidence as to which one is better and whether or not the patient is complying. This prototype is thought to be a way to start to build the evidence base but that assumes it can be used directly by the patient in their home.

Fourthly, the 3-D visualisation prototype utilises a neutral figure to represent the patient; the participants agreed that the neutral appearance choice is more acceptable than a simple video because people do not like to see themselves especially when the progression of a condition results in a deterioration and/or deformation of their body. Although, there are concerns regarding cost and communication changes, as technology is becoming less expensive over time and people are getting more engaged in technology, it is seen as something that might become readily available for patients to use at home and shared with the professionals.

Thus, the value of the research can be concluded and categorized as following:

- Representing the patient with a 3-D neutral figure is agreed to be sensible especially while the deformation of patients’ body happened.
- This is the first attempt to integrate several measures, such as subjective assessment, objective assessment and exercise activity, which were thought to be useful by the participants regarding to representing the multi-symptom condition within one single tool.
- The development of this prototype not only meets the request from the practice for computerized documenting of the AS treatment, also, it is capable of augmenting the existing assessment and feedback for AS in various ways by visualizing in 3-D.
- The proposed assessment and feedback models for AS are accepted by the participants as the basis for assessment and feedback for AS.
- Assessment of AS patient can be augmented by visualizing the complex movements in an accurate way and by visually comparisons over a period of time.
• Feedback of AS can be augmented by adding meaningful feedback allowing the patient as the central actor in the information transmission, therefore, the feedback information is not uni-directional any more.

• Regarding key physiotherapy exercise, it can contribute in the following ways: first, an audit of compliance can be built in to help to monitor the patient over time instead of basing on their diaries; second, it might help in starting to build evidence around the optimum exercises to be used which is clearly lacking in practice.

• The overall trend of disease development is simple and clear within this prototype. Visualisation of this condition changing over time regarding to both subjective/objective scores is thought to be very useful.

• It is thought that the use of this prototype would facilitate the Multi-discipline team communication.
Chapter 7

7 Summary and Conclusions

This chapter summarises the thesis. The thesis is critically evaluated in terms of research aims and objectives, contributions and limitations. Conclusions are presented and future work is considered.

7.1 Thesis Summary

This research began with a broad scan of the literature of VR applications in healthcare. Then the scope was refined to focus on 3-D visualisation applications, particularly those involving in assessment and feedback for chronic conditions. AS was selected as the test condition to research, for reasons related to both the visual nature of its symptoms and its treatment. Thereafter, the research question was refined to consider the perceived value of 3-D visualisation upon assessment and feedback for AS. The focus was on supporting the physiotherapist professional in the client's assessment and in helping to manage the patients' condition via self management over a longer period of time. This latter part was not directly evaluated by patients as this would have been too early nevertheless the physiotherapists perceived there would be value in achieving this.

Chapter 1 provided an overview of the research and a guide to the thesis. The motivation behind the research and the reason of choosing AS as an exemplar condition were discussed.

In Chapter 2, a systematic review was conducted with a focus on 3-D visualisation and how it might help assessment and feedback for AS. This review defined the scope of this thesis and ensured its originality by examining existing VR/3-D visualisation applications in therapy. Several research gaps were found. Although VR has been
researched in relation to pain, exercise and even fatigue, there is no research looking at integrating several tools for one condition that relates to multiple symptoms. It has been showed that 3-D visualisation is potentially appropriate to augment assessment and feedback and is likely to improve upon existing measurement practice from what has been found from an extensive review of current 2-D based assessment instrument for AS. The role of physiotherapist was discussed.

Chapter 3 summarized the research design and methods used in each stage. It included development of therapeutic VR models, proposal of assessment and feedback models, development of prototype and qualitative evaluation. Motion data that mapped on the 3-D visualisation prototype was collected in a laboratory environment using healthy adults. The evaluation of this prototype was qualitative sessions involving clinical professionals, i.e. physiotherapists and experienced academics. Ethical issues and recruiting the participants were discussed.

Chapter 4 discussed the possibility of envisioning an integrated VR tool set for the assessment and feedback of AS regarding different symptoms and prioritised an incremental solution to develop an evaluation tool. A physical therapy model has been summarized according to the information generated from current resources. The elements that identified within this model were seen as "facets", and a comprehensive VR model has been proposed envisioning a tool for each facet. The incremental solution was seen as possible, so VR tools for other facets such as pain, fatigue could at some stage be created by other researchers. The prioritised process was to create an evaluation tool that focused on assessment and feedback and particularly applied to the exercise.

In chapter 5, investigation of the prototype was discussed. Formalised assessment and feedback models have been proposed since none were reported in available literature. These models set the baseline and defined the scope of the prototype. A 3-D virtual person has been selected as the presentation assistant, called "avatar". For usefulness, motion data and measurement data were collected and mapped on the 3-D avatar. The selected two assessment instruments, i.e. BASFI and BASMI, and approved NASS AS exercises have been successfully presented by the 3-D avatar, including:

- BASFI (subjective)
  - Q. 2 "bending forward from the waist to pick up a pen from the floor without an aid"
Q. 4 “getting out of an armless dining chair without using your hands or any help”
Q. 8 “looking over your shoulder without turning your body”

- Recommended NASS exercises considered for BASFI Q. 9 “please indicate your ability in doing physically demanding activities (e.g. physio exercises, gardening, sport)”.
  - I. “Spinal side flexion”
  - II. “Spinal rotation”
  - III. “Neck rotation”
  - IV. “Hamstring stretch”

- BASMI (Objective)
  - I. “Lumbar side flexion”
  - II. “Tragus to wall” distance measurement

Its 3-D functionalities, such as 3-D visualisation of a range of activities, its integration capability, meaningful feedback and potential integration of other facets were discussed.

Chapter 6 described the qualitative evaluation. This evaluation comprised a pilot study, a focus group and an interview. The pilot study was conducted resolving some strategy problems, and the data was also included in the overall analysis process. The data from the sessions were processed, via thematic analysis, utilizing content analysis software. A model of existing physiotherapy practice has been approved by participants that it captured the general process in practice. Feedback from the participants was very positive. They all thought that if this prototype could be used in practice by physiotherapists, it would be beneficial and helpful for the clinician and potentially beneficial for the patient over a period of time.

The value of the research can be concluded and categorized as following:

- Representing the patient with a 3-D neutral figure is agreed to be sensible especially while the deformation of patients’ body happened.
- This is the first attempt to integrate several measures, such as subjective assessment, objective assessment and exercise activity, which were thought to be useful by the participants regarding to representing the multi-symptom condition within one single tool.
• The development of this prototype not only meets the request from the practice for computerized documenting of the AS treatment, also, it is capable of augmenting the existing assessment and feedback for AS in various ways by visualizing in 3-D.

• The proposed assessment and feedback models for AS are accepted by the participants as the basis for assessment and feedback for AS.

• Assessment of AS patient can be augmented by visualizing the complex movements in an accurate way and by visually comparisons over a period of time.

• Feedback of AS can be augmented by adding meaningful feedback allowing the patient as the central actor in the information transmission, therefore, the feedback information is not uni-directional any more.

• Regarding key physiotherapy exercise, it can contribute in the following ways: first, an audit of compliance can be built in to help to monitor the patient over time instead of basing on their diaries; second, it might help in starting to build evidence around the optimum exercises to be used which is clearly lacking in practice.

• The overall trend of disease development is simple and clear within this prototype. Visualisation of this condition changing over time regarding to both subjective/objective scores is thought to be very useful.

• It is thought that the use of this prototype would facilitate the Multi-discipline team communication.

7.2 Assessment of the Thesis Aim and Objectives

As stated in Chapter 1, the thesis aim and objectives were as follows:

The aim of this thesis was:

To investigate, from the perspective of the physiotherapist who has to assess AS clients, the perceived role and value of 3-D visualisation technology in the assessment and feedback activities.

The objectives were:

• To develop formalised assessment and feedback models for AS, which provide a context for researching and designing useful and usable tools;
To develop a prototype which uses 3-D visualisation tools to deal with the assessment and feedback of AS in a more integrated way, which particularly applied to physiotherapy exercises;

To evaluate the perceived value of the prototype and the proposed models to physiotherapists, with a view to extending their use to the patient and the wider therapeutic services.

The aim and attendant objectives were accomplished in this thesis. Chapter 2 and Chapter 4 explained the possibility and potential benefit to integrate several VR/3-D visualisation tools for the evaluation of a chronic condition, i.e. AS, relating to multi symptoms. Chapter 3 discussed the design of such a research project and research methods used. In Chapter 5, formalised assessment and feedback models were proposed for AS, providing a context for researching useful and usable tools. Within their scope, a prototype was developed and discussed in full detail. The prototype’s functionalities, e.g. 3-D visualisation of a range of activities, integration capability and meaningful feedback etc. were discussed. Chapter 6 described a qualitative evaluation of this prototype involving physiotherapists and academic experts. The results from the sessions were discussed summarizing the perceived value of the prototype. The results indicate that the 3-D visualisation can play a role in augmenting assessment and feedback of AS from the clinical professional’s perspective. The conclusions are that there would be great value in applying 3-D visualisation to assessment and feedback of AS in relieving the clinical professional’s pressure in practice and potentially augment the patient’s condition self management over a long period of time.

While reliability is concerned with the accuracy of the actual procedure, validity is concerned with the study’s success at measuring what the researchers set out to measure. Procedures are taken to ensure that the results are trustworthy. In the qualitative evaluation, questions were pilot-tested to ensure that the participants understood them; senior moderators were appropriately appointed for the situation because of their experience, background and sensitivity; the participants were carefully listened to; areas of ambiguity were sought out; and systematic analysis procedures were used. Accepted protocol was followed to ensure that the results are trustworthy and accurate. However, the study was not repeated in order to test this prototype’s reliability, and the qualitative evaluation is highly subjective. This study was not designed to be generalized. The goal was to go in-depth into a topic, and therefore the amount of time was conducted
CHAPTER 7 SUMMARY AND CONCLUSIONS

researching with a small number of people. The results cannot be generalized. When a person wants to use the results they should think about whether the findings can transfer into another environment.

7.3 Contribution

This work investigated the perceived value of a 3-D visualisation system that can be used by the clinical professionals in practice, augmenting assessment and feedback of AS with respect to subjective measures, objective measures and exercise perceptions. The design of a neutral avatar that can show multiple facets has shown that it is possible to represent multiple symptoms of a chronic condition in a unified way.

A physical therapy model is summarized basing on the current literature and information from a variety of sources. This physical therapy model provides an overall view of the current therapy domain and becomes the basis towards a more comprehensive VR therapeutic environment. Within the identified facets in this model, i.e. patient literature, pain management, relaxation, exercise and evaluation, the evaluation tool is envisioned as a single conceptual tool which combines the patient literature facet with the evaluation facet. At the same time, the exercise facet is closely connected with the evaluation facet and integrated into a single visualisation tool as part of this thesis.

Formal assessment and feedback models for AS have been proposed and validated, and no such models have been reported in the current literature of which are aware. These models provide concepts which help to capture the information, albeit in a simplified form. Within these models’ scope, a prototype has been designed and developed so as to study the perceived value of 3-D visualisation technology in augmenting assessment and feedback for AS. Although visualisation techniques have been deployed for individual symptoms (see literature (Hoffman et al., 2004), (Krijn et al., 2007b)), this is the first attempt to integrate several assessment tools within a single visual scale. A 3-D virtual person has been designed as the main vehicle for presentation rather than relying upon an abstract 2-D instruments. This is held to be much clearer and believed to be useful and durable especially with respect to presenting the actual exercise activity. The qualitative evaluation sessions consisting of participants from both academic and practice environments provide very positive feedback. They all believe that 3-D visualisation technology has great value in augmenting assessment and feedback of
AS for them should it become available in practice. Furthermore, it provided the potential means to obtaining subjective assessments, objective assessments and supporting exercise activity via one tool. Almost a side effect of this research is that such a tool can increase the knowledge of AS by providing more accurate and comprehensive assessments and more meaningful feedback over time. This has the potential to change the way the patient, clinicians and the service as a whole manage this chronic condition. The potential detailed clinical value and technical value that 3-D visualisation technology can bring to practice are summarized in Chapter 6.

7.4 Thesis Limitations

A greater number of focus groups would have given extra record in the findings. The participants were recruited from the Northwest Physiotherapy Networking and most of them showed great interest in this work. After the meeting, more physiotherapists showed interest in the focus group sessions when they heard about this research project. However, the requirement for a participant to be an expert in AS, restricted their number as there are only a relatively few such experts in the country.

Originally, the inclusion of patient’s trials was considered for the evaluation sessions. It would have been premature because the prototype needed evaluation from the clinical perspective first, given that the patient is vulnerable and that patient safety should always be taken into consideration in such research. This prototype may have had an adverse effect without a prior evaluation. For example, a safety trigger was suggested to be added into this tool, when it is used by the patient alone to avoid risk of over exercise.

Although the eventual goal of the researcher is to move this prototype from the lab environment into routine practice and even into the patient’s home, it was necessary to get the clinician’s assurance that this was an appropriate way to go. Future research will require direct patient participation and the relevant ethical and time constraints will be built in when this next stage is planned.

As regards “cost”, motion data were captured in a laboratory environment using expensive hardware. This is one of the main concerns directed at this work and applies to usability as well as to cost. However, this is a relatively early point in the technology’s development, and this situation is expected to change in the near future in order to meet practitioner requirements for lower cost and portability, e.g., VR therapy programs can
now be ported onto desktop environments. And complex game stations with motion tracking and cameras, i.e. Wii®, and 3-D television are entering the home.

7.5 Conclusions

This research specifically contributes to the understanding of 3-D visualisation in assessment and its associated feedback for AS, a chronic condition with multiple symptoms. The assessment of any chronic disease is an integral part of the treatment, in the case of AS, it is particularly important and there is growing awareness that the current protocols and means of taking measurements are both inaccurate and inconsistent. Early decisions, such as choosing AS as an exemplar condition and involving physiotherapists in the process of validity of the prototype developed have been proved to be useful and durable. The new emphasis currently being placed on information within the NHS, makes the current research a timely contribution.

The assessment and feedback models for AS set the baseline for this research as definitions and models were lacking in the literature. Within the scope of these models, a prototype has been created that can integrate several views of this condition. The expense of hardware is still a concern. Current literature still seems to emphasize the stand alone nature of many VR applications, yet this work has shown that 3-D visualisation, as the core element of VR, can be used in and as part of an incremental process towards creating an integrated complex VR therapeutic environment.

The prototype has utilised a neutral figure to represent the patient, and this was shown to be an appropriate use of the technology; the evaluation participants agreed that the neutral appearance is more acceptable than a simple video because people do not like to see themselves especially when the progression of a condition results in a deterioration and/or deformation of their body. The capability of integrating several separate assessment instruments, such as BASFI, BASMI etc, is believed to be novel and helpful and helps with a more unified view. The capability to represent other symptoms, such as pain etc, is also believed to be useful and brings body charts and the existing Indices together. From the clinical professionals', i.e. physiotherapist', point of view, visualizing the patient's movement in 3-D would be more accurate than current practice. Visualizing physiotherapy activity in 3-D can play a helpful role in educating the patient and providing meaningful feedback since it is often difficult to explain and for patients to understand what is required and what is being shown. This prototype can more than meet
the current demand for more measurement for AS in practice. For example, visualisation of the patient’s condition as it changes over time is seen as more powerful than simply presenting the patient and the clinician with sets of both subjective and objective scores. With the prototype, the overall trend of disease development is easy to visualise. Furthermore new potential was suggested by the physiotherapists who could see this information tool improving communication within the multi-disciplinary team.

While this prototype is applied to assessing exercise, it may be that a future implementation has a role for monitoring and improving the patient’s compliance to a particular treatment regime. Used routinely, it has the potential to become a visual patient’s diary, and lends itself to an audit of compliance which might capture frequency, quality and variations of exercise as actually done by the patient rather than from what they report from memory. Thereafter, it might help on starting to build evidence of optimum exercises used based on coverage of function/mobility and pain, since currently the exercise prescription lacks the authority of a standard as there is little hard evidence available at this time.

It can concluded that 3-D visualisation of the AS condition, its symptoms and its treatment via exercise is a valuable technique as demonstrated by the prototype. The professional clinicians and academics believe it can provide augmented assessment and meaningful feedback to the various stakeholders; the patient’s view is obviously critical too but this is necessarily the next step in future research.

7.6 Future Work

A taxonomy of VR applications in therapy was proposed in Chapter 2 to organize and classify the existing applications. Further relationships were deliberately ignored in order to avoid clutter and to make the map easier to view at this stage of the development. A more sophisticated ontology may be developed in the future work with further cross references added to reveal further relationships and permit more attention to be paid to the meaning of each category and its scope. This is important as development is happening very quickly in this area and even now the terms used are not clear as to their scope and meaning. It has been noted that the standards for terms used within this area are lacking and therefore a better taxonomy and clearer terminology will help with the understanding and integration of diverse works that are on-going.
As shown in Figure 15, the overview of the research path, clinical trials involving patients could form part of the next step research. In order to move this prototype into the practice and even into the patients' home, it is essential to have patient input into the design process. It has been suggested in the evaluation sessions that involvement of patients would gain very useful information from their perspective. Refinement of the prototype is desired prior to further implementation. For example, algorithms that provide automatic objective measurement results could be added into the prototype for usefulness. And a safety alarm should be added into the prototype with clear trigger criteria if this prototype is used by the patient themselves, and the interface too may change dramatically for patient use.

The research is a move towards a comprehensive VR therapeutic environment, a set of VR tools have been designed and the evaluation tool is seen as key for the integration and was prioritised in this work. To complement the whole VR environment, other VR tools may be developed or integrated where relevant to do so. For example, the pain management tool, could be extended as research into distraction from pain has been researched extensively; however, the way this might be done and integrated would require significant research.

This prototype is primarily directed at the assessment and feedback processes, be it from the clinical and/or from the patient perspective. However it is clear that such a prototype may help the patient to engage much more with assessing and with managing their own condition. It is capable of providing a unified view of a complex, chronic condition and a range of therapies. This type of development therefore, will also have considerable implications for existing and possibly future PROMs, going much further than the current information tools. It will provide opportunities for psychologists and health behaviourists as well as for health service managers who seek to understand changes in the shape, efficiency and effectiveness of delivered therapeutic services. In this respect this prototype can be seen as a starting point and as a catalyst for a wide range of related research that may be pursued in the future.
Appendix A: Bath Ankylosing Spondylitis
Functional Index (BASFI)

Please draw a mark on each line below to indicate your level of ability with each of the following activities during the past month.

**HOW DO YOU FIND:**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Putting on your socks or tights without help or aids (e.g. sock aid)?</td>
<td>EASY ____________________________ IMPOSSIBLE</td>
</tr>
<tr>
<td>2</td>
<td>Bending forward from the waist to pick up a pen from the floor without an aid?</td>
<td>EASY ____________________________ IMPOSSIBLE</td>
</tr>
<tr>
<td>3</td>
<td>Reaching up to a high shelf without help or aids (e.g. helping hand)?</td>
<td>EASY ____________________________ IMPOSSIBLE</td>
</tr>
<tr>
<td>4</td>
<td>Getting out of an arm-less dining chair without using your hands or any help?</td>
<td>EASY ____________________________ IMPOSSIBLE</td>
</tr>
<tr>
<td>5</td>
<td>Getting up off the floor - without help - from lying on your back?</td>
<td>EASY ____________________________ IMPOSSIBLE</td>
</tr>
<tr>
<td>6</td>
<td>Standing unsupported for ten minutes without discomfort?</td>
<td>EASY ____________________________ IMPOSSIBLE</td>
</tr>
<tr>
<td>7</td>
<td>Climbing 12-15 steps without using a handrail or walking aid (one foot on each step)?</td>
<td>EASY ____________________________ IMPOSSIBLE</td>
</tr>
<tr>
<td>8</td>
<td>Looking over your shoulder without turning your body?</td>
<td>EASY ____________________________ IMPOSSIBLE</td>
</tr>
<tr>
<td>9</td>
<td>Doing physically demanding activities (e.g. physio exercises, gardening, sport)?</td>
<td>EASY ____________________________ IMPOSSIBLE</td>
</tr>
<tr>
<td>10</td>
<td>Doing a full day's activities at home or at work?</td>
<td>EASY ____________________________ IMPOSSIBLE</td>
</tr>
</tbody>
</table>

**TOTAL OUT OF 100**

**TOTAL / 10 (BASFI SCORE)**

**BASFI Score Calculation**

Score from all questions are calculated using a ruler and added. This figure is divided by 10 to obtain an average. This is the BASFI score. The higher the BASFI score, the more severe the patient's limitation of function due to their AS.
Appendix B: Bath Ankylosing Spondylitis Disease Activity Index (BASDAI)

a If you are currently taking medication for your AS, please give the name and dose that is on the bottle/packet.
b Please mark on the line below to indicate the effectiveness of the medication in relieving your symptoms.

NO EFFECT ................................................................. VERY
EFFECTIVE

Please draw a mark on each line below to indicate your level of ability with each of the following activities during the past week.

1 How would you describe the overall level of fatigue/tiredness you have experienced?
NONE ................................................................. VERY
SEVERE

2 How would you describe the overall level of AS neck, back or hip pain you have had?
NONE ................................................................. VERY
SEVERE

3 How would you describe the overall level of pain/swelling in joints other than neck, back or hips you have had?
NONE ................................................................. VERY
SEVERE

4 How would you describe the overall level of discomfort you have had from any areas tender to touch or pressure?
NONE ................................................................. VERY
SEVERE

5 How would you describe the overall level of discomfort you have had from the time you wake up?
NONE ................................................................. VERY
SEVERE

6 How long does your morning stiffness last from the time you wake up?

0 ½ 1 1½ 2 or more
hours

MEAN OF 5&6
TOTAL OF 1 TO 4 ADDED TO MEAN OF 5&6 (TOTAL OUT OF 50)
TOTAL / 5 (BASDAI SCORE)

**BASDAI Score Calculation**
Score from all questions are calculated using a ruler. The mean measurement (score) of questions 5 and 6 is added to the scores from questions 1 to 4. This total is then divided by 5 to give the average. This is the BASDAI score. The higher the BASDAI score, the more severe the patients disability due to their AS.
Appendix C: Bath Ankylosing Spondylitis Metrology Index (BASMI)

To convert these measurements into BASMI scores, please refer to table 2

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Measurement</th>
<th>Mean</th>
<th>BASMI score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
<td>Right</td>
<td></td>
</tr>
<tr>
<td>Lumbar side flexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tragus to wall distance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cervical spine rotation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lumbar spine flexion</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(modified Schober's index)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermalleolar distance</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total score

BASMI score=Total/5=

Tables 2: Calculating the scores for each of the BASMI measurements

<table>
<thead>
<tr>
<th>Tragus to wall (cm)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>≥37</td>
</tr>
<tr>
<td>&gt;7.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>≤0.7</td>
</tr>
<tr>
<td>≥120</td>
<td></td>
<td>10-12.9</td>
<td>13-15.9</td>
<td>16-18.9</td>
<td>19-21.9</td>
<td>22-24.9</td>
<td>25-27.9</td>
<td>28-30.9</td>
<td>31-33.9</td>
<td>34-36.9</td>
<td>≥37</td>
</tr>
<tr>
<td>Cervical Rotation (degrees)</td>
<td>≥85</td>
<td>76.6-85</td>
<td>68.1-76.5</td>
<td>59.6-68</td>
<td>51.1-59.5</td>
<td>42.6-51</td>
<td>34.1-42.5</td>
<td>25.6-34</td>
<td>17.1-25.5</td>
<td>8.6-17</td>
<td>≤8.5</td>
</tr>
<tr>
<td>Lumbar Side Flexion (cm)</td>
<td>≥20</td>
<td>18-20</td>
<td>15.9-17.9</td>
<td>13.8-15.8</td>
<td>11.7-13.7</td>
<td>9.6-11.6</td>
<td>7.5-9.5</td>
<td>5.4-7.4</td>
<td>3.3-5.3</td>
<td>1.2-3.2</td>
<td>≤1.2</td>
</tr>
</tbody>
</table>
Appendix D: Bath Ankylosing Spondylitis Global Score (BAS-G)

PLEASE CHECK, IF YOU DOWNLOAD ANY BATH INDICES, THAT ANY 10 CM LINES ON THE INDICES, DO PRINT AS 10 CM IN LENGTH. IF THEY DO NOT, THIS CAN AFFECT ACCURACY OF SCORING.

TOTAL / 10

How have you been over the last week?

VERY GOOD ____________________________________________ VERY BAD

How have you been over the last six months?

VERY GOOD ____________________________________________ VERY BAD

TOTAL OUT OF 20

TOTAL / 2 (BAS-G SCORE)

BAS-G Score
Scores from the 2 questions are calculated using a ruler and added. This figure is divided by 2 to obtain an average; this is the BAS-G score. The higher the BAS-G score, the more severe the effect of AS on the patient’s life.

Please Note:
When using visual analogue scales of a set length (10 cm in the case of the Bath Indices), great care must be taken in reproducing assessment paperwork as repeated photocopying, for example, may distort the length of the lines and therefore will affect the accuracy of the scoring.
### Appendix E: Bath Ankylosing Spondylitis Radiology Index (BASRI) for Spine

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
<th>System applies to both the lumbar and the cervical spine (grade each as 0-4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Normal</td>
<td>No change</td>
</tr>
<tr>
<td>1</td>
<td>Suspicious</td>
<td>No definite change</td>
</tr>
<tr>
<td>2</td>
<td>Mild</td>
<td>any number of erosions, squaring, or sclerosis, with or without syndesmophytes, on ≤ 2 vertebrae</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>Syndesmophytes on ≥ 3 vertebrae, with or without fusion involving 2 vertebrae</td>
</tr>
<tr>
<td>4</td>
<td>Severe</td>
<td>Fusion involving ≥ 3 vertebrae</td>
</tr>
</tbody>
</table>

The sum of the scores for the cervical spine, the lumbar spine, and the sacroiliac joints is called the BASRI-s.
Appendix F: Ankylosing Spondylitis Quality of Life (ASQoL)

Please read each item carefully and tick the one response that applies best to you at the moment.

1. My condition limits the places I can go
   - Yes
   - No

2. I sometimes feel like crying
   - Yes
   - No

3. I have difficulty dressing
   - Yes
   - No

4. I struggle to do jobs around the house
   - Yes
   - No

5. It's impossible to sleep
   - Yes
   - No

6. I am unable to join in activities with my friends/family
   - Yes
   - No

7. I am tired all the time
   - Yes
   - No

8. I have to keep stopping what I am doing to rest
   - Yes
   - No

9. I have unbearable pain
   - Yes
   - No

10. It takes a long time to get going in the morning
    - Yes
      - No

11. I am unable to do jobs round the house
    - Yes
      - No

12. I get tired easily
    - Yes
      - No

13. I often get frustrated
    - Yes
      - No

14. The pain is always here
    - Yes
      - No

15. I feel I miss out on a lot
    - Yes
      - No

16. I find it difficult to wash my hair
    - Yes
      - No

17. My condition gets me down
    - Yes
      - No

18. I worry about letting people down
    - Yes
      - No

Each statement on the ASQoL is given a score of "1" or "0". A score of "1" is given where the item is affirmed, indicating adverse QoL. All item scores are summed to give a total score or index. Scores can range from 0 (good QoL) and 18 (poor QoL). Case with more than three missing responses (i.e. more than 20%) cannot be allocated a total score. For cases with between one and three missing responses, the total score is calculated as follows: \( T=18x/18-m \) where \( T \) is the total score, \( x \) is the total score for the items affirmed and \( m \) is the number of missing items.
Participant Information Sheet (Healthy Volunteer)
Developing a 3-Dimensional Assessment/Feedback System for Ankylosing Spondylitis

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully.

Ankylosing Spondylitis (AS) suffers need to assess their condition frequently. The current means of assessment are largely governed by a set of questionnaire related to function, range of movement etc. We have developed a way of visualizing assessment/feedback, which goes beyond the current means. To move this prototype system from the laboratory to practice, we will need expert clinical evaluation so as to assess its feasibility, functionality and desirability. The evaluation will be formative and instrumental in building a better system for therapeutic measurement and lead to a better evidence base for practice.

Why have you been chosen?
You are being invited to take part in the study because of your active interest and expertise related to AS. We will recruit 4-5 people with expertise in the area to the study for your opinions and perceptions.

Do you have to take part?
No. It is up to you to decide whether or not to take part. If you do, you will be given this information sheet to keep and be asked to sign a consent form, but you are free to withdraw at any time without giving a reason.

What will be involved if you want to participate?
The qualitative evaluation of the research will be organized as focus group interviews. The interview will be recorded. Only the researcher will see the video and translate it. The duration of this study is approximately two hours.

What are the possible benefits of taking part?
You will not receive clinical benefit by taking part in this research but, taking part in this research project will provide evidence for Continuing Professional Development (CPD). The system will enable health care professionals to make faster and more accurate assessments of patients in the future. The patients will be the ultimate beneficiaries, permitting them to self assess in safety and to provide meaningful data as to their state and progress. It will give us important information for future studies to enhance the effectiveness of physiotherapy intervention. If you wish, acknowledgement will be given in any publications that result from the evaluation. As a participant we will provide you with the results from the evaluation.

What will happen if I don’t want to carry on with the study?
You can withdraw from the study at any time without giving. If you do decide to withdraw, any data we have collected will be retained and used as part of the study, unless you specifically wish it to be deleted.

**Will my taking part in this study be kept confidential?**
Any information obtained in connection with this study will be treated as privileged and confidential. All information will be anonymised so that you cannot be identified, except by a single paper form which will be stored securely in a lockable filing cabinet at Salford University. The research team, their colleagues, the sponsors and people who need to audit the conduct of our research will have access to the identifiable forms. All computer records and the data will be coded so individuals can not be identified. The data will be analysed to complete the study as outlined above. We will also keep the data for a period and may use it in future studies. For example, we may wish to combine the data from this study with that of future studies to enable us to use more powerful analysis techniques. Ethical approval will not normally be sought for these studies.

**What will happen to the results of the research study?**
The results of this study will be published in scientific and clinical journals and conferences. They will also be feedback to health care professionals who helped with the study and other professionals who are interested in the research. If successful, we intend to further develop the system to make it commercially available, so that other people can use it. None of the people who have taken part in the study will be identifiable from any of the results, unless you specifically wish to be named.

**Who is organising and funding the research?**
This study is part of a PhD study and run through the Centre for Applied Health and Psychological Research (CAHPR). Funding costs to reimburse expenses for participant are being sought from Wyeth Pharmaceuticals, who sponsored the original meeting.

**Who has reviewed the study?**
The original idea for this study and how it was to be carried out have been reviewed by the student supervisor, and two physiotherapy practitioners, with over 25 years of experience with AS. It was approved by the University Research Ethics Committee.

**What do you do now?**
A member of the research team will contact you. S/he will answer any questions you have and you can tell him/her whether you wish to take part in the study. If you wish to take part we will arrange a time for the meeting at your convenience.

**Contact Details:**
If you have any questions or would like more information, please do not hesitate to contact:

Ms Shijuan Li
CAHPR
Brian Blatchford Building, Frederick Road Campus
University of Salford
Salford, M6 6PU
Tel: 0161 295 2017
Email: s.li@pgr.salford.ac.uk
Appendix H: Consent Form

Consen Form For Healthy Volunteers

Centre for Applied Health and Psychological Research (CAHPR)
Brian Blatchford Building
Frederick Road
University of Salford, Salford, M6 6PU

Developing A 3-Dimensional Assessment/Feedback System for Ankylosing Spondylitis

Name of Researcher: Shijuan Li

Please initial or tick the box

1. I confirm that I have read and understand the information sheet dated February 2009 for the above study and have had the opportunity to ask questions.

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.

3. I agree to take part in the above study.

4. I gave permission to be recorded.

5. I would like to volunteer as an interviewee.

6. I agree to keep the details of the piece of equipment that is being tested confidential, except in circumstances where I am required to divulge the information by law.

_________________________  ____________________________  ____________________________
Name of Physiotherapist  Date  Signature

Shijuan Li

_________________________  ____________________________
Name of Researcher  Date  Signature
Appendix I: Agenda

Agenda for Focus Evaluation Group of 3-D Visualisation Tool for AS

17th /23rd September 2009
PO 41 (1st floor), Brian Blatchford Building, Frederick Road Campus
University of Salford
Map: http://www.salford.ac.uk/travel/

6.00pm – 6.30pm  Sign up with refreshments
6.30pm – 6.45pm  Welcome and Introduction
6.45pm – 7.35pm  Assessment, Feedback & Discussion

20 minutes break with refreshments

7.55pm – 8.45pm  Demonstration, Review & Discussion

9.00pm close

This focus group is supported by Wyeth Pharmaceuticals & the School of Health Care Professions, University of Salford
Appendix J: NASS Exercise List

1. Exercises in Lying
   1a Bridging
   1b Spinal Rotation

2. Exercises in 4 Point Kneeling
   2a Cat Stretch
   2b Superman Stretch

3. Chair Exercises in Sitting
   3a Spinal Side Flexion
   3b Spinal Rotation
   3c Neck Rotation

4. Leg Stretches
   4a Hamstring Stretch
   4b Hip Flexor Stretch
   4b Hip Flexor Stretch (continue)

5. Posture Stretch
References


Calin, A. (2001) Defining outcome in ankylosing spondylitis: Where have we been, where are we and where do we go from here? CPD Rheumatology, 2, 77-80.


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Morgan, D. L. (1997) Focus groups as qualitative research, London, SAGE.


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