Can a computer expert system aid the process of clinical decision-making in podiatry?

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Abstract

The aim of this research was to investigate the clinical decision-making processes used in podiatry and hence to investigate if a computer expert system could be used to aid the process of clinical decision-making. This was achieved through a sequence of four empirical studies.

The initial study used card sorts to investigate seven expert podiatrists' perceptions of and attitudes toward diagnostic aids, and in particular how podiatrists viewed expert systems. The results showed that expert systems are perceived as different in kind from other diagnostic aids such as X-rays or blood tests.

The second study was conducted using one expert and one novice podiatrist and used a task analysis to investigate the types of tasks and skills undertaken by a podiatrist during the diagnosis of a patient in different clinical environments. The results indicate that the work is highly schematised and involves routine tasks such as nail care and callus reduction. In clinic, podiatrists perform many tasks quickly. There was little difference between the number of tasks per minute undertaken in a general clinic and the number of tasks in a specialist diabetes clinic. Considering the speed of diagnosis, it is postulated that both expert and novice podiatrists' use of schemata, pattern matching, and tacit and implicit knowledge dominates their diagnostic activity during consultations.

The third study focused on how clinical reasoning and decision-making occur during consultations with a patient. Think-aloud protocols were used to investigate the differences in the clinical reasoning process between five expert and nine novice podiatrists. The speed of diagnosis and general lack of causal assertions suggest that use of schemata and tacit knowledge dominate the diagnosis process for *both* experts and novices. *In a general setting*, the novices produced four common clinical reasoning themes. These indicate that pattern recognition is a common method of diagnosis. However, there was an increase in the number of clinical reasoning themes used by experts *in a specialist setting*, indicating novice–expert differences.

The fourth study used laddering interviews on a mixture of twelve NHS and private podiatrists to investigate why podiatrists used certain clinical reasoning themes. A hierarchical value map was derived, showing that, at an initial response level to the laddering questions, certain values were important: the palpation of the foot, building a picture of the foot condition, and being able to use clinical reasoning frequently and immediately. The emphases on palpation and immediacy of reasoning suggest that an expert system is unlikely to serve podiatrists' needs in clinics.

This research has provided a new understanding of the clinical reasoning processes used in podiatry. A podiatrist has a very busy timeline when diagnosing a patient and predominantly uses (and values) tacit knowledge, implicit learning, and compiled skills during consultations. There is little evidence for the need or desire for an expert system in clinical podiatry practice. However, if such an expert system were to be created, then:

(a) it would have to be fast and non-intrusive so it can fit into a very busy consultation timeline,

(b) it would need a knowledge base that could account for diagnosis of foot and leg conditions based on pattern recognition, and

(c) it might be most valuable in the form of a decision support system for professional development that included the full range of expert diagnostic themes.

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Chapter 1: Introduction

1.1 Background to the research

According to Merriman (Merriman 1993) the aims of podiatry services are to maintain tissue viability and improve foot function. A report by Help the Aged (Jones and Campbell 2005) states that podiatry is provided by the NHS under primary care services and traditionally aimed to treat three categories of people: people over the age of 60, school children and expectant mothers. However, since the 1990s the emphasis has changed to those with a podiatric need and excludes social foot care.

The number of patients treated by NHS podiatry services in England has been provided by the Department of Health from annual return KT 23 and has been published in summary form. According to the summary information for 2004–5 (Department of Health 2005), the number of new episodes of podiatry care was 769,000, about 4% fewer than in 2003–4. The number of different persons seen in the year was 2.0 million, also about 4% fewer than in 2003–4. The apparent discrepancy in these statistics stems from the fact that a new episode of care is only recorded if it began in that year, whereas the total number of different patients seen includes those receiving both new and continuing episodes of care.

Given the number of patients treated, the NHS needs to ensure that the treatment provided is of a good standard. One possible method of ensuring that this occurs is to use a computer expert system. According to Curran and Jagger (1997) the diagnostic agreement between podiatrists can be improved by the use of a computer expert system and hence the quality of the treatment provided will improve too. However, this raises the question how much access podiatrists have to NHS computers. According to Sullivan and Mitchell (1995) computers in primary care have not been available for clinical medicine but have been used in areas such as computerised tomography. They state that in the 1960s computers were used for collating patient data, in the 1970s for linking primary and secondary care, in the 1980s computers were provided for GPs and in the 1990s the Internet was used to obtain and review information for a consultation.

If computers have not really been available for use in NHS primary care, why will computers become more accessible to podiatrists in a clinical situation in the future? The reason for this can be found in NHS IT programmes such as *Information for Health* (Department of Health 2005) and *Connecting for Health* (Department for Health 2005). One of the aims of these projects is to provide an electronic patient record and twenty-four-hour online access to patient records. This means that hardware and software will need to be provided for podiatrists to use in podiatry clinics to record data about patient treatments. With such access to computers for clinics, the use of computer expert systems may become a reality for podiatrists.

1.2 Overall research aim

The overall research aim is to investigate the clinical decision-making processes used in podiatry and hence determine if a computer expert system could aid the process of clinical decision-making.

1.3 The study

Following an introductory chapter, a review of the literature for the whole thesis is contained in chapter 2. This chapter reviews the literature for artificial intelligence, attitude theory, personal construct theory and finally knowledge and decision-making.

The aims of the research were achieved through a sequence of four empirical studies, described below.

The first of the four studies is described in chapter 3. This investigates podiatrists' perceptions of and attitudes toward diagnostic aids, and in particular how podiatrists view expert systems.

Studies two and three are discussed in chapter 4 and focus on how clinical reasoning and decision-making occur during consultations with a patient. Think-aloud protocols are used to investigate the differences in the clinical reasoning process between expert and novice podiatrists.

The final study in chapter 5 uses laddering interviews to investigate the values behind why podiatrists use certain clinical reasoning themes.

Chapter 2: Literature Reviews

2.1 Literature review on expert systems

This section reviews the literature on expert systems and provides examples of the application of them. Suggestions are given of why expert systems have been widely used in industry and why they have experienced low usage in the medical domain despite in many cases increasing the performance of medical experts.

2.1.1 Introduction

In reviewing the area of artificial intelligence it is important to consider what is meant by artificial intelligence and what its origins are. This can be explored through the work of Durkin who states:

"In 1956, a small group of computer scientists attended a summer workshop sponsored by IBM at Dartmouth College. Their discussion focused on their present research effort in automatic theorem proving and new programming languages. They also discussed ways that this work might be directed for developing a computer that could simulate human reasoning. This conference marked the birth of artificial intelligence." (Durkin 1994, p 3)

A definition of artificial intelligence by Durkin is:

"A field of study in computer science that pursues the goal of making a computer reason in a manner similar to humans." (Durkin 1994, p 3)

Another definition by Cawsey (Cawsey 1997) states:

"Artificial intelligence is a broad field, and means different things to different people. It is concerned with getting computers to do tasks that require human intelligence." (Cawsey 1997, p 1)

Durkin (1994) notes that most of the early work in artificial intelligence was academic in nature and in the 1950s scientists were concerned with getting computers to play games such as chess and checkers. According to Durkin

(Durkin 1994) a turning point for artificial intelligence came in 1978 when NASA wanted to sample soil on Mars in an unmanned space mission. This according to Durkin (Durkin 1994) was a beacon that would guide researchers, and it became known as DENDRAL. The name DENDRAL refers to the research project, which was conducted at Stanford University from 1965 to1980 under Joshua Lederberg, Edward Feigenbaum, Bruce Buchanan and Carl Djerassi as principal investigators. DENDRAL originally stood for DENDRitic ALgorithm, a procedure for exhaustively and non-redundantly enumerating all the topologically distinct arrangements of any given set of atoms, consistent with the rules of chemical valence. This paved the way for expert systems. According to Durkin (Durkin 1994), Ed Feigenbaum at Stanford University then developed the concepts of knowledge-based systems or expert systems.

What is an expert system? There are many definitions. Durkin (1994) states that "an expert system is a computer programme designed to model the problem-solving ability of a human expert". They are known by various names such as decision support systems or smart systems. One of the reasons for this variety of names reflects differences in the systems. For instance, a decision support system is usually intended to support an expert, whereas many expert systems are intended to replace the expert, at least for a subset of the expert's tasks. Another reason reflects the hostility that was aroused in the professions by the concept of attempting to replace a human expert with software; terms such as "knowledge-based system" were considered less confrontational.

2.1.2 Concepts about artificial intelligence

According to Durkin (1994), expert systems consist of a user interface and a database with software that processes and distils the knowledge of a panel of experts in a particular field. There is an inference engine with an interpreter to analyse and process rules, and a knowledge base that contains much of the problem-solving knowledge for the domain. The discipline of building expert systems is known as knowledge engineering. This involves knowledge acquisition, a process of acquiring the knowledge of a human expert or of other sources such as books and manuals, and knowledge elicitation, which is the process of coaxing information out of human experts. Knowledge representation is also involved and is the process of encoding the knowledge for use by the expert system; common methods of doing this include rules, frames and nets. Expert systems are typically intended to tackle problems that would normally require a human expert such as a doctor or a geologist. Typical application areas include domains where problems need to be solved quickly, and where there are problems with availability of human experts. A classic example is drilling problems on North Sea oil rigs, where delays cost large amounts of money and where there can be severe logistical problems in getting human experts onto the rig. The MUD system described below (Kahn and Mc Dermott 1984) was developed for use in this domain and is a well-known example. In the USA a company called N L Baroid, an oil drilling company, created MUD to analyse drilling fluids or *muds* that are pumped down shafts to facilitate drilling. On deep or difficult wells a site engineer often has to sample over 20 mud parameters. By using MUD the engineer can be more certain of analytical consistency. Indeed, when MUD diagnosed a problem of mud contamination in the North Sea that human experts had misdiagnosed Baroids profits increased.

Examples of the use of expert systems in industry include the work of analysts at the American Express Company (Stern and Stern 1990) who built an expert system to check credit limits and approve requests for additional credit. The service to customers is improved through speed. This system is called "The Authorizer's Assistant", and now performs searches in seconds and states whether or not the applicant is creditworthy.

Honeywell (Stern and Stern 1990) built an expert system to help field service technicians diagnose problems in commercial air conditioning systems. The technician's personal ability could range from average to excellent but the expert system ensured that service quality was uniformly high. Tasks that require employees to make consistent decisions and remain alert over long periods of time, often under difficult circumstances, lend themselves to expert systems.

In 1996 (Coakes and Merchant 1996) found that 50 out of 214 organisations used expert systems for a variety of applications ranging from strategic to operational. The majority of the firms using expert systems were in the financial services sector and used the systems for routine decision-making such as mortgage and loan processing in order to increase efficiency and maintain competitiveness.

In the domain of medicine, Shortliffe (Shortliffe 1975) describes two types of expert systems in healthcare: those that assist physicians with determining the correct diagnosis, and those that assist with decisions about what to do once a diagnosis has been made, i.e. what tests to order, whether to treat or what therapy to give. An example of an expert system in healthcare is one used for diagnosis of abdominal pain (De Dombal 1993). This system uses sensitivity, specificity and disease prevalence data for various signs, symptoms and test results to calculate using Bayes's theorem the probability of seven possible explanations for acute abdominal obstruction.

De Dombal (1993) notes that the most popular techniques are based on Bayes's theorem, which considers the probability that a disease will occur within a population, as well as the symptom probability for that disease, to determine the presence or absence of a particular disease entity.

According to De Dombal (1993) computers in patient care have often been associated with monitoring cardiovascular and respiratory systems. This type of monitoring frees the nurse from repetitive and routine tasks while providing accurate and precise measurements. An example of this type of programme is the ALERT programme, which is implemented in conjunction with HELP(Johnson 1985). The HELP system pioneered many of the issues involved in bringing expert systems into the clinical workplace. In the late 1970s the system was installed throughout all departments of a hospital and was in effect an early hospital information system. It used medical decision logic modules of the "if ... then..." type often linked into complex trees. Decision modules containing algorithms were used to evaluate patient data. Sophisticated logic is used in the algorithmic approach to decision-making. Automatic processing occurs to determine any new decision when new patient data are entered. Decisions are generated in the form of treatment protocols, analytical interpretations and warning alerts. The philosophy underlying the HELP system is to improve patient care by facilitating the acquisition of complex data and subsequent treatment in the most efficient manner. This enhances the nursing management of patients. Berner *et al.* (Berner 1994) assessed the diagnostic capabilities of four internal medicine diagnostic systems: Dxplain, Iliad, Meditel and QMR. They found no single computer programme scored better than the others, but each programme suggested on average approximately two additional diagnoses per case that the experts found relevant but had not originally considered. They concluded that physicians who can identify and use the relevant information and ignore the irrelevant information that can be produced should use the programme.

According to Sullivan and Mitchell (1995) 90% of all general practices in Britain are computerised, with as much as £47 million spent on primary care computing. Many of these computers are used to carry out clerical tasks and repeat prescribing. In addition 55% of general practitioners use desktop computers to access clinical data during consultations. So why are expert systems not commonplace in medicine? According to Hobbs *et al.* (Hobbs 1996) the principal reasons are lack of agreed national standards, a failure of systems to examine the needs of users adequately, and the profusion of different systems that do not communicate with each other.

In 1986, a study of eight hospitals suggested that the implementation of expert systems improved diagnosis by 20%, and reduced perforation rates for appendicitis and unnecessary operations by half (Adams, Chan et al. 1986). A more recent large-scale study involving 64 European hospitals reported by De Dombal (1993) produced results from 19 countries and supports the conclusions of Adams *et al.* (1986). Table 1 shows that the percentage of initial diagnostic accuracy increased from 48% to 65.9% with the use of a decision support system and that the percentage of perforated appendicitis and operations that were not required (negative appendectomy) decreased from 30% to 15.6%. De Dombal (1993) concludes that decision support systems improve patient outcome and avoid resource wastage.

Table 1: Results of a European multicentre trial involving 64 hospitals and patients with acute abdominal pain

	Unaided %	Support system aided	
		Low%–High%	Mean % (14,963 cases)
Initial diagnostic accuracy	48	56.7–80.9	65.9
Post investigation accuracy	66	69.8–96.1	82.6
Perforated appendicitis rate	27	0.00–35.3	13.6
Negative appendectomy rate	30	1.50–34.2	15.6

This evidence provides an argument that the performance of inexperienced surgeons improves to match that of senior colleagues, with benefits to the patient and to NHS expenditure. This may also be true for other clinicians and is certainly worth investigating for podiatry.

A different approach to computer-assisted decision support was the MYCIN program developed by Ed Shortliffe at the University of Stanford in the USA (Shortliffe 1989). This system did not emphasise diagnosis but concentrated on appropriate management of patients who have infections.

Knowledge of infectious disease in MYCIN was represented as production rules, each of which constitutes a statement of the "if" (antecedents) "then" (consequence) type. The programme used rules and could determine which rules to use and how to chain them together to make decisions about a case. For example,

IF

1. the infection which requires therapy is meningitis,
2. organisms were not seen on the stain of the culture,
3. the type of the infection is bacterial,
4. the patient does not have a head injury defect

and

5. the age of the patient is between 15 years and 55 years,

THEN

the organisms that might be causing the infection are *diplococcus* pneumonia and *neisseria meningitidis*.

An evaluation by Yu in (Johnson 1985) found that MYCIN gave advice that compared favourably with that offered by experts. It was never used clinically, however, as in the 1970s it was not cost effective since large mainframe computers were required. However, it did lead to the development of expert systems and the commercialisation of the rule-based approach to artificial intelligence. Other expert systems include INTERNIST-1/QMR developed by Miller *et al.* in Johnson (1985) which supports diagnostic problem-solving in internal medicine and ONCOCIN, Stanford University (Shortliffe 1981), which provides therapeutic recommendations for cancer treatment.

Montgomery *et al.* (Montgomery 2000), however, investigated the effect of a computer-based clinical support system and a risk chart on absolute cardiovascular risk, blood pressure and prescribing of cardiovascular drugs in hypertensive patients. This study concluded that the computer-based clinical decision support system did not confer any benefit in absolute risk reduction or blood pressure control and required further development and evaluation before use in clinical care could be recommended. In addition a 1989 study from Scotland alleged that the computer "contributed precisely nothing" (Sutton 1989).

A systematic review in the mid 1990s of expert systems (Johnstone, Langton et al. 1994) found only 28 controlled trials relating to expert systems categorised into the topics of dosing, diagnosis, preventive care and quality assurance. The review concluded: “Strong evidence exists that expert systems can improve physician performance”.

This low number of controlled trials and hence low uptake of expert systems in medicine is quite surprising given that the potential of computer-assisted medical decision-making was first recognised in the late 1950s (Ledley 1959). The reasons for the low adoption of expert systems may well be technical. For example work by Heathfield *et al.* (1988) involved the computer grading of breast cancer followed by the diagnosis of malignancy in breast cytology specimens (Heathfield, Kirkham et al. 1990). They felt that this type of system was representative of many at the time addressing a constrained problem domain, representing clinical knowledge as production rules (holding 75–100 rules) and employing backward chaining inference mechanisms. The pathology system never progressed beyond a prototype. This failure could be attributed to technical issues, such as problems encountered when scaling rule bases above a certain size (Schwartz, Patil et al. 1987), and to the inadequacy of rules to mimic the complexity of medical reasoning (Szolovits, Patil et al. 1988).

In contrast to technical solutions another possible explanation for the low uptake of expert systems is attitudinal factors to them. Further studies by Heathfield provide a good illustration of this point. Heathfield *et al.* (1991) reported that the majority of systems developed were aimed at diagnosis, which did not correlate well with actual tasks faced by clinicians, which often involved therapy, predicting prognosis or gathering information. They reported that developers never intended to provide fully working systems, but used medical problems solely as interesting application areas when in pursuit of a higher degree. Thus their development methods and user requirements were gathered in a haphazard fashion. Further work by Heathfield has shown that the major barriers to the uptake of expert systems are professional and attitudinal and not ones requiring a technical solution (Heathfield 1997).There is an extensive literature on attitudes to information technology and medicine. For example, in England Simpson and Kenrich (Simpson and Kenrich 1997) surveyed the attitude of 208 nurses in a general hospital of 500 beds, and measured their computer-related attitudes using Stronge and Brodt's questionnaire. Although nurses' computer-related attitudes were generally positive, significant differences were found in relation to age, length of service, job title and nursing unit. In a similar study in Australia (Marasovic, Kenney et al. 1997) showed that age, nursing experience and education were factors that had a positive influence on the desire to use computers in a critical care environment. In the more specific context of podiatry, a study by Curran and Jagger (Curran and Jagger 1997) found that computer expert systems were potentially useful in podiatry. In the first part of an inter-observer error study, 40 independent podiatrists observed ten slides of common foot and leg disorders. Each observer was supplied with text describing the patient's subjective symptoms and the anatomical level of the condition to be diagnosed from the slides. The results indicated poor agreement in diagnosis of common foot and leg conditions. The identical methodology was used in the second part of the trial except this time the observers had access to a computer expert system before viewing the slides. The median gain using the software was significantly different in that two more slides were correctly identified (median gain = 2, $p < 0.0001$). This study suggests that a computer expert system may aid podiatrists in making a correct diagnosis.

Within podiatry, however, there are few examples of expert systems in use. One that has been used, according to McGrath, is known as PEDEX. This worked by using the most characteristic features of diseases, ranking them into a score form to which a percentage prediction was given as "the most likely" disease present. Photographs and video clips of diseases were also included to aid diagnosis. McGrath states that two podiatrists, Bennett and Tinsley, tried the expert system in Australia and claimed a 77% diagnosis success rate (McGrath 1996).

2.1.3 Summary

Artificial intelligence and expert systems have existed since 1956 and have been out-performing human expert systems in a range of industrial domains for over 20 years. There has been some use of expert systems in medicine but there has been little uptake of these expert systems by the medical profession. This is surprising in a profession where better performance can save lives, and this is an issue with significant implications. The instances where expert systems appear to offer clear advantages are in diagnosis, e.g. in reducing the perforation rates for appendicitis and in the early diagnostic expert systems such as MYCIN, EXPERT and INTERNIST. Some other expert systems, one looking at cardiovascular risk, blood pressure and prescribing of cardiovascular drugs in hypertensive patients, appear to make little difference according to Montgomery *et al.* (2000). This study concluded that the computer-based clinical decision support system did not confer any benefit in absolute risk reduction or blood pressure control and required further development and evaluation before use in clinical care could be recommended.

There is some evidence that expert systems are useful in podiatry and such a system, called PEDEX, has been created in Australia. Work by Curran and Jagger in 1997 also suggests that a computer expert system can aid diagnoses in podiatry. In general, though, why has there been so little uptake of a technology that appears to promise so much, especially when medicine has adopted other high-technology products such as computer-assisted tomography so enthusiastically? Part of the answer appears to involve technical issues such as lack of national standards for communication between systems and a failure of systems to examine the needs of users adequately, but according to Heathfield (Heathfield 1997) there appears to be a significant amount of resistance to expert systems because of attitudinal factors to their use in actual healthcare practice.

2.2 Literature review on attitude theory

This section reviews attitude theory and how it could be utilised to measure attitudes to expert systems in podiatry. A review is undertaken of the common attitudinal scales and the limitations of each scale are noted. Given the problems associated with the use of each scale it is recommended that personal construct theory be reviewed and considered to see how useful this may be in measuring attitudes to expert systems.

2.2.1 Introduction

In order to understand attitude theory it is important to define what is meant by the word "attitude". According to Hogg and Vaughan:

"Attitude is derived from the Latin word aptus, which means 'fit and ready for action'. This ancient meaning refers to something that is directly observable, such as a boxer in a boxing ring. Today, however, supporters of the concept see it as a construct which, though not directly observable, precedes behaviour and guides our options for action." (Hogg and Vaughan 1995, p 109)

Attitude research in psychology and the social sciences has generated many hundreds of studies, but during the 1960s and 1970s research and theorising into attitudes went into decline, to some extent as a result of concerns about the apparent lack of relationship between attitudes as measured and behaviour as recorded. During the 1980s, however, attitudes again became a focus of interest for social psychologists, stimulated considerably by modern cognitive psychology.

Although attitudes have been the subject of considerable research for decades, there is still little consensus about the optimal choice of technique for eliciting attitudes. The problem is not caused by a lack of research in the area, or of elicitation techniques; a book on qualitative research methods alone runs to over 600 pages (Densin 1978). At the heart of this problem is the tension between reflecting individual variation on the one hand, usually involving qualitative approaches, and making usable generalisations on the other hand, usually involving quantitative approaches.

2.2.2 Concepts about attitude theory

As Hogg and Vaughan state:

"Measuring an attitude is not an easy task since attitudes cannot be observed directly." (Hogg and Vaughan 1995, p 132)

According to Hogg and Vaughan an important part of this tradition involves the use of attitude scales. Five techniques in particular have been refined and used extensively in the measurement of these scales. They are

- Bogardus scale
- Thurstone scale
- Likert scale
- Guttman scale
- Osgood scale

In order to highlight the underlying theoretical and methodological issues facing researchers in this area, the scales are reviewed individually in order of their creation.

First, in 1925 Bogardus brought out a social distance scale, subsequently revised, that has been widely used in the USA. The social distance scale, which has become a classic technique in measuring attitudes towards ethnic groups, lists a number of relationships to which members of the group might be admitted. The respondent is asked to indicate, for specified nationality or racial groups, the relationship to which he would be willing to admit members of each group. His attitude is measured by the closeness of relationship that he is willing to accept. Apart from complicated instructions, at first sight there seems little to criticise in this scale. The idea of expressing ethnic prejudice as "social distance" seems reasonable. However, criticism has been directed against questionable linearity and unequal intervals.

Second, Thurstone in 1928 developed his method of equal-appearing intervals in his study of attitudes towards religion (Thurstone 1928). Thurstone viewed attitudes as lying along an evaluative continuum ranging from favourable to unfavourable. The ordering of these statements could be such that there appeared to be an equal distance between adjacent statements on the continuum. Therefore one can make judgements about the degree of discrepancy among different people's attitudes. The Thurstone method of equal-appearing intervals has been widely used. Scales have been constructed to measure attitude towards war, the church and capital punishment. One of the disadvantages is the practical one that it is very tedious and time consuming to construct.

To cope with this problem Rensis Likert in 1932, whilst working for a PhD in psychology at the University of Columbia, developed a different technique (Likert 1932). A series of attitude statements are presented, and respondents check their extent of agreement or disagreement with the statements using a five-point scale, with the points usually labelled strongly agree, agree, undecided, disagree, strongly disagree. In contrast to a Thurstone scale, a Likert scale is usually more statistically reliable and less time consuming to construct. When a number of statements of agreement or disagreement are used then a person's scores on the various items are summed. The resulting total is used as an index of the person's attitude. When developing a Likert scale, researchers find that not all questions will correlate with the total. Some will be more effective measures of attitude than others. Those that do not correlate highly with the total are dropped, and the ones that are left are used as a summed index of a person's attitude. Likert did not assume equal intervals between scales. For example, it is quite possible that the difference between agree and strongly agree is much larger than the difference between agree and undecided. This means that a Likert scale can provide information on the ordering of people's attitudes on a continuum but is unable to indicate how close or far apart attitudes might be.

Likert's method of scale construction is similar to Thurstone's in the initial collecting and editing of a variety of opinion statements. The remaining statements are then rated by a sample group of participants on the five-point response scale in terms of their own opinions about the statements. This is in contrast to the Thurstone scale approach, where ratings are made by trained judges and based not on personal opinions but on some relatively objective evaluation of where statements fall on a continuum. The Likert scale is composed of those items that best differentiate between sample participants with the highest and lowest total scores. In contrast to a Thurstone scale a Likert scale is usually more statistically reliable and also less time consuming to construct. Unlike the Thurstone scale, it is not intended to tap an absolute range of attitude scores (determined by judges). Rather, the range reflects directly the attitudes of the participants who constitute the sample.

Following this, Louis Guttman in 1950 developed the Guttman scale or scalogram method (Guttman 1950). It is based on the assumption that a single, unidimensional trait can be measured by a set of statements that are ordered along a continuum of difficulty acceptance. The statements range from those that are easy for most people to accept to those that few people would accept. Such scale items are cumulative, since the acceptance of one item implies that the person accepts those of lesser magnitude. To the extent that all this is true, one can predict a person's attitude towards other statements on the basis of knowing the most difficult item they will accept. None of these scales actually achieves equality of intervals nor do they have a zero point (Shaw 1966).

In contrast to approaches where participants indicate agreement with opinion statements, Charles Osgood *et al.* (Osgood, Succi et al. 1957) studied attitudes by focusing on the meaning that people give to a word or concept. He developed the semantic differential scale. Underlying this technique is the assumption of a hypothetical semantic space of an unknown number of dimensions, in which the meaning of any word or concept can be represented as a particular point. The connotative meaning is the meaning a word suggests apart from the thing it explicitly denotes or names. The word "friend" is thought to be good and the word "enemy" bad. According to Osgood, this evaluative dimension corresponds to our definition of an attitude. The procedure is to have people judge a particular concept on a set of semantic scales. The idea or topic to be rated is listed at the top of the page, and underneath are several seven-point scales that have words at each end. These scales are defined by verbal opposites with a mid-point of neutrality. Participants mark the space on the scale that indicates their feeling about the topic.

The major advantage of this approach is that the researcher does not have to make up questions for attitudes being studied. When several pairs of words are used, the resulting attitude score is generally reliable. A disadvantage is that the measure can be too simple. Furthermore, although this approach can provide a lot of information about a concept, it is not clear how the concept's meaning for a person is related to opinion statements they make about it. Combinations of the Likert scale and the semantic differential have been used successfully to deal with quite complex evaluations. For example, voters can be asked to evaluate various issues using a semantic differential scale. Then, using a Likert scale, they can be asked how they think each candidate stands on particular issues. Combining the two measures enables us to predict for whom they will vote (Ajzen and Fishbein 1980).

According to Hogg and Vaughan (Hogg and Vaughan 1995), whenever attitude researchers ask participants questions, there is the possibility that participants will be reluctant to reveal their true feelings. Although numerous techniques have been developed and advocated to overcome such problems, these have often raised questions about ethics in the research process, especially if participants do not know their attitudes are being measured (Hogg and Vaughan 1995). A good example of this is the so-called bogus pipeline technique (Jones and Sigall 1991) which involved convincing participants that they could hide their true attitudes. Participants were connected to a machine resembling a lie detector and were told that the machine could measure both the strength and the direction of a person's emotional responses, thus revealing a person's true attitudes and implying that there was no point in lying. It appears that participants are indeed convinced by the bogus pipeline and are less likely to conceal socially undesirable attitudes such as racial prejudice when this technique is used

(Allen 1975) (Quigley-Fernandez and Tedeschi 1978). However, the essential feature of the technique is a deception, and this raises profound ethical questions about its use.

Even when there is agreement about how an attitude might be defined and then measured, the ways in which data are then treated can vary markedly from one investigation to another. Hogg and Vaughan (1995) state that a great variety of measures (and operational definitions) are employed to measure attitudes, and there should not be any surprise that results in this area often conflict. They feel investigators who use attitudinal scales do so on the basis of ease of measurement or intuition, and this may be one reason why some researchers wanted to abandon attitude research in the 1960s and 1970s. There is also a poor correlation with an attitude a person has and the type of behaviour they display. Wicker (Wicker 1969) concluded that the correlation between attitudes and behaviour is seldom as high as 0.3 (when squared this indicates that only 9% of the variability in a behaviour is accounted for by attitude).

Fishbein and Ajzen (Fishbein and Ajzen 1974) argued that a better fit with behaviour can follow if an evaluative component is incorporated with a belief component. Fishbein went on to offer a technique of measurement involving a weighting of each contributing belief, underlying an attitude domain, by the strength of its relationship to the attitude object. Fishbein's technique has had considerable impact in a variety of behavioural settings such as consumer and marketing research (Assael 1981) and politics (Bowman and Fishbein 1978).

2.2.3 Summary

Although attitudes have been the subject of considerable research for decades, there is still little consensus about the optimal choice of technique for eliciting attitudes. All five attitudinal scales described have some inherent problems in eliciting people's attitudes. Combinations of the Likert scale and the Osgood semantic differential have been used successfully to deal with quite complex evaluations. For example, voters can be asked to evaluate various issues using a semantic differential scale.

It was suggested that the huge problems associated with defining and accurately measuring attitudes meant the area was almost abandoned in the 1960s and 1970s. An answer to this problem was to design experiments in which participants did not realise that their attitudes were being measured, as occurred in the bogus pipeline experiment. Today, it is no longer acceptable on ethical grounds to deliberately deceive participants in this way.

Given the lack of a valid and reliable technique for measuring attitudes it may be useful to focus on another research technique to measure attitudes of podiatrists to expert systems.

Literature review on personal construct theory

2.3.1 Introduction

This section considers Kelly's personal construct theory and how it may give rise to a technique for measuring attitudes, in this case to the use of expert systems in podiatry. The key assumption of personal construct theory is that everybody has a personal model of their world and each individual actively constructs his/her model by categorising the world around him/her, and in this way they make sense of the world and develop attitudes towards their world. By a thorough understanding of personal construct theory we may be able to use methodology based on this theory such as laddering and card sorts to investigate attitudes and behaviours of podiatrists to expert systems.

2.3.2 Concepts about personal construct theory

Let us first consider where personal construct theory derives from. It is from the ideas of George Kelly, a clinical psychologist who first developed the theory about how people make sense of the world around them, and how they relate to the world outside. He presented his theory in his major work *The Psychology of Personal Constructs* (Kelly 1955). The basis of this theory is that we are all different with differing construct systems. This means we all construct and interpret events differently. Bannister and Fransella (1986) note the contribution Kelly made in the field of psychology. To paraphrase them, they state that he provided more imaginative ways of exploring and construing; by doing so he developed a view of our constructs as hierarchical and patterned into subsystems and therefore liberated psychology from what he called "the dread disease of hardening of the categories".

In order to understand personal construct theory there is a need to consider Kelly's theories in detail. His theory commences with what he called his "fruitful metaphor". He had noticed that scientists and therapists often displayed a peculiar attitude towards people and tended to look down on clients and see them as victims of their sexual energies or conditioning histories. Kelly thought that these ordinary people were scientists too and had constructions of their reality and engaged in behaviours that tested those expectations, as scientists do experiments to test hypotheses.

Kelly organised his theory into a fundamental postulate and eleven corollaries. The following is a discussion of the fundamental postulate and the corollaries, which are considered under separate section headings.

- Construction
- Experience
- Individuality
- Organisation
- Dichotomy
- Choice
- Range
- Modulation
- Fragmentation
- Commonality
- Sociality

Kelly's fundamental postulate states that:

"A person's processes are psychologically channalised by the ways in which he anticipates events." (Kelly 1955, p 46)

A critique of Kelly's work is provided by Bannister and Fransella (1986). They state that the fundamental postulate is Kelly's attempt to state what a person is in business for, which in Kelly's terms is to understand their own nature and the nature of the world and to test that understanding in terms of how it guides them and enables them to see into the immediate and long-term future. Bannister and Fransella (1986) feel that the fundamental postulate is Kelly's answer to the age-old argument of whether it is nature or nurture that determines our life, whether we are controlled by our environment or living in terms of our personality. This is the central movement in the scientific process: from hypothesis to experiment or observation. There now follows a description of the corollaries as put forward by George Kelly.

Construction corollary

"A person anticipates events by construing their replications." (Kelly 1955, p 50)

An interpretation of this statement is provided by Bannister and Fransella (1986) who provide an example. The dinner we ate yesterday is not the same dinner that we ate today, but our use of the construct dinner is an explicit recognition of the sameness, some replication, which we wish to affirm. Thus, underlying our making sense of our world and of our lives is our continual detection of repeated themes, our categorising of these themes and our segmenting of our world in terms of them. This is the step from theory to hypothesis using a construction system (knowledge and understanding to anticipation).

Experience corollary

"A person's construction system varies as he successively construes the replication of events." (Kelly 1955, p 52)

Bannister and Fransella (1986) conclude that the personal construct theory implies that people continually develop. They believe that development is not simply the prerogative of children and adolescents, as the tradition of "developmental psychology" would have us believe. When things do not happen in the way they have in the past, we have to adapt to reconstruct. This alters our future experience and we learn.

Individuality corollary

"Persons differ from each other in their construction of events." (Kelly 1955, p 55)

Bannister and Fransella (1986) argue that the fundamental mystery of human psychology is covered by the question "Why is it that two people in exactly the same situation behave in different ways?" They feel that they are not in the same situation and each one sees the situation through the goggles of their personal construct system. We differ from others in how we perceive and interpret a situation.

Organisation corollary

"Each person characteristically evolves, for their convenience in anticipating events, a construction system embracing ordinal relationships between constructs." (Kelly 1955, p 56)

Bannister and Fransella (1986) imply that the term system in the phrase "a personal construct system" means that a person's constructs are interrelated. In this corollary Kelly is stressing that the relationship is often one of inclusion, of subsuming. For some people the construct traditional jazz versus modern jazz may be subsumed as a subordinate implication of the construct good jazz versus bad jazz, and both poles of the construct might be subsumed under the music end of the construct music versus noise.

Dichotomy corollary

"A person's construction system is composed of a finite number of dichotomous constructs." (Kelly 1955, p 59)

Bannister and Fransella (1986) feel that Kelly is arguing here that it is more useful to see constructs as having two poles, a pole of affirmation and a negative pole, rather than see them as concepts or categories of a unipolar type. He is asserting that we might find it more useful to think about them as if they were bipolar and we can thus envisage a variety of relationships between them. Kelly's invention of the grid method as a way of exploring personal constructs relies on this principle.

Choice corollary

"Persons choose for themselves that alternative in a dichotomised construct through which they anticipate the greater possibility for the elaboration of their system." (Kelly 1955, p 64)

According to Bannister and Fransella (1986) this is the corollary whereby Kelly tucks the tail of his theoretical snake into its mouth. If we are in business to anticipate events and if we do this by developing personal construct systems then we will move in those directions that seem to elaborate our construct systems.

Range corollary

"A construct is convenient for the anticipation of a finite range of events only." (Kelly 1955, p 68)

Bannister and Fransella (1986) state that this follows from the original assertion that constructs are bipolar and finite in number. Kelly is here stressing that he is not simply refurbishing the old notion of a concept. The concept of furniture as a general abstraction includes tables, chairs, desks, commodes and so forth and contrasts with everything that is not included in the category of furniture.

Modulation corollary

"The variation in a person's construction system is limited by the permeability of the constructs within whose range of convenience the variants lie." (Kelly 1955, p 77)

Kelly's psychology is a psychology of change. He argues that a person is a "form of motion", not a static object which is occasionally kicked into movement. When we are faced by a "new" situation, if we generally traffic in permeable constructs, we can use them to make sense out of new events which confront us. If our constructs tend to be impermeable, we may take pains to make sure that we do not encounter "new" situations or else we may force them into the existing system however badly they fit.

Fragmentation corollary

"A person may successively employ a variety of construction subsystems which are inferentially incompatible with each other." (Kelly 1955, p 83)

Bannister and Fransella (1986) suggest that Kelly is proposing a further parameter of change, a parameter that suggests that change is not and need not be logical in the simple sense of that term.

Commonality corollary

"To the extent that one person employs a construction of experience which is similar to that employed by another, their processes are psychologically similar to those of the other person." (Kelly 1955, p 83)

Bannister and Fransella (1986) note that this is the complement of the individuality corollary and stresses that people are not similar because they have experienced similar events, nor, for that matter, similar because they appear along some limited timeline to be manifesting similar behaviour, nor similar because they utter the same verbal labels. People are similar because they construe the implication of events in similar ways. They are similar with respect to events that have the same meaning for them.

Sociality corollary

"The extent that one person construes the construction processes of another; they may play a role in a social process involving the other person." (Kelly 1955, p 95)

Bannister and Fransella (1986) state that this is a key corollary in that it insists that interpersonal interaction is in terms of each person's understanding of the other. They provide an example of interacting for a long time with a child and playing a role in the social process with that child. This does not imply that our construct system is the same as the child's – only that our construct system gives us a meaningful picture of the child's construct system.

We store our experience in the form of constructs or as Kelly refers to them as "useful concepts" or "transparent templates". These templates are placed on the world and they guide our perceptions and behaviours. He often refers to them as personal constructs, emphasising they are ours and ours alone. Kelly also refers to them as bipolar constructs, e.g. where there is thin then there must be fat. Constructs have names like good–bad, happy–sad, introvert–extrovert. Constructs can be non-verbal such as the feeling of "falling in love". Constructs are not just floating around unconnected or you would not be able to use one piece of information to get another.

With all these constructs, and all these poles, how do we choose our behaviour? Kelly says that we will choose to do what we anticipate. He puts forward the notion that each individual has a point of view from which he sees the world as being real. These cluster round a model in which people make sense of the world by dividing it up into things (elements) that can be described by appropriate attributes (constructs). There are various assumptions about the nature of entities and constructs: for instance, that there is enough similarity across individuals to allow us to communicate with each other, but enough divergence for each individual to be different. According to Bannister and Fransella (1986) Kelly was not a self-publicist and he developed the personal construct theory over many years. Kelly's theory rests on the assumption that people are actively engaged in making sense of and extending their experience: he expressed this most succinctly as "man is a scientist".

People make sense of their world by categorising it and it is assumed that they are able to do this with reasonable validity and reliability.

A construct is defined as an attribute used to describe something and falls within a range of convenience and a focus of convenience. A construct's range of convenience comprises all those things to which the user would find its application useful. A construct's focus of convenience comprises those particular things to which the user would find its application maximally useful. These are the elements upon which the construct is likely to have been formed originally (Bannister and Fransella 1986).
As an example, the construct "light" or "heavy" may be useful when discussing the weight of an object but not useful in the context of the distance between two points. The level to which participants identify constructs in common will demonstrate the commonality corollary, the extent to which one person employs a construction of experience that is similar to that employed by another; his processes are psychologically similar to those of the other person (Fransella and Bannister 1971).

2.3.3 Techniques based on personal construct theory

Techniques deriving from Kelly's personal construct theory include repertory grids, laddering and card sorts. Let us first consider repertory grids.

Repertory grid

All forms of repertory grid derive from George Kelly's original role repertory test (Kelly 1955). According to Bannister and Fransella (1971) the technique is a method of quantifying and statistically analysing relationships between the categories used by a participant in performing a complex sorting task. According to Rugg and McGeorge (2002) a repertory grid is based on an object–attribute matrix. The cell values in the grid usually contain numbers for the Likert-type semantic scales and may for example rank on a scale of 1 to 10. It is highly suited for statistical analysis but is not so well suited for other types of data. Repertory grids are useful for representing knowledge that is binary or scalar. Unfortunately, not all knowledge is of this sort; knowledge may also be nominal, i.e. consisting of discrete categories which are semantically related but do not form any sort of scale. An example in the domain of types of automobile is "place of manufacture", where the possible values might include "USA", "UK", "Japan". Although these categories are clearly related to each other, there is no simple way to represent this in standard repertory grids. It is possible to represent each place of manufacture as a separate construct, and then represent each element using binary values – for instance, the construct "made in the USA?" could have the values "yes" and "no" – but this involves treating each place of manufacture separately, thus losing the semantic relationship between the categories, and is also very cumbersome.

Laddering

The other technique for consideration is laddering. Laddering is a technique initially developed by Hinkle (Hinkle 1965). Like repertory grids, laddering originated from Kelly's work. It has been used in a number of fields, e.g. in architecture to examine people's perception of room designs (Honikman 1977) or advertising (Reynolds and Guttman 1988). Laddering assumes that the respondent's knowledge is organised as a polyhierarchy, i.e. a multidimensional set of hierarchies, and assumes that the knowledge is categorical, i.e. nominal values arranged in categories. It resembles an interview in which the interviewer uses a limited set of standardised questions or probes. Laddering is an efficient technique for eliciting information from participants, particularly for goals, values, classes and explanations of subjective terms (Rugg and Mc George 2002).

Laddering on goals and values starts by relating to something a participant has previously stated or perhaps something that a researcher has previously found and then they are asked to elaborate on it further. The researcher will repeat what the participant has stated and, for example, say you mentioned X and Y earlier, will ask "Which of these do you prefer and why?" (Rugg and Mc George 2002).

Card sorts

The final technique for consideration is card sorts. Card sorting is a technique that can be used to elicit and therefore understand the categories people use to form attitudes towards their world. Card sorts can be used to investigate the commonality and the differences that are used in the categorisation by the participants in the card sort. A participant is asked to sort a set of cards into groups, each with a name of a domain entity. The participant then tells the researcher what the criterion was for the sorting and what the group was (Maiden and Rugg 1996).This helps build a picture of the attitude they have towards their world. According to Cataldo *et al.* (1970) card sorts can be used to measure attitudes and behaviour and show good reliability and validity when tested.

According to Rugg and McGeorge (2002) the main advantage of card sorts is the inverse of their main disadvantage. Since the cards contain little information, there are no problems with extra detail affecting the sorting process. The main disadvantage is it requires the participants to understand the entities printed on the card.

2.3.4 Summary

In Kelly's view we all develop a set of personal constructs that we use to make sense of the world and the people in it. The constructs are *bipolar* in that they have two ends and will vary from one person to another. Thus, his psychology is a *psychology of individual differences.*

People can be seen as differing from each other, not only because there might have been differences in the events which they have sought to anticipate, but also because there are different approaches to the anticipation of the same events.

It is important to note the word “personal” in “personal construct theory”. We will not all have the same constructs in our repertory.

The key assumption of personal construct theory is that everybody has a personal model of their world and each individual actively constructs his/her model by categorising the world around him/her; in this way people make sense of the world and develop attitudes towards their world. There are a range of techniques that can be used to explore personal constructs such as repertory grid technique, laddering and card sorts. The technique of card sorts is based on personal construct theory and may well prove to be a useful method in investigating the attitudes of podiatrists and nurses to computer expert systems; it will enable the identification of categories that are used in the use of expert systems. This will be done in chapter 3, and laddering seems a useful technique for interviewing podiatrists in chapter 5.

2.4 Literature review on knowledge, skills and clinical reasoning

2.4.1 Introduction

If expert systems are to be used within the domain of podiatry it is important to understand the types of knowledge used in podiatry and to consider the types of skills that are undertaken by a podiatrist using that knowledge to see if an expert system would fit into a podiatrist's daily workload. This section provides a review about the nature of knowledge and the types of knowledge that exist. A review of task analysis is undertaken as a method for investigating the skills and knowledge used by a podiatrist during a consultation or treatment. We then take a different focus and considers aspects of clinical reasoning and possible models for understanding how podiatrists make clinical decisions.

2.4.2 Concepts about knowledge and clinical reasoning

This section provides a review of the types of knowledge that a clinician must have and how this knowledge relates to clinical practice. Initially the work on knowledge as related to healthcare by Higgs and Titchen (2001) and Norman (1985) is considered. In contrast to this the literature on knowledge and its application in requirements engineering by Maiden and Rugg ((Rugg and Maiden 1996) is discussed.

2.4.2.1 Knowledge

Higgs and Titchen (Higgs and Titchen 2001) attempt to define what is meant by a profession and state:

"A 'profession' is an occupational group that is able to claim a body of knowledge distinctively to itself, whose members are able to practise competently, autonomously and with accountability, and whose members contribute to the development of the profession's knowledge base."
(Higgs and Titchen 2001, p 4)

As podiatry has emerged as a profession and has become involved in professional practice, propositional knowledge has been sought to provide the foundation for a knowledge base. Higgs and Titchen (Higgs and Titchen 2001) state:

"Professional practice is concerned with the manner in which practitioners perform the roles and tasks of their profession in conjunction with individuals who are their clients or patients." (Higgs and Titchen 2001, p 4)

Schön called the field of professional practice a "swampy" area, because many of the decisions made in managing problems are based on data that are often uncertain, ambiguous or hidden (Schon 1987). Effective professional practice relies on both theoretical knowledge and knowledge from professional practice experience.

According to Higgs and Titchen:

"Epistemology is the study of knowledge and knowledge generation. It is concerned with the relationship between the knower and the known." (Higgs and Titchen 2001, p 5)

The knowledge that clinicians bring to a patient encounter is a primary feature of the therapeutic intervention (Jensen, Shepard et al. 1992).

Higgs and Titchen (1995) suggest that this knowledge takes three forms:

(1) propositional, theoretical or scientific knowledge;

(2) professional craft knowledge or knowing how to do something;

(3) personal knowledge about oneself as a person and in relationship with others.

According to Higgs and Titchen:

"Knowledge is a fundamental element in the definition and operation of a profession. Firstly the body of knowledge of a profession is a key to delineating and describing the profession, and generation of knowledge by the profession is a charter of being a profession." (Higgs and Titchen 2001, p 23)

Gilbert Ryle provided a simple dichotomy for medical education (Ryle 1949): "knowing what" from "knowing how". Knowing what is book knowledge and knowing how is practical knowledge. Ryle (1949) acknowledged that there are two ways of "knowing that" something happened: you were there yourself or you believe reliable evidence, sometimes from witnesses who were there. This commonly produces propositional knowledge but it can only be known after the event, known as *a posteriori*. In some knowledge areas such as religion and mathematics, most people who believe this knowledge do so on the basis of faith or pure reasoning, known as *a priori* knowledge. Paradigms are frameworks through which people generate and use knowledge, and ontologies (world views) are rules to view the paradigms.

If computer-based expert systems are to be considered for use in podiatry it is important to consider the various types of knowledge and decision-making that may be used in the podiatry profession to be able to understand the type of system that may be required. In order to achieve this it is necessary to review what knowledge and skills are involved in a profession such as podiatry and to review what types of knowledge may be required.

What constitutes essential knowledge in the allied health professions? One model of medical knowledge was proposed by Norman (Norman 1985) and includes:

(1) clinical and technical skills, which might be seen largely in the domain of craft knowledge;

(2) knowledge and understanding (largely propositional);

(3) interpersonal attributes (largely personal);

(4) problem-solving and clinical judgement (across domains).

Diagnosis, decision-making and management involve integrating propositional knowledge, experience-based knowledge and craft skills. According to Michael Eraut this differentiation becomes even more complex after student graduation (Eraut 1994). Much more attention is being given to the process of reflection, building on the model of Donald Schön (Schon 1987) who highlighted the value of reflection in raising the awareness of tacit knowledge. Eraut (Eraut 1994) felt this was a very important concept during experiential learning to transform knowing-in-action into knowledge-in-action. He states that *Educating the Reflective Practitioner* has probably been the most quoted book on professional expertise during the last ten years. Its success derives from many factors and includes a devastating critique of the dominant "technical rationality" model of professional knowledge. Schön's critique is based on two complementary arguments. First, there are severe limitations to what can be achieved by a purely positivist approach in the complexities of the real world, as it can only tackle simple problems. Second, the technical rationality model fails to take into account how professionals work in practice to achieve desired goals. Eraut (Eraut 1994) notes that Schön proceeds mainly by example and metaphor rather than by sustained argument. Several critics have argued that Schön fails to identify what is entailed in the reflective process and ignores time as a factor in making decisions.

Clinical reasoning is a focus of modern practice and problem-based learning (Sefton, Gordon et al. 2000) supports this. Evidence-based medicine (Sackett, Richardson et al. 1997) involves locating valid sources of knowledge and providing a critical evaluation including framing questions, searching databases, and appraising and applying information to specific situations.

Another approach to knowledge is the ACRE framework (Rugg and Maiden 1996). This framework assists requirements engineers when choosing methods for acquiring requirements of software-intensive systems. It also considers the knowledge about the system domain and environment. This framework provides methods for acquiring requirements from stake-holders, rather than mining requirements from documents. Maiden and Rugg (1996) acknowledge that requirements engineers are familiar with methods such as observation, interviewing and using documentation for acquiring knowledge but each is insufficient in isolation to capture complete requirements. The ACRE framework argues that more than one acquisition method is needed to capture the full range of complex requirements for most software-intensive systems and it provides guidelines for selecting from a broad range of different methods with different features from different backgrounds. ACRE brings methods from software engineering and the social sciences together into a single framework and its core guidelines for method selection are derived from theories of cognition and social interaction.

The framework offers examples of twelve acquisition methods, describes each method, preconditions for its use, and perceived strengths and weaknesses and is designed to aid method selection for one acquisition session. The ACRE framework considers the type of domain knowledge to acquire as another factor influencing the choice of method; it follows standard software engineering practices. In contrast to Higgs and Titchen (2001) who classify knowledge into propositional knowledge, professional craft knowledge and personal knowledge, ACRE divides knowledge into three types: behaviour, process and data. The ACRE framework states that most methods are effective for acquiring behaviour but acquiring data is problematic as most stake-holders are more aware of their own actions than the information around them. ACRE suggests that card sorting and laddering are often the most effective methods for acquiring data as both methods explicitly acquire categorical and hierarchical knowledge about domains which is useful for defining classes, entities and attributes.

When considering domain knowledge, the framework makes a distinction between non-tacit, semi-tacit and tacit knowledge. Non-tacit knowledge is accessible to accurate introspection using interviewing. Semi-tacit knowledge is accessible but only with appropriate methods. Tacit knowledge is not accessible to any form of valid introspection.

At this point it is necessary to review the different types of knowledge possessed by a podiatry practitioner and they will be considered separately. Let us first consider the concept of schemata.

Schemata

The nature of knowledge structures and their use in clinical reasoning is illustrated in the use of schemata (abstractions or representations of previous experience). Schemata theory attempts to describe how acquired knowledge is organised and represented and how such cognitive structures facilitate the use of knowledge in particular ways (Glaser 1984);(Sowa 1984). According to Sowa (Sowa 1984) Immanuel Kant introduced the term "schemata" in 1781 for a rule that organises perceptions into a unitary whole, and the psychologist Otto Selz chose the term "schemata" as a basis for his theory of schematic anticipation. Selz's schemata are a network of concepts and relations that guides the thinking process. Sowa (Sowa 1984) mentions that physiologist Sir Henry Head proposed a schemata theory in the 1890s that all changes of posture are measured before they enter consciousness and proposed the word schemata to describe the physiological actions involved. Head noted that by means of perpetual alterations in position we are always building up a postural model of ourselves which constantly changes. Every new posture and movement is recorded onto plastic schemata. Further considerations of this type of schemata were proposed by Sir Frederick Bartlett (Bartlett 1961). Bartlett dislikes the word schemata used in Head's context and creates a new definition.

According to Barlett a schemata is:

"An active organisation of past reactions, or of past experiences, which must always be supposed to be operating in any well-adapted organic response." (Bartlett 1961, p 201)

Determination by schemata is the most fundamental of all the ways in which we can be influenced by reactions and experiences that happened some time ago. Bartlett states that if Head's use of the term is correct then schemata are built up in chronological order. Bartlett bases his theory of remembering on schemata.

Bartlett (1961) provides an example of how schemata may operate:

"In the spring of 1917 one of my subjects (students) first read the story entitled *The War of the Ghosts*. She repeated it half an hour later. She left Cambridge shortly after this, but returned in two years. In the summer of 1919 she saw me cycling along King's Parade, in the town of Cambridge. The girl thought she ought to know me and seemed puzzled; she then muttered Egulac and Calama, the two proper names belonging to the story." (Bartlett 1961, p 208)

Bartlett states that later she built around these names an incident or two. To paraphrase Bartlett, "The immediate return of certain detail is common enough and it certainly looks very much like the direct re-excitation of certain traces. The need to remember becomes active, an attitude is set up, in the form of sensory images, or just as often, of isolated words, some part of the event which has to remembered recurs, and the event is then reconstructed on the basis of the relation of this specific bit of material to the general mass of relevant past experience or reactions, the latter functioning, after the manner of 'schemata' as an active organised setting."

Subsequent workers have acknowledged the importance of schemata and have found that schemata are particularly valuable in that they provide background knowledge, often tacit knowledge, which helps people interpret new information. New events are labelled "instantiations" of these schemata. As new instances are interpreted, the prior knowledge constructions or schemata are tested.

Propositional knowledge

From the work of Michael Polyani (Polanyi 1958), in western philosophy knowledge has been classed into two categories, propositional knowledge (knowing that) and non-propositional knowledge (knowing how). From 1952 to 1958, Polyani worked to transform his Gifford lectures presented in North America into *Personal Knowledge: Towards a Post Critical Philosophy*, the book that represents Polyani's mature philosophy. As a contribution to the philosophy of science, this book criticises the ideal of objectivity and is part of the mid century shift in the philosophy of science toward interest in scientific practice. The critical component of the work is an attack upon the ideal of objectivity as it was presented in science and philosophy at mid century. The constructive (as opposed to critical) philosophy in this book, however, represents Polyani's developing interest in epistemology; he carefully works out his own epistemological model and sets forth a broad framework within which to think about knowledge as personal. Propositional knowledge is derived through research and scholarship, with an attempt to generalise findings. It tends to be public, objective knowledge of the field and knowledge of the external world (Benner and Tanner 1987; Benner 1987; Biggs and Telfer 1987). The outcomes of research are often stated as propositions which claim to be ascertions of facts or truths. Non-propositional knowledge can be divided into professional craft knowledge (knowing how) and personal knowledge (knowledge which is tied to the individual's reality or experience). In podiatry it is likely that propositional knowledge provides a basis for analysing patients' physical and psychosocial problems and also a basis for understanding the results of investigations and tests.

Professional craft knowledge

Professional craft knowledge was a term coined in mainstream education by Brown and McIntyre (1993). The word "craft" implies work in which performance is improved through experience, although it may be seen to denigrate healthcare professions if taken out of context. Schön (Schon 1987) found that there is an increasing concern about the growing gap between the research-based propositional knowledge taught in professional schools and the practical knowledge and actual competencies required of practitioners in the field. Schön feels that outstanding practitioners may not have more propositional knowledge but more "wisdom", "talent" and "artistry". This knowledge somehow needs to be incorporated into propositional knowledge. Professional craft knowledge is often tacit and unarticulated and sometimes intuitive. The knowledge is brought to bear spontaneously in the care of patients (Brown 1988). It underpins the practitioner's rapid and fluent response to the situation. For podiatrists it is likely that this form of knowledge enables them to determine the timing and selection of important data to consolidate a clinical problem. It may also be integrated with propositional knowledge to be able to understand the significance of certain cues.

Tacit knowledge

Polyani (1967) coined the term "tacit knowledge" and described it as the stock of professional knowledge that experts possess that is not processed in a focused cognitive manner but rather lies on a not quite conscious level where the knowledge is accessible through acting, judging and performing. It is the type of knowledge gained through experience, sometimes referred to as what we know but cannot tell.

Tacit knowledge means that an expert can act quickly and do what is required, or act before they think. It is not mindless action but is simply expertise that does not have to be processed via lengthier channels of cognition.

Tacit knowledge which is not available to conscious introspection can be subdivided into implicit learning (Seger 1994) and compiled skills (Anderson 1990). Implicit learning according to Seger is non-episodic learning of complex information in an incidental manner, without awareness of what has been learned. Implicit learning may require a certain minimal amount of attention and may depend on attentional and working memory mechanisms. The result of implicit learning is implicit knowledge in the form of abstract representations rather than verbatim or aggregate representations, i.e.

learning proceeds straight from the training set of large numbers of examples into the brain without any intermediate conscious cognitive processes.

The ACRE framework (Rugg and Maiden 1996) promotes use of observational methods for acquiring both compiled and implicit knowledge since the respondent does not have to be aware of such knowledge. Professional craft knowledge is often unarticulated because it involves knowledge and judgement which are intuitive and which, further, are gained through experience rather than formal teaching. In nursing, Liaschenko (Liaschenko 1998) discussed nursing epistemology. She identified four types of knowledge used by nurses. The first type of knowledge is "therapeutic effectiveness", which is scientific knowledge. The other types of knowledge, which are professional craft knowledge, are "knowledge of how to get things done", "knowledge of patient experience" and "knowledge of the limits of medicine". It is difficult to develop this knowledge unless you work within the healthcare system. You cannot know the meaning of illness to patients unless you meet with them and talk to them. Thus professional craft knowledge is not an abstract body of knowledge, but knowledge relating to ill dependent persons in clinical circumstances.

Compiled skills were initially learned explicitly, but subsequently became habitualised and speeded up to the point where the conscious component was lost. Examples include touch-typing and changing gear in a car. Asking people what they are doing during a compiled skill usually leads to a breakdown in performance when a conscious component is added to the task.

Tacit knowledge may include a significant amount of pattern matching which is very fast. For example, it occurs when recognising a familiar human face. A result from research into expertise was the extent to which experts use matching against a huge learned set of previous instances rather than sequential logic as a way of operating (Chi, Glaser et al. 1989).

Semi-tacit knowledge

Semi-tacit knowledge is a term that applies to a wide range of memory types. These are short-term memory, recall versus recognition, taken for granted knowledge, and front and back versions.

Short-term memory is probably the most widely known of these types. It is a limited storage space, with a capacity of about seven items plus or minus two, as demonstrated in a classic paper by George Miller from Harvard University (Miller 1956), and has a duration of a few seconds. Recall versus recognition is another aspect of memory structure. Recall is active memory, when information is deliberately retrieved from memory. Recognition is passive memory, when a specified item is compared to what is stored in memory to search for a match. Recognition is usually more powerful than recall, e.g. people have difficulty remembering states of the USA but can recognise a much larger number of people if shown a list of names.

Front and back versions are, respectively, the public consumption and behind the scenes versions of reality. They are derived from Erving Goffman's metaphor of stage performance (Goffman 1959). The front version is not intended to deceive but is in many professions viewed by group members as a professional image to be maintained. Taken for granted knowledge is knowledge which one participant in a communication assumes to be known by the other participant (Grice 1975). It is not normally stated explicitly, e.g, “my father, who is a man”, because it is taken for granted that a father is a man.

Consensus on a term that captures the diverse and dynamic nature of the knowledge accrued through experience is important for effective communication and understanding amongst practitioners, educators and researchers. Many terms have been used but fall short of capturing this craft knowledge. Carper’s (Carper 1978) patterns of knowing (aesthetic, ethical and personal) put ethical, artificial and fixed boundaries around knowledge, while her patterns underplay practical experience. The term practical knowledge (Benner 1987) avoids parcelling up knowledge and emphasising practical experience, but fails in the interpersonal and aesthetic connotations. Although Macleod’s term (Macleod 1990) “knowing in practice” includes the imbuing of practical knowledge with theoretical knowledge, and as such is the most suitable analytical term, it still seems to miss the personal, interpersonal and aesthetic connotations or feel. Schön used the term “professional artistry”, but the concept of artistry might be construed as the peak of practice and not as everyday work.

According to Butt (Butt 1985) personal knowledge is a category of knowledge with particular relevance to clinical reasoning in health professions. He stated that it is the result of the individual’s personal experiences and reflections on these experiences. The individual’s internal frame of reference and store of personal knowledge shape the architecture of the self and the individual's construction of reality, and create what could be termed the individual's unique personal intentionality. Clinicians need to develop a personal knowledge base that will enable them to understand dignity, independence and support. Hundert felt that this was achieved through the development of a dynamic reflective equilibrium (Hundert 1987).

Procedural knowledge

Procedural (Biggs 1987) or practical (Benner 1987) knowledge encompasses practical experience and skills. It underpins the practitioner's quick response to a situation. Short-term, taken for granted goals are achieved by strategies which take into account of, and show sensitivity to, a multiplicity of variables. The practitioner may make highly skilled judgements without being conscious of a deliberate way of acting. This knowledge may remain hidden unless the practitioner documents everyday practice.

2.4.2.2 Introduction to clinical reasoning

In order to understand how a podiatrist is making a clinical decision during a consultation or treatment it is important to understand the process of clinical reasoning and the various models that have been used to study it. This will enable a model(s) to be selected to study clinical decision-making in podiatry, which will be the focus later in chapter 4.

Theories of clinical reasoning

The first movements in clinical reasoning began in the 1950s and 1970s and were mainly dominated by the psychometric approach of the behaviourist school of psychology and then in the following two decades by the cognitive school of psychology and by development of alternative research perspectives.

Early studies of medical reasoning had as their goal the assessment of clinical skills of physicians and medical students, as these skills produced mastery of their subject. The dominant research paradigm was therefore a psychometric one, in which emphasis was placed on general skills, defined in terms of observable behaviours, through the use of psychometric tests. These early studies often developed the instruments for studying clinical performance rather than characterising clinical reasoning.

Vu (Vu 1979) notes that one of the main objectives of medical education is to help students develop the ability to solve medical problems. Medical problem-solving incorporates several processes. These include gathering data, developing and verifying hypotheses, evaluating results and making final clinical decisions. Students learn this clinical diagnostic process by working with real patients. Performance is assessed by direct observation. It is often difficult to find enough patients with a wide range of diseases to enable the students to have a breadth and depth of diseases to promote diagnostic skills. Vu notes that simulation methods were widely used by participants to simulate the physician–patient encounter, and could be of various kinds, including written patient descriptions, real patient simulations and computer simulations. According to Vu the observation-based method is where students are expected to gather appropriate data from the history and physical examination, and then derive tentative hypotheses or diagnoses, collect more data as needed, and arrive at an appropriate diagnosis. Then they must prescribe treatment and judge its effects on the patient. With the observation method, students are observed on the various aspects that constitute diagnostic problem-solving and are evaluated by means of rating scales and written reports and/or faculty impressions. Barro (Barro 1973) in reviewing the major studies on the observation method focused on three important issues relevant to this method:

(a) the dimensions of performance to be included;
(b) the definitions and differentiation between "good" and "bad" performances along each dimension;
(c) the weight to be allocated to each category of performance.

She concluded that more evidence is still needed to decide whether direct observation is a valid and reliable measure of medical problem-solving performance. In addition, this method needs refinement because it is unstandardised and incomplete, because the cognitive skills to be evaluated are generally listed in a global manner and because it is interpreted differently by different evaluators.

Cognitive era

The production of the work *A Study of Thinking* by Bruner *et al.* in 1956 led to an emphasis on concept formation and a departure from the behaviourist school of thought. An early example of such work is by Elstein *et al.* (1978) at Michigan State University (Elstein 1978) which was largely based on the work of Newall and Simon in the late 1950s (Newall and Simon 1972) in which the performance of experts is compared with that of novices. The work of De Groot (De Groot 1965) on chess masters meant that medical reasoning was focused upon developing a characterisation of clinical reasoning and a specification of the knowledge structures and processes used during clinical reasoning. The tool of Elstein *et al.* is essentially an observation tool rather than an evaluation instrument. Some modifications were made to the Patient Management Problem scoring and format; it became known as the modified Patient Management Problem and allowed two main kinds of observation:

(1) the natural sequence of processes a participant would utilise to manage patients;

(2) the order in which information is collected.

Three scores are calculated instead of five: efficiency, thoroughness and diagnostic accuracy. The reliability of the modified Patient Management Problem was estimated using the Angoff formula on internal consistency (Angoff 1953) and produced a weak reliability estimate.

Regression and Bayesian estimation models

Regression and Bayesian estimation models typically start with a formal model of decision-making and then collect data, which are compared with the model. The models may be simple regression models, Bayesian estimation models or decision-theoretic models (Christensen 1991). Decision theory has its roots in game theory (Neumann and Morgenstern 1944). This theory deals with making decisions in situations of uncertainty. The basic principle is that a rational person should maximise his/her expected utility. It was thought that the theory actually described human decision-making, but Tversky and Kahneman (Tversky and Kahneman 1974) describe it as a descriptive theory as it may not be normal or rational because participants do not show behaviour according to the models but biases that depart from them. It has also been shown that the frequency of events that fit people's ideas of a prototypical or representative case are often overestimated. Small probabilities tend to be overestimated and large probabilities tend to be underestimated (Tversky and Kahneman 1981).

Another example of numerical models are Bayesian models. These are weighted additive models because the decision process has the form of an additive function. The basic principle of Bayesian inference is that posterior probability is a function of two variables, the prior probability and the strength of the evidence. The participant is asked to generate a series of attributes that are most important for a given situation, e.g. a clinical case, and rank them in order of preference. Once this is done, a set of weights is gathered for each of the attributes. The data are then combined into a decision formula and a decision is generated from the model. This is used either to help the human decision-maker arrive at a good decision or as a descriptor of the decision-maker's behaviour. The model assumes that the decision function is linear and assumes that the participant knows the alternatives. This has led researchers such as Fox (Fox 1988) to argue for an expansion in the study of decision-making processes to include the selection of attributes and the reaching of a decision.

2.4.2.3 Tools for investigating clinical reasoning

The ACRE framework (Rugg and Maiden 1996) suggests that there are different methods for acquiring knowledge; some of these are depicted in Table 2.

Table 2: Effectiveness of methods for acquiring knowledge with different internal representations, adapted from ACRE (Rugg and Maiden 1996)

Internal knowledge	Observation	Unstructured interviews	Structured interviews	Protocols	Card sorting	Laddering	Brainstorm
Future system knowledge	NO	YES	YES	NO	—	YES	YES
Non-tacit knowledge	—	YES	YES	YES	YES	YES	YES
Recognised knowledge	NO	NO	NO	—	YES	—	YES
Taken for granted knowledge	YES	—	—	YES	—	—	—
Working memory knowledge	NO	NO	NO	YES	NO	NO	NO
Compiled knowledge	YES	—	—	YES	—	—	—
Implicit knowledge	YES	—	—	YES	—	—	—
Tacit knowledge	YES	—	—	YES	—	—	—

Although the ACRE framework suggests methods for acquiring knowledge, there are other methods to be found in the literature on healthcare. At this point it is useful to review these techniques.

Record-based method

Problem-solving processes can also be assessed in retrospect from recorded information. Weed (Weed 1968) devised the problem-oriented medical record. This calls for a "systematic account of the data, the development of plans and treatment of each problem". In theory, the problem-oriented medical record provides a structure that describes the thought processes of each physician and indirectly reveals the approach to problems that the physician uses.

Simulated method

Besides assessing problem-solving processes and skills through observation and chart review, other instruments have been devised using simulated physician–patient encounters. These include Patient Management Problems, the Diagnostic Management Problem, the Simulated Patient, and the Computer-based System. One of the earliest instruments used was the test for diagnostic skills devised by Rimoldi (Rimoldi 1961). This test of diagnostic skills was amongst the first for studying diagnosis from a psychometric viewpoint. The test is a clinical case, which describes a report on a patient. The participant then inquires about the patient by requesting additional information. The information is provided on cue cards with a question on one side and the answer on the other. The nature and chronological sequence of the questions are studied to evaluate the participants' level of clinical reasoning skills. The results characterised the behaviour of physicians as more focused than medical students, i.e. they asked fewer and more appropriate questions. The Rimoldi Test for Diagnostic Skills appears to measure some aspects of problem-solving ability and possesses a degree of content validity. The reliability of this instrument has not been established.

Patient Management Problem

Barro (Barro 1973), in an attempt to assess the different aspects of clinical competency of the National Board of Medical Examiners in the USA, utilised Patient Management Problems (PMPs). The Board's PMPs are designed to measure nine different aspects of clinical competency: history, physical examination, tests to be used, diagnostic acumen, treatment, care implemented, continuing care, physician–patient relationship and responsibilities as a physician. In these PMPs students are given general information about the patient, results from the physical and data from the diagnostic tests. They study the information and decide what to do next. After selecting a course of action they are instructed to turn to a separate answer book which contains a series of inked blocks. As they remove the ink for their selected choices, the students gain information about the results of the course of action selected. After each selection, the situation changes, a new problem develops, and new decisions must be made. This step-by-step progression, wherein each step is accompanied by an increment of information, is characteristic of this testing method (which is also called linear programmed testing). Students proceed in a step-by-step fashion through a sequential unfolding of a series of problems and cannot change any answers made. The responses, whether they are correct or incorrect, are clearly apparent to the scorer. The total score a student receives is "the number of indicated procedures selected plus the incorrect procedures avoided". Barro states that the content validity does not assess proportionately all nine areas of clinical competence it assumes to assess. Taylor compared the performance of the interns and third-year medical students using PMPs and found the performance of the former was better than the latter. These results imply that the PMPs on the National Board of Medical Examiners seem to measure "something that is occurring in direct clinical training. That the thing learned is relevant to actual practice" (Barro 1973).

Diagnostic Management Problem

In a similar attempt to measure the process used by students in solving clinical problems, as well as to provide an easier way to score performance, Helfer (Helfer 1971) created a new instrument called the Diagnostic Management Problem (DMP). It is a modified version of both the Rimoldi test and PMPs. In this instrument the participants are presented with 96 cards, which represent one clinical problem. Each card contains a specific historical fact, a physical finding and a laboratory result. The participants are also told the setting in which they are working and are given a brief description of the case and an index sheet which itemises the type of information available on each of the numbered cards. The students proceed to work through the problem by selecting as many cards as they desire and in any order they want. They record on an answer sheet the number of each card selected and the order in which the cards are chosen. Primary and secondary diagnoses are also recorded. Student scores are based on their performance and compared with defined criteria. Each student receives four scores: process, efficiency, competence, and diagnostic scores. These scores are based on the order in which the cards are selected, the total number of cards chosen, and the usefulness of the selected cards. According to Vu (Vu 1979) although DMPs provide an easier method of scoring and a finer breakdown of the scores compared to the revised and modified PMPs, all three formats have one main disadvantage in that they all include a cueing aspect in their instruments. All three formats, by listing possible options and alternatives from which students can choose, provide clues for diagnosis that are not readily available in real-life situations. In effect, this characteristic may introduce a biased measurement of performance in the cued situations that can provide higher scores of performance than uncued situations, especially in poorer students.

Computer-based Examination

Another patient management simulation that has been developed to measure patient management skills is the Computer-based Examination (CBX). This system was derived from a project at the University of Wisconsin with the support of the National Board of Medical Examiners. In this system, students operate a standard computer terminal using the CBX model to do a work-up of a patient case. The simulation starts by presenting a patient complaint. Users can then interact with the computer in order to gather information, order tests and formulate diagnoses. The computer also provides information about the progress of the patient and test results. Analysis of the user's performance is based on the efficiency with which they handle the various cases and the sequence and degree of efficiency of the tests and therapies they ordered.

Patient Simulation

The development of computer science and the first notions of simulated thought processes led Hovland (Hovland 1960) to a more qualitative approach. The Patient Simulation consists of physicians interacting with patients who are trained actors. As in real-world medicine the physicians assess the history and physical and decide which data are needed and what laboratory tests are necessary. The Patient Simulation is used in many different ways. Elstein *et al.* (Elstein 1978) undertook some pioneering work which covered more than a decade. He used several methods and developed these methods to maximise information as no one method was ideal. For example, although simulated patients capture real-life situations they may fail to capture hidden cognitive processes. Recall tasks may identify clinical reasoning processes to be isolated and studied in more depth. Elstein *et al.* (1978) videotaped the work-ups and encouraged physicians to think aloud by giving accounts of their decisions and relating their thoughts at different points in the interview. This kind of introspection technique was used as an attempt to move beyond observable behaviours and into thought processes involved in physician problem-solving. In using simulated patients Elstein *et al.* (1978) found the technique beneficial in determining, defining and tracing the processes involved in problem-solving. In addition, construct and content validity of the Patient Simulation were confirmed, but discriminate validity was not. In other words, performance with Patient Simulations did not provide a clear discrimination between "criteria" and "non-criteria" physicians because individual physician performance varied from one case to another.

Feltovitch *et al.* (Feltovitch 1984) investigated clinical reasoning and found that experts differed from novices in terms of quality of knowledge structures.

Input–output models

Input–output models may involve perceptual aspects of expertise (Lesgold, Rubinson et al. 1988). In this type of study, participants are presented with a series of slides, e.g. X-rays, and then asked to recall information from the slides. The goal is to show how variations in the participants's interpretation, e.g. a verbal protocol, relate to the experimental conditions, e.g. the type of slide. The data are then quantified and subjected to statistical analysis; this is an input–output model. Sometimes only individual participants are used to search for invariance (what is similar across all individuals). These approaches have been used in artificial intelligence (Clancey 1997).This views the process of thinking and reasoning as part of the people's attempt to engage in interaction with the external environment.

Verbal reports

Verbal reports may require a participants to report on their thoughts whilst engaging in a cognitive task. This method can be criticised as new information and new cognitive thought processes that the participants may not have used at the time of the performance may be introduced. Think-aloud protocols have been widely used in clinical reasoning and expertise research (Kassirer, Kuipers et al. 1982) and explanation protocols (Patel and Groen 1986).

In typical think-aloud protocols the participant is presented with a clinical case, often written, ranging from a sentence to case notes or laboratory findings. The participant is asked to read the information and verbalise whatever thoughts come to mind. Once collected the protocol is subjected to an analysis aimed at uncovering the cognitive processes and the information used. The analysis of the protocol is then compared to a reference or domain model of the task to be solved, which may have been provided by an expert collaborator or from printed information on the topic such as a textbook.

Retrospective protocols

Retrospective protocols are collected after the situation described has already happened and are usually analysed in the same manner as think-aloud protocols. It was proposed by Newall and Simon (Newall and Simon 1972) that in retrospective protocols verbalisations do not refer to contents in the short-term memory alone but are a mixture of long- and short-term memory. In fact the two methods of think-aloud and retrospective protocols may be used to complement each other.

Explanation protocols

Vimla Patel and Guy Groen (Patel and Groen 1986) used this method. They collected recall protocols which had failed so far to detect expert/novice differences between participants at different levels of expertise in medicine. Later they developed the explanation protocol method. This method consists of asking the participant to explain the pathophysiology of a case. The explanation is then presented in the form of a propositional structure. The analysis consists of several steps.

First, segment the subject protocol (the explanation of the case) into clauses according to Winograd (Winograd 1972) and then determine the propositions in each clause by taking each idea as a separate proposition. Then relate the propositions in a semantic network in which the relations between propositions are labelled following the prepositional grammar developed by Frederiksen (Frederiksen 1975). A semantic network is a structure of concepts and relations amongst concepts. Concepts are represented as nodes and relations are represented as links between nodes, according to graph theory notations (Sowa 1984).

Higgs and Titchen (1995) suggest that the semantic networks contain mostly conditional and causal links. Thus a semantic network is a connected graph in which the connections amongst concepts as well as the direction of reasoning are represented. A graph is connected if there exists a path (directed or undirected) between any two nodes. The types of nodes correspond either to data given in the problem or to hypothesised information. Reasoning is characterised in the following form. When the direction of the relations is from the given data in a problem to a hypothesised node, it is coded as forward or data-driven reasoning. When the link is from the hypothesised node to explain the data in the problem, it is coded as backward or hypothesis-driven reasoning. A series of inferences between the two is coded as elaboration.

This methodology has enabled investigation into some aspects of expert diagnostic reasoning in diagnostic tasks. Patel and Groen's techniques of propositional analysis are used to examine the protocols of seven cardiologists in a task involving the diagnosis of a case of acute bacterial endocarditis and an explanation of its underlying pathophysiology (Patel and

Groen 1986). It is shown that the explanations of a physician making an accurate diagnosis can be accounted for in terms of a model consisting of pure forward reasoning through a network of causal rules, actuated by relevant propositions embedded in the stimulus text. These rules appear to derive from the physician's underlying knowledge base rather than any information in the text itself. In contrast, participants with inaccurate diagnoses tend to make use of a mixture of forward and backward reasoning, beginning with a high level hypothesis and proceeding in a top-down fashion to the propositions embedded in stimulus text or the generation of irrelevant rules.

Discourse analysis

Discourse analysis has been used to analyse verbal data. This technique has its origins in linguistics and psycholinguistics, and specifically in the study of texts. Discourse analysis began by examining simple forms of linguistic performance, such as morphemes and lexical units. The morpheme is the smallest unit that relates sound and meaning.

- Meaning "dog" <===> Sound [dag] (English).
- Meaning "dog" <===> Sound [kanis] (Latin).
- Speakers must MEMORISE each morpheme.
- The collection of morphemes is one thing that speakers know about their language.
- The sounds that are used to make up the morphemes are arbitrary. There is nothing about dogs that forces the word for "dog" to contain [g] or [k] or [d].

A lexical form is an abstract unit representing a set of word forms differing only in inflection and not in core meaning. Here are some examples of lexical forms in English. The lexeme, *brooch* n. "a large ornamental pin with a clasp, worn by women" has a single lexical unit with a single lexical form representing the two word forms, *brooch* and *brooches.*

What started as a research programme in linguistics was extended to memory and reasoning and decision-making. Another methodology influenced by the theories of discourse is the phenomenological approach (Marton and Saljo 1976). Here the focus is on investigating general approaches and knowledge that individuals use to learn and understand a situation or problem. The emphasis is on the ways people find individual differences in how people approach the phenomena around them. Ramsden (Ramsden, Whelan et al. 1989) used this approach in medicine by asking participants to study medical records, taking as much time as they needed. They were then asked questions in a non-directed way with the aim of eliciting information about their understanding of the problem and their ways of solving it. The analysis consists of ways of generating categories that can meaningfully characterise what participants are doing from their perspective.

Interpretive methods

Qualitative methodology has become increasingly important in the social sciences. Ethnographers such as Benner (Benner 1984) argue that quantitative approaches produce meaningless numbers whilst important social aspects are not understood. They feel social sciences need rich descriptive data that take into account changes in behaviour. Rather than investigating from outside the researcher becomes part of the community he/she is studying.

Benner (1984) studied nursing expertise. Paired interviews were conducted with novice and expert nurses about a situation that was common to both. Benner's research is based on the models of skill acquisition and expertise developed by Dreyfus and Dreyfus (Dreyfus and Dreyfus 1986) whose work was influenced by Martin Heidegger (Heidegger 1962). The Dreyfus model has five levels commencing with novice, advanced beginner, competent, proficient and finally expert. The Dreyfus brothers' model of skills acquisition is based almost entirely on learning from experience with only occasional reference to theoretical learning or the development of fluency on standard tasks. The pathway to competence is characterised mainly by the ability to recognise features of practical situations and to discriminate between them, to carry out routine procedures under pressure and to plan ahead. Competence is the climax of rule-guided learning and discovering how to cope in crowded, pressurised contexts. Proficiency marks the onset of quite a different approach to the job: normal behaviour is not just routine but semi-automatic – situations are apprehended more deeply and the abnormal is quickly spotted and given attention. Thus progress beyond competence depends on a more holistic approach to situational understanding. Progression from proficiency to expertise finally happens when the decision-making as well as the situational understanding become more intuitive rather than analytical and thus require more experience. The most expert performance is ongoing and non-reflective; experts according to the Dreyfus model do not deliberate but critically reflect on their own intuition.

Benner's method consists of interpreting each situation by independent observers/interpreters and then comparing their interpretations and reaching consensus about the meaning of the situations. The idea here is to capture experiences in terms of their interpretations of the problem.

Situated cognition

Situated cognition has developed in recent years to study thinking and reasoning and emphasises the contextual aspects of cognition. The situated approach involves the rich ethnographic description of persons acting in their environment, as reasoning is conceived of taking place in interactions with situations rather than as a set of processes occurring in someone's mind. Videotaping and video analysis software are essential tools in the situated perspective (Roschelle and Goldman 1991). The method allows a better characterisation of cognitive processing, by providing non-verbal information such as gestures and gazes. The information can be used to support verbal data or provide new hypotheses.

Task analysis

If computer expert systems are to be considered for use in an allied health profession such as podiatry, then it is important to gain an understanding of the type of knowledge involved. In order to understand the type of skills undertaken and the knowledge utilised by a podiatrist a task analysis needs to be undertaken. This should help us to understand if an expert system can be utilised during the consultation and treatment process. Trying to make sense of what people should do or what they actually do is the business of task analysis (Diaper 1989). For some people task analysis is concerned with gathering task information, and for others it is about representing that information. There is little consensus about what is to be analysed. For some it is about eliciting the actual behaviour of those people known to be competent at a task. Others are more concerned with focusing on what could, in principle, be achieved by a human being. Other approaches focus upon the goals that need to be achieved to meet system requirements, and then explore the ways in which the human operator may be limited in achieving those goals or the means by which they may be achieved.

Many different approaches to examining human performance described under the banner of general task analysis have appeared since the 1950s. Examples are the papers by (Miller 1962) and (Wilson, Barnard et al. 1988). However, hierarchical task analysis, developed by Annett and Duncan (Annett and Duncan 1967) as a general form of task analysis, capable of dealing with cognitive as well as motor tasks, embodies principles relevant to human–computer interface tasks and may be more useful in this thesis. Task analysis is useful to the extent that it helps us to improve design or implementation of systems or, at least, to focus upon areas of poor human performance. Task analysis involves gathering information, representing it in an appropriate manner, and then utilising this representation to establish the system's improvements. A form of hierarchical task analysis will be used to investigate whether it is possible to incorporate an expert system into a podiatry clinic. This is the methodology used in chapter 4 of this thesis.

2.4.3 Summary

Consideration was given to what constitutes a profession and what is meant by professional practice. Epistemology was defined as the study of knowledge and at an encounter with a patient Higgs and Titchen (1995) divided clinical knowledge into propositional knowledge, professional craft knowledge and personal knowledge. Propositional knowledge is derived through research and scholarship. Non-propositional knowledge can be divided into professional craft knowledge (knowing how) and personal knowledge (knowledge which is tied to the individual's reality or experience).

The ACRE framework (Maiden and Rugg 1996) argues that more than one acquisition method is needed to capture the full range of requirements for most complex software-intensive systems, and it provides guidelines for selecting from a broad range of different methods with different features from different backgrounds. ACRE brings methods from software engineering and the social sciences together into a single framework and its core guidelines for method selection are derived from theories of cognition and social interaction. Michael Polyani coined the term "tacit knowledge" and described it as the stock of professional knowledge that experts possess. This type of tacit knowledge can be subdivided into compiled skills and implicit learning; these are initially learned explicitly but subsequently become habitualised and speeded up to the point where the conscious component is lost. If computer expert systems are to be considered for use in an allied health profession such as podiatry, then it is important to gain an understanding of the type of knowledge and skills that are utilised by a podiatrist to see if an expert system will fit into a podiatrist's daily work pattern. In order to understand the type of knowledge and skills possessed by podiatrists it is important to consider a task analysis of their work pattern.

There are various models for investigating how a medical practitioner makes clinical decisions. The models can be taken from healthcare and from software engineering. Each approach was discussed in some detail. These models have developed from the 1950s, e.g. in the so-called cognitive era of decision-making, up to the situated cognition models in the 1990s. Given the limitations of the models mentioned in the review it seems unlikely that any single model will be useful in investigating clinical decisions in podiatry as there are some inherent flaws in most of the models, e.g. the reliability of the modified PMPs was estimated using the Angoff formula on internal consistency (Angoff 1953) and produced a weak reliability estimate. A better approach to investigating clinical decision-making in podiatry will be to use a hybrid model and this will be the focus for chapter 4.

Chapter 3: Attitudes to Expert Systems

3.1 Introduction

This chapter investigates podiatrists' perceptions of and attitudes toward diagnostic aids, and in particular how podiatrists view expert systems. This leads on to the question of whether an expert system should be developed for podiatry, with all of the expenditure involved, and whether the podiatrists would actually use it during a consultation.

3.2 Card sorts

Given the weakness of some of the attitudinal scales discussed in chapter 2, e.g. the Bogardus and Likert scales, the methodology chosen for this study is card sorts. The card sorts methodology was discussed in more detail in chapter 2 but according to Maiden and Rugg (1996) card sorting is a technique that can be used to elicit and therefore understand the categories people use to form attitudes towards their world. Card sorts can be used to investigate the commonality and the differences that are used in the categorisation by the participants in the card sorts. A participant is asked to sort a set of cards into groups, with a name of a domain entity on each one.

The participant then tells the researcher what the criterion was for the sorting and what the group was.

The advantages of using card sorts are that the information obtained is in a standardised format and suitable for automation. Sessions are recorded verbatim and do not require coding or transcription prior to statistical analysis. As respondents generate their own constructs as a basis for sorting cards they are not confined by the imposition of constructs predefined by the interviewer. Maiden and Rugg note that the imposition of a framework, or constructs, may result in the omission of important issues not identified or foreseen by the interviewer, a problem that may occur with structured interviews or questionnaires (Maiden and Rugg 1996). A disadvantage of card sorts is that the knowledge elicited is "flat" object–attribute value knowledge and attributes relating to classes, structures and procedures would not be identified (Maiden and Rugg 1996). Card sorts may not elicit some types of knowledge including taken for granted knowledge and implicit knowledge as detailed by Maiden and Rugg (1996). Taken for granted knowledge is knowledge that is not referred to during communication because it is taken for granted by the communicator, and implicit knowledge is knowledge that has been acquired unconsciously. Another disadvantage concerns the collation of constructs into groups of superordinate constructs in order to investigate commonality across respondents. This process was carried out by an independent judge who assembled the constructs into superordinate constructs. This was necessary, as Kelly points out, because people do not always mean what they say and sometimes find it difficult to verbalise personal constructs in a way that people understand (Kelly 1955).

3.3 Study sample

Work by Gerrard (Gerrard 1995) suggests that there may be a gender difference when using card sorts, in that females may sort cards in a different manner to males. Work by Carswell (Carswell 2000) has shown this to be true. To control for these factors the participants were selected as follows. There were two groups involved in the study, a group of podiatrists and a group of nurses. Each group had seven participants, composed of podiatry lecturers and nursing lecturers from the staff of University College Northampton. These participants were thought likely to understand the hospital investigations and laboratory tests and expert systems as they are teachers and researchers in their respective domains. There were five male lecturers and two female lecturers in each group.

3.4 Design

Choosing the entities

The entities chosen were seven hospital investigations and laboratory tests as featured in a podiatry textbook, *Assessment of the Lower Limb* (Merriman and Tollafield 1996). The role of the podiatrist in foot disorders is an expanding one. As the knowledge of foot pathology has increased so has the complexity of referred cases and clinical regimes. Many clinical diagnoses can only be confirmed by specialist tests (Merriman and Tollafield 1996). It is for this reason that hospital investigations and laboratory tests were chosen for this study. It was thought that an expert system would fit well with these types of tests, as an application of an expert system may well be to enter findings from a patient to produce a diagnosis, rather like the findings from hospital investigations or a laboratory test could be used to produce a diagnosis. So a card labelled "expert system" was added to the other seven tests. This was the card that could be used to investigate podiatrists' and nurses' attitudes to expert systems when used as a test for a diagnosis.

The eight cards used were as follows:

- Histology
- Biochemistry
- Blood analysis
- Microbiology
- Urinalysis
- Radiology
- Expert system
- Ultrasound

Procedure

Each card measured the same size and was a standard small filing card, 150 × 100 mm in size with the words printed onto the card. In the top right-hand corner a number from 1 to 8 was placed to identify each card for recording purposes, as recommended by Rugg and McGeorge (1997).

The frame and instructions

A frame was developed so that each participant was given the same instructions throughout. The frame encouraged each respondent to state the viewpoint from which they were answering the sort, e.g. as a teacher or as a practitioner.

The same frame and instructions were given to each participant prior to the sort and can be found in Appendix A (A.1).

Conducting the session

Once the respondents had been given the frame and the instructions and clearly understood what was involved in the session, they were given the cards and asked to sort them into groups, with one group for each category, using only one criterion for the sorting. One viewpoint was requested for each criterion.

The participants looked at all items at the start of the session before they did any sorting so that they were fully aware of the range of items to be sorted.

The participants had their own choice of category. The sort involved participants choosing a construct by which to assess the cards and then placing the cards into groups according to the construct. The sorting procedure was repeated until participants had identified all constructs to their satisfaction.

Once the participant stopped sorting, the interviewer requested the criterion and viewpoint for the sort. Next the names of the groups were requested.

Recording the session

The recording for the session was paper-based. The method was to write the name, the sort number, the viewpoint and the criterion as shown below.

Date
Name
Sort 1
Viewpoint
Criterion

Following the sort a count was undertaken to make sure all items were accounted for and the results were noted on a plain piece of paper. An example is given in Appendix A (A.2).

3.5 Ethical considerations

The participants were lecturers in podiatry and nursing at University College Northampton. As there was no ethical committee at the time of this study no permission was required from the University College. However, ethical considerations of proposed empirical studies were taken into account during the research degree approval process by the Research Degrees Board.

3.6 Data analysis

Results

Participants grasped the concept of card sorts rapidly and produced a range of sorts based on their own constructs. The results of the sorts can be found in Appendix A (A.2).

Table 3: Total number of constructs and viewpoints generated by podiatrists and nurses

Participants	Total number of constructs
Podiatrists	53
Nurses	41

Table 4: Total number of categories generated by podiatrists and nurses

Participants	Total number of categories
Podiatrists	149
Nurses	95

Table 5: Frequency of categories used by podiatrists for each construct

Number of categories used by podiatrists	Frequency	Percentage
1	2	1.34
2	19	12.75
3	19	12.75
4	10	6.71
5	1	0.67
6	2	1.34

Table 5 shows that the podiatrists generated mostly dichotomous and trichotomous sorts for the majority of constructs.

Table 6: Frequency of categories used by nurses for each construct

Number of categories generated by nurses	Frequency	Percentage
1	4	9.76
2	25	60.98
3	8	19.51
4	3	7.32
5	1	2.44

Table 6 shows that the nurses generated mostly dichotomous sorts for the majority of constructs.

The following tables show the constructs and viewpoints generated by the podiatrists and nurses in verbatim format (i.e. in the participants's own words). It can be seen that some of the constructs and viewpoints are similar and hence later they are grouped as superordinate constructs and viewpoints.

Table 7: Verbatim constructs for podiatrists

Construct	Frequency of occurrence for podiatrists
Hospital investigations and laboratory groups	7
Diagnostic aids	1
Analysis of results	1
Cost	1
Time	1
Frequency	1
Pre-op preparation	1
Obtaining living tissue for analysis	1
Skin breakage	1
Type of interpretation	1
Type of sample	1
Teaching topics	1
Layperson terms	1
Useful to podiatrists	1
Year of BSc Podiatry course in which teaching topic is relevant	1
Accessibility of diagnosis	1
Place of diagnosis	1
Medical fields	1
Podiatry in house/hospital-based tests	2
All useful in podiatry	1
Budget	1
Medical criteria for grouping investigations	1
Need for specialist training	1
Analysis related to branches of medicine	1
Diagnosis	1
Invasion	1
Body fluids or not	1
Tests done to myself	1
Tests performed by me	1
Quantitative versus qualitative	1
Computer or not	1
Tests used in rheumatoid arthritis	1
Included or not included on BSc Podiatry course UCN	1
Useful in diagnosis in pregnancy	1
Self-test or not	1
Alphabetical order	1
Hospital based	1
Diagnosis	1
Investigation of patient surgically	1
Need for referral for alternative treatment	1
Test applicable prior to surgery	1
Post-op tests to support post-op care of patient	1
Dealing with complications of surgery	1
Ethics	1
To differentiate bone from soft tissue problems	1
Financial cost of the test	1

Table 8: Verbatim viewpoints generated by podiatrists

Viewpoints of podiatrists	Frequency
Paramedical	1
In situ clinical based/hospital based	1
From a microbiology/radiology view	1
All practitioners should undertake these areas	1
Obtainable/unobtainable	1
Medical criteria for grouping investigations	1
Podiatrists do not have access to prescription-only medicines	1
Podiatric/surgical model	1
Medical/podiatric model for aftercare of the patient	1
Medical/podiatric surgical model	1
Minimise litigation	1
Common use of these clinical tests	1
Budget needs to be cost effective	1
Teacher	2
Teaching	1
As a healthcare professional	1
As a layperson	2
As a patient	1
GP perspective	2
As a podiatrist in the clinic	7
System use	1
Physical method	1
Risk assessment	1
Cost	1

Time	1
Frequency	1
Ease of application	1
Pre-op preparation	1
Podiatrist	3
Invasiveness	1
Type of skill required	1
Type of sample	1
Filing system	1
Patient	1
As a clinical podiatrist	5
As an observer	1
Branches of medicine	1
Surgical	1

Table 9: Verbatim viewpoints generated by nurses

Viewpoint	Frequency of occurrence for nurses
Healthcare professional	11
Medical model	2
As a nurse in a hospital	6
As a nurse	1
Health sociologist	1
As a nurse speaking to a patient	1
General perspective	1
As a husband	1
As a health service user	1
As a nurse at the initial point of registration	8

It can be seen that some of the categories produced by the nurses and podiatrists in verbatim format (in the participants's own words) show common themes, e.g. there are similar constructs and viewpoints relating to diagnosis. In order to examine the distribution of commonality it is necessary to group the categories identified into superordinate constructs and superordinate viewpoints. This procedure was carried out using an independent judge who was a member of the lecturing staff from the School of Health at the University of Northampton.

Superordinate constructs

The superordinate constructs are shown in the tables below.

Table 10a: Superordinate constructs for the podiatrists

Superordinate construct	Constructs included
Diagnostic	Diagnostic or therapeutic
Education	The study of Level of specialist knowledge Easy to identify in the curriculum
Analysis	Analysis Analysis of terminology Biochemical analysis
Invasiveness	Invasiveness versus non-invasiveness Invasion
Tests	Tests for patients Availability of the test
Investigation	Types of investigation Nursing investigation or not Nature of examination
Differentiation	Multidimensional
Technology	Human versus information technology Technology
Groupings	Specialist group versus expertise
Pathology	Specimen needed or not
Interpretation	Immediacy of result
Usefulness	Things I am familiar with
Anatomy	Parts of the body
Employment	Jobs my wife did/did not do Activities dependant on other healthcare professionals
Treatment	Essential to modern medical treatment
Patient	Patient accessibility
Nursing	Nurses need to know Influences direct nurse Focus for mental health nursing Focus for acute nursing

Table 10b: Superordinate constructs for the nurses

Superordinate construct	Constructs included
Diagnostic	Diagnostic aids Accessibility of diagnosis Place of diagnosis Diagnosis Useful in diagnosis of pregnancy
Financial	Cost Budget Financial cost of the test
Time	Time
Education	Teaching topic Need for specialist training Included or not included in BSc Podiatry course at UCN
Analysis	Analysis of results Frequency Analysis related to branches of medicine
Invasiveness	Invasion
Tests	Podiatry in-house/hospital-based test Tests done to myself Tests performed by me Qualitative versus quantitative Tests used in rheumatoid arthritis Self-test or not Hospital based Test applicable prior to surgery Post-op tests to support post-op care of the patient
Investigation	Medical criteria for grouping investigations Investigation of patient surgically
Surgical	Pre-op preparation Dealing with complications of surgery
Differentiation	To differentiate bone from soft tissue problems
Technology	Computer or not
Groupings	Hospital investigations and laboratory groups
Ethics	Ethics
Pathology	Obtaining living tissue for analysis Skin breakage Type of sample Body fluids present or not
Interpretation	Type of interpretation Medical fields
Usefulness	All useful in podiatry
Referral	Need for referral for alternative treatment

Table 11: Superordinate constructs for podiatrists and nurses

Superordinate construct	Podiatrists	Nurses	Total
Diagnostic	6	1	7
Education	3	2	5
Analysis	3	3	6
Invasiveness	1	2	3
Tests	9	1	10
Investigation	2	2	4
Differentiation	1	1	2
Technology	1	2	3
Groupings	1	1	2
Pathology	4	1	5
Interpretation	2	1	3
Usefulness	1	1	2
Financial	3	0	3
Time	1	0	1
Surgical	2	0	2
Ethics	1	0	1
Referral	1	0	1
Anatomy	0	1	1
Employment	0	2	2
Treatment	0	1	1
Patient	0	1	1
Nursing	0	4	4

When coded as superordinate constructs the number of constructs was reduced from 53 for podiatrists and 41 for nurses to 17 for both nurses and podiatrists.

There was a lack of commonality in that there were no superordinate constructs relating to financial, time, surgical, ethics and referral for the nurses and a lack of superordinate constructs relating to anatomy, employment, treatment, patient and nursing for podiatrists.

The superordinate constructs generated most frequently by both nurses and podiatrists were tests, diagnosis and analysis.

Table 12: Superordinate viewpoints

Participants	Number of viewpoints (verbatim)
Podiatrists	38
Nurses	10

In order to investigate the commonality of these verbatim viewpoints superordinate viewpoints were produced.

Table 13: Superordinate viewpoints for podiatrists

Superordinate viewpoint	Viewpoints included
Type of model	Medical criteria for grouping investigation Podiatric /surgical model Medical/podiatric model for aftercare of patient Medical/podiatric surgical model Surgical Risk assessment Branches of medicine Type of skill required
Type of setting	*In situ* clinical/hospital based
Criteria	Filing system
Access to drugs	Podiatrists do not have access to prescription-only drugs
Legal	Minimise litigation
Financial	Budget need to be cost effective Cost
Occupational	Paramedical Teacher Teaching As a healthcare professional As a podiatrists in the clinic Podiatrist As a clinical podiatrist
Type of user	As a layperson As a patient GP perspective System use Patient As an observer
Time	Time Frequency
Type of test	From a microbiology/radiology view Common use of these clinical tests Physical method Pre-op preparation Type of sample
Degree of compulsion	All practitioners should undertake these areas
Ease of use	Obtainable/unobtainable Ease of application
Degree of invasion	Invasiveness

Table 14: Superordinate viewpoints for nurses

Superordinate viewpoint	Viewpoints used
Occupational	Healthcare professional As a nurse in a hospital As a nurse Health sociologist As a nurse speaking to a patient As a nurse at initial point of registration
Type of model	Medical model General perspective
Type of user	As a husband As a health service user

Table 15: Superordinate viewpoints of nurses and podiatrists

Superordinate viewpoints	Podiatrists	Nurses	Total
Type of model	8	2	10
Type of setting	1	0	1
Criteria	1	0	1
Access to drugs	1	0	1
Legal	1	0	1
Financial	1	0	1
Occupational	7	6	13
Type of user	6	2	8
Time	2	0	2
Type of test	5	0	5
Degree of compulsion	1	0	1
Ease of use	2	0	2
Degree of invasion	1	0	1

When given as superordinate viewpoints the total number of viewpoints for podiatrists reduces from 38 to 12 and from 10 to 3 for the nurses. Overall, the podiatrists carried out the card sort exercise using more verbatim and superordinate viewpoints than the nurses. For both nurses and podiatrists the viewpoint used most often related to their occupation, the type of model used and the type of user.

The aim of the analysis of the card sorts was to find out whether the instances of co-occurrence between any pair of cards would be higher or lower than that of another pair of cards. This was achieved using version 1 of card sorts software developed by a company called Eidesis. This software is not commercially available but was made available through the owner of Eidesis for this study. The software counted the number of times a particular card occurred with another card. The results from the software were then placed into a Microsoft Excel Spreadsheet and this was used to produce the co-occurrence matrix for final analysis. Particular interest was taken in the expert systems card 7 and its co-occurrence with other cards. This would allow insight into the attitudes of podiatrists and nurses towards the use of computer expert systems in hospital investigations and laboratory tests.

Table 16: Co-occurrence matrix of card sorts for nurses

Cards	1	2	3	4	5	6	7	8	
1		31	19	32	17	26	9	22	1
2	31		27	30	22	24	9	22	2
3	19	27		21	34	16	9	18	3
4	32	30	21		20	24	13	20	4
5	17	22	34	20		14	13	16	5
6	26	24	16	24	14		17	35	6
7	9	9	9	13	13	17		16	7
8	22	22	18	20	16	35	16		8
	1	2	3	4	5	6	7	8	

Table 17: Co-occurrence matrix of card sorts for podiatrists

Cards	1	2	3	4	5	6	7	8	
1		23	25	37	24	22	10	20	1
2	23		36	25	33	15	8	15	2
3	25	36		25	39	20	7	18	3
4	37	25	25		25	23	13	21	4
5	24	33	39	25		21	9	22	5
6	22	15	20	23	21		15	43	6
7	10	8	7	13	9	15		14	7
8	20	15	18	21	22	43	14		8
	1	2	3	4	5	6	7	8	

Table 18: Co-occurrence matrices of card sorts for nurses and podiatrists

Cards	1	2	3	4	5	6	7	8	
1		54	44	69	41	48	19	42	1
2	54		63	55	55	39	17	37	2
3	44	63		46	73	36	16	36	3
4	69	55	46		45	47	26	41	4
5	41	55	73	45		35	22	38	5
6	48	39	36	47	35		32	78	6
7	19	17	16	26	22	32		30	7
8	42	37	36	41	38	78	30		8
	1	2	3	4	5	6	7	8	

Nurse co-occurrence matrix

The highest co-occurrence of cards was between card 6 for radiology and card 8 for ultrasound and the lowest co-occurrence was between card 7 for expert system and card 3 for blood analysis

Podiatrist co-occurrence matrix

The highest co-occurrence of cards was between card 6 for radiology and card 8 for ultrasound and the lowest co-occurrence was between card 7 for expert system and card 3 for blood analysis.

Podiatrist and nurse co-occurrence matrix

It can be noted from Table 18 that card 7 for expert systems has the lowest co-occurrence with other cards.

Expert system card for nurses

Card 7, the expert system card, occurred most often with card 6 for radiology and least often with cards 1 for histology, card 2 for biochemistry and card 3 for blood analysis.

Expert system card for podiatrists

Card 7, the expert system card, occurred most often with card 6 for radiology and least often with card 3 for blood analysis.

3.7 Strengths and limitations of card sorts

Card sorts make a useful contribution in the elicitation of information about expert systems, as the respondents generated a large number of constructs from a chosen point of view with a minimum amount of time (most sessions lasted less than 45 minutes). In choosing a suitable technique to elicit information one must consider the biasing effects and misleading conclusions that are associated with experimental research. These effects have been recognised for decades and commonly attributed to the experimenter who carries out the study rather than to the investigator who designs and has the major responsibility for the study. Classic examples of the experimenter effect can be found in the literature and include personal attributes effect, the failure to follow procedure effect, the mis-recording effect, the fudging effect and the unintentional expectancy effect (Rosenthal 1966); (Rosenthal and Rosnow

1969); (Adair 1973). Theodore Barber challenged this approach by describing the important role of the investigator. He describes investigator effects as well as experimenter effects, where investigator effects include the paradigm effect, the experimental design effect, the loose procedure effect, the data analysis effect and the fudging effect (Barber 1976). The limitations of the method were that the co-occurrence matrices have the advantage of showing very clearly that there is a low co-occurrence of the expert system card with the other cards, which may imply that podiatrists and nurses see this card as different to the other cards. However, this matrix does not allow us to say how significant the difference is nor does it allow us to know whether the difference is due to the attitudes of podiatrists and nurses or to some other unknown factor. The low percentage of "don't know" responses suggests that the participants were not responding from a position of ignorance about expert systems. The participants' categorisations of diagnostic aids also provide rich evidence about the work context into which an expert system would have to fit. In order to see how podiatrists and nurses view expert systems we need to consider the constructs produced by the podiatrists and the nurses. The results show that the podiatrists produced a greater number of constructs (53) than the nurses (41) and that the podiatrists produced more categories (149) than the nurses (95). When recorded as superordinate constructs the podiatrists still produced more constructs (41) than the nurses (17). According to Rugg and McGeorge, up to 20 or more constructs might be expected when dealing with experts (Rugg and Mc George 1997). The constructs produced by both podiatrists and nurses do not refer to expert systems as separate entities. The podiatrists refer to "computer or not" and the nurses to "human versus information technology". The fact that the constructs do not single out expert systems may indicate that healthcare professionals may be willing to use them or that they are ambivalent towards their use in hospital investigations and laboratory tests. No separate superordinate constructs were produced for expert systems nor were many constructs produced about information technology. This may indicate that both podiatrists and nurses construe that expert systems could be a part of everyday testing of patients or that expert systems are so far removed from everyday testing that they do not get any form of consideration during the construing process. The podiatrists when undertaking the construing process using card sorts used a wider range of viewpoints (38) than the nurses (10) and they produced more superordinate viewpoints (12) than the nurses (3). The superordinate viewpoints show that the podiatrists and nurses generate most of their constructs from the viewpoint of occupation, then from the viewpoint of type of model used and then by the type of user.

It would appear that podiatrists produced a greater number of views during the construing process but do not consider themselves from the viewpoint of users of expert systems or in the wider sense from the viewpoint of users of information technology.

3.8 Discussion

This study produced a rich amount of information from the podiatrists and nurses on expert systems and hospital investigations and laboratory tests. Card sorts are a useful technique for eliciting information about how podiatrists and nurses construe the use of expert systems as a diagnostic aid in investigating a patient's health. The results show that podiatrists produced more constructs than nurses when undertaking a card sort and this may relate to greater expertise in the field of hospital investigations and laboratory tests. Podiatrists also produced a greater number of viewpoints during the construing process than nurses, which may indicate that podiatrists have a wider and different view of this particular domain. For both nurses and podiatrists there was a low co-occurrence of the card for expert systems with the other cards for hospital investigations and laboratory tests. This may indicate that both professional groups have a different attitude towards expert systems than they do to conventional testing. So it may be that if an expert system was constructed for podiatry the attitudes of podiatrists would mean that they would show a low uptake of the system. Podiatrists and nurses tend to generate constructs most frequently from the viewpoint of occupation but neither group viewed the sorts as users of expert systems or as users of information technology. Perhaps the knowledge and skills possessed by a podiatrist or a nurse mean that such as system may not be required or may be perceived as not being required.

3.9 Summary

It is sometimes difficult to make a diagnosis in podiatry and expert systems may help to improve the situation. Card sorts methodology may be a useful technique to explore attitudes towards the use of expert systems within a domain. Although card sorts have been widely used for decades, they have tended to be viewed as an informal technique for initial exploration. More recent work in knowledge acquisition and in requirements acquisition has changed the situation, by developing more powerful, formalised versions of card sorts.

The aim of this study was to investigate podiatrists' perceptions of and attitudes toward diagnostic aids, and in particular how podiatrists viewed expert systems. In order to investigate this, two groups of seven participants composed of podiatry lecturers and nursing lecturers were asked to sort cards containing various diagnostic aids.

The results showed that expert systems are viewed as very different in kind from the other diagnostic aids.

The knowledge and skills possessed by a podiatrist are the focus for the next chapter to see if an expert system would fit into a podiatrist's daily workload and to identify if there are any differences between novice and expert practitioners in terms of the types of knowledge used when they make a diagnosis.

Chapter 4: Clinical Reasoning

This chapter is divided in two sections. The first part outlines how the skills required by a podiatrist were identified. This was conducted to establish if an expert system would fit into a podiatrist's workload. To address this question a task analysis was conducted.

The second part identified if there were any differences between novice and expert practitioners in terms of the types of knowledge used by podiatrists when they make a diagnosis. To address this, think-aloud protocols were used as the methodology. This was conducted to investigate what type of expert system may be required for use in podiatry.

4.1 Task analysis

In order to identify the skills performed by podiatrists a task analysis was undertaken. The concept of task analysis was discussed extensively in section 2.4. The reason for this choice of technique is that a task analysis will be capable of dealing with cognitive as well as motor tasks and will illuminate the type of skills and tasks performed by a podiatrist during a treatment.

4.1.1 Location of the study

The study took place in a large NHS Community Primary Care Trust that employs podiatrists. The study was conducted in Autumn 2001.

4.1.2 Population

Two NHS podiatry clinics were observed and each clinic featured a single participant (podiatrist). A routine general clinic and a specialist hospital diabetes clinic were chosen, as this provided two different podiatric environments. This was important as it may be postulated that decision-making in a specialist setting is different from that in a more general clinic. The general podiatry practitioner held a Senior Podiatrist grade post and the specialist podiatrist was at Chief Podiatrist grade; these grades would be typical for these types of post.

4.1.3 Design

The podiatrists were informed by the author that they would be observed and timed by the author using a stopwatch for each task they were undertaking during and after patient treatment. They each treated ten patients and the tasks undertaken were written down as free text. These were later analysed for type of task and the amount of time they had spent accomplishing each task. The time spent treating patients was recorded as “on-line” time and the time between patients was recorded as “off-line” time.

4.1.4 Ethical considerations

The chair of the Local Research Ethical Committee was contacted regarding the procedure for approval for this study. Their opinion was that this study did not require Local Research Ethical Committee approval as it did not involve treating patients. This would not be true if this study were repeated today with the introduction of the Research Governance Framework (Department of Health 2001) and the subsequent changes in ethical procedures for the UK. However, every effort was made to conduct the study in an ethical manner. For example, informed consent was taken and the data produced were kept secure in a locked filing cabinet and on a password-protected computer.

4.1.5 Results

The results as a whole are presented in Tables 19 and 20 and the mean number of tasks per minute is shown in Figure 1.

Table 19: Type of tasks occurring during a specialist clinic

			Minutes into the consultation															
Type of task occurring	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18 Sum of task
Opens door	10																	10
Greets patient	9																	9
Inspects feet	5	1	1															7
Asks information	4	1	1															6
Checks medical history																		
Writes in patient record																		
Obtains gloves		1						1										2
Puts gloves on	1	1																2
Obtains instruments	2	2																4
Washes old instruments																		
Places instruments in autoclave																		
Elevates chair																		
Palpates pulses		1																1
Visual inspection of feet																		
Swabs feet																		
Obtains scalpel handle		1						1										2
Obtains nail nippers	1	2																3
Obtains instruments	1	1																2
Cuts nails	1	5	5	3	3	3	1	1										22
Files nails			1	3	3		2											9
Reduces callus			2	2	1	2	2	3	3	4	2	1						22
Applies a dressing																		
Clears away debris tray																		
Lets patient off chair														1				1
Takes record																		
Makes a phone call																		

Bar codes notes																			
Makes an appointment																			
Gives patient an appointment																			
Writes up patient record																			
Shows patient out of clinic					2				1	1		1	2	1	1	1			10
Answers the telephone																			
Washes hands										1	1								2
Uses electric file																			
Takes a cast																			
Dresses foot										1	1		1						3
Cuts out a pad				1	1	1						1	1	1					6
Applies a pad							1	1	1										3
Leaves room	1							1											2
Comes back in room		1																	1
Tests sensation with a monofilament		1																	1
Obtains X-ray form					1	1	1												3
Gives advice				1		1	2			1									5
Explains information				1															1
Probes nails		1					1												2
Sprays feet with op site												1							1
Talks to a doctor		1				1													2
Dresses a toe																			
Checks footwear			1																1
Packs up a case					1	1													2
Applies a dressing								1	1	1									3
Obtains tweezers and file		1																	1
Debrides an area		1	1	1	1														4

Table 20: Types of task occurring during a general podiatry clinic

	Minutes into the consultation																					
Type of task	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**Sum**
Opens door	10																					10
Greets patient	9																					9
Inspects feet	4	2	1																			7
Asks information	3	5	2	1				1														12
Checks medical history	6	1								1												8
Writes in patient record	1																					1
Obtains gloves	2	1	1																			4
Puts gloves on	2	1	1																			4
Obtains instruments		2	1		1																	4
Washes old instruments																						
Places instruments in autoclave																						
Elevates chair	2	2																				4
Palpates pulse			1																			1
Visual inspection of feet	1	1																				2
Swabs feet		4																				4
Obtains scalpel handle			2				1															3
Obtains nail nippers																						
Obtains instruments																						
Cuts nails	1	3	7	6	3	2	1	1														24
Files nails					2	2	2	2		1												9
Reduces callus		1	1	2	4	5	5	4	5	4	3	3	3	3	1	1	1	1				47
Applies a dressing									1													1
Clears away debris tray							1															1
Lets patient off chair							1			1	2		1						1			6
Takes record																						
Makes a phone call																						
Bar codes notes																						
Makes an appointment																						
Gives patient an appointment																						
Writes up patient record	1	1					1	1		1	2	1	2	2	1					1		14
Shows patient out of clinic												2	1								1	4

Answers the telephone																						
Washes hands																						
Uses electric file																						
Takes a cast																						
Dresses an ulcer																						
Cuts out a pad																						
Applies a pad																						
Checks medication																						
Checks info for blood count																						
Clears away debris tray																						
Cleans instruments																						
Waits for patient																						
Checks medication	1	1																				2
Checks blood count				1																		1
Waits for patient to put on socks										1	1	1										3
Cleans instruments									1	1		1										3
Waits for patient	1									1												2
Probes nails		1																				1
Talks to patient																1						1
Puts tubegauze on																	1	1				2
Gives advice								1						1	1							3
Clears a nail spike				1	1	1	1	1	1	1												7

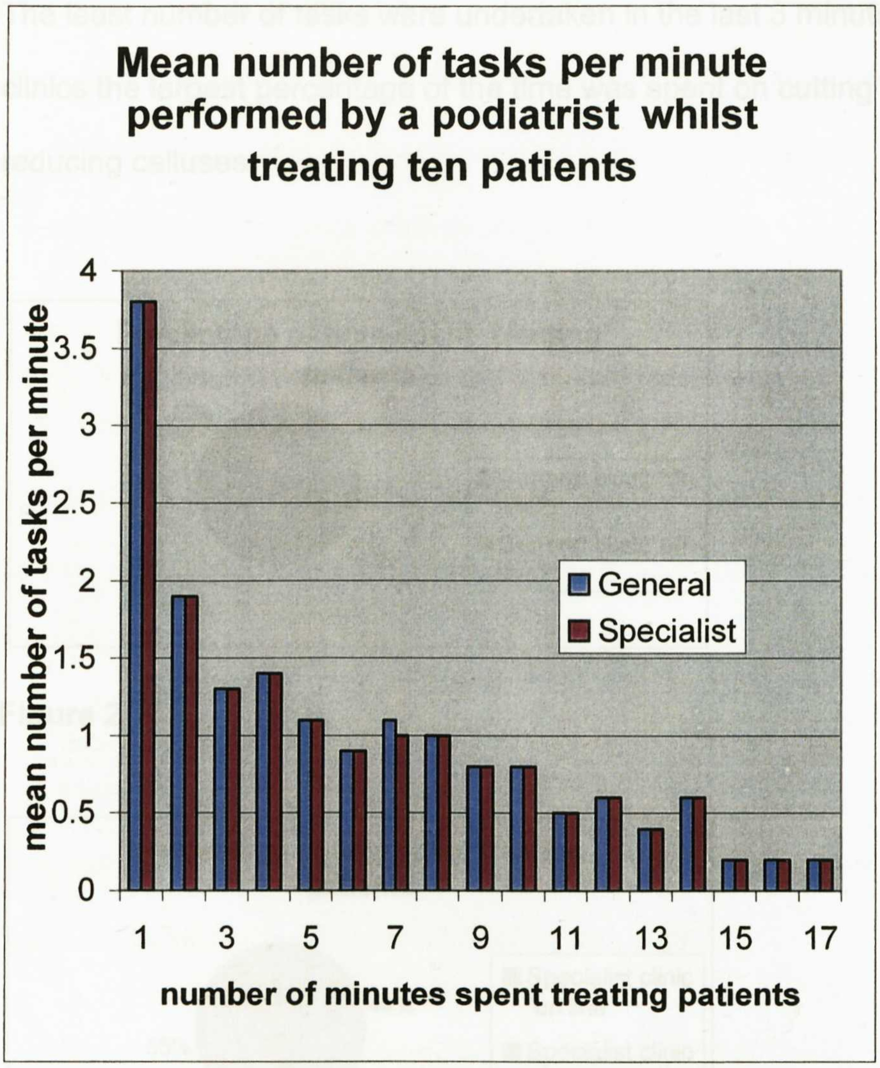


Figure 1

From the task analysis it can be seen that there is very little difference between the mean number of tasks undertaken in a general clinic and the number of tasks undertaken in a specialist diabetes clinic. All of the patients treated were given a standard podiatry appointment of 20 minutes. However, none of the patients took longer than 17 minutes for their treatment – hence the maximum number of 17 minutes shown in Figure 1. Most of the tasks were undertaken before minute 3.

The least number of tasks were undertaken in the last 3 minutes. In both clinics the largest percentage of the time was spent on cutting nails and reducing calluses.

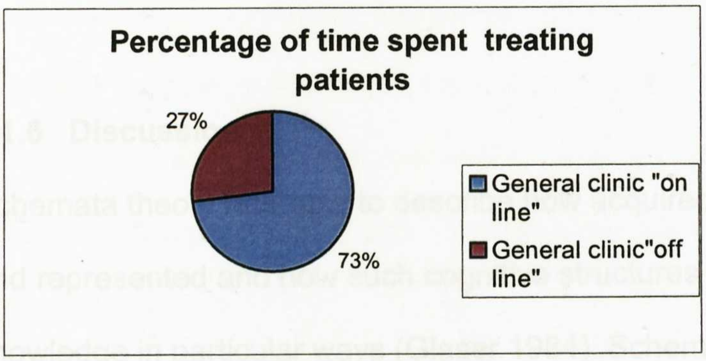


Figure 2

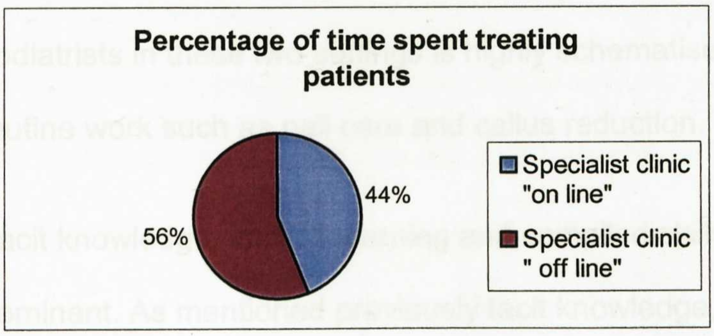


Figure 3

The results shown in Figures 2 and 3 show that 73% of time is spent "on-line" in a general clinic and 27% of the time is spent "off-line". However, in a specialist clinic a greater proportion of time is spent "off-line" – 56% compared with 44% "on-line". The "off-line" time in the diabetes clinic included tasks such as making appointments for patients, writing letters, liaising with other healthcare workers about the patient they had just seen and preparing the clinic for the next patient. The "off-line" time in the general clinic included making appointments for patients, but a very large part of the time was writing in the patient case notes and preparing the clinic for the next patient. Much less time in the general clinic was spent in liaising with other healthcare professionals and on tasks such as the writing of letters.

4.1.6 Discussion

Schemata theory attempts to describe how acquired knowledge is organised and represented and how such cognitive structures facilitate the use of knowledge in particular ways (Glaser 1984). Schemata theory is very applicable in this situation, as a result of the high number of tasks occurring in the first minutes of treatment. The result indicated that the work undertaken by podiatrists in these two settings is highly schematised as much of it involves routine work such as nail care and callus reduction.

Tacit knowledge, implicit learning and compiled skills are also likely to be dominant. As mentioned previously tacit knowledge, which is not available to conscious introspection, can be subdivided into implicit learning (Seger 1994) and compiled skills (Anderson 1990). Tacit knowledge may include a significant amount of pattern matching, which is very fast, e.g. it occurs when recognising a human familiar face. A result from research into expertise was the extent to which experts use matching, against a huge learned set of previous instances, rather than sequential logic as a way of operating (Chi, Glaser et al. 1989). Implicit learning according to Seger (1994) is non-episodic learning of complex information in an incidental manner, without awareness of what has been learned. Implicit learning may require a certain minimal amount of attention and may depend on attentional and working memory mechanisms. Seger (1994) feels that the result of implicit learning is implicit knowledge in the form of abstract representations rather than verbatim or aggregate representations. Learning proceeds straight from the training set of large numbers of examples into the brain without any intermediate conscious cognitive processes. Compiled skills were initially learned explicitly but subsequently became habitualised and speeded up to the point where the conscious component was lost. Examples include touch-typing and changing gear in a car.

In relation to the task analysis implicit learning may account for a large number of skills occurring during the first few minutes of a treatment as the podiatrist may have become habitualised to the tasks that occur during those first few minutes. Towards the end of the treatment time the tasks mainly involve padding of the foot and showing the patient out of the clinic.

4.1.7 Summary

The main objective of the first section of chapter 4 was to investigate the type of clinical reasoning skills and knowledge required when podiatrists in different clinical environments undertake podiatry treatment, in order to investigate the type of expert system that may be required in podiatry.

In order to compare podiatrists, two podiatrists were observed. One was a general podiatrist and the other specialised in diabetes. Each clinical task undertaken by the podiatrists was recorded and timed during and after patient treatment.

The results showed there was very little difference between the number of tasks per minute undertaken in a general clinic and in a specialist diabetes clinic.

The conclusion for this study was that podiatrists in both a generalist setting and a specialist setting accomplish similar tasks during the treatment of a patient. As a result of the speed of treatment it is postulated that both podiatrists use schemata, pattern matching and tacit and implicit knowledge and this dominates their diagnostic activity during consultations.

Given the findings from the task analysis it was necessary to investigate how clinical reasoning and decision-making occurs during the treatment of a podiatry patient. This required the selection of a suitable methodology. This is the focus for the next study that used think-aloud protocols.

4.2 Think-aloud protocols

4.2.1 Introduction

In typical think-aloud protocols participants are presented with a clinical case, which may be a real patient or may be written. Written material could range from a sentence to case notes or laboratory findings. The participant is asked to read the information and verbalise whatever thoughts come into mind. These are audio-taped and are then subjected to an analysis aimed at uncovering the cognitive processes and the information used.

4.2.2 Design

The study was divided into two parts: part A to look at differences between experts and novices in a general podiatry setting, and part B to extend this to investigate differences between experts in specialist podiatric areas.

The first investigation (A) was conducted in general NHS podiatry clinics around Northamptonshire. The second investigation (B) involved two long-standing specialist areas in podiatry, namely biomechanics and surgery, as these require additional expertise beyond that possessed at undergraduate level. These studies were conducted in specialist NHS clinics in Northamptonshire.

The methodology for the two studies is described below.

4.2.3 Population

The participants for study A were five experts who were placement instructors for the Northampton School of Podiatry and nine novices who were year 2 and year 3 students from the same school.

The participants for study B were three experienced podiatrists who specialise in biomechanics and three experienced podiatrists who specialise in surgery. These were podiatrists who have a role in instructing students at the Northampton School of Podiatry in biomechanics and surgery so were experts in their field. They observed a combined total of 43 patients attending clinics for biomechanics and surgery at a large general hospital.

For study A, a condition of the lower limb was selected from one of the patients who attended the clinic. A novice who was a second-year student in podiatry was then asked to make a diagnosis of the selected condition and to think aloud as he/she made his/her diagnosis, which was recorded onto audio-tape. The expert, a placement instructor for the Northampton School of Podiatry, who could not hear the diagnosis made by the novice, was then asked to enter the clinic and to repeat the task again with the same patient. This was repeated for all the novices and all the experts.

For study B a condition of the foot was selected by the author. The experts in biomechanics were asked to think aloud as they made a diagnosis of biomechanical conditions and the experts in surgery were asked to think aloud as they made diagnoses of surgical conditions. These were recorded onto audio-tape and were later analysed for content. The transcriptions can be found in Appendix B (B.1 for the surgeons and B.2 biomechanists).

4.2.4 Ethical considerations

For study A Local Research Ethical Committee (LREC) approval 03/16 was given by Northampton Medical Research/Ethics Committee on 17th March 2003. For study B LREC approval 03/16 was given by Leicester Two LREC on 31st October 2003. (Letter of approval attached at the end of the thesis)

4.2.5 Analysis

The term NVivo is derived from "*in vivo*" and has its roots in grounded theory (Glaser and Strauss 1967). It refers to the use of words (themes) taken directly from a participant in a setting to name entities known as nodes.

Themes in NVivo are defined by Gibbs (Gibbs 2002) as a set of ideas or concepts derived either from prior theory or from respondents' lived experience which can be used to establish a set of nodes at which text (themes) can be coded. A node is defined by Gibbs (Gibbs 2002) as an object that represents an idea, theory, dimension, characteristic of the data. Gibbs provides the following example of how a node arises. He states that participants may use the term "at my age" to refer to the idea that they found age a problem in getting a job; "at my age" can then be used as the name of a node.

This method of analysis was used for both study A and study B. The audio-tape recordings produced by the podiatrists were transcribed into written text. Then using a grounded theory approach (Glaser and Strauss 1967) themes emerging out of the written text were used to produced nodes that represented a mechanism for making a diagnosis.

4.2.6 Results

Study A

The transcripts were analysed using NVivo for common themes for clinical reasoning in podiatry. Below are the themes that were produced with some examples of the audio-tape recordings produced by the podiatrists.

- Visual cues

"We are looking at a lady's – er – left foot and we can see a marked hallux valgus deformity – em – with dorsal osteophytic lipping and some redness on the medial aspect – em – of the lesion, of the deformity. – em – I can see this deformity because it is there."

- Touch

"Dorsal bony exostosis. I am making that diagnosis because it's hard on palpation as opposed to a bursa. Treatment options would be conservative as in shoe stretch or dorsal balloon patch."

- Questions for the patients

"Looks quite swollen, looks like oedema around both ankles." Asks the patient a question: "Does the swelling go down in a morning or is it there all the time?"

- Diagnostic statement by podiatrist

"This might be due to a prominent sub second MPJt – em – possibly due to the slightly retracted second toe leading to pressure and perhaps also footwear not cushioning the area enough from pain from a prominent joint."

The clinical reasoning that was used most often was visual cues. This type of cue involves mechanisms such as pattern recognition. Only one expert used touch and three experts asked questions of the patient before making a diagnosis. Using the same methodology the exercise was repeated for the novices.

The contents of the transcripts were analysed for common diagnostic themes using NVivo. Below are the themes that emerged for the novices with some examples of the audio-tape recordings.

- Visual cue

"Em – I would call, say, that this condition is a hallux valgus or hallux abductovalgus – em – because there is a bony prominence. – em – The hallux – em – is abducted away from the midline of the body – em – Its

underriding the second toe – em – There is a little redness over the bony prominence and that is about it."

- Touch cue

"I would describe this area – er – under the first metatarsal phalangeal joint as an area of callus. I would say that because – er – the area is slightly – er – raised – em – the area feels harder than the rest of the skin. So the difference in texture, and its very slightly – er – discoloured too, a sort of yellow coloration as opposed to the rest of the skin which is quite pink."

- Questions for the patient

"Mrs X has swelling oedema on both ankles – em." Asks patient a question: "Do you have heart problems?" Patient: "I have had a bypass, yes." Podiatrist: "You've had a bypass, yes, I can see the scar up here." Podiatrist: "Are you on diuretics?" Patient: "No." Patient: "That was caused by an accident." Podiatrist: "The swelling?" Patient: "The swelling?" Podiatrist: "Yes." Podiatrist: "– em – High arch profile suggesting, I do not know, I would like to see Mrs X standing before I would know if there is talo navicular bulging."

- Diagnostic statement by podiatrist

"I would describe this as haemosiderosis. The patient is on Warfarin, has had heart problems, probably had oedema, which has affected this particular patient." (61)

Again the theme that was used most often was visual cue with one novice using touch and two novices asking questions to the patient before making a diagnosis.

Study B

The analysis proceeded as in the previous study. All of the transcripts were analysed for common clinical reasoning and coded to nodes within NVivo. A common pattern appeared at the nodes whereby the biomechanics experts and surgeons produced nine identical nodes.

Below are the themes with some examples of the audio-tape recordings.

- Visual cue

"Let's have a look at the shoulders – seems low on right with activity, knees straight ahead, feet abducted, narrow base of gait, toes gripping the ground, overuse of extensors."

- Touch cue

"The osteophytes are dorsally rather than medially and she has got severe restriction of movement. Certainly on the X-ray it shows no joint space at all."

- Questions for the patient

"Is it sharp or stabbing very sharp? "It's very sharp. It's not an aching pain." "And then it is gone?"

- Diagnostic statement by podiatrist

Put your feet together. There is some tibial varum and the post tibial tendon can add to the high foot posture index we are getting. His father is also hypermobile. We do find it runs in families.

- Examination of the patient

"We need to check the lateral and medial collateral ligaments, and cruciates."

- General statement by podiatrist

"It is shearing stress."

- Results of patient examination

"The lateral collateral ligament off the knee seems OK."

- Statement by patient

"A couple of years ago I felt something go in my foot – thought it was a sprain. It interrupts my work."

- Treatment aim

"We need to try some temporary devices so I will build them up a little."

4.2.7 Discussion

From the think-aloud protocols it would appear that the podiatrists rely on schemata and tacit knowledge as many of the themes involved many visual cues. Polyani (Polyani 1967) coined the term tacit knowledge and described it as the stock of professional knowledge that experts have that is not processed in a focused cognitive manner but rather lies on a not quite conscious level where the knowledge is accessible through acting, judging and performing. It is the type of knowledge gained through experience, sometimes referred to as what we know but cannot tell. Tacit knowledge means an expert can act quickly and do what is required, or act before they think. It is not mindless action but is simply expertise that does not have to be processed before lengthier channels of cognition.

Researchers have acknowledged the importance of schemata and have found that they are particularly valuable in that they provide background knowledge. Noting the rapid speed of diagnosis and the general lack of causal assertions, podiatrists, both expert and novice, seem to arrive at a diagnosis by a process involving schemata and tacit knowledge. The themes produced by experts and novices in a general setting appear to be the same and indicate that pattern recognition is a very common method through which a diagnosis is made.

However, further analysis of the data for the biomechanists and surgeons produced nine common themes for clinical reasoning that occurred when three experts in each area of podiatric biomechanics and podiatric surgery made a diagnosis. Some of the themes were common to experts in a generalist setting and in a specialist setting. However, for experts in a specialist setting additional themes emerged. These extra themes were examination of the patient, general statement by the podiatrist, results of patient examination, statement by patient and treatment aim.

These results suggest that experts within specialist areas of podiatry choose or are required to examine the patient for a longer period of time as the conditions manifested are more complex. Another explanation is that they simply have longer appointments and more time to spend with the patient and therefore more time for examination. The experts in a specialist setting may also be in a better position to request hospital investigations and laboratory tests and use these as an aid to clinical reasoning and diagnosis. This is not an easy task to accomplish in a community setting where the podiatrist often has to request tests via the patient's general practitioner which may take time or may not be sanctioned by the general practitioner.

The experts within the specialism may also have a sophisticated level of categorisation and may be more specialised at integrating propositional knowledge, experience-based knowledge and craft skills. These expert specialists may wish to ask questions of the podiatrists to reduce the problem space and to aid the production of a diagnosis.

The experts in a specialist setting reflect on the treatment aims more than those in a generalist setting. This may be a method for the expert specialists to suggest a treatment to the patient based on their diagnosis as the specialist treatment may be more complex than those in a generalist setting. The expert generalists may not need as much information as the treatments are more obvious. This is consistent with the work of Schön (Schon 1987) who highlighted the value of reflection-in-action in raising the awareness of tacit knowledge. An example of reflection-in-action is Titchen's study of nurses (Titchen 1998) which demonstrated that having an expert nurse working alongside a novice nurse engaged the latter in critical reflection. This may be an interesting concept to investigate for podiatrists. Eraut (Eraut 1994) felt reflection was a very important concept during experiential learning to transform knowing-in-action into knowledge-in-action.

The expert specialist podiatrists may activate many ready-made illness scripts (Feltovich and Barrows 1984) that organise many enabling conditions and consequences associated with a specific disease. Activation will be triggered by these enabling conditions and consequences. This is a process that is generally automatic and "unconscious" and occurs as long as the new information from a patient matches an active illness script. If this process does not happen then active clinical reasoning may occur via a different clinical reasoning mechanism, e.g. the hypothetic-deductive approach (Feltovich and Barrows 1984) . This reasoning approach involves the generation of hypotheses based on clinical data and knowledge. This involves inductive reasoning moving from a set of specific observations to a generalisation and deductive reasoning moving from a generalisation to a conclusion in relation to a specific test (Ridderikhoff 1989).

From the speed of the diagnosis made by both expert and novice podiatrists this process was not readily identifiable from this study but it may be an area for further investigation.

It could also be postulated that the expert specialist podiatrists may also utilise professional craft knowledge (Brown and McIntyre 1993) in generating more clinical reasoning themes than novice and expert generalist podiatrists. This term incorporates the notion of clinical intuitive knowledge or professional judgement and this may be more readily available to the expert specialists.

The process of using think-aloud protocols has some limitations. The process of thinking out aloud may have slowed down the cognitive process of the podiatrists. Second, there may have been a "Hawthorne effect" (Mayo 1933) as the podiatrists were being observed which could have influenced the tasks performed. Both of these may have had an effect on the results.

In conclusion, this study has suggested methods for clinical reasoning by experts and novices in a general setting and experts in a specialist setting. Some of the themes used in clinical reasoning are common to experts in general podiatry practice and specialist podiatry practice. All of the generalist themes were used by the specialists. However, there was an increase in the number of themes used by experts in a specialist setting compared with a general setting.

Considering the speed of diagnosis, it is postulated that both expert and novice podiatrists' use of schemata, pattern matching, and tacit and implicit knowledge dominates their diagnostic activity during consultations.
The expert specialist podiatrists may have produced more clinical reasoning themes than the novices because of processes such as reflection-in-action, illness scripts and professional craft knowledge.

4.2.8 Summary

The aim of the final section of chapter 4 was to investigate clinical reasoning in podiatry in both expert and novice podiatrists.

In order to achieve this, think-aloud protocols were used to investigate the clinical reasoning of expert and novice podiatrists in general and specialist clinics. The think-aloud protocols were later analysed for content and themes.

The speed of diagnosis and general lack of causal assertions suggest that use of schemata and tacit knowledge dominate the diagnosis process for *both* expert and novices. *In a general setting*, both experts and novices produced the same four common clinical reasoning themes. These indicate that pattern recognition is a common method of diagnosis. There is an increase in the number of clinical reasoning themes used by experts *in a specialist setting*, indicating novice–expert differences

However, it is still not apparent why these particular themes are used for clinical reasoning and this is investigated in chapter 5.

Chapter 5: Interviews

5.1 Introduction

In chapter 4, think-aloud protocols were used to investigate clinical reasoning in expert and novice podiatrists in general podiatry practice and in experts within two specialist areas in podiatry. The results from these think-aloud protocols for the expert and novices in general practice showed that the following types of clinical reasoning are used when they make a clinical diagnosis.

- Visual cue
- Touch cue
- Questions for the patient
- Diagnostic statement by podiatrist

These methods were also used by experts in the two specialist areas of surgery and biomechanics but in addition the study using the specialist expert podiatrists revealed the following.

- Examination of the patient
- General statement by podiatrist
- Statement by patient
- Treatment aim

This chapter explores the process of clinical reasoning by podiatrists and why certain mechanisms tend to be favoured by them in making a diagnosis. The findings from this study will contribute to the overall research question of whether expert systems would be of value in podiatry. Establishing or understanding the methods of clinical reasoning could identify whether an expert system is required for use in podiatry and the type of system that should be built. The findings would identify the type of knowledge that should be represented in the system, and whether it should have many visual cues such as pictures or be based on the type of knowledge a podiatrist gains from touch.

In order to investigate these aspects the technique of laddering was used and is described below.

5.2 Laddering technique

According to Wansink (Wansink 2003) laddering allows one to gain access to people's structures, beliefs and values that cannot be obtained from semi-structured interviews or questionnaires as the technique assesses deeper reasons for people's actions. Laddering is a well-established technique first developed by Hinckle (1965). It originated in clinical psychology and personality theory, specifically in Kelly's (1955) personal construct theory. A central tenet of personal construct theory is that all human activity can be seen as the process of trying to anticipate future events, and a set of components called constructs are used to help make these predictions. The laddering technique developed by Hinckle allows the direct elicitation of progressively higher order constructs (Fransella and Bannister 1977), thus allowing for investigations of more global aspects of the respondent's construct system. Within the personal construct theory framework, laddering has been viewed as an adjunct to the better-known technique of repertory grid. It is particularly suitable for investigating respondents' goals and motivations in a structured, systematic manner that should fit well with a typical structured survey. According to Reynolds and Gutman (1988) it is being increasingly used in a variety of fields, ranging from requirements engineering to market research. Reynolds and Gutman used laddering to examine consumers' overall value structures. Laddering appears superficially to be similar to a structured interview, but it is draws on several literatures, such as graph theory and facet theory, to provide a much richer knowledge representation than is possible using structured interviews.

There are some limitations to the use of laddering. For example, laddering assumes that the respondent's knowledge is organised as a polyhierarchy, i.e. a multidimensional set of hierarchies, and that the knowledge is categorical, i.e. nominal values arranged in categories. This was not thought to be a concern for this study.

A good explanation and a practical use of laddering are provided by Wansink (2003). He describes laddering as similar to the classical picture of a psychologist interviewing a patient on a couch, revealing insights into their lives that are not immediately apparent. The psychologist tries to get to the root of the problem through questioning. Wansink (2003) used laddering to investigate why consumers choose particular brands to purchase. Building on the work of Reynolds and Gutman (1988), he suggests that laddering uses a series of progressive questions that allow an interviewer to understand how a product's attributes, the consequences of using it, and the personal values it satisfies are linked together. This builds into a hierarchical value map, in which the attributes describe the physical properties of the product and the consequences are the outcomes, derived from attributes, which the customer associates with use of the product. Values are derived from associations between consequences and personal values and are frequently deep emotional needs; they often represent the real reason why people buy high equity brands.

Wansink (2003) mentions that attributes only scratch the surface of why people buy certain products but from these attributes the interviewer can begin to move towards the values behind these purchases through probing "why" questions. It is then that the consumer reveals personal reflections that are one step closer to finding the personal values people had that drove the purchase. Often many consequences are revealed by a consumer about a purchase they have made but value statements may only be revealed after two questions or as many as 20 questions.

Wansink states on page 114:

"The object of a laddering interview is to uncover how product attributes, usage, consequences, and personal values are linked in a person's mind. Doing so will help create a meaningful mental map of the consumer's view towards the target product and by combining the maps of similar consumers a large, more exhaustive map can be developed."

5.3 Methods

Laddering was used in this study on clinical reasoning to find the root reason why podiatrists use certain methods of clinical reasoning to make a diagnosis. Initial seed questions were used to identify the process of clinical reasoning and were followed by two "why" probe questions, to establish the consequences for that reasoning. The reason for restricting the number of "why" questions to two is given in the next section.

5.4 Ethical considerations

Any research involving NHS staff must be approved by an NHS Ethics Committee before it can proceed. The protocol for this study was submitted to Leicester Two Local Research Ethics Committee who required that it had approval from a Multi Research Ethics Committee as podiatrists were being questioned across the UK. As a condition of approval the Multi Research Ethics Committee requested that only questions directly related to the research question were asked. They also requested that people's values were not elicited as these values were not adding to the information on clinical reasoning. So for ethical reasons the laddering process had to stop after two "why" probe questions. This was adequate for this study as the aim of the laddering process was to focus on reasoning and not to intrude into people's personal values.

Permission for the study was granted on 25th November 2004, MREC ref number 04/Q2502/79. (Letter of approval attached at the end of the thesis)

5.5 Population

Sampling frame

The sampling frame used was a freely available, public domain database of the Society of Chiropodists and Podiatrists that provides the names and contact details of practising members of the Society of Chiropodists and Podiatrists. The participants were a mixture of NHS and private podiatry practitioners selected from this frame, as described below.

Sample

Every tenth member from the Society of Chiropodists database was selected to participate in the study. Each participant identified through this process was written to with full details of the study and asked for their consent to be contacted to participate in a telephone interview using laddering. If they gave their consent then they were entered into the study in order of reply. After ten participants had been interviewed a similar pattern of response was found to emerge, indicating that saturation of data had occurred. A further two interviews were then conducted. As these revealed no further new information, the sampling was concluded, giving a total sample of twelve participants.

5.6 Design

The survey involved a short list of prepared questions for respondents based on some of the findings about clinical reasoning from chapter 4.

As previously mentioned the laddering used in this study could not proceed beyond two "why" probes in order not to enter into people's personal values. For these reasons five questions and one further question about computer-aided diagnosis were formulated. After each answer to the short list of prepared questions, laddering was used to elicit the respondent's higher-level goals and values relating to that question. The questions can be found in Appendix C (C.1).

Procedure

Each podiatrist was interviewed by telephone and the information was recorded on audio-tape. Before asking the questions each podiatrist was read a statement to ensure that they were given consistent information. A copy can be found in Appendix C (C.1).

After the frame was read to each participant they were asked the six seed questions as shown in Appendix C.

5.7 Analysis

Each question was analysed using a similar method to that used in a study by Wansink (2003). This aimed to produce an initial response to each of the six questions from each podiatrist followed by two levels of consequences for that response. An example of this table can be found in Appendix C.

This produced a hierarchical value map as to why the podiatrists used certain strategies to produce a diagnosis in podiatry.

A content analysis of the participants response was undertaken to produce what Wansink (2003) refers to as the key laddering insights. An example of the key laddering insights can be found in Appendix C.

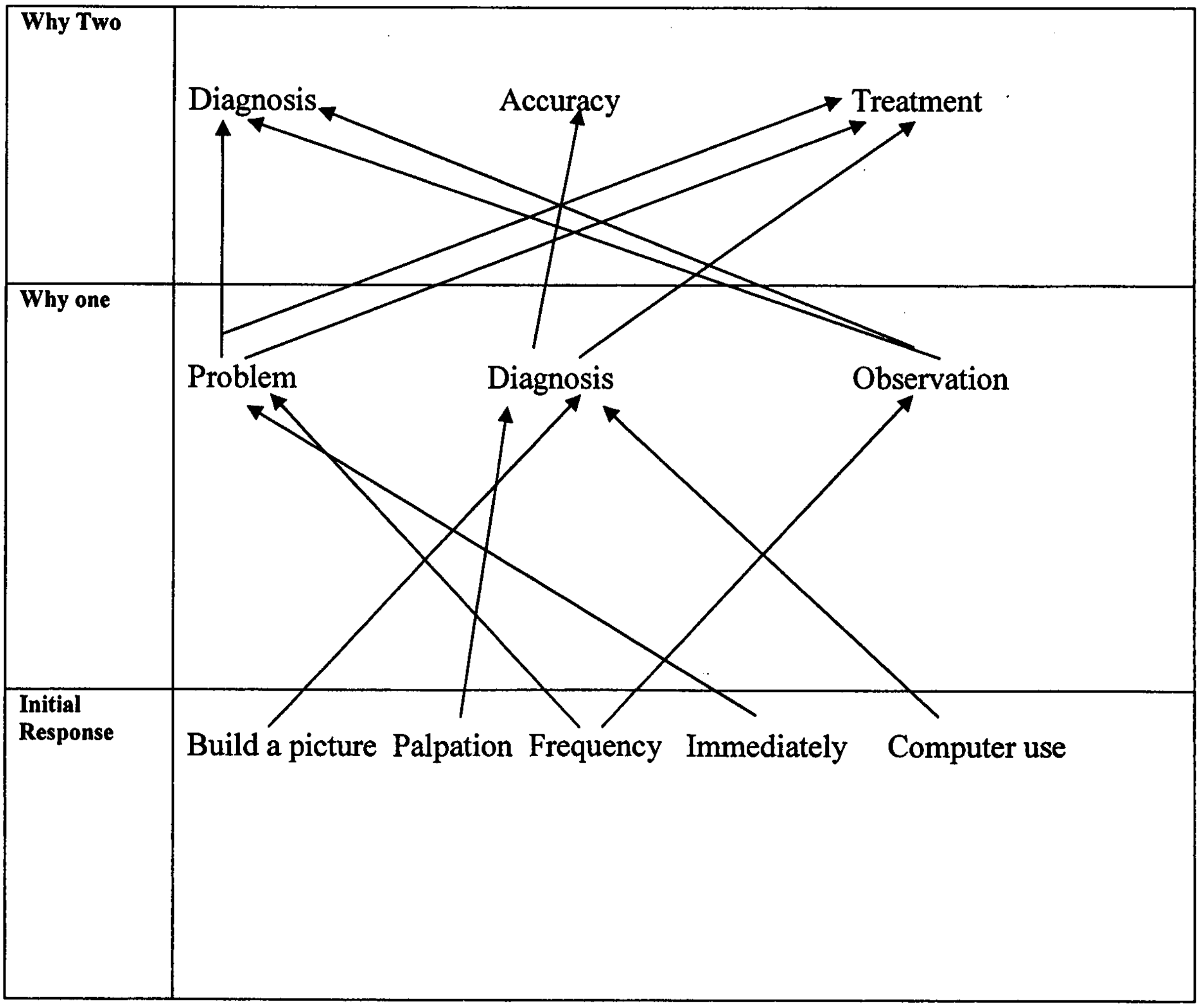
This procedure was followed for all the podiatrists. An example of the procedure for nine podiatrists is shown in Appendix C.

The most common themes from these key laddering insights were then used to produce a hierarchical attributes–consequences table for question 1. An example can be found in Appendix C. The same procedure was followed for all six questions.

5.8 Results

The responses were collated to produce a hierarchical value map for the six questions on clinical reasoning asked of the twelve podiatrists.

Table 21: Hierarchical value map for clinical reasoning for twelve podiatrists



The information provided at each level of the table was generated from the most frequently occurring key laddering insights across the twelve podiatrists.

The hierarchical value map is a graphical description of the laddering interviews and is used to view the relationship between the initial response and the two "why" probes across all twelve podiatrists. It shows how the podiatrists being interviewed "climb the ladder" of clinical reasoning and depicts the root reasons for using the mechanisms of clinical reasoning found in the previous study.

At an initial response level certain values were important: the palpation of the foot, building a picture of a foot condition and being able to use clinical reasoning frequently and immediately.

At "why one" level other values become important: the value of observation of a foot condition and knowing about the problem with a foot in order to formulate a diagnosis.

At "why two" level accuracy of the diagnosis was a very important value as from this the podiatrists could start to formulate a treatment plan.

The results of the hierarchical value map must be interpreted in response to the laddering questions asked of the podiatrists. These questions were asked as they were the themes identified from chapter 4 as being frequently used when podiatrists make diagnoses.

Although these themes are mentioned earlier they are repeated here for ease of interpretation of the results. The clinical reasoning themes were:

- Visual signs of the foot
- Questions asked of the patient
- The podiatrist's own sense of touch
- What the patient tells the podiatrist
- Physically examine the patient
- When a podiatrist envisages using a computer

In response to laddering from these themes the hierarchical value map shows there to be five basic core values at the heart of the podiatrist's clinical reasoning process produced as a response to the laddering.

The frequency and immediacy of when the reasoning themes were used were confirmed by examples from three of the participants in the study as being the following: participant one, "*Er – all the time*"; participant two, "*When I have the patient in front of me*"; participant three, "*A lot of things*".

Palpation of the foot is a very important value for podiatrists. The reasons for which are illustrated by the following examples: participant four, "*Looking for ranges of motion etc.*"; participant five, "*Abnormality, feeling for pulses – em – for example a swelling, how does it feel under pressure – er – is it for example fluctuant or hard – it might be a bony abnormality*"; participant six, "*Palpating pulses to see if they have ischaemia or not*".

Podiatrists are not familiar with using computer technology in relation to their practice. Participant seven stated:

"A computer? My answer to that can only be a guess. I do not use a computer at the moment during a diagnosis, especially while the patient is with me during the appointment – my imagination could run wild. Em – I can give an example to record patient data or information from a population."

At the next value level in the hierachical value map the themes are used to investigate the problem with the foot. Participants reported that they do this to *"assess the vascular status"*, *"in order to ascertain the problem"*. And *"– em – it is the first test you do to determine ischaemia and then on to Doppler if you cannot feel their pulses."*

A similar set of responses was built for each question.

5.9 Discussion

According to Durkin (1994) computer expert systems are typically intended to tackle problems that would normally require a human expert such as a doctor or a geologist. Typical applications for expert systems include domains where problems need to be solved quickly, and where there are problems with availability of human experts – a classic example is drilling problems on North Sea oil rigs, where delays cost large amounts of money and where there can be severe logistical problems in getting human experts onto the rig.

Expert systems according to Jackson (Jackson 1999) solve problems by heuristics commonly known as "rules of thumb" which encode pieces of knowledge about how to solve a problem in a domain. He also states that there are problems of constructing an expert system based on personal experience rather than formal training, namely it is much more difficult than eliciting either particular facts or general principles. He states that problems that can be solved by the enumeration of associations between observable patterns of data and classes of events are well suited to expert systems. For example, operational problems in engineering systems, such as heating or air conditioning, can be monitored and diagnosed by rule-based expert systems. Problems in the construction industry or computer industry which require a skeletal plan lend themselves to expert systems; an example of this from the computer industry is R1. This is a program that configured VAX computer systems by checking the spatial arrangement of components.

So, from this study, are computer expert systems going to benefit podiatrists in aiding their clinical reasoning and their diagnosis?

From the hierarchical value map, at an initial response level to the laddering questions, certain values were important: the palpation of the foot, building a picture of the foot condition, and being able to use clinical reasoning frequently and immediately. At "why one" level the value of observation and knowing about the problem were important values and at "why two"level the accuracy of the diagnosis and formulation of a treatment plan became important. The emphasis on palpation and immediacy of clinical reasoning suggests that the podiatrists may be using tacit knowledge and schemata. A major advantage for practitioners is that tacit knowledge can normally be used much more swiftly than non-tacit knowledge.

Schemata are a related way of organising knowledge into predefined patterns. This type of knowledge was first identified by Bartlett (1961). Subsequent workers (Sowa 1984) have acknowledged the importance of schemata and have found that they are particularly valuable in that they provide background knowledge, often tacit knowledge, which helps people interpret new information. New events are labelled "instantiations" of the schemata. As new instances are interpreted, the prior knowledge constructions or schemata are tested. Like tacit knowledge, schemata have the advantage of speed in problem-solving, because they make use of pre-existing knowledge rather than tackling each case from scratch.

The emphasis on palpation, observation and immediacy of clinical reasoning suggests that an expert system is unlikely to serve podiatrists' needs in clinics. Tacit knowledge, schemata, observations and palpation are not mechanisms of clinical reasoning that are best supported by an expert system, because they involve feel and personal interpretation, not heuristics or patterns of data. Tacit knowledge and schemata are usually deployed very swiftly – normally a matter of seconds. Similarly, observation involves visual pattern matching, which human beings can do easily but which is difficult for software to process. The same principle applies to palpation. The end result is that the mechanisms which podiatrists prefer to use in diagnosis are normally so swift that an expert system would not offer any savings in time; they also depend on sensory data (visual pattern recognition and tactile information) of types which expert systems have difficulty in processing.

According to Curran and Jagger (1997) accuracy of diagnoses made by podiatrists could be improved by a computer expert system. Their study focused on podiatrists making diagnoses from photographs of conditions. That study, however, focused on the scope for improving error rates in ideal conditions, rather than on the practical issues involved in providing appropriate support to the practitioner in the workplace. The results of the present study suggest that, although there is room for improvement in diagnosis, computer expert systems are not the optimum type of technology to support podiatrists in clinical reasoning and making a diagnosis.

5.10 Summary

The clinical reasoning themes produced in a previous study were used for laddering interviews on a sample of twelve podiatrists to investigate their clinical reasoning skills, to see whether a computer expert system could aid diagnosis in podiatry.

Laddering interviews with these podiatrists led to the production of a hierarchical value map for clinical reasoning in podiatry. From this hierarchical value map it would appear that podiatrists rely on tacit knowledge and schemata as mechanisms of clinical reasoning. These mechanisms are not well suited for software systems, and therefore computer expert systems may not be the best technology to support podiatrists in clinical reasoning and diagnosis.

Chapter 6: Discussion, Conclusions and Recommendations

6.1 Introduction

This chapter is a discussion of the studies undertaken during this thesis and commences by reiterating the research question and giving a brief explanation of the results and conclusions. This will be followed by outlining any limitations of the studies and a discussion on the wider implications of the findings to podiatry, with recommendations for future work. Finally the contribution to knowledge generated through this thesis will be stated.

The overarching question for this research was: investigate the clinical decision-making processes used in podiatry and hence investigate if a computer expert system could aid the process of clinical decision-making.

The initial study investigated podiatrists' perceptions of and attitude toward diagnostic aids, and in particular how podiatrists viewed expert systems. The results showed that expert systems are perceived as different in kind from other diagnostic aids such as X-rays or blood tests.

The second study asked the following question: would an expert system fit into a podiatrist's workload?

The second study used a task analysis to investigate the types of tasks undertaken by a podiatrist and the skills required during the diagnosis of a patient in different clinical environments. The results indicate that the work is highly schematised and involves routine tasks such as nail care and callus reduction. In clinic, podiatrists perform many tasks quickly. There was little difference between the number of tasks per minute undertaken in a general clinic and the number undertaken in a specialised diabetes clinic. Considering the speed of diagnosis, it is postulated that both expert and novice podiatrists' use of schemata, pattern matching, and tacit and implicit knowledge dominates their diagnostic activity during consultations.

Tacit knowledge and schemata are usually deployed very swiftly – normally in a matter of seconds. Similarly, observation involves visual pattern matching, which human beings can do easily but which is difficult for software to process. The end result of this is that the mechanisms which podiatrists prefer to use in diagnosis are normally so swift that an expert system would not offer any savings in time; they also depend on sensory data (visual pattern recognition and tactile information) of types which expert systems have difficulty in processing.

The third study asked the following question: is there a difference in the clinical reasoning process between expert and novice podiatrists?

The third study focused on how clinical reasoning and decision-making occur during consultations with a patient. Think-aloud protocols were used to investigate the differences in the clinical reasoning process between expert and novice podiatrists. The speed of diagnosis and general lack of causal reasoning suggest that the use of schemata and tacit knowledge dominates the diagnosis process for both experts and novices. In a *general setting*, novices produced four common clinical reasoning themes. These indicate that pattern recognition is a common method of diagnosis. There is an increase in the number of clinical reasoning themes used by experts in a *specialist setting*, indicating novice–expert differences.

The final study investigated the following: the values of clinical reasoning used by podiatrists.

The final study used laddering interviews to investigate why podiatrists used certain clinical reasoning themes. A hierarchical value map was derived, showing that, at an initial response level to the laddering questions, certain values were important: the palpation of the foot, building a picture of the foot condition, and being able to use clinical reasoning frequently and immediately. The emphasis on palpation and immediacy of reasoning suggest that an expert system is unlikely to serve podiatrists' needs in clinics.

6.2 Limitations of the studies

In the initial study the experts were university lecturers in podiatry. It was taken for granted that they were experts by virtue of their role in teaching. However, Marasovic *et al.* (1997) showed that age, nursing experience and education were factors that had a positive influence on the desire to use computers in a critical care environment. Although this environment is different to podiatry, no attempt was made to control for these factors in the card sorts study. Future work may wish to achieve this when selecting the participants for a study.

In the second study two different podiatrists in two different clinics were observed whilst seeing only ten cases. It may be that if the podiatrists in the diabetes clinic were swapped into the general clinic they may still spend more time "off-line". This may be an individual trait rather than a clinic setting driven task difference. Future studies may wish to control for these factors and it would be interesting to see the result.

In the third study the process of thinking out aloud may have slowed down the cognitive process of the podiatrists, so there is a possibility that this may have had an effect on the result. The fact that the podiatrists were being observed, the "Hawthorne effect" (Mayo 1933), may have influenced what tasks the podiatrists achieved and may have had an effect on the result. Future study designs may wish to control for these factors.

6.3 Discussion of implications of the findings to podiatry

The key finding from this study is that a podiatrist has a very busy timeline when diagnosing a patient and predominantly uses (and values) tacit knowledge, implicit learning, and compiled skills during consultations. There is little evidence for the need or desire for an expert system in clinical podiatry practice.

There is a paucity of literature with regard to clinical reasoning in both journals and standard podiatry textbooks. Indeed this thesis makes a contribution to the knowledge in this area by explicitly investigating clinical reasoning in podiatry. With this relative absence of research to address the topic directly, comparisons about clinical reasoning must be drawn with other healthcare professions.

There is a common thread throughout the studies in this thesis that podiatrists use pattern recognition, tacit knowledge and schemata as mechanisms for clinical reasoning. Pattern recognition or inductive reasoning has been supported in medicine by a number of researchers (Hamilton 1966; Scadding 1967; Gorry 1970). In the medical profession (Groen and Patel 1985) identified that expert reasoning in non-problematic situations resembled pattern recognition but (Elstein 1994) argues that experts do consider and evaluate alternatives when confronted with problematic situations. Given that this thesis demonstrated little difference between experts and novices in clinical reasoning, perhaps the foot and leg conditions faced by podiatrists are not problematic in their diagnosis. Therefore, foot and leg conditions do not require what Patel and Groen (1986) call backward reasoning, where the re-interpretation of data or the acquisition of new clarifying data is invoked in order to test a hypothesis, and forward reasoning, in which data analysis results in hypothesis generation. The results from the study using laddering suggest that the podiatrists need to palpate feet and have values for frequent and immediate diagnosis. These are entities that are very much "hands on" and would not be best supported by a computer expert system.

In a Norwegian study (Mattingly, Fleming et al. 1997) found that occupational therapists had a wealth of practical tacit knowledge and could do what was required quickly and smoothly in much less time than it took to explain their actions. They felt this might give rise to credibility issues as the occupational therapists do not have a rich language to describe their practice, unlike physicians and other health professionals. From the findings of this thesis this may well be the case for podiatrists, who used copious tacit knowledge in their clinical reasoning.

The absence of forward or backward chaining reasoning mechanisms and the use of pattern recognition, tacit knowledge and schemata are good evidence to suggest that a computer expert system would not really be required for podiatrists as their reasoning is very rapid and decisions are made quickly in far less time than it would take to consult with an expert system. Expert systems are not useful for representing this type of knowledge as the software would find it difficult to process.

Currently the podiatry curriculum teaches clinical reasoning implicitly. Findings from this thesis raise the question of whether the curriculum for podiatry degree courses should explicitly teach a certain model of clinical reasoning. Which model of clinical reasoning should students choose to emulate? The choice could be hypothetico-deductive reasoning (Elstein, Shulman et al. 1978), pattern recognition (Barrows and Feltovitch 1987), problem-solving (Bashook 1976) or the models of backward or forward reasoning (Patel and Groen 1986). Certainly the findings from this thesis would suggest that pattern recognition would be a very suitable first choice for teaching to podiatry students as this is the method used to make a diagnosis. What about the other models? It may be surprising to many podiatrists that specialist areas within the podiatry profession do not use models of clinical reasoning other than pattern recognition. The reason for studying the experts in surgery and biomechanics was that it was thought that they may not rely totally on pattern recognition because some of the problems they treat may not be visible as they are beneath the skin or within the joints of the body. However, the results from this thesis show that both specialist areas use pattern recognition, schemata and tacit knowledge. Like their generalist podiatry colleagues they make little use of hypothetico-deductive reasoning and problem-solving in making a diagnosis. Although this thesis has made a contribution to clinical reasoning in podiatry this is an area for further consideration.

For example, although qualified podiatrists may not benefit from an expert system it raises the question of whether students may benefit from using one during their training. Although this thesis showed little difference in clinical reasoning skills between expert podiatrists and novice second-year podiatry students, first-year students may benefit from using an expert system and this may be worth further investigation.

Although podiatrists may not use or benefit from an expert system, this may not be the case for a future skill mix in podiatry. For example, podiatry assistants or foot care assistants are employed by the NHS and trained in-house to perform some basic routine foot care, e.g. nail care. Their scope of practice is much reduced from the podiatrists who have completed a three-year degree training. However, there has been informal debate as to whether their scope of practice could be increased to perform techniques such as diagnosis of corns and calluses and then to provide scalpel work to remove the latter from the foot. This is currently one of the areas of expertise of a podiatrist. If foot care assistants had access to expert systems during a podiatry consultation then they may be able to increase their scope of practice, as they would have access to a knowledge base that may enable them to diagnose foot conditions or make suggestions as to the best type of treatment for a particular condition. This would create a diagnostic and/or treatment based expert system for novices rather than a diagnostic expert system for experts. This may be worthy of further investigation if podiatry assistants are to be used to undertake work requiring greater knowledge and expertise than they currently possess. With the use of a computer expert system, a foot care assistant could achieve basic podiatry diagnoses.

According to De Dombal (1993) computer expert systems have been used successfully for diagnosing abdominal pain and attaching probabilities to the diagnosis being correct. This type of system may be very useful to podiatry assistants who would need help in making a diagnosis of a foot or leg condition. This type of expert system used sensitivity, specificity, and disease prevalence data for various signs, symptoms and test results to calculate, using Bayes's theorem, the probability of seven possible explanations for acute abdominal obstruction. De Dombal (1993) notes that an expert system that uses Bayes's theorem considers the probability that a disease will occur within a population, as well as the symptom probability for that disease, to determine the presence or absence of a particular disease entity. It is open to question whether a diagnostic expert system could be used to predict the probability of foot conditions as there is a lack of prevalence data for foot and leg conditions in podiatry. A recent report by Help the Aged (Jones and Campbell 2005) estimated the prevalence of corns and calluses to be as low as 50.2% and as high as 64.8%. This would make it very difficult to create an expert system that could use Bayes's theory of probability to predict that a certain foot condition would occur unless further work could be undertaken on the prevalence of foot and leg conditions.

This thesis focused on diagnosis of foot and leg conditions but it may be interesting to consider podiatry treatments. A study by (Heathfield 1991) reported that the majority of expert systems developed were aimed at diagnosis, which did not correlate well with actual tasks faced by clinicians; these often involved therapy, predicting prognosis or gathering information. Other work by Heathfield *et al.* (1988), for example, involved the computer grading of breast cancer, followed by the diagnosis of malignancy in breast cytology specimens (Heathfield, Kirkham et al. 1990). They felt that this type of system was representative of many at the time addressing a constrained problem domain, representing clinical knowledge as production rules (holding 75–100 rules) and employing backward chaining inference mechanisms. She reported that developers never intended to provide fully working systems, but used medical problems solely as interesting application areas when in pursuit of a higher degree. Thus their development methods and user requirements were gathered in a haphazard fashion. Given that the same clinical reasoning themes were used by expert and novices in a general podiatry clinic and that diagnosis appears to be based more on pattern recognition than on causal assertions, then perhaps the best use of an expert system in podiatry is not for diagnosis. Future studies may wish to consider whether expert systems may be better utilised in other areas of podiatry, e.g. in planning treatment options for patients.

6.4 The conclusion from this thesis

A podiatrist has a very busy timeline when diagnosing a patient and predominantly uses (and values) tacit knowledge, implicit learning, and compiled skills during consultations. There is little evidence for the need or desire for an expert system in clinical podiatry practice. However, if such an expert system was to be created, then:

(a) it would have to be fast and non-intrusive enough to fit into a busy consultation timeline,

(b) it would need a knowledge base that could account for diagnosis of foot and leg conditions based on pattern recognition, and

(c) it might be most valuable in the form of a decision support system for professional development which included the full range of expert diagnostic themes.

Appendix A: Card Sorts

A.1 Frame for card sorts

The frame for the card sorts was as follows.

"The items named on these cards are various diagnostic aids that can be used when investigating a patient's current health.

I would like you to sort these cards from whatever criteria you like, and from whatever viewpoint you consider relevant. It would be very helpful if you could say which viewpoint you are using each time you sort the cards."

A.2 Instructions for card sorts

The instructions were as follows:

You will be given some cards to sort. Each card will have the name of a diagnostic aid written on it. I would like you to sort the cards into groups, using one criterion at a time. When you have finished sorting, please tell me what the criterion was for that sort, and what the groups were into which you sorted the cards, so that we can record this. Once this has been done, we would like you to sort the cards again, using a different criterion, and then to keep on sorting them until you have run out of criteria.

For example, if the task was sorting different types of cars, your first criterion might be "place of manufacture" and the groups might be " American", "British", "French" etc.; the second criterion might be "cost", with the groups being "expensive", "medium" and "cheap".

You are welcome to use any criteria you like, and any groups you like, including "don't know", "not sure" and "not applicable". The main thing is to use only one criterion for each sort – please do not lump two or more in together. If you are not sure about something, just ask.

You may have noticed that cards are numbered: this is for convenience when recording the results. The numbering is random, so please don't use that as a criterion for sorting!

Thank you for your help.

A.3 Responses from podiatrists to the card sorts

Card sorts

Sort 1

Viewpoint As a clinical podiatrist

Criterion Invasion

Groups	8, 5, 4, 7, 6 Non-invasive	2 Both	1, 3 Invasive

Sort 2

Viewpoint As a clinical podiatrist

Criterion Body fluids or not

Groups	3, 5 Tests on body fluids	7, 4, 2 May or may not be a body fluid	1, 6, 8 Not body fluids

Sort 3

Viewpoint As a patient

Criterion Tests done to myself

Groups	3, 2, 6, 5 Test done to me	4, 7, 8, 1 Tests not done to me

Sort 4

Viewpoint As a clinical podiatrist

Criterion Tests performed by me

Groups	4, 5, 6, 2, 3, 1, 8	7
	Tests I have done	Tests I have not done

Sort 5

Viewpoint As a clinical podiatrist

Criterion Quantitative versus qualitative

Groups	3, 2, 5	7	6, 4, 8, 1
	Tests which are quantitative	Not sure	Qualitative or descriptive

Sort 6

Viewpoint As an observer

Criterion Computer or not

Groups	8, 6, 7	2, 3	1, 4, 5
	Tests that need a computer	Tests that might require a computer	No computer required

Sort 7

Viewpoint As a clinical podiatrist

Criterion Tests used in the diagnosis of rheumatoid arthritis (RhA)

Groups	6, 1, 3	7	2, 8, 5, 4
	Tests used to diagnose RhA	Not sure	Tests not used to diagnose RhA

Sort 8

Viewpoint As a podiatry lecturer

Criterion Included/not included on BSc (Hons) Podiatry course, University College Northampton

Groups	3, 1, 6, 4, 5, 8, 2	7
	Tests taught on BSc (Hons) Podiatry course	Tests not taught on BSc (Hons) Podiatry course

Sort 9

Viewpoint As a layperson

Criterion Useful in diagnosis of pregnancy

Groups	5, 3, 2, 8	7	4, 6, 1
	Tests can be used to determine pregnancy	Not sure	Not useful in determining pregnancy

Sort 10

Viewpoint As a healthcare professional

Criterion Self-test or not

Groups	5, 7, 2, 3	1, 4, 6, 8
	Tests patients can perform	Tests require the help of a professional

Appendix B: Transcripts

B.1 Surgery transcripts combined

Surgeon 1

Patient 1

Referred by the GP to the foot and ankle clinic and we triage out those patients we do not need. This lady has had pain of an aching nature in the right MPJt for years, gradually getting worse; real trouble in shoes; almost as big a problem as the actual pain.

We will go through a presurgical assessment because we cannot tell by looking. It is a bunion; the question is, is it bump pain or joint pain? "I don't wear fashion shoes but it has always been a bit iffy." OK, we need a medical history. "I have had tachycardia for two years and take these (gives a list of medication)." "You take Aspirin?" "Yes. Do I stop it?" "No, I would rather you continue to take it. Any allergies?" "Yes, Ampicillin." "Any digestion problems, constipation or diarrhoea? I take it you are not pregnant." "I would make history if I was." "Any arthritis, back pain?" "I know my bone density is low; I had a hysterectomy at 36 and my sisters have osteoporosis." "We will put you onto the list today; it will be a couple of months." (195)

Patient 2

A tibial sesamoidectomy was done here and later a fibular sesamoidectomy as that was a bit arthritic. "How are those orthoses?" "Not made any difference really." Clinically the foot looks good as the sesamoids take the weight and they have been removed as they were arthritic; then they are not there to walk so the metatarsal heads are taking the pressure which they were not designed to do. "What do you think to the insoles?" "I think they have not taken me up enough." "We need to try some temporary devices so I will build them up a little. I would like to see you again to see how things are going on in a few weeks' time." (121)

Patient 3

Suspected neuroma was operated on last year and the patient has some pain around the scar.

"This is where the surgery site was and it is tight there." "I have massaged it! It is tough stuff scar tissue – nature designed it to be so. The scar tissue will always contract and will pull toes out of line." "It is quite sore there." "That is the joint. Is the pain inside on the top or underneath?" "On the top." "We tend to do two injections of steroid for this, half and half." "I have to walk to town – will it be OK?" "Yes, it should be fine." (Steroid injection given.) (112)

Patient 4

She came to see another surgeon last time. She has pain in the MPJts and it could be valgus or rigidus. They often look very similar. It is what the Americans are calling hallux valgus rigidus, an arthritic equivalent. The X-rays show arthritis, no surprise really, with a long first metatarsal. I think we need some steroid into here. I am such a fan of this. I could not function without it. (Steroid given.) (76)

Patient 5

(Podiatrist looking at an X ray.) Surgery seven weeks ago. A wire put in and it did not hold it as firm as we would like, so another one was put in and it held it more firmly. The alignment of all the bone looks good – I am really pleased with that. Some evidence there of post-operative swelling. (59)

Patient 6

"How long has that been there?" "Not that long." "One month or two months?" "Yes." "This has been operated on before. Well, no prizes for the diagnosis – an ingrowing toe nail. This is really a foot surgery clinic so I need to refer you back to the community podiatrists who really deal with these. You can have it done here." (61)

Patient 7

"You have come from the School of Podiatry?" "Yes, the University." "We will have a look." I work on NLDOCAP, nature, location, duration, onset etc. "What is your problem Mrs X?" "I have had it a few years and lost my husband so I could not have anything done. Now I have a partner I can – I am not on my own. I have done the podiatry rounds over twelve months." "Is it getting better, worse or staying the same?" "Not getting any better." "How do you feel about surgery?" "Well, it is inevitable really; it is not going to get any better." "No. If you did not wear shoes then you would not need surgery but we do not live in a climate where that is possible. Can I see you standing down?" OK, she needs that joint there taking out. "Two ways of doing it – can take it and straighten the toes with sutures or we can take it out and use a wire the second toe. In my experience the fusion is more stable than holding it with sutures. That is my recommendation. If you want to go ahead then we need X-rays and presurgical assessment – it will be a day case and under local analgesic. What do you say?" "Yes." "Right, we will book you in. Here is your X-ray form. I will clerk some details." (234)

Patient 8

"You have come from the School of Podiatry?" "Yes. I want it straightened." "What is the problem with the toe my dear?" "Well, it sticks right up and I put a pad on it or it would rub on my shoes." "How long has it been a problem for you?" "Oh, about a year." "Getting better, getting worse or staying the same?" "Staying the same." "There was talk of removing the toes in 2001?" "Yes, but my husband died and I put it off." "You can have the second toe off or the big toe straightened and then the second toe straightened. It is ten minutes to take the toe off or one hour to do the straightening." "OK. I don't want to be too long. I am on my own." "You will need someone to stay with you irrespective of the amount of surgery." "Can I walk on it?" "Oh yes." "Can I be in hospital for this?" "Not really as I do not have access to the beds. We do all these as outpatient. Do you have anybody to stay with you?" "Not really but I could find someone." "Can you stand down Mrs X? Quite a prominence, with toes that are that deformed there is usually more callus. Do you need surgery or is padding OK?" "Well, I really want to wear my shoes." "Do you want to go forward for surgery?" "Yes, I would like to." "OK. We will fill out the forms." (256)

Surgeon 2

Patient 1

"Has it settled down because you stubbed it shortly after?" "Well, yes, I think it is the gait." "Yes, sure, it became swollen. Are you getting any discomfort on the end of here. Generally it has settled down and you are happy with it are you? That is gradually disappearing, the callus that you get where the suture line is. Have you put any cream into it?" "I cannot really get to it." "OK. Well, we will discharge you today." (82)

Patient 2

"How are you doing with this?" "It is not too bad actually." "Right, are you creaming this well?" "Yes." "Still looks dry at the bottom end there. We are down to nice solid tissue without the bursae over the top." "Yes." "Right now the important thing is how does this feel when it is moved? That is fantastic isn't it. You could not do that before." "Yes." "So you have been a good girl and done all the exercises." "Yes." "The back of the heel is cracking. Have you got a foot file? Could you file and cream it?" "I am creaming it." "The backless shoes will also let this dry out. There is lots of repair going on so it will take about a year; we can discharge you today but if you get any problems you can always come back to us but you must cream it. Is there anything you want to ask?" "No, that is fine." (171)

Patient 3

"It is this part that is giving you the trouble" (patient has otoform to space out toes from previous surgery). "It is possible to bring that toe down. You would still need to wear something like this. We would need to fuse that joint there because if we made it movable it would come back the way it is now. So we need to fuse it so it is straight and with the wedge it should form a buttress, so are you happy to go forward with this?" "Would you consider taking this off?" "No, not really. That would not be the answer. It would be much better to fuse it. We would pin it and hold the toe. It will be sore for a little while. Do we have any X-rays?" "No." "We really need to have some so I would like to book you back in with X-rays and this will give us the final decision as to what to do." (169)

Patient 4

"How is ...?" "Not too bad." "Where do you get the most pain?" "Here." "It has settled down quite well; it is nice and straight and we are only six weeks so things are healing up. Is there anything that does upset it?" "Standing up at work." "How long can you stand?" "I stood for an hour this morning." "You are coping though. Are you creaming it? Well, keep on doing that. It will take a little while to settle down; do not overdo things. If it starts to get sore then take it easy. I will see you in six weeks' time and it should have settled down. Just try and get back into things gently. Is there anything you want to ask me?" "No, not really." (135)

Patient 5

She had vaso-spasm post-operatively for probably 24 hours after because of the tension brought about by the K-wires. This has placed stress on the dorsal vessels. This has caused tissue death and if you look at the toes themselves the necrosis is on the dorsal distal aspects. Now the third toe is not as bad as the second toe and is more or less completely re-epithelised throughout although the tip may take a little bit longer and we may have lost the nail on there. Again dorsally there is necrotic tissue there and the tip of the toe is mummified and as I cut into you can see the autolysis going on so it is very much a case today of removing as much necrotic tissue as possible to remove as much fluid as possible. (136)

Patient 6

(Observes X-ray before patient comes in.) Off the cuboid it could be an accessory or it could be off peroneus longus but if you look at the dorsum this may be where the problem is. You can see that here. Let's have a look clinically.

"You saw someone at the school." "Yes, some students and a man in charge and I saw someone here and he advised X rays." "This is the main problem here." "Yes. I could not wear anything which went over here." "So it was mainly from the strap is it?" "I saw a podiatrist who advised various things such as padding." "Is the pain only there when you wear a strap?" "Yes. Otherwise it is fine really." "Does it hurt when I do this?" "Ooh, yes, it does." "It is not entirely boney. Can you feel a little bit of tissue here? You have damaged it at some time." "Yes, I fell off some beach sandals and damaged it about 10 years ago." "We could shave all this bone down and there is a little fluid-filled sac which you have made yourself that will need taking out. It would make it sore and it may re-occur again with your foot type. It may be that avoiding any strap on it and padding it out, the surgery should be really left until it is spoiling your quality of life." "Yes, sounds like a good idea. The operation is really extreme; I think I will hang on." "Carry on with some padding and things and if you need to come back to us then please do; we have your X-rays." (279)

Patient 7

"OK, tell me all." "We are getting there." "Can you stand on it for me? It has come down a long way now. Does that hurt?" "It is a little tender." "It is getting there. It is doing a lot better you know and I think the time has come to get some orthoses to help. I will refer you to the podiatrist near to your home." (69)

Surgeon 3

Patient 1

"It has been very painful." "Have you been icing your foot at all?" "No, I have not." "So you have been taking painkillers and resting?" "Resting a lot." "Have you been keeping your foot up." "Up – I am spending most of my time in bed because I find it easier; it is playing up around the side. I can feel it, know what I mean." (Podiatric surgeon cuts off dressing.) "It's red, it's hot. Initially, I am thinking post-op infection. It is probably likely in this case if there is an infection to be a pin tract infection because these are the main portal of entry for bugs and it is not uncommon with percutaneous K-wires to have pin tract infections. I will take your stitches out first." "Is there an infection?" "Do you feel the painkillers are helping at the moment. Do you have to take them again?" "Yes. I do not feel well in myself now. It is unusual for me." "Do you feel a bit fluey? I am not putting words in your mouth." "I had one occasion when I got up and felt really sick. My lips started to tingle and I went back to bed, put the electric blanket on and went back to sleep. Woke up and felt better." "I think you need some antibiotics. I will contact your GP." (237)

Patient 2

"It has been so painful." "Your foot has been painful has it? What have you been taking?" "Codeine and Paracetamol." "How is the foot feeling now?" "Very painful."

" How many do you take per day?" "A few." "Well, it has healed quite nicely actually; if I push there is it uncomfortable?" "Yes – yes." "This lady had several procedures in one sitting. The wounds have healed. Slight erythema on the lateral side but there is no infection, otherwise there would be dehiscence of the wound, the wound would be open – em – some degree of tenderness due to the amount of surgery in one sitting. Otherwise they are looking good." (117 words)

Patient 3

"Fifth toe – er – wound has healed nicely. It is a twelve-week review. The scar line is quite thin. It usually takes a year for the scar line to remodel but you can see at this stage that the skin incision is not that obvious. Are you having any trouble with the fifth toe?" "Just a bit sore if you are on your feet for a long while." "It is quite normal to have a fat toe for about six months." (81 words)

Patient 4

"Got a large Haglands deformity – em – with overlying bursae at the retro calcaneal area, evidence of previous surgery, there is a scar line laterally here. You can feel, if you palpate, a large boney mass; if you palpate the soft tissues there is an overlying bursa which runs laterally to medially. It is quite big." (55 words)

Patient 5

(Looking at an X-ray) "Forty-eight-year-old patient with pain in the right first MPJt dorsal plantar view of right foot, weight bearing. X-ray demonstrates reduced joint space of first MPJt peripheral osteophytosis with joint mouse on the lateral side of the joint; the first metarsal is longer than the second. Look at medial oblique view again, demonstrates similar findings, primarily osteophytosis with reduced joint space of first MPJt which is synonymous with degenerative joint disease and it has a small joint mouse on the lateral side of the joint. If we look at lateral weight bearing view it demonstrates a dorsiflexed first ray with dorsal osteophytosis of the metatarsal head and base of proximal phalanx. The other feature is a large Steindlers process on the postero-lateral aspect of the talus." (125 words)

Patient 6

"What this lady has got is primarily hallux rigidus deformity because of the bump. The osteophytes are dorsally rather than medially and she has got severe restriction of movement. Certainly on the X-ray it shows no joint space at all; peripheral osteophytosis, but one thing we are seeing more and more with this condition is a certain amount of hallux abductus interphalangeas where the distal phalanx abductus on the proximal phalanx. At a glance it looks like hallux valgus but radiologically all this enlargement is due to the osteophytosis." (88 words)

B.2 Biomechanics transcripts combined

Biomechanist 1

Patient 1

We will check the Beighton scale. Can you put your hand like this? And on the other hand. Excellent. Can you roll your sleeves up for me and stretch? Can you stand here for me as tall as you can go – excellent. Can you bend forwards and put your hand on the floor, legs straight and roll up your trouser legs, to look at tibial alignment to see if there is a varus component. Put your feet together. There is some tibial varum and the post tibial tendon can add to the high foot posture index we are getting. His father is also hypermobile. We do find it runs in families. (110 words)

Patient 2

From examination I have found that there is a high Beighton scale, ligamentous laxity; she has got genu valgum and we will give her a valgus filler to straighten up; some antetorsion because of the ligamentous laxity. (37 words)

Patient 3

The patient has painful bilateral heels; there is ligamentous laxity. Can you turn your legs to me? Did the insoles help? Does it hurt on toes? When the foot is dorsiflexed you can see the windlass is very tight. Obviously we aim to fit insoles to help the windlass mechanism to help relieve the stress on the plantar aponeurosis. You need exercises for the gastrocnemia and also massage therapy in the morning before he gets out of bed as the weight goes on the plantar aponeurosis and a cold can of coke on the plantar aponeurosis or crushed wrapped ice in a tea towel at night. (105 words)

Patient 4

There is pain in the knee on the medial side of the knee. We need to check the lateral and medial collateral ligaments, and cruciates. He has got rather a lump on the tibial tubercle. Mother states: "This week he can hardly put his foot down". Insoles should put his feet into a better position. I think a little bit of ice therapy too and some hamstring exercises because the foot has been rolling in. It has probably hurt the medial side. (83 words)

Patient 5

Go to the door and come back – slightly wider base of gait. Go onto tippy toes and back down again, the main problem – do you play football, do you like David Beckham? – no real problems but like the dentist we need to check in one year. (46 words)

Patient 6

She is walking on her toes. Had a difficult birth but the neurological checks seem fine. Spongy feel to the end of the range of motion. It hurts all up there. Exercises that were prescribed have helped. Paediatric physiotherapy have been involved who have checked the hips but surgery on the hip has not been ruled out. We will recommend exercises but it does require a concerted effort to improve. (70 words)

Patient 7

I like to see my patient walk first and then examine in a methodological way. She has a lump on the foot and she likes to do dance; she had an infection 18 months ago and as it cleared up she got a lump – it is unusual for this age. Foot posture index about 6 and the Beighton scale about 6; hallux limitus is present. "Do you have physio for your cystic fibrosis?" "No, my mum does it." Shearing stress is present but we will deal with that lesion. (90 words)

Patient 8

Referred by the physio with ligamentous laxity and she has some insoles but there still seems to be some wobble medially. "Can you walk for us please?" She has an early heel lift and she is pronating. "And one more time." Some of it may be the shoes which have worn medially. We will fit insoles but she may need some new shoes and insoles will be much better. She may need some stretching for the posterior muscles by sitting against a wall and holding for 15–20 seconds. (88 words)

Biomechanist 2

Patient 1

Feels quite loose ligamented and the ankle feels quite loose. "You have gone over on it some time ago?" There is a little bit of eversion and an awful lot of inversion, bit limited at first MPJt, same on other side. Knees hyperextend in keeping with lig laxity; there is no spot, no point of definite pain. If it was an old sprain or recurrence of damage to the tissue that had healed round there she would go through the ceiling by pressing on that but she is not. The nature of pain, it comes and goes; if she clicks it may indicate nerve or capsular but I would expect there to be some after pain if she was pinching capsule but the foot usually pronates; interesting fact is the boots which hold her stable around the ankle are helping her which could mean entrapment of a nerve such as superficial peroneal and get a shooting. "Is it sharp or stabbing very sharp?" "It's very sharp. It's not an aching pain." "And then it is gone?" "I rotate it. It loosens it up." The other thing it could be, she has had a number of ankle sprains, is thickening or fibrosis. There is no background ache like, ooh I know I have done, it sounds like a pinching of capsule. (221 words)

Patient 2

"What position do you play?" "Midfield." "Are you a bit small for that?" "I am one of the biggest." He has casted already but I wonder what happens at propulsion. I know the purist would suggest this. There is a Kirby skive here. "Where is the pain? Any pain in there?" What goes across here the retinaculum and may be in keeping with his instability; he has a nice high arch foot; there may be an overuse of the extensors.

Shoulders are level. Not too sure about arm swing. Very abducted gait; he is placing his feet down lots of extensor activity; he is not that early heel lift – perhaps because of the laxity medially rolling off right more than the left. Certainly not propulsive, he is medially rolling off, knees externally rotating. (134 words)

Patient 3

"Who is the physio you are working with?" "Over at the hospital." "How long have you been doing the exercises for?" "Since last September." "Where is it hurting? The exercises are not helping because you are tightening the quad muscles and pushing the patellae down and the pain would feel stress like. I cannot work out how they are helping the back. I would advise stopping the exercises and not doing them again if the pain goes away. We will renew the insoles." (86 words)

Patient 4

"Pain in the knee. I have had some pads in my shoes." "Is the pain in there?" "Slightly, more here." "What sort of pain are you getting? Pain in that structure?" "Yes, there." "Is it sharp? It is patella tendonitis and iliotibial band friction syndrome. The reason I say that is it is a collapsing foot that turns in and puts stress and strain on there and some torsion on there and perhaps it is made worse as the tibial tuberosity is laterally placed that increase the Q angle and there will be more of a twist and if he has a nice high arch foot non weight bearing. The subtalar joint axis is high which will mean the foot does pronate; there is a greater conversion of transverse plane movement putting extra strain on the structures." (138 words)

Patient 5

"I will have a twist." "What type of pain?" "It's not sharp. It is more of a dull aching type pain." "Is it in that bit?" "It hurts after resting. I am a runner. I do marathons about 50 plus per week on the road, 9 minute mile pace." "What sort of work do you do?" "I am a trolley dolly here at the hospital." "There is hardly any external rotation is there which is interesting; it's all internal. The patella is well placed, good muscle, tibia is a little bit curved, a little bit rear foot varusy. What is going on here? Some lipping. She is propulsing on a fairly mobile foot. How long do you spend stretching?" "Not long." "Could be a need for stabilising the back of the foot. Let's have a look at the shoulders. Seems low on right with the activity knees straight ahead, feet abducted, narrow base of gait, toes gripping the ground, overuse of extensors." (168 words)

Patient 6

"Trouble with swelling on the dorsum of the foot." "Did the insoles help at all?" "Not really. They have tried strapping." "Did it help? The pain you are getting is along here?" "Getting a burning sensation." "Burning pain usually tenosynovitis. Not sure why the insoles did not work. How long have you had it?" "A couple of years I felt something go in my foot, thought it was a sprain. It interrupts my work." "A burning pain. Is it burning here? You have a nice tendon there in tibialis anterior, could be tenosynovitis of that. Did the insoles help for the first week?" "Yes, they did." "OK, we will make some more." (122 words)

Patient 7

"What has been the problem?" "They said metatarsalgia." "You are getting pain in the arch of the foot? When are you getting it?" "In the middle when I am playing." "It wasn't there at the start? After the game?" "Not as much after." "You are a tennis player? What courts do you play on?" "Hard courts." "The pain is here. Any pain there?"

"This is what you are playing tennis in? I think we need an arch D, a met pad, for the forefoot. All my court players I like to put a heel wedge in." (99 words)

Patient 8

"I have insoles. It doesn't cure the pain." "Where is the pain? Where isn't it? These insoles need toughening up and the pain may start to go." "On the left foot it has never been quite right." "Just a bit lumpy and I will modify them. We will boost these up and see how the pain goes." (63 words)

Biomechanist 3

Patient 1

Young girl aged 24 came in with pain in her right ankle 3 months ago. Sudden onset stabbing pain and eased by rest. She had an injury to her ankle on the medial mallelus in 1997 after a road traffic accident. It was pinned and the pins were removed 2001 and she has swelling. Her gait, so the jeans are restricting her in terms of walking, a little bit of genu valgum. The fourth and fifth toes are curling a little bit; everything else proximal is looking good. It is my feeling we need to restrict the motion at the ankle joint and try to pronate the subtalar joint a little more to help some of this pain. The excessive motion seems to be causing some of the pain in the area; the motion does not need to be restricted entirely, otherwise she will not be able to get around. (150 words)

Patient 2

Came in with callus over the medial aspect of the hallux; little bit of diffuse callus across the forefoot and fifth metatarsal. The insoles are spreading the load across the forefoot and there may be excess pronation in the subtalar joint. A moderate amount of support is provided in the arch. We need to change the alignment and pressure under the forefoot a little more. (65 words)

Patient 3

She is a teacher of modern and ballet and presents with pain in the area of the navicular; she has insoles and is getting pain in both feet. The insoles are a cover for an EVA arch support. "When I was in bed my ankles ached and the pain went up the inside of my leg to the knee. I felt this was incorrect so I took the insoles out; then the time after that with no shoes on at all I have a pain in my toes." "Just to recap: no shoes, pain in the little toes. With these new orthoses there is still pain?" The issue here is a compromise between the insoles and the dance shoes; the cambrelle cover may not be the best and seems to absorb moisture. We need to have more room in the shoes and change the arch fillers to more of a mid foot device and change the top cover. (159 words)

Patient 4

She has come to the clinic with right hip pain and occasionally right knee and occasional left hip. She does sports as part of the curriculum and runs about 1500 m; there are pump bumps on both heels. She has bursae on the knees. I need to have a look at you. I internally rotate the hip – it should be equal and symmetrical at 15 years of age. There is plenty of motion. She is pretty flexible. It looks as though there is more external rotation with the hip joint flexed way above 45 degrees, about 65 degrees. This may be excessive and causing some of the hip pain. The lateral collateral ligament off the knee seems OK. Let's have a look at you walking. Shoulders seem balanced; the patellae are squinting most of the way through the gait cycle; the foot seems normal, only slightly rolled, and there is some genu valgum. I am not sure if the foot pain relates to the hip pain but we could strap the foot and see what effect that has. (177 words)

Patient 5

"What kind of sports do you play?" "I am a referee." He has ankle pain and knee pain from the rupture of the Achilles. "I did both." "Crikey, how did you manage that?" "It was a tackle." "End of your career?" "Yes." The callus, he seems to have uneven loading. "Have you ever had forefoot padding?" "I do it myself really." Some off the gel pads may help the load on the little toes and prevent the load on the football boots. (90 words)

Patient 6

This patient has had high dye strapping and we need to make sure strapping is OK on the other foot.

"Let's have a look at you walking. Roll your pants up to mid calf. Oh, you have shorts, that would be better. Walk at normal speed. Not a lot stands out but it may be the fact he is a sports person that is giving iliotibial band. He has had good response from the other foot so it may be OK on this, but we could go for foot orthoses too." "Is there anything else I should be doing such as stretching? Is my gait OK?" "No, not really. Your gait seems fine but some strapping and insoles might help." (122 words)

Appendix C: Laddering

C.1 Laddering interviews

Statement

I am going to ask you six questions about the method by which podiatrists may make a diagnosis. The responses you give will be recorded to tape and analysed for the content. The questions are based on a previous study undertaken as part of my PhD. The goal of the questioning is to gain an insight into how you see the area of making a diagnosis in podiatry and your reasons for using different diagnostic methods. You may withdraw yourself from the study at any point if you do not wish to continue. There are no wrong or right answers.

The following seed questions were approved by the Multi Research Ethics Committee for the telephone interviews using laddering. After the frame was read to each podiatrist they were asked the six seed questions shown below.

(1) When would you use visual signs to make a diagnosis of a foot condition?

Why?

Why?

(2) When would you question the patient as part of making a diagnosis about a foot condition?

Why?

Why?

(3) When do you rely on your own sense of touch when making a diagnosis?

Why?

Why?

(4) When do you take into consideration what the patient tells you when making a diagnosis?

Why?

Why?

(5) When would you need to physically examine the patient before making a diagnosis?

Why?

Why?

(6) When would you envisage using a computer to make a diagnosis?

Why?

Why?

For each question the response was audio-taped. The podiatrists were asked the initial seed question and then two "why" probes were used to ladder. After the session had finished the tape was transcribed for analysis.

This process can be illustrated through the following example from one podiatrist when they were asked the first of the six seed questions.

C.2 Analysis of laddering interviews

This first question was

(1) When would you use visual signs to make a diagnosis of a foot condition?

The initial response was

"A lot of things."

Why?

Em – I suppose because – em – pretty much when looking at the foot of a client or patient you would straightaway look at the feet and start examining.

Why?

That is what you do.

As an example of how the content analysis was undertaken the following table shows how the key laddering insights were produced for one participant responding to question 1 (as shown above): When would you use visual signs to make a diagnosis of a foot condition?

Question	Participants response	Key laddering insight
IR	**A lot of things**	**Frequently**
W1	Em – I suppose because – em – pretty much when looking at the foot of a client or patient you would straightaway look at the feet and start examining	Obvious observation
W2	That is what you do	Procedure for diagnosis

Key to the table:

IR, initial response

W1, "Why" probe 1

W2, "Why" probe 2

C.3 Examples of key laddering insights

Initial response	Response to the first "why" question	Response to the second "why" question
Frequently	Obvious observation	Procedure for diagnosis
Frequently	Obvious observation	Procedure for diagnosis
Frequently	NOT obvious observation	NOT procedure
Frequently	Obvious observation	Procedure for diagnosis
Frequently	Obvious observation	Procedure for diagnosis
Frequently	Obvious observation	Procedure for diagnosis
Frequently	Obvious observation	Uncertainty
Frequently	Obvious observation	Procedure for diagnosis
Frequently	Obvious observation	Procedure

The table was constructed by using the most frequently occurring categories from the table above (section C.2).

The following is an example of such a table for question 1.

Consequence	**Procedure for diagnosis**
Consequence	**Obvious observation**
Initial response	**Frequently**

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