
A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

Brian Lawrence Hanisch
BSc (Adelaide University)

School of Business Information Technology
College of Business
RMIT University
June 2009
Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; and any editorial work paid or unpaid carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed.

Brian L Hanisch
Acknowledgements

Whoever thought I would undertake a PhD? Well, it has happened and it seems only yesterday the possibility was raised over a chance lunch with my soon to be supervisor, Professor Brian Corbitt. Brian, thank you for opening my eyes to the opportunity and for your interest in the research and development I performed at SpeechNet. Without this, it is unlikely that I would have ever contemplated a PhD.

It was through my wife, Dr Jo Hanisch that Brian was introduced to my research and therefore Jo has been a key influence behind me undertaking my PhD. Jo, you have been with me from the beginning of this journey. You have been through the trials and tribulations of developing commercial speech-enabled software products, and been with me all the way through the PhD. For your love and belief in what I do, and for your moral and financial support, I will be eternally grateful. We are a team and together we continue to experience the joys and challenges of life. You know I have much love for you.

As an IS practitioner and research student I have enormous respect for you Brian. Your enormous capacity to understand complex areas and ability to hone in on the important aspects is inspiring. I really enjoyed your management and supervisory approach. You provided guidance when needed, and let me experience the journey to its fullest. This is really appreciated. Thank you for insightful comments and always doing what you said you would do. I could not have asked for a better supervisor.

Jo, I greatly appreciate you showing me the academic ropes. We have had great fun in jointly researching, publishing and presenting at IS conferences both in Australia and overseas. I have learnt so much along the way, particularly moving from practitioner-speak to well supported academic argument. Thank you for the opportunity to view the world of IS from an academic researcher’s perspective.

I would like to make special thanks to Yuji Yokoo. Your analytical thinking and IT skills in natural language understanding and generally IT are exceptional. I have enjoyed discussing the very complex technical issues associated with speech-enabled applications with you.

Thank you to everyone in the School of Business Information Technology, RMIT University, Melbourne. You have made me feel very welcome – right from day one.
I wish to express my thanks to all of the participants in this research. They cannot be named here, but I do appreciate your time and effort in providing the extensive notes and interviews which form the valuable data for this research.

Brian Hanisch

June 2009
In loving memory of my parents, Monica and Keith Hanisch
Abstract

Spoken language human computer interfaces are prone to very poor speech recognition accuracy, and the productivity gains that businesses have sought by implementing such interfaces have proven difficult to achieve. An elite sporting club (ESC) which employed a system with poor speech recognition accuracy established a systems development project seeking improvements to the accuracy with the specific aim to significantly gain efficiencies in the capture of elite athlete injury data. This research seeks to understand how an improved speech-enabled application (ISEA) applies spoken language technology to capture elite athlete injury data, thereby obtaining a holistic and in-depth understanding of the influences of ISEA on the injury management process operating at the ESC.

The research was conducted in an organisational setting of one elite sporting club across two strands of enquiry: 1) spoken language human computer interfaces, and 2) injury management with a specific emphasis on its application in elite sports. From existing theory, a conceptual framework was developed providing an in-depth understanding of the areas of enquiry. This was used as a basis from which to develop and extend theory in the areas of IS; spoken language systems and development; elite athlete injury management; and injury management information systems. From the results of the interpretive study undertaken as part of this research, the conceptual framework was refined.

Key outcomes of this research include 1) the construction of a generic IT architecture model for speech-enabled applications to facilitate the IT design of speech-enabled business systems; and 2) a speech systems development model specifically tailored for spoken language systems development. The speech systems development model is constructed from practice as performed during the development of ISEA and extends the theory associated with iterative/evolutionary systems development lifecycle models.

An unexpected outcome from this research is that the athlete’s performance, and not the injury, is strategic to the ESC and leads to a competitive advantage. Further, the research uncovered that a community of practice supporting athlete performance management is critical to its support of the club’s strategic directions.

The research has established that the use of spoken language human computer interfaces, can influence business process activities and lead to unexpected business improvement outcomes. The research highlights that these business improvement outcomes occurred as a direct result of the system’s design and its use within the organisation being tightly integrated. The use of spoken language technology to improve the business process enabled the timely capture of injury data, which facilitated knowledge sharing and therefore increased the value of this information.
# Table of Contents

Abstract ........................................................................................................................................... vi
Table of Contents ........................................................................................................................ vii
List of Figures ................................................................................................................................. vii
List of Tables .................................................................................................................................... xi

## Chapter 1 Introduction
1.1 Overview of this research ................................................................................................. 1
1.2 Background ..................................................................................................................... 2
1.3 Significance and motivation .......................................................................................... 4
1.4 Outline of the research .................................................................................................. 8
1.5 Organisation of the thesis ............................................................................................. 9

## Chapter 2 Literature review
2.1 Introduction .................................................................................................................... 12
2.2 Background ................................................................................................................... 13
2.3 Speech-enabled applications ......................................................................................... 15
   2.3.1 Speech-enabled applications overview ............................................................... 15
   2.3.2 Summary and discussion in the context of the present research ....................... 21
2.4 Systems development methods and models ................................................................. 23
   2.4.1 Systems development lifecycle models overview .............................................. 23
   2.4.2 Spoken language systems development ............................................................ 30
   2.4.3 Summary and discussion in the context of the present research ....................... 33
2.5 Injury management ....................................................................................................... 34
   2.5.1 Introduction .......................................................................................................... 34
   2.5.2 Injury management - an industry perspective .................................................... 35
   2.5.3 Athlete injury prevention .................................................................................... 37
   2.5.4 Summary and discussion in the context of the present research ....................... 42
2.6 Conceptual framework ................................................................................................. 43
2.7 Conclusion ..................................................................................................................... 47

## Chapter 3 Research methodology
3.1 Introduction .................................................................................................................... 49
   3.1.1 Overview of research methods ............................................................................. 50
   3.2 Rationale for this research methodology ................................................................. 52
   3.3 The research process ................................................................................................. 55
      3.3.1 The structure of the research ............................................................................ 55
      3.3.2 The researcher’s role ......................................................................................... 57
      3.3.3 Data gathering ................................................................................................ 59
   3.4 Data management and control .................................................................................. 62
      3.4.1 Data analysis .................................................................................................... 63
      3.4.2 Quality and integrity of research ...................................................................... 65
   3.5 Conclusion .................................................................................................................. 67

## Chapter 4 Description of the improved speech-enabled application (ISEA) .... 69
4.1 Introduction .................................................................................................. 69
4.2 The problem to be solved ............................................................................. 70
4.3 ISEA description .......................................................................................... 73
   4.3.1 Demonstration of ISEA user interface versus InjuryTracker™ ............... 75
   4.3.2 Systems development approach ............................................................... 96
   4.3.3 Language modelling study ..................................................................... 104
   4.3.4 Module-1 - Audio capture and speech to text transcription ................. 113
   4.3.5 Module-2 - Consultation text interpretation, validation and correction 114
   4.3.6 Module-3 – InjuryTracker_DB update .................................................. 118
   4.3.7 Speech improvement project .................................................................. 124
4.4 Generic IT architecture model ................................................................... 131
4.5 The ISEA development process ................................................................. 136
4.6 Conclusion ................................................................................................. 141

Chapter 5 Evaluation of the implemented improved speech-enabled application (ISEA) .................................................................................................... 143
5.1 Introduction ................................................................................................ 143
5.2 Background ................................................................................................ 144
5.3 Users’ perspectives of ISEA ...................................................................... 146
   5.3.1 Speech recognition ................................................................................. 146
   5.3.2 Quality of data capture ........................................................................... 152
5.4 Injury management .................................................................................... 158
   5.4.1 Importance of injuries at ESC ............................................................... 158
   5.4.2 Definition of elite athlete injury ............................................................ 160
   5.4.3 Injury prevention .................................................................................... 164
   5.4.4 Differentiation between athletes and other workers ......................... 169
5.5 Performance and injury management at ESC .......................................... 174
5.6 Conclusion ................................................................................................. 178

Chapter 6 Unexpected outcomes emerging from this research; and conceptual framework revisited ............................................................................... 181
6.1 Introduction................................................................................................ 181
6.2 Overview of knowledge transfer and sharing through communities of practice – A theoretical perspective ................................................. 182
6.3 Knowledge sharing through PPT as a community of practice................... 185
6.4 Competitive advantage through PERFORM ............................................. 192
6.5 Strategic positioning of ISEA ................................................................. 197
   6.5.1 Summary ................................................................................................. 202
6.6 Revisiting the conceptual framework .......................................................... 203
6.7 Conclusion ................................................................................................. 206

Chapter 7 Conclusion ............................................................................................. 208
7.1 Introduction ................................................................................................ 208
7.2 Key findings of the research ...................................................................... 208
7.3 Research contributions ............................................................................... 211
7.4 Summary of this research...........................................................................214
7.4.1 What are the components of a speech-enabled software application?...215
7.4.2 What are the processes involved in developing a speech-enabled software application? ........................................................................................................216
7.4.3 How has the speech-enabled application influenced the data capture of injury data? ........................................................................................................216
7.4.4 How does the implementation of the speech-enabled software application influence the injury management business process? ...............................217

7.5 Methodological contribution......................................................................217
7.6 Limitations .................................................................................................218
7.7 Implications for practitioners.......................................................................220
7.8 Future research...........................................................................................221

References ........................................................................................................224
Appendix A ........................................................................................................235
Appendix B ........................................................................................................240
LIST OF FIGURES

Figure 2.1 The Waterfall model................................................................................ 25
Figure 2.2 The ‘V’ model ........................................................................................ 26
Figure 2.3 The Spiral model ..................................................................................... 27
Figure 2.4 Comparison between Waterfall and iterative development methods ...... 29
Figure 2.5 Dialogue engineering life-cycle phase .................................................... 33
Figure 2.6 The ‘sequence of prevention’ of sports injuries ....................................... 38
Figure 2.7 The Translating Research into Injury Prevention Practice (TRIPP) framework ............................................................................................... 40
Figure 2.8 Conceptual framework (spoken language injury management information systems) ............................................................................... 45
Figure 3.1 Structure of the research.......................................................................... 56
Figure 4.1 ESC injury data capture process before ISEA versus proposed ISEA process ........................................................................................................ 72
Figure 4.2 ESC business cycle................................................................................ 100
Figure 4.3 ISEA next stage development approach............................................... 102
Figure 4.4 ISEA execution stages........................................................................... 103
Figure 4.5 The generic speech-enabled application IT architecture model .......... 132
Figure 4.6 Speech systems development model (SpeechDM).............................. 137
Figure 5.1 Elite athlete performance management model (PERFORM)............ 177
Figure 6.1 Revised conceptual framework ............................................................. 204
**LIST OF TABLES**

Table 3.1  
SpeechNet and ESC participants ................................................................. 60

Table 3.2  
Application of Interpretive Research Principles ...................................... 66

Table 4.1  
Examples of terms and how they were recorded in InjuryTracker_DB ........ 110

Table 4.2  
ISEA language template ............................................................................. 111

Table 4.3  
Physical representation of spoken language in INJURY table ................. 121

Table 4.4  
Mapping of spoken language to INJURY.DBF fields .............................. 122

Table 4.5  
Example spoken language discourses where IMLM is not used in DNS ... 129

Table 4.6  
Example spoken language discourses where IMLM is used in DNS ......... 130
Chapter 1 INTRODUCTION

1.1 OVERVIEW OF THIS RESEARCH

This thesis is a study of the development and implementation of a speech-enabled software application in an elite sporting club (ESC), and how this application impacts on the ESC’s injury management of elite athletes. This research:

1) undertakes a detailed analysis of the technology used in speech-enabled applications with a specific emphasis on the development of spoken language systems;

2) considers how poor speech recognition accuracy, a barrier to effective deployment of speech applications (Bach, 2007) can be overcome to an acceptable level in complex business operational environments;

3) investigates how spoken language technology supports the information system associated with the injury management process; and

4) analyses the information system and business impacts of applying artificial intelligence in the form of speech recognition and natural language as the human computer interface mode of data entry to a business application that supports a critical business process.

Importantly this research considers the injury management information system at the ESC from two perspectives: 1) its structure and functioning; and 2) its organisational context (Flynn, 1998). According to Carey, Galletta, Kim, Te’eni, Wildemuth and Zhang (2004), the overarching goal of HCI is to achieve both organisational and individual user effectiveness and efficiency, while ensuring system functionality and usability, effective user interaction support, and enhancing the user experience when interacting with the system. For this reason, the research describes the spoken language human computer interface (HCI) and its influences on the business processes and activities with particular interest in the efficiency of speech-enabled data capture. The IS researcher’s perspective affords emphasis on managerial and organisational contexts by focusing on the analysis of tasks and outcomes at a level that is relevant to organisational performance and effectiveness (Zhang, Nah, &
Benbasat, 2005). Hence, the HCI is investigated from an IS perspective, as the software developed and then implemented occurred in an organisational setting with definite managerial, business and human factors considered. This research seeks to explore whether the overriding success factors for speech-enabled applications, is reliant on the system design’s support of the organisation context (Flynn, 1998) and not the technology alone.

The background and motivations for this research are now discussed.

1.2 BACKGROUND

Tracking injuries sustained by elite athletes has been a major concern over many decades for coaches and trainers in elite sporting clubs as they attempt to understand the impact those injuries have on the athlete’s treatment and subsequent performance. Within the past two decades specialist software has existed to:

1) track the injury;

2) record the corresponding treatment; and

3) document the athlete’s training schedule and rehabilitation, so they may return to competition (Presagia, 2007).

Today, injury tracking is considered as just one part of injury management.

The ESC in this research is a professional sporting club at the elite level that exists within a league of similar sized clubs which are highly competitive at the national level in Australia. There are 16 clubs that comprise the league. Each club fields one team in the competition and is restricted to 44 players per club (ESC to SpeechNet e-mail, 27 June 2006). This equates to a total of approximately 700 players in the competition. While there is a short pre-season competition lasting 3 weeks, the main premiership season consists of 22 weeks of competition plus 4 weeks of final series. The last week of the final series is the grand final, which is played between the two top teams in the competition. The grand final winner wins the league’s premiership title for that season, which is a highly revered title by the 16 clubs. Achieving the premiership title improves the financial stability of the club as it often leads to growth
in supporter numbers and increased sponsorship revenue to fund the club’s business operations. The clubs are governed by an independent league regulator (Association), to which they are accountable and financially dependent (Marjoribanks, 2006). The Association is a professional league which attracts substantial revenue through television and Internet rights, and more recently mobile phone services. In 2007, the Association’s industry sector contributed A$3.417 billion to the Australia economy, and attracted approximately 7.5 million spectator attendances to league games (AFL, 2008). To facilitate teams competing on an equal basis, “player payments are capped at approximately A$6.75 million per club” (ESC to SpeechNet e-mail, 27 June 2006).

While the league regulator holds a considerable power base (Stewart, Nicholson, & Dickson, 2005), the clubs have some autonomy to pursue activities that best suit their needs, such as training methods and performance measurements. For example, many clubs have opted for some form of software application to track athletes’ injuries. The ESC in this study is considered within the Association as a financially sound and very competitive club. They are well resourced with both staff and money to position them as one of the top clubs in the competition. Having the capability to execute their business strategy is essential to ensure the club is in a strong competitive position to contest the premiership. All clubs have similar demands in fielding a competitive team, but some do not have the capability to deliver equally (ESC to SpeechNet e-mail, 27 June 2006).

Prior to this study, the researcher actively participated in the development and implementation of the improved speech-enabled application (ISEA) conducted by SpeechNet on behalf of the ESC. The SpeechNet and ESC project work was formalised through a commercial contract. The researcher performed both the business analyst and project manager job roles in the ISEA development project team. The researcher therefore is a participant observer (DeWalt & DeWalt, 2002) in this study. This has significant implications in terms of the scope, quality and completeness of the research data that was collected. As a business analyst, the researcher immersed himself in the organisation, uncovering the business problems in the organisation and making recommendations on information systems (IS) solutions in conjunction with key ESC personnel. As the project manager, the researcher obtained a first hand account of business process improvements and other cultural and
organisational issues from steering committee meetings and other management meetings. Essentially, the researcher obtained insights into both operational and management issues and developed in-depth understanding of the business pressures and drivers for change in the organisation beyond the information technology (IT) application. This is vital to obtaining a holistic and in-depth understanding of the IS adoption in the ESC.

Further, it highlights the broad scope of this research, dealing with the end-to-end influences that address the research topic and the research questions. Rather than covering the technology solution only, this research explores the business issues surrounding the implementation of the IS in the work environment. While the commercial perspective of this research continues in the future, the researcher now has the opportunity to go beyond, to study as well as reflect on, the processes and influences that are part of the commercial venture. The researcher continues to be immersed in the natural setting of the problem area.

1.3 SIGNIFICANCE AND MOTIVATION

I have a keen interest in the application of artificial intelligence in business information systems. More specifically, my interests lay in human computer interaction using speech recognition and natural language as the user interface mode to business applications. There is a growing interdependence between systems, applications, services and critical business functions (Applegate, Austin, & Soule, 2009; Laudon & Laudon, 2004), and data volumes have increased substantially as organisations harness technology to improve business efficiency and to create a business advantage (Applegate et al., 2009). Applying technology to efficiently capture large volumes of data is the prime interest for this research. That is, can the application of both speech recognition and natural language technologies be applied to critical business functions to enable more efficient and timely capture of critical business data?

While graphical user interfaces provide a significant improvement on text-based, menu-driven systems of the 1970’s and 80’s these can be complex to use. Implementing a common ‘look and feel’ across applications, particularly around web browser ‘look and feel’ attributes, has improved the intuitiveness of these applications
for basic functions such as print, save and open. However, many of the other application’s functions remain hidden to the user. Without training, or considerable time exploring the application through the graphical user interface menus, users generally do not know how to perform or may not even be aware of the many functional capabilities of an application (MacKenzie & Soukoreff, 2002). The introduction of new and emerging technologies to support mobile devices, such as personal digital assistants, iPods, and mobile phones, poses many challenges for developers to build effective user interfaces (Canny, 2006). The challenge for developers is to determine how to design the user interface in such a way that users can intuitively access the full range of application functions, and do this within the constraints of a small screen which displays information and navigation menus. Adding a virtual keyboard to the user interface so that data can be entered, further impacts on screen design. Hence, performing simple tasks on a mobile phone can involve “multiple menus, options and sub-menu paths to access each application” (Hampshire, 2006, p.3) which impacts on the application’s user friendliness. Apple Inc. has made considerable advancements with this limited screen size by the effective use of touch screens and new technologies such as:

1) Glide, flick, pinch technology using the multi-touch touch screen interface; which allows a user to glide through music albums, flick through photos and enlarge them with a pinch of the finger, and zoom in and out on a section of the web. Having this capability means application data can utilize most of the 3.5 inch display screen for the display of information rather than lose this space to buttons and other control functionality (Apple Inc, 2009);

2) Accelerometer; which detects rotation of the iPod touch device and automatically changes the viewing from portrait to landscape and vice versa. The technology can also be used to control a game using movements. In this case the Accelerometer technology is used as a steering wheel to control directional movements in games (Apple Inc, 2009).

Both these technologies enhance the usability of applications and reduce the need to construct a complex set of screens and/or menus to perform the same function. For similar reasons, speech recognition has been used to improve the usability of devices...
and applications. In 2006, there were over 50 million mobile phones equipped with speech recognition software to overcome the complexities associated with user interface design and device usability (Hampshire, 2006).

However, business data entry is not ad hoc or simple; it is usually large in volume; the data are often critical to business operations; and considerable resources are required to enter data. Performing large volume and complex data entry is not well suited to mobile devices (MacKenzie et al., 2002). Further, from personal experience as a practitioner, data entry on a PC can also be complex requiring many screens to navigate in order to complete one transaction.

I argue that current graphical user interfaces are increasingly complex and at times very difficult for users to navigate. Office automation applications are a good example where users restrict their application usage and training to “small-chunk, immediate, work-driven, relevant learning” (Gupta & Bostrom, 2006, p.179). In the following discussion I provide a brief example to demonstrate how a common function is often complex, frustrating and time consuming to unfamiliar users of an application.

Where, for example is the software function to connect a computer to an external data display projector in Windows Vista? While this is a common need for presenters to know the location of the function, it is not intuitive. This is how to find it:

1) Go to desktop screen on a PC running Microsoft Windows Vista;

2) Right-click mouse;

3) Select personalize from drop down list;

4) Select display setting from a list of other functions;

5) Now connect your PC to data projector.

From this short example, it is possible to understand that simpler, quicker and more intuitive interfaces, such as speech recognition are needed.

Hence, a significant motivation for this research is to investigate whether speech recognition and natural language understanding technologies can be used in a
business context to improve the efficiency of the HCI, resulting in usability improvements to the application. This research is timely as there is a growing interest in using speech recognition in business applications (Washburn, 2002; Zhang, Brown, Mersereau, & Clements, 2002). Advances in natural language processing and speech recognition technology “promise ubiquitous and personalised access to information, communication and entertainment services” (Gilbert, Knight, & Young, 2008, p.15). Spoken language as we know is the most natural way to communicate. Spoken language provides the means to communicate in some instances very complex requirements in a simple way. To perform an equivalent transaction via a graphical user interface may require navigating many different screens to perform the same functions. Further, spoken language is not constrained to using exactly the same phrase for a given transaction. Language is generally free form with many different ways to construct phrases with similar meaning (Bangalore & Johnston, 2003).

Hence, I argue spoken language:

1) provides a user interface independent of a fixed process to follow when entering data;

2) can describe simple and very complex application requests; and

3) is independent of the difficulty for the request to be executed by the application.

Extracting meaning from spoken language is a complex process which has resulted in many different models and approaches proposed to interpret and understand what has been said (De Mori, Bechet, Hakkani-Tur, McTear, Riccardi, & Tur, 2008). Interpretation of spoken language is further complicated by poor speech recognition accuracy (Gilbert et al., 2008). Poor speech recognition accuracy results in incorrectly transcribed words of what is spoken. As a result, if a “whole utterance is unreliable [due to poor speech recognition] then the word contained in that utterance is likely to be incorrect” (De Mori et al., 2008, p.55). Even in cases where the spoken language has been transcribed correctly by the speech recognition engine, the spoken language usually lacks the explicit punctuation and formatting (Ostendorf et al., 2008) of normal written documents, to facilitate understanding of what was said.
The ESC provides an excellent organisational context for the investigation into the use of speech-enabled applications in a real organisational setting, as it has special needs in relation to accessing timely information regarding its athletes. At the Association or code level of elite sports, there has been a distinct trend towards ensuring that trainers and coaches consistently collect and control knowledge of injuries (Kessler, Summerton, & Graham, 2006); and associated with this is an increasing volume of data with various types of information needed.

The focus of this research is therefore the development and implementation of innovative software with a new HCI to capture the critical injury management data at the ESC. This research describes the use of technology at the cutting edge (Jessup & Valacich, 2006) which results in influencing the injury management business processes. Of necessity therefore, this research describes the software and the innovative HCI. However, the interest lay not merely in describing the technology, but includes an investigation into the influences of it on the business processes resulting from the new HCI.

Expected outcomes of this research include: obtaining an in-depth understanding of the technology issues and software engineering practices surrounding developing spoken language systems, and determining the influences the purpose-built spoken language technology application has on the success of the business process it supports. Exploring both the technology and its influences on the business process provides a valuable contribution to a perceived gap in the IS literature. Specifically, the gap pertains to the application of spoken language technology as a means to capture injury data which is necessary to support a complex and vital business process in an elite sporting club.

1.4 Outline of the Research

This research describes the development and implementation of an improved speech-enabled application (ISEA), which captures knowledge contemporaneously, therefore enabling improved quality and efficiency of data analysis, as well as improved management of critical knowledge. The aim of the research is to describe how the business processes of injury management are influenced in an elite sporting club as a
result of the introduction of a speech-enabled software application. Hence, the research question framed to address this aim is:

“How does the development and implementation of speech-enabled software influence the injury management business processes of an elite sporting club?”

The sub questions associated with this are:

a) What are the components of a speech-enabled software application?

b) What are the processes involved in developing a speech-enabled software application?

c) How has the speech-enabled application influenced the capture of injury data?

 d) How does the implementation of the speech-enabled software application influence the injury management business processes?

This research through both the examination of ISEA, and an interpretive case study, determines whether ISEA is an enabler for the timely capture of injury data.

1.5 ORGANISATION OF THE THESIS

Chapter 1 – Introduction

Chapter 1 commences with a brief overview of the research. The elite sporting club (ESC) is introduced and its relevance to this research is highlighted. The significance and motivation for this research is then discussed, followed by an outline of the research, including the elaboration of the research questions.

Chapter 2 – Literature Review

Chapter 2 provides a review of the current literature across two strands of enquiry: 1) spoken language human computer interfaces; and 2) injury management, with specific emphasis on its application in elite sports. The chapter commences with a brief introduction to artificial intelligence. As the development of speech-enabled applications is a main area of investigation, the review of the literature includes
systems development methods and models, with a focus on speech-enabled application development for business systems. Finally, Chapter 2 presents a conceptual framework developed from the literature.

Chapter 3 – Research Methodology

Chapter 3 provides a detailed description and justification of the research design and methodology used for this research. Chapter 3 begins with describing the organisational context and in so doing establishes the scope for this research. With the study scope set, Chapter 3 moves to providing a general discussion of research methods as input to describing and justifying the study’s research methodology. Chapter 3 then outlines the research process undertaken and considers the major inputs, processes and research outcomes. The methods of data collection and management, and the associated roles of the researcher and participants are then discussed.

Chapter 4 – Description of the improved speech-enabled application (ISEA)

Chapter 4 provides an in-depth description of ISEA. The chapter begins with a discussion surrounding the business problem that ISEA solves. This underpins the evaluation/assessment of whether ISEA results in business improvements specifically through solving the business problems as identified by the ESC. Chapter 4 then describes the software development approach adopted by the ISEA project team. This provides an excellent insight into systems development methods for speech-enabled application development. Specifically, the systems development activities associated with incorporating spoken language into human computer interfaces are analysed. In particular, systems development activities are viewed from two perspectives: 1) speech recognition; and 2) natural language understanding. Finally, a detailed description of the processes performed and techniques used to improve speech recognition accuracy is provided.

Chapter 5 – Evaluation of the implemented improved speech-enabled application (ISEA)

Immediately following development, ISEA was implemented at the ESC. Chapter 5 describes the users’ views of the implemented application and its impact on the injury
management business process operating at the ESC. In doing so, injury management is defined from the ESC’s perspective. Specifically, Chapter 5 provides an in-depth analysis of: 1) the users’ perspectives of ISEA and their views of spoken language technology; and 2) the injury management process ISEA supports.

Chapter 6 – Unexpected outcomes emerging from this research; and conceptual framework revisited

Chapter 6 continues the analysis of the research data and discusses the unexpected outcomes emerging from the study. The unexpected outcomes cover knowledge transfer and sharing, communities of practice, and competitive advantage. Chapter 6 then revisits the conceptual framework developed in Chapter 2, and considers the impacts of the research findings on this conceptual framework.

Chapter 7 – Conclusion

Chapter 7 commences with the key findings of the research. The limitations of the research, implications for practitioners, and future research are then discussed.
Chapter 2 LITERATURE REVIEW

2.1 INTRODUCTION

This chapter provides an in-depth review of the current literature relevant to speech-enabled applications and injury management. Both speech recognition and natural language are key components of the technical architecture of speech-enabled applications (Dybkjær & Bernsen, 2002). Speech recognition and natural language understanding have made significant advancements over the last decade with many examples of this technology’s prevalence in today’s society; such as machine language translation (Jurafsky & Martin, 2000), bank balance enquiries, movie schedule enquiries, and intelligent homes (AAAI, 2009). This literature review outlines the current themes in contemporary speech technology research, and its relevance to business. The review includes a description of the application of speech technology in business, with specific focus on the health domain. Issues concerning current research and problem areas which require further research are discussed. As such, the literature review provides a baseline to review in context the contributions of this research.

The literature is reviewed across two strands of enquiry: 1) spoken language human computer interfaces; and 2) injury management, with a specific emphasis on its application in elite sports. The review surrounding spoken language human computer interfaces provides details of the technology used in spoken language systems and describes the issues associated with spoken language understanding. Nuances of spoken language and domain specific language in the area of health are also investigated. As the development of speech-enabled applications are a key area of investigation in this study, a review of the literature surrounding systems development methods and models, with a focus on speech-enabled application development for business systems is included.

Overall, the literature review aims to address the research questions from several perspectives:

1) speech recognition and issues associated with speech recognition accuracy;
2) spoken language and how this differs from written communication; hence its impacts on the HCI discourse;

3) models/techniques used to improve speech recognition accuracy and natural language understanding; and

4) the injury management business process.

Speech recognition and natural language research stems from computer science research and more specifically the research field of artificial intelligence (AI) (AAAI, 2009). While the terms such as ‘natural language processing’ are used often in the AI research field, they require further explanation. The chapter therefore commences with a background review of AI, including definitions of speech recognition and natural language processing.

2.2 BACKGROUND

The Association for the Advancement of Artificial Intelligence defines AI as “the scientific understanding of the mechanisms underlying thought and intelligent behaviour and their embodiment in machines” (AAAI, 2009, p.1). The embodiment in machines refers to the engineering and construction of computer programs and machines that are capable of solving problems to achieve real world outcomes (McCarthy, 2007). Hence, it is argued, these machines demonstrate intelligence. Put simply, AI performs tasks usually undertaken by natural intelligence (Lamont, 2007). There has been much debate for over 50 years in the literature concerning AI, and whether computers can think. The question, “Can machines think?” was first postulated by Alan Mathison Turing as a question that needed to be proved. In Turing’s (1950) classic AI paper entitled “Computing machinery and intelligence”, Turing proposed a test to answer this question (Saygin, Cicekli, & Akman, 2000; Oppy & Dowe, 2008).

This test, known today as the Turing Test, is a simple game called “The Imitation Game” (Turing, 1950) to determine whether a digital computer could perform as well as humans in the game (Oppy & Dowe, 2008). The imitation game works as follows. Two people and a computer participate in the game. One person is allocated the role of interrogator. The computer is an intelligent machine with the role of responding to
questions in a human way. The other human participant’s role is to convince the interrogator that the other participant is a machine and that they are human. The human participants communicate via a computer terminal. The interrogator through asking a series of questions is required to determine which of the other two participants is the computer. To win the game, the interrogator must correctly determine which of the other two participants is the machine (Jurafsky & Martin 2000). More importantly, “if the responses from the computer were indistinguishable from that of a human the computer could be said to be thinking” (Loebner, 2009, p.1). Interestingly, creating a computer that is considered human-like in thinking has not been achieved. To further this quest, Hugh Loebner in 1990 pledged a prize of US$100,000 for the first computer whose responses were indistinguishable from a human's (Loebner, 2009). The challenge continues to claim the prize. AI researchers from around the world are no doubt readying themselves for the next Loebner Prize Contest being held in September 2009 at Brighton, UK (Loebner, 2009).

Speech recognition and natural language understanding are two key strands of inquiry within the research field of Artificial Intelligence (McCarthy, 2007; Turban, Leidner, McLean, & Wetherbe, 2008). Speech recognition is a term used to describe a computer software application that turns spoken utterances into words (Turban, McLean, & Wetherbe, 2002). The speech recognition engine is the technology component in the speech recognition package which performs the task of recognising the words in the spoken utterance. Natural language understanding is the process of using computational linguistic programs that can understand human language at the same level of competency as a human (Shapiro, 1992). This field is generally known as natural language processing (Loebner, 2009). Natural Language can be in the form of written documents and/or spoken language (Sheffield, 2009). A goal of natural language processing is to allow the use of natural language (human language) to interact with computers (Jurafsky & Martin, 2000) to perform the same functions as typical graphical user interfaces provide in an application. Spoken language is a natural form of communication requiring sophisticated natural language processing to understand what has been said. The importance of speech recognition in HCI has resulted in the research fields of speech and language technologies evolving into the research area of spoken language technology (Gilbert et al., 2008).
A focus of the present research is speech-enabled applications which use both speech recognition and natural language processing to interpret and understand spoken language. Hence, the literature review now discusses speech-enabled applications and the contemporary research surrounding them.

2.3 SPEECH-ENABLED APPLICATIONS

2.3.1 SPEECH-ENABLED APPLICATIONS OVERVIEW

In the past, research has mainly centred on improvements to speech recognition accuracy and natural language understanding of complete works (Saygin et al., 2000) such as books, manuscripts or other published works (Saygin et al., 2000), and broadcast news for spoken language processing research (Ostendorf et al., 2008). Books and manuscripts provide an excellent corpus for linguistic analysis purposes. Establishing a set of corpora for spoken language is far more difficult (Ostendorf et al., 2008) as spoken language lacks the structure of written texts. To undertake linguistic analysis, large samples of language are required. For this reason, broadcast news has been used to create corpora suitable to simulate the spoken language to interact with a speech HCI (Ostendorf et al., 2008). For domain specific linguistic analysis, techniques such as wizard-of-oz (Fraser & Gilbert, 1991) have been used to create corpora (Dahlbäck, Jönsson, & Ahrenberg, 1993), which attempt to achieve two aims:

1) capture the language that is used to interact with a speech HCI; and

2) simulate a speech interface without the need to include speech recognition technology to transcribe the spoken language.

In wizard-of-oz studies, the HCI is set up in such a way that the user believes they are interacting with a computer and that the computer is interpreting, understanding and executing their spoken language discourse (Fraser & Gilbert, 1991). However, a person, instead of the computer, listens to the user; performing the interpretation, understanding and execution of the user’s spoken language discourse. Using this technique allows the developers of spoken language applications to focus on the user’s language to interact with the application without the need to consider the
potential corruption of the user’s natural language due to technology issues, such as poor speech recognition accuracy (Alapetite, 2008). In this way, the user is not constrained by what they say, and is not impacted or distracted by technology. Similarly, the experiment is not constrained by technology issues associated with poor speech recognition accuracy. Hence, the spoken language samples collected provide a true reflection of the natural language used to interact with the application. Whether natural language understanding computer programs can be written to interpret and understand language is not part of this analysis activity. The wizard-of-oz technique has been used by many researchers, such as Alapetite (2008), as a technique to model the spoken language of users to interact with the HCI.

Speech-enabled applications are proving to be successful from a business perspective (AAAI, 2009; Washburn, 2002) even though speech recognition accuracy has been poor (Lewis & Powers, 2002). Developing speech recognition engines that reliably and correctly recognise words has been far more complex than first envisaged. Research in this area has occurred for over forty years and still continues today with many challenges unresolved. The problem is that each “person's voice is different, and words can be spoken in a range of different nuances, tones and emotions” (Hampshire, 2006, p.2). Speech signal data is “enormously rich in information” (Bernsen, 2007, p.1) requiring sophisticated algorithms and fast computer processing power to successfully recognise spoken words in a timely way. Often the environment in which the user speaks is noisy, further impacting on the speech recognition algorithm’s ability to recognise spoken words correctly (Lewis & Powers, 2002). Speech recognition accuracy can fall dramatically from up to 98% in quiet office environments to 50% in environments with high background noise levels (Hampshire, 2006).

Over the last decade there has been significant improvements in speech recognition accuracy in commercial off-the-shelf packages, such as Dragon Naturally Speaking™ with claims of speech recognition accuracy of up to 99% being achieved ‘out of the box’ (Nuance, 2008). Other than the 3 to 5 minute enrolment of a new user to establish their voice profile, there is no significant training of the speech recognition engine required. New releases of Dragon Naturally Speaking™ continue to promise an ever-increasing improvement in speech recognition accuracy (Nuance, 2008).
The use of speech recognition has been mainly limited to speech-to-text dictation (Hampshire, 2006; Nuance, 2008) but also includes speech interfaces to office automation tools such as e-mail, spreadsheets and web browsing. Generally, speaking is faster than typing resulting in improvements in efficiency and productivity. However, poor speech recognition accuracy, which requires re-work to correct the errors of poorly transcribed text, can diminish these efficiency gains. Speech interfaces have been successful in business applications, such as travel bookings, financial account information retrieval, and general customer support services (Hampshire, 2006). The success of these stems from improvements to speech recognition accuracy brought about by constraining the grammar and vocabulary of the user’s spoken language (Hampshire, 2006). Some of these systems require two-way interaction between the user and the application to verify, confirm and/or repeat user requests. This impacts on the efficiency of the interaction between the user and the application, and can result in the user “looking for a way to opt out of the speech system” (Bach, 2007, p.4).

Speech interfaces can also be used to enter data directly into applications (Hampshire, 2006). That is, speech recognition is used, instead of a keyboard, to enter data into the application’s graphical user interface data entry forms. Assuming good speech recognition accuracy is achieved, using speech as the data entry modality can result in productivity improvements.

In reality speech recognition errors continue to occur, particularly as the applications become more sophisticated. As Jennifer Lai (a leader in speech technology at IBM) states, the three greatest challenges in speech technology are “accuracy, accuracy, accuracy” (Bach, 2007, p.4). Overcoming these speech recognition errors; dealing with the subsequent incompleteness of transcribed spoken language (Jeong & Lee, 2008); and “how to make natural-language understanding systems robust to recognition errors” (Moore, 1995, p.1), are key challenges for developers of speech-enabled applications. Typical software applications that use ‘point and click’ and keyboard data entry user interfaces do not need to consider errors generated by the technology elements of the keyboard and mouse. However, in speech applications, developers need to account for errors introduced by speech recognition technology,
and develop techniques, not only to detect errors, but to implement solutions that will correct the errors (Bach, 2007).

Understanding spoken language discourses automatically is compounded by the structure of the spoken language, as it is usually devoid of punctuation and sentence boundaries, and contains self-corrections, hesitations and repetitions (De Mori et al., 2008; Gilbert et al., 2008). Natural language texts contain punctuations and clear sentence boundaries which aid human understanding of what is written. Spoken language discourses, on the other hand, lack structure, and rely on spectral information including laughter and prosodic features, such as fundamental voice frequency (pitch), duration, and energy patterns to identify sentence and text segment boundaries (Ostendorf et al., 2008). Humans readily detect changes in pitch in person-to-person discourses, and associate a drop in pitch as an end of sentence indicator. Facial expressions also provide humans cues to dialogue inferences, enhancing their understanding of the discourse. From a computer science perspective, considerable research is being undertaken to incorporate a number of techniques including lexical information, spectral and prosodic cues to uncover text segment boundaries (Ostendorf et al., 2008). When humans speak naturally, if something incorrect is said, there is the tendency to make corrections while continuing to speak. In contrast, when typing into a word processor the incorrect text will be deleted and the correct text inserted. Hence, spoken language will contain both the incorrect and correct text; usually with no cue to identify this change. Automatically undertaking natural language understanding of spoken language is therefore very complex. As De Mori et al. (2008) state, natural language understanding of free form text is still years away.

To understand spoken language, the discourse requires transcribing by a speech recognition engine, such as Dragon Naturally Speaking™. The assumption is that the speech recognition engine correctly recognises the words in the spoken language. This assumption is no different than a person translating between primary languages, such as English and Mandarin. The confidence in the translation is dependent on the translator’s considered expertise in this area. If the translator often misinterprets expressions and words, then the translated text will be viewed with suspicion. It may be questioned, even if the translation looks correct, whether the translation truly reflects what was said? This is a similar problem for spoken language systems. Poor
speech recognition accuracy produces low quality transcribed spoken language and results in “decreasing application-level performance” (Jeong & Lee, 2008, p. 2.2). Low quality transcribed spoken language leads to incorrect interpretation and understanding of the spoken language, and may result in incorrect data recorded about critical information of the business. Hence, a challenge for spoken language systems is to be robust to the errors introduced from poor recognition accuracy (De Mori et al., 2008; Ostendorf et al., 2008).

While one hundred percent speech recognition accuracy would be ideal, speech recognition accuracy deteriorates significantly in today’s operational business environment, which is noisy, contains telephones ringing, has humans using complex language, and relies on the correct positioning of microphones (Lewis & Powers, 2002). Business work environments differ markedly to a laboratory testing environment where conditions are controlled. There are many examples in the literature (such as Alapetite, 2008; Patrick, Wang, & Budd, 2007) which highlight the complexities associated with the grammar and vocabulary used in the health industries to describe medical details of patients, and their corresponding high pressured and noisy operational environments.

Alapetite (2008) conducted a simulation of six anaesthetists entering anaesthesia patient records using a speech input interface to assess the usability of speech recognition in a realistic work environment. Alapetite (2008) found that speech recognition accuracy was poor in the operational environment, and therefore negatively impacted on the aims of the experiment. A partial wizard-of-oz technique was adopted to remove the dependence on the speech recognition technology component from the experiment. That is, the limitation of poor speech recognition accuracy was removed from the experiment, and a human used to perform the transcription. Patrick et al. (2007), while not using a spoken language interface, aimed to automatically convert free text clinical notes into a medical ontology. Patrick et al. (2007, p.219) found “that clinical notes about patients written by general practitioners, are in a less structured and often minimal grammatical form” compared with formal written reports.
Speech interfaces to improve the HCI with business systems have experienced problems concerning poor speech recognition. This has occurred even though employees use personal speaker-dependent speech recognition engines. Munteanu, Baecker, Penn, Toms and James (2006) state that the language (grammar and vocabulary) in the work environment is complex, therefore requiring significant training of the speech recognition engine. Further, even after training, the speech recognition accuracy is still considered inadequate and in some cases unacceptable for general rollout across the business. Alapetite (2008) also emphasised that substantial training of the speech recognition system by each user is required to obtain the improvements in data quality of the transcribed spoken language. Generally, if a “whole utterance is unreliable, then the word contained in that utterance is likely to be incorrect” (De Mori et al., 2008, p.55). Poor speech recognition of even one word in spoken language can result in unexpected outcomes of natural language understanding. Even the nature of a phrase could result in the wrong interpretation of the transcribed spoken language. For example, a doctor could describe an athlete’s injury as ‘swelling of the left knee but can X-ray’ highlighting that even though there is still swelling of the knee, an X-ray is required to fully diagnose the underlying problem. This is quite different to the situation where for the same spoken language, the speech recognition engine translation is only partially correct and could lead to quite different outcomes. For example, ‘swelling of left knee but can play’. In this case the interpretation is that even though there is swelling of the knee, the athlete can continue to play. This clearly was not the Doctor’s intention. User confidence in the correctness of the data stored, leads to confidence in the use of this data, and for business decision-making based on this data.

Extracting meaning from a spoken utterance is “a key problem in many applications of SLT [spoken language technology]” (Gilbert et al., 2008, p.15) particularly if errors have been introduced due to poor speech recognition. Language understanding of incorrect transcribed spoken language implies that the language understanding process will generate inaccurate interpretations of the spoken language. The challenge therefore is building general natural language systems that are robust to poor speech recognition but these are “still many years away” (Gilbert et al., 2008, p.15). However, by restricting the language and grammar of the spoken language within a domain, the prospects of extracting meaning from the utterance are increased.
substantially and more pragmatic solutions possible (Gilbert et al., 2008). Jeong and Lee (2008) have suggested the use of “a reference semantic frame or template … [to] extract meanings from the recognized user’s utterances” (Jeong & Lee, 2008, p.2). “Several studies have demonstrated that segmentation and punctuation prediction significantly impact language processing performance” (Ostendorf et al., 2008, p.60). Being able to segment words into paragraphs, and sentences by combining lexical information from a word recogniser helps provide cues related to syntactic and semantic constraints (Ostendorf et al., 2008) of spoken language. Extracting meaning in spoken language allows: identification and correction of speech recognition errors; and repair of incomplete utterances (Ostendorf et al., 2008).

2.3.2 SUMMARY AND DISCUSSION IN THE CONTEXT OF THE PRESENT RESEARCH

Considerable research effort has focused on identifying the problems associated with speech recognition accuracy and natural language understanding of spoken language. Several techniques and approaches have been identified to improve speech recognition accuracy but it is clear from the literature that post speech recognition error correction is still required. Similarly, several techniques have been identified to facilitate segment boundary identification in spoken language to improve the understanding of spoken language. Research has been undertaken in operational business environments and the common issues of noisy environments and complex language are key challenges for effective use of spoken language in the workplace (Gilbert et al., 2008; Lewis & Powers, 2002).

I argue that the techniques discussed, may improve speech recognition accuracy and natural language understanding, and be applied in developing a spoken language system for the capture of injury data for an elite sporting club. Specifically, this research is considering the application of spoken language technology to capture elite athlete injury data in elite sporting clubs, which has not been documented in the literature previously.

To date, studies such as those by Alapetite (2008) and Patrick et al. (2007) are experimental. Further, Patrick et al. (2007) only considers the natural language understanding components of written clinical notes. This research goes beyond
experiment and isolated components of a complete system, and evaluates the speech-enabled application which is in full operation at the ESC, and which provides end-to-end support to the critical injury management business process of the ESC.

In general, the current literature lacks an IS perspective. The focus of spoken language systems research centres on spoken language technology. I argue that an IS perspective is required to understand how spoken language technology supports business processes, and to determine whether it contributes to the overall success of the business system. Further, I argue that the adoption of an IS perspective is essential to the application of spoken language systems in the business environment.

Speech interfaces today are similar to the early days of GUIs where generation one of these applications in the workplace were technology focussed (Canny, 2006). As a practitioner during this period, the researcher recounts that the early implementations of GUI technology were simply existing test-based menu driven systems with the ability to use a mouse to navigate the screen. That is, beyond looking better, the addition of GUI technologies did not fundamentally change how the application operated. However, as we have seen over the last decade, that integration of GUI with the business process has resulted in sophisticated systems to streamline business operations (Kendall & Kendall, 2005). I argue therefore, that speech interfaces require the same level of sophistication to ensure that they are integrated with business processes, and then the true value of spoken language technology will be realised, resulting in their subsequent widespread adoption by business.

Primarily, the aim of the improved speech-enabled application at the ESC is to improve poor speech recognition accuracy to an acceptable level, and to enable the data capture of important injury information of elite athletes using speech technology. The key business driver for using speech technology was to improve the efficiency of entering injury data. A secondary aim of the speech-enabled application was to facilitate improvements in the timeliness of injury data so that this information could be used for the management of athlete injuries. I argue that improvements to speech recognition accuracy alone will not achieve these aims. The solution should be driven from an IS perspective; therefore considering how speech technology can support the business process of injury management. Hence, the IS solution is assessed in terms of
its ability to integrate speech technology with the injury management system, and to deliver the business process improvements sought by the club.

The literature review now considers the processes involved in developing spoken language systems.

2.4 SYSTEMS DEVELOPMENT METHODS AND MODELS

To establish a baseline to discuss the literature surrounding spoken language systems development processes, this section commences with an overview of a selection of the most prominent generic systems development lifecycle models relevant to this research. Of specific interest to this research are models based on iterative systems development approaches, as these appear most relevant to the situation faced at the ESC under study, and to current spoken language systems and development. The review then presents an analysis of current research pertaining to spoken language systems development.

2.4.1 SYSTEMS DEVELOPMENT LIFECYCLE MODELS OVERVIEW

The role of IS in organisations has expanded and become more important over time (Laudon & Laudon, 2007). Today’s IS involve a broader scope, as IS are more complex and affect more people (Laudon & Laudon, 2007). This changing role of IS includes the support of business strategies, enabling more flexibility in organisation structure and the redefinition of markets that these businesses access (Applegate et al., 2007). An organisation’s adoption of new ways of working can provide the opportunity for a competitive edge (Turban et al., 2008). In this way IS plays a key role in enabling the organisation to develop a competitive advantage.

Business strategic planning is influenced by the introduction of IS into organisations (Applegate et al, 2007). Whether an organisation decides to develop their own IS or acquire a package solution, high performing organisations adopt a best practice management approach to IS projects (Schwalbe, 2007). Best practice “is an optimal way recognised by industry to achieve a stated goal or objective” (PMI, 2003, as cited in Schwalbe, 2007, p. 21) which in systems development refers to all the tasks and activities associated with introducing a particular information system into the business
environment (Cadle & Yeates, 2008; Schwalbe, 2007). The tasks and activities typically include requirements gathering, software construction and all IT aspects and workplace impacts, such as training and business process re-engineering. Systems development projects are costly and can require several years before they are completed. Whether projects are small or large, it has been argued that they should use a formal approach to improve the quality of the outcome and to reduce risk of failure (Schwalbe, 2007). The formal process organisations and professionals use to deliver IS is the software engineering process which provides the framework for “cost-effective development of high-quality software systems” (Sommerville, 2004, p. 4).

Systems are often characterised as following a life cycle known as the Systems Development Life Cycle (SDLC). The life cycle commences at project initiation and follows a series of phases through to implementation, maintenance and decommissioning of the system (Cadle & Yeates, 2008; Laudon & Laudon, 2007; Sommerville, 2008). The software engineering process uses this framework to manage systems development projects (Sommerville, 2008). Over the years, there has been considerable research conducted with attempts to minimise the risk of failure when creating a new or modifying an existing system (Alter, 1992; Cadle & Yeates, 2008; McLeod & Smith, 1996; Sommerville, 2004). According to Cadle and Yeates (2008), an appreciation of the various models used in developing IS is needed so that the most appropriate model is selected to meet the constraints of time, cost, quality, resources and risk which are placed on the project. Many systems development models are based on two foundational lifecycle models, the Waterfall model and the Spiral model (Cadle & Yeates, 2008).

Royce originally published the Waterfall model in 1970 (McLeod & Smith, 1996), to introduce formality into the systems development process. The Waterfall model aimed to introduce some rigour to the development process. Key to the Waterfall model approach is that development of an IS occurs over a number of discrete stages which are linked, with the completion of each stage required before the next stage commences, as indicated in Figure 2.1 (Cadle & Yeates, 2008; McLeod & Smith, 1996; Sommerville, 2004). The output from the previous stage becomes the input for each subsequent stage (Cadle & Yeates, 2008). Adopting this waterfall approach to
systems development can be problematic however, as errors that originate in earlier phases, such as the ‘Analysis’ phase, may not be detected until the system is implemented. Viewing each phase as discrete and sequential in execution can therefore result in costly rework (Boehm, 1981; Martin, 1993).

Nevertheless, the Waterfall model provides a useful basis to understand the processes involved in systems development, and is the basis for many software development process models, including the ‘V’ and iterative development models (Cadle & Yeates, 2008; Sommerville, 2004).

The ‘V’ Model is a variation of the Waterfall model, with the phases represented in a V shape as depicted in Figure 2.2. The ‘V’ model introduces the project activity of validation of the deliverables from each phase of the Waterfall model (Cadle & Yeates, 2008). Where defects are found in deliverables they are referred back to the corresponding development phase in the model (Hughes & Cotterell, 1999) thus introducing quality assurance rigour to the processes of systems development.
The Spiral model, developed by Boehm in 1988, introduces a concept of evolutionary systems development or iterative development which distinguishes this model’s systems development approach from the Waterfall model (Cadle & Yeates, 2008). The significance of the model is that each sweep, as indicated in Figure 2.3, represents consideration of a greater level of detail for that phase with evaluation of the phase before moving in greater detail to the subsequent phase (Boehm, 1988; Hughes & Cotterell, 1999). At the start, the centre of the spiral, the requirements are usually poorly understood but these are progressively refined with each sweep around the spiral (Boehm 1988; Cadle & Yeates, 2008). According to Larman (2004, p.9)  “iterative development is an approach to building software in which the overall lifecycle is composed of several iterations in sequence”. Therefore, each iteration is in essence a mini-project composed of requirements engineering, systems design, programming and testing. The completion of an iteration allows for the release of a partially tested and completed system. Each iteration includes production quality programming; hence the iteration does not finish with the requirements engineering.

Figure 2.2 - The ‘V’ model (Source: Hughes & Cotterell, (1999, p.66)
phase (Larman, 2004). Further the resulting software is not a prototype but a subset of the final product. “Evolutionary iterative development implies that the requirements, plan, estimates and solution evolve or are refined over the course of the iterations, rather than fully ‘frozen’ in a major up-front specification effort” (Larman, 2004, p.15) before the development commences. This is a key point of differentiation between iterative development models which are cyclic, and sequential models such as the Waterfall model. Sequential models assume each phase is completed for the whole systems development project before work commences on the next and subsequent phases.

![Figure 2.3 - The Spiral model (Adapted from Boehm, 1988; Thayer & Dorfman, 1990)](image)

Iterative development methods consist of four phases including requirements planning, user design, construction and cutover (Avison & Fitzgerald, 2003). These phases are very similar to the Waterfall model. However, how the phases are executed differs significantly from the sequential approaches such as the Waterfall model. There are many forms of iterative development methods (Cadle & Yeates, 2008);
however, they generally involve a number of techniques which enable the requirements to be developed iteratively. The tools and techniques include prototyping (Somerville, 2008) and joint applications design (Kendall & Kendall, 2005), where the users and IS specialists jointly design the system in a participative approach. Hence, system developers value close consultation with users concerning their requirements and embrace change (Cockburn, 2002) as the requirements evolve over the course of the project.

The Agile development method is an example of an iterative development methodology (Cockburn, 2002). Agile development methods apply time-boxed iterative development cycles which are rapid and flexible in response to change (Cockburn, 2002; Larman, 2004). For a methodology to be Agile software development, it has been argued that it must subscribe to the following four principles. One must value:

1) “Individuals and interactions over process and tools;

2) Working software over comprehensive documentation;

3) Customer collaboration over contract negotiation; and

4) Responding to change over following a plan” (Cockburn, 2002, p.213).

Agile systems development results in smaller iterations; hence closer interaction with the user is required. Essentially, the Agile approach recognises that requirements need to evolve (Cockburn, 2002). A comparison between the Waterfall approach, iterative development and extreme programming (XP), the most common Agile methodology (Beck, 1999), is shown in Figure 2.4.
Figure 2.4 demonstrates that similar phases are involved in each method. The Waterfall model highlights that each phase is executed once for the systems development project. For iterative development projects these phases are executed many times for a given project, as requirements evolve. The iteration through the phases continues until the system requirements have been fully implemented. The key difference between typical iterative development methods and XP is that the time-boxing of iterations results in many more iterations through the phases (Beck, 1999). That is, smaller increments are progressively implemented.

A broad overview of system development life cycle models and methods relevant to this thesis has been provided in this section. They are relevant, as they provide a baseline reference for discussion and comparison of the literature pertaining to the speech-enabled applications systems development approaches. Spoken language systems development includes the extra system components of speech recognition and language understanding, which are not typically included in the majority of contemporary applications. This research aims to investigate whether the inclusion of these technologies in applications impacts on the systems development approach adopted in spoken language development projects.
Of particular interest is the software engineering methods used to capture the natural language requirements involved in HCI spoken language discourse. Of further interest are the methods used by developers to improve speech recognition accuracy, and the processes involved in building robust natural language understanding programs capable of handling the nuances associated with spoken language input. With this in mind, Section 2.4.2 reviews the current literature relating to software engineering practices associated with the development of speech-enabled applications. The investigation considers the software engineering practices from a whole systems development perspective. The intention is not to be prescriptive for the activities of a particular phase of systems development. Instead, the review adopts a holistic approach in determining overall processes involved in spoken language systems development.

This study considers speech-enabled applications within a business context and information systems perspective. Hence, this research investigates systems development from a complete systems development viewpoint, to ascertain the important link between technology and software engineering practices in achieving successful business outcomes. Spoken language systems development is now discussed.

### 2.4.2 Spoken Language Systems Development

Systems that include the use of speech recognition and natural language understanding in the HCI are known as ‘spoken language dialogue systems’ (SLDS) (Dybkjær & Bernsen, 2002). The key focus of SLDS development is the user interface and the activities involved in interfacing speech with the application. Examples of spoken language interfaces are mobile phone information retrieval and car navigation (Jeong & Lee, 2008) which use a speech interface to interact with the application.

On the surface it appears that ISEA can be classified as a spoken language dialogue system. This is partly so, as ISEA uses speech recognition and natural language understanding (Dybkjær & Bernsen, 2002) in the HCI. However, ISEA does more than provide a spoken language interface to an existing application. The ISEA speech interface is designed to integrate with the ESC injury management business process.
Prior to ISEA, the ESC “investigated a couple of ‘off the shelf’ voice response software packages” (ESC to Association proposal, 20 September 2006, p.2) to act as a SLDS to their existing injury tracking application. That is, speech recognition was used in conjunction with the natural language understanding capabilities of the speech recognition software to provide a spoken language interface to the injury tracking application. Voice commands were used to navigate the injury tracking application and for injury data entry into fields. However, these speech recognition packages did not result in the necessary improvements to data entry efficiency (ESC to Association proposal, 20 September 2006). Hence, the implementation of a simple speech interface did not achieve the business outcomes required.

Speech integration with an application, (rather than a speech interface to an application), impacts directly on the way speech-enabled applications are developed. The focus of current research centres on speech interface development and the techniques to build effective speech interfaces (Bangalore & Johnston, 2003; Dubinsky, Catarci, & Kimani, 2007; Dybkjaer & Bernsen, 2002; Jeong & Lee, 2008) rather than systems development processes to build applications with the intent to integrate spoken language technology with the system.

As Dubinsky et al. (2007) state, speech interface development is viewed in terms of user evaluation across 4 methods:

1) cognitive walkthrough technique;

2) heuristic analysis technique;

3) wizard-of-oz; and

4) the think aloud technique.

There is congruence, however, among researchers on the use of the iterative systems development method or similar methods used for SLDS (Bangalore & Johnston, 2003; Dubinsky et al., 2007; Dybkjaer & Bernsen, 2002). Speech interface development “should iteratively understand the users’ needs, provide evaluation measures with respect to users’ needs, and improve the interface design and implementation in a way that each such cycle refines our product” (Dubinsky et al.,
But the theory lacks formalised methods for spoken language systems development. There is a gap in the literature concerning the processes involved in developing speech-enabled applications such as ISEA.

Bernsen’s (2002) position paper on where the speech field will go in the next 10 years highlights to the European Network of Excellence in Human Language Technologies (ELSNET) Brainstorming Workshop that “software engineering best practice in development and evaluation specialised for various speech-systems…remains ill-described in the literature” (Bernsen, 2002, p.14). The focus of research into spoken language systems has, and continues to be, predominately from a computer science perspective. The computer science research revolves around resolving very complex technical issues relating to improving speech recognition accuracy as part of speech recognition engine development, and development of generalised language understanding models to improve spoken language understanding (Jurafsky & Martin, 2000). Research into spoken language systems development from an IS perspective is essentially a new area of inquiry.

Dybkjær and Bernsen (2002) have undertaken some research into software engineering practices with the aim of describing the dialogue systems development lifecycle phases to follow when undertaking SLDS development. The model is shown in Figure 2.5. Dybkjær and Bernsen (2002) adapted the iterative systems development method and aligned this to the concept of evaluation from the ‘V’ systems development model. The phases of analysis, design, simulation, construction and integration were used to represent the 5 iterative development phases of the methodology (Dybkjær & Bernsen, 2002). The simulation phase represents prototyping of the spoken language dialogue user interface using the wizard-of-oz (Dahlbäck et al., 1993) technique.

A deficiency of the model Dybkjær and Bernsen (2002) proposed is that it does not identify the key software engineering processes involved in speech-enabled application development. Rather, it merely adds quality assurance activities specific to SLDS, to evaluate the deliverables associated with the spoken language user interface system components.
This is a serious limitation of the model, as this narrow focus lacks a holistic business systems development perspective. Hence, the model does not adequately identify the system development processes required to facilitate the spoken language application components support of the business process.

![Diagram of Dialogue engineering life-cycle phase](image)

**Figure 2.5 - Dialogue engineering life-cycle phase (Dybkjær & Bernsen, 2002, p. 6, figure 5)**

Overall, there is a significant gap in the literature when assessing the implications of including spoken language technology in the HCI and the subsequent impacts on the systems development lifecycle (SDLC) and related systems development models currently used in the development of business systems.

### 2.4.3 SUMMARY AND DISCUSSION IN THE CONTEXT OF THE PRESENT RESEARCH

This review has highlighted a significant gap in the literature pertaining to speech systems development methods, with no evidence of further research in software engineering best practice since the Dybkjær and Bernsen’s (2002) research paper. While Bernsen (2002) contends that software engineering best practice for speech-enabled systems development is ill-described in the literature, the lack of further research suggests the area has not been identified as a key issue requiring
investigation, and remains as a specialist field in the IT industry. Reasons for this may include the limited deployment of speech technology into the core operations of business, and therefore the improvements to software engineering practices for speech technology projects were not considered a key issue.

However, I argue that systems development methods which address the inclusion of spoken language as a user interface mode do require investigation, as there are now many examples demonstrating speech technologies employed in business applications (Turban et al, 2008). Hence, the need for software engineering best practice in these types of systems is becoming more important.

The ESC provides an excellent insight into the processes involved in the development of spoken language systems, as the system under investigation supports a core business process at the club, which in turn requires a well managed software engineering approach to achieve the desired business outcomes. This research aims to contribute to the software engineering best practice body of knowledge by uncovering the systems development approach adopted by the ISEA project team. Further, I argue that the ISEA systems development approach provides a major leap forward in understanding the processes involved in developing speech-enabled applications, where at its core is the use of speech recognition and natural language understanding technology.

The literature review now changes focus from the technology of speech-enabled applications to a review of the business process that it supports in the ESC. A review of the literature surrounding the injury management business process with an emphasis on injury management within an elite sporting organisation context is undertaken. The review establishes a baseline definition of injury management and the injury management business process.

2.5 INJURY MANAGEMENT

2.5.1 INTRODUCTION

Injury management is mainly centred on medical practitioners’ perspectives describing the steps and techniques they use in treating a particular injury (Lew,
Thomander, Chew, & Bleiberg, 2007). The current literature does not consider injury management as an end-to-end business process, nor does it consider injury management from a management perspective. Sports science has traditionally been “governed by advances in sports medicine” (Chalmers, 2002, p. iv23). Notwithstanding, the medical literature is of value to this research as it provides a credible basis from which to develop theory.

An extensive review of the health, information systems and sports science literature was undertaken. This uncovered considerable relevant literature that aids in drawing together the strands of enquiry of the current theory in sports science and medicine, general processes of injury management as viewed by researchers in the area of sports science and medicine, and general industry’s view of injury management. Using this as theoretical underpinning, this research aims to establish the components of a framework from which the process of injury management at the ESC can be investigated.

The literature review commences with an analysis of injury management from a worker’s compensation perspective, which is now discussed.

2.5.2 Injury Management - An Industry Perspective

Injury management is a commonly used term in workers compensation to describe the processes involved in an injured worker’s timely, safe and durable return to work following an injury (Workers Rehabilitation and Compensation Act 1988, cited in WorkCover, 2004). WorkCoverTAS (2008, p.5) defines an injured worker as “a worker who has sustained a work-related injury”, and considers injury management is a coordinated and managed process with the aim of restoring the injured worker to their pre-injury work capacity. Further, a work-related injury is defined “as an injury or disease in relation to which compensation is or may be payable under the Workers Rehabilitation and Compensation Act 1988” (WorkCoverTAS, 2008, p.7). A closer examination of injury management reveals that the focus of the process is not just the injury of the worker, but includes retraining of the injured worker in cases where alternative duties are required due to ongoing problems with the injury (WorkCoverTAS, 2008).
Hence it is expected in some instances that the worker will not fully recover from the injury and in these circumstances alternative job roles will be considered to facilitate the earliest return to work. The treatment, rehabilitation and subsequent return to work needs to occur within financial constraints which requires an injury management plan to be established to minimise workers compensation claims. The injury management process should be cost efficient and result in lower costs to employers and the workers compensation system (WorkCoverTAS, 2008). Injury management in this context is a concept recognising that employers and injured workers are the primary stakeholders in the workers compensation system, with the injury management process being transparent, cost-efficient and effective (WorkCover, 2004). Key principles of injury management include early intervention, proactive management and rehabilitation policies to achieve ‘return-to-work’ goals (WorkCover, 2004). Injury management as part of the workers compensation process is sequential with a clear start and finish. As WorkCoverSA (2008) and WorkCoverTAS (2008) state, injury management incorporates the following steps:

1) Intervention and assessment of injury.
   Step 1 of the injury management process commences with an intervention to assess the worker’s injury claim;

2) Diagnosis.
   The injured worker’s problem is then diagnosed and an injury management plan established to coordinate and manage their treatment, rehabilitation and their eventual return to work (WorkCoverTAS, 2008);

3) Treatment.
   The injury of the worker is treated by a medical practitioner;

4) Rehabilitation.
   This is a managed process involving medical and occupational rehabilitation services which is aimed at returning injured workers to employment. Rehabilitation is an important step in determining whether the injured worker is able to return to work; and
5) Return to work.

The injured worker has been assessed as ready for return to work. In some cases it might be necessary to intervene in the workplace to assist the worker’s return to work (WorkCoverSA, 2008). It is expected that treatment may need to be reassessed and modified but the aim of the long term therapy of injury workers is generally not supported and “will cease when no further improvement in function is attainable” (WorkCoverSA, 2008, p. 29). Hence, the aim of the injury management process is for the injured work to return to work, and to leave the injury management process once this has occurred (WorkCoverSA, 2008; WorkCoverTAS, 2008).

2.5.3 Athlete Injury Prevention

Injury prevention has become a significant research area and its industry prominence is highlighted by the establishment of injury prevention world conferences, such as the ‘World Conference on Sports Injury Prevention’ as a vehicle to share knowledge between researchers and practitioners. Timpka, Ekstrand and Svanström (2006) suggest that one in five injuries in the industrialised world is sports-related, which indicates why “sports injury prevention is emerging as a new field in medicine” (Bahr, 2008, p.1).

The link between sports and injuries has been well documented through epidemiological studies which show that sport increases the likelihood of injuries occurring (Bahr, 2008; Chalmers, 2002). As human activity moves from a brisk walk to running, and jumping and tackling on a football field, the probability of incurring an injury increases significantly (Bahr, 2008). van Mechelen, Hlobil and Kemper (1992) describe the sequence of prevention of sport injuries (known as the van Mechelen model), to assist researchers interested in injury prevention to examine the progress of injury prevention measures (Chalmers, 2002). The model was derived from the public health prevention model to reflect the sports injury context (Finch, 2006). van Mechelen’s model is illustrated in Figure 2.6.

Step 1 of van Mechelen’s model determines the injury problem, which includes describing the injury, its severity and how it occurred. Once the injury is described,
Step 2 undertakes an in-depth analysis of the cause, origins, reasons and mechanisms leading to the injury. This information is essential for identifying preventative measures. Based on the outputs from Step 2, Step 3 develops strategies and other injury preventative measures that can be introduced to reduce the future risk of injury or at least the severity of the injury. Once new measures have been introduced, they are evaluated to determine their effectiveness. This occurs in Step 4 of the model. Step 4 is performed in conjunction with Step 1 as the assessment of the effectiveness of preventative measures must be evaluated against new injuries that emerge for which the preventative measures were to address.

Chalmers (2002) states that generally the use of van Mechelen’s model has not progressed beyond Step 1. That is, most effort has been expended in the collection of information pertaining to the description of the injury. Interestingly, a few years later this situation only progressed slightly to Step 2. As Finch (2006, p. 4) states, “general sports injury research field is still needing to largely move beyond stage [Step] 2”. Cumps, Verhagen, Aerts and Meeusen (2008) support this view but go further to state...
that the methodology to support Step 2 is particularly lacking, as it does not include the fundamental role that sports science research plays in establishing the aetiology of injuries, that is to understand the origins, causes, severity and mechanism of the injuries (Finch, 2006). Finch (2006) highlights that many studies in injury prevention only report the descriptive incident of injury due to limitations associated with the methods used for data collection, timeliness of the data collection, poor definition of injury and its severity, and univariate statistical descriptions of the data, leading to poor data analysis. This is consistent with Chalmers (2002) who also emphasises that injury data capture is still not occurring to the level required for in-depth analysis in Step 2 of van Mechelen’s model. Without high quality injury data, injury prevention measures cannot be determined with a high level of confidence. This is a key point which highlights the importance of having a well supported organisational business process to provide the mechanisms required to capture this data. An ad hoc approach to injury prevention fails at Step 1 of van Mechelen’s model when data are not captured adequately.

Generally, the four stage model has been useful to build evidence-based practice (Fowler & Lee, 2007) concerning sports injuries, but has limitations surrounding the implementation of preventative measures (Finch, 2006). To address this, Finch (2006) developed the TRIPP model (Figure 2.7) which adds several new steps to van Mechelen’s model. Stages 1 through to 4 of the TRIPP model correspond to Steps 1 through to 4 of the van Mechelen model, as illustrated in Figure 2.7.

The TRIPP framework (Finch, 2006) recognises that complete evidence-based prevention requires:

1) injury problem description;

2) understanding of the aetiology of the injury;

3) development of preventative measures and undertaking efficacy research of these interventions;

4) relating interventions to individual athlete contexts and adapt these interventions to suit individual athlete needs;

5) development of implementation strategies of the interventions to ensure effective real-world rollout of these interventions; and
6) evaluation of the interventions to determine their effectiveness within the implementation context (Finch, 2006).

---

**TRIPP**

STAGE 1 - Injury surveillance

STAGE 2 - Establish aetiology and mechanisms of injury

STAGE 3 - Develop preventative measures

STAGE 4 - “Ideal conditions”/scientific evaluation

STAGE 5 - Describe intervention context to inform implementation strategies

STAGE 6 - Evaluate effectiveness of preventive measures

---

*Figure 2.7 - The Translating Research into Injury Prevention Practice (TRIPP) framework (Adapted from Finch (2006, p.4))*

The key differences between the van Mechelen and TRIPP models are understanding the implementation context and ensuring injury preventative measures are tailored to real-world outcomes. Cumps et al. (2008) support the use of the TRIPP framework for injury prevention, but propose the TRIPP model requires further extensions to support the multi-disciplinary approach required in formulating strategies for injury prevention.

Prevention of injuries necessitates input from many research areas, thereby requiring a multi-disciplinary approach to be incorporated in the sports injury prevention frameworks and models. Key to both models is the collection of good quality epidemiological and aetiological information about the injury. There is general consensus in the literature (Chalmers, 2002; Cumps et al., 2008; Finch, 2006) that effective injury prevention requires:
1) an in depth description of the injury and its severity;

2) an aetiology assessment of an injury and magnitude of the injury;

3) strategies and methods to reduce the risk of injuries and/or severity of the injury; and

4) an assessment program to evaluate the success or otherwise of injury prevention strategies and methods.

This injury prevention process is sequential and iterative, requiring the collection of data at each step to feedback as input into the process.

The concept of tracking an athlete’s injuries has a history stretching back to the 1950s with coaches and trainers recording the type of injury and impacts of the injury on their training schedule (Presagia, 2007). Injury tracking software is available and has automated the processes of recording athlete injuries, including their severity; where and when they occurred; the treatment recommended by medical practitioners; and the necessary rehabilitation required (Presagia, 2007). At the association or code level of elite sports, there has been a distinct trend towards ensuring that trainers and coaches consistently collect and control knowledge of injuries to:

1) comply with risk management policies;

2) provide an identified level of injury knowledge across clubs; and

3) maintain current insurance costs (Association presentation, 15 November 2007).

This has resulted from increasing litigation from players (AFL, 2005), and the subsequent need to provide evidence that players have been correctly diagnosed, treated and rehabilitated before returning to competition (Kessler et al., 2006). This suggests that there are two business drivers for tracking elite athlete injuries:

1) better injury management to improve athlete recovery and performance; and

2) organisation governance to ensure duty-of-care compliance for their elite athletes.
It appears therefore that consistent data collection is not occurring, which is a major concern for the ESC and their Association from two perspectives:

1) from a management perspective the ESC are concerned that if an athlete is not treated correctly then this places the club at risk of legal action, and may result in a significant compensation payout to the athlete; and

2) the ESC requires coaches, trainers and other professional staff to use the information collected as part of performing their job function to improve their work performance.

Marjoribanks (2006) suggests that the organisational dynamics of professional sporting codes or associations require that while the clubs are competitive on the field, there is considerable communication and co-operation required between clubs over shared interests. Injury tracking across the clubs is one such issue that is high profile in the media and among players and their supporters, as injuries cause public concern at all levels of the game (AFL, 2005). Further, it is increasingly important that players moving between clubs have access to prior injury records. To achieve this, a consistent level of data collection is required across the Association.

2.5.4 Summary and Discussion in the Context of the Present Research

Section 2.5.3 identified 3 models: 1) van Mechelen; 2) TRIPP; and 3) Workers compensation injury management process; to establish baseline theory surrounding injury management.

From the reviews of these models, it is evident there is a large gap in the literature surrounding elite athlete injury management, sports information systems and the business processes they support. In the absence of specific literature in this area, the review has established a baseline understanding of the business functions involved in sports injury prevention through the analysis of the van Mechelen and TRIPP models, and sought to understand the generally accepted business practice for workers compensation injury management.
I argue that elite sporting clubs are performing injury management and that injury prevention is also a key area of concern for elite sporting organisations. This research aims to determine whether the injury management process at the ESC incorporates injury management and injury prevention, and whether the van Mechelen, TRIPP and workers compensation business functions can be applied to the injury management business process at the ESC. Hence, this research aims to obtain an in-depth understanding of the processes performed by the ESC in undertaking injury management.

Another important finding from the literature is that a multi-disciplinary approach to athlete injury management is instrumental to its success (Cumps et al., 2008; Dennis, 2006; Finch, 2006). Hence, this research endeavours to determine if the success of the ESC injury management business process supports this need.

Key to successful injury management and prevention is high quality data (Chalmers, 2002; Finch, 2006). This literature review has uncovered a major impediment to effective injury management and injury prevention: the efficient capture of injury data at an adequate level so that analysis may be performed. Without this, both injury management and injury prevention business functions cannot occur. Therefore, of particular interest in this research are the systems which support the important business function of capture of injury data relating to elite athletes. I argue that inadequate systems support of the business functions of injury management will negatively impact on the ESC’s ability to undertake effective injury management. This research aims to understand the influences of the implemented improved speech-enabled application on the data capture of injury data.

2.6 CONCEPTUAL FRAMEWORK

This research assesses whether speech recognition and natural language understanding improvement techniques discussed in the literature review can be applied to an existing speech-enabled application to improve its performance in an operational business environment. Specifically, this research considers the application of spoken language technology to capture elite athlete injury data in elite sporting clubs, which has not been documented in the literature previously. The objective of the research is not to test computer science algorithms to improve speech recognition
and language understanding, but to ascertain whether these technologies can be applied to a real business system; and if so, how this is achieved from the application of technology perspective. From this, a clear picture is established of the techniques used to improve speech recognition accuracy and natural language understanding to a satisfactory level for business to accept this as a feasible technology to support key business functions.

Hence recalling the research question, this study addresses the question:

*How does the development and implementation of speech-enabled software influence the injury management business processes of an elite sporting club?*

Figure 2.8 represents the conceptual framework that emerged from the literature to address the research question; including the sub-questions. The conceptual framework is designed around two strands of enquiry:

1) spoken language human computer interfaces; and

2) injury management, with a specific emphasis on its application in elite sports.

The literature raised issues surrounding speech recognition accuracy (Jeong & Lee, 2008), spoken language understanding (Gilbert et al., 2008) and software engineering practice (Bernsen, 2002). These were identified as key inhibitors to the successful deployment of spoken language systems in business and are represented by the orange rectangle in Figure 2.8.

The literature review provided many examples of techniques that could be utilised in the development of spoken language systems to improve speech recognition accuracy and understanding of spoken language. I argue, on the basis of the current literature, that these techniques can be applied to injury management information systems to facilitate the capture of elite athlete injury data. This has not been documented in the literature previously.

The investigation into these technologies is considered from two perspectives:

1) the developer’s perspective to investigate the impact of these technologies on ISEA; and
The research sub-questions framed for this investigation are:

*What are the components of a speech-enabled software application?*

*Has the speech-enabled application resulted in improvements to the capture of injury data?*

In Figure 2.8, the inhibitor, software engineering practice for spoken language systems development, is ill-described in the literature (Bernsen, 2002). This is counter to business quality practices which require repeatable and optimal processes to achieve organisation goals and objectives (PMI, 2003, as cited in Schwalbe, 2007). As Schwalbe (2007) states, software engineering best practice uses a formal approach to reduce the risk of project failure and to improve the quality of the system developed. The absence of a systems development model for spoken language application
development puts such projects at significant risk, as project management is not based on systems development models that are tailored to this type of project.

Therefore, I argue that the success of spoken language systems development projects should be considered from both the technology and management (Avison & Fitzgerald, 2003) perspectives, as they are important for the future development of spoken language business systems. Undertaking an investigation into the ISEA development processes is a valuable contribution to the systems development and software engineering body of knowledge. The research sub-question framed to address this inhibitor is:

*What are the processes involved in developing a speech enabled software application?*

Similarly, injury management is dependent on several enablers to be effective. The enablers are represented by the yellow rectangle in Figure 2.8. They are identified from the literature as:

1) a multi-disciplinary approach to injury management (Cumps et al., 2008; Dennis, 2006; Finch, 2006);

2) the capture of high quality injury data (Chalmers, 2002; Finch, 2006); and

3) timeliness of injury data (Finch, 2006).

Of interest to this research is understanding whether improvements to the inhibitors influence these enablers. This is represented as the blue arrow between the rectangle – ‘Spoken Language Application’ and the rectangle – ‘Methods to Address Enablers’. The “complexity [that] arises from the inter-relationship, inter-action and inter-connectivity of elements within a system and its environment “ (Mitleton-Kelly, 2003, p.2) and more specifically the work functions associated with the business process (Kotonya & Sommerville, 1998) suggest that this is a key area of investigation for this research. The development of an “effective information system requires thorough analyses of user information needs” (Byrd, Cossick, & Zmud, 1992, p.117). For this research to be complete, and to ensure an overall IS perspective, the technology of ISEA, the injury management business process, and the influences of ISEA on the
injury management process, require in-depth analysis. Undertaking this analysis provides the means to assess the “impact upon the ability of the developed system[s] to meet customers’ needs” (Carroll & Swatman, 1997, p.2), and the resulting user’s acceptance of the system (Hocking, 1996). This analysis is represented by the rectangle – ‘Injury Management Information System’. The injury management framework, represented in Figure 2.8 as the rectangle – ‘Injury Management Framework’, forms the theory basis by which the injury management business process at the ESC is investigated.

The injury management framework is developed from theory and encapsulates the three models:

1) van Mechelen model;
2) TRIPP model; and
3) WorkCover injury management process.

As part of this analysis the enabler ‘multi-disciplinary approach’ is analysed within the context of the ESC injury management business process. The research sub-question framed to address the enablers is:

How does the implementation of the speech-enabled software application influence the injury management business process?

The proposed conceptual framework provides a baseline to undertake an in-depth understanding of the areas of enquiry for this research, to develop and extend theory in the areas of: IS; spoken language systems technology and development approach; elite athlete injury management; and injury management business systems.

2.7 CONCLUSION

This chapter has provided a review of the literature pertaining to:

1) the technology used in speech-enabled applications;
2) the methods used to develop speech-enabled applications; and
3) injury management with a focus on elite sports.

Establishing an understanding across these three areas was essential to formulate the proposed conceptual framework. The literature highlighted several areas where theory can be tested in the elite athlete business environment in the important area of injury data capture. The review also identified several areas which are ill-described in the literature and where this study can contribute to the body of knowledge for the respective research areas.

The literature review established a baseline understanding of the business functions involved in sports injury prevention, and the business functions associated with injured workers returning to work as part of the workers compensation system. Together these areas form the basis from which theory is developed for the injury management of elite athletes in elite sporting organisations. Capture of injury data was identified in the literature as an essential requirement for the successful implementation of injury management. It is from this perspective that ISEA is assessed to determine whether it influences the injury management business process.

A further outcome of this review is that it identified a significant gap in the literature relating to software engineering best practice for spoken language systems development. Several systems development models were reviewed with the aim to form the basis from which the theory of spoken language systems development could occur.

The conceptual framework has been developed and from this the research areas to be investigated identified. The research method adopted to address the research question and sub-questions is now discussed in Chapter 3.
Chapter 3 RESEARCH METHODOLOGY

3.1 INTRODUCTION

Prior to this research and the development and implementation of the improved speech-enabled application (ISEA), the ESC used speech recognition in an elementary manner to enter data directly into the club’s existing injury tracking software (InjuryTracker™). ESC’s aim for using speech recognition was to improve the efficiency of their injury data capture process. However, their speech interface was prone to very poor speech recognition accuracy, and the productivity gains they sought were not achieved. This prompted the club to establish a systems development project to improve the speech recognition accuracy, with the specific aim to achieve significant gains in efficiency for data capture. Section 4.2 provides a detailed description of the problem to be solved.

ESC’s identification that the existing data capture process was inadequate marked the starting point for this study, with a research scope including:

1) an organisational setting of one elite sporting club;

2) the injury management of elite athletes associated with the club;

3) the development of ISEA; and

4) an evaluation of the implemented ISEA in relation to its influence on the injury management business process operating at the club.

The research methodology selected is based on this study’s conceptual framework, as discussed in Section 2.6, and the literature surrounding research methods as described in this chapter. This research is exploratory (Neuman, 1994; Yin, 2002) and adopts an interpretive case study (Neuman, 1994; Stake, 1995) research methodology to investigate and address the research question. This chapter includes the rationale for choosing an interpretive case study research method as an appropriate research approach to address the research questions as outlined in Section 1.3. The chapter begins with an overview of research methods which will form the basis for the justification of the research approach selected for this study.
3.1.1 OVERVIEW OF RESEARCH METHODS

Research originates from a research problem which is unresolved in the literature (Bouma, 1996). All research requires a clear definition of the aims and purposes of the research and from this formulation of research questions can be performed. Valid research is underpinned by the selection and execution of the most appropriate research methodology to answer the research questions under investigation (Trauth, 2001; Yin, 2002). Neuman (1994, p.8) defines a research method as “ideas, rules, techniques and approaches that the scientific community uses”. Rules and techniques imply that the research method follows a formal series of steps to answer the research questions. These include identification of a knowledge problem; precise formulation of the problem; examination of the background knowledge; hypothesis creation and testing, critical examination and statistical processing of the data collected; evaluation of the hypothesis; and determination of the impact on existing knowledge (Gay & Diehl, 1992; McGraw, 2007). That is, the research method follows a set procedure or plan (Neuman, 1994). Key activities in the plan are the collection of data and information in an attempt to answer the research questions (Stake, 1995). By following this approach it is envisaged issue-relevant meanings will emerge (Stake, 1995) which will contribute to the discipline’s body of knowledge.

Research approaches are commonly classified as quantitative or qualitative (Myers, 2007). Qualitative research involves the use of qualitative data, such as interviews, documents, and participant observation data, to understand and explain social phenomena (Myers, 2007) conducted in a natural setting (Creswell, 1998); while quantitative methods include survey methods, laboratory experiments, formal methods (e.g. econometrics) and numerical methods such as mathematical modelling (Myers, 2007). Quantitative methods specialize in quantities (numbers) and the interpretation of these numbers is viewed as strong scientific evidence of how a phenomenon works. This emphasis on numerical analysis is key to positivism, which defines a scientific theory as one that can be falsified (Straub, Gefen, & Boudreau, 2004). This type of research provides the mechanisms to statistically analyse data in relation to the research question. Adopting a quantitative approach within a business context does not necessarily reflect reality, or may not elucidate reasons and meanings for actions taken. Hence, the quantitative approach can oversimplify the real world
operational environment. As Galliers (1992) states, the weakness of this approach lies in the fact that the “limited extent to which identified relationships exist in the real world due to oversimplification of the experimental situation and the isolation of such situations from most of the variables that are found in the real world” (p.150).

The epistemological research assumptions about knowledge and how it can be obtained guides the researcher (Myers, 2007) in the selection of the most appropriate research method for the study. The underlying research epistemologies are: positivist, critical, and interpretive (Myers, 2007).

“Positivist studies generally attempt to test theory, in an attempt to increase the predictive understanding of phenomena” (Myers, 2007, p.1). Orlikowski and Baroudi (1991, p.5) classify IS research as positivist if there is evidence of formal propositions, quantifiable measures of variables, hypothesis testing, and the drawing of inferences about a phenomenon from the sample to a stated population.

Critical researchers assume that “social reality is historically constituted and that it is produced and reproduced by people” (Varey, Wood-Harper, & Wood, 2002, p.232). Cecez-Kecmanovic (2001, p.141) considers that critical IS research involves “a process of inquiry that seeks to achieve emancipatory, (that is, it should help to eliminate the causes of alienation and domination (Myers, 2007)), social change by going beyond the apparent to reveal hidden agendas, concealed inequalities and tacit manipulation”. Cecez-Kecmanovic (2001, p.142) continues that critical IS researchers go further than interpretivism “to expose inherent conflicts and contradictions, hidden structures and mechanisms accountable for these influences” in contemporary society.

Interpretive methods in IS are “aimed at producing an understanding of the context of the information system, and the process whereby the information system influences and is influenced by the context” (Walsham, 1993, p.4-5). Interpretivism is an epistemological position, “concerned with approaches to the understanding of reality and asserting that all such knowledge is necessarily a social construction and thus subjective” (Walsham, 1993, p.5). Interpretive researchers start with “the assumption that access to reality (given or socially constructed) is only through social constructions such as language, consciousness and shared meanings” (Myers, 2007, p.4). Types of interpretive research include ethnographies, action research and case
studies. Interpretive ethnographers (Wynn 1979; Zuboff, 1988) immerse themselves in the lives of the people they study (Lewis, 1995, p.380) and seek to place the phenomena studied in their social and cultural context (Burgess, 1985; Myers, 2007). Ethnographic research is usually exploratory (Carspecken, 1996), and an important aspect of this research method is that the data collection and analysis occur simultaneously (Burgess, 1985). The ethnographers observe first-hand (Trauth, 2001), record, and participate in the field (Marcus & Fischer, 1986), and then describe personal observations (Amit, 2000). A clear distinction between ethnographic and other research methods such as action research is the requirement for the researcher to be a detached observer (Mumford as cited in Trauth, 2001). While similar to ethnographers in that they observe first-hand, an action researcher is “actively associated with assisting change taking place in organisations” (Burgess, 1985; Mumford as cited in Trauth, 2001, p.46). Hence, there are both practical and theoretical outcomes for action research (Mumford as cited in Trauth, 2001).

This general overview of research approaches provides the basis for developing the argument to justify the research methodology, an interpretive case study, which is now discussed.

### 3.2 RATIONALE FOR THIS RESEARCH METHODOLOGY

Prior to the commencement of this study, the researcher participated as a practitioner in the SpeechNet ISEA development project team, performing the specific roles of project manager and business analyst in the development of ISEA. In these roles, the researcher influenced the decisions, recommended solutions and actioned these recommendations. However, during the ISEA development and implementation, the researcher was not undertaking research, but instead was employed as a practitioner to carry out systems development activities. Hence, prior to this study, only practitioner work activities and no research activities were undertaken as part of the ISEA development and implementation project. This point is significant to determining the rationale supporting research methodology selection for the study.

As a practitioner, the researcher performed similar activities to action researchers, who act as change agents performing the role of developing a solution to a practical problem of value to the organisation (Mathiassen et al., 2009). However, action
researchers also perform an additional role simultaneously developing theoretical knowledge of value to a research community (Mathiassen et al., 2009). That is, action researchers produce both practical and theoretical outcomes (Mumford as cited in Trauth, 2001; Baskerville & Wood-Harper, 1998; Mathiassen et al., 2009). Davison (1998) provides an exemplar for action research (Myers, 2007) and supports this view. Davison (1998, p.3-11) states as rationale for selecting action research:

“Our identification with action research is as follows: we are interested in exploring a hitherto unexplored situation - the use of GSS in business and professional environments in Hong Kong, thereby allowing us to develop theories that are appropriate to the use of GSS in Hong Kong.” (GSS is a Group Support Information System).

Davison (1998, p.3-11) continues:

“We are also interested in obtaining feedback from the situation we are investigating, analysing this feedback and using it to change the existing conditions, and hopefully improve them. Whilst we can obtain information through a survey, as well as through other sources, we cannot use this information directly in the case without intervening in the phenomena we are studying - the meeting groups and their electronic support. The action element is also present in the fact that we are introducing the technology to the groups: it is not extant.”

Davison’s (1998) selection of action research is based on two underlying premises: 1) the technology “is not extant”; and 2) the aim of the research is “exploring a hitherto unexplored situation … thereby allowing us to develop theories” (Davison, 1998). This research does not align with either of these premises. During the development and implementation of ISEA, the intent was not to develop theory (Davison, 1998) but instead to deliver project outcomes as per a commercial contract. Further, this research commenced after ISEA had been implemented, hence ISEA already existed. Therefore, the epistemological position for this research is not to “change the existing conditions… the action element” (Davison, 199, p.3-11). For these reasons, action research is not considered as a suitable research method for the proposed study even though the researcher (as a practitioner) was actively associated with assisting
organisational change and is not a detached observer (Mumford as cited in Trauth, 2001).

A close examination of the research questions and sub-questions (p.9) reveals they are asking “what” and “how” questions, which are associated with exploratory (qualitative) research (Neuman, 1994; Yin, 2002). Through interviews, documents and observation, the researcher can explore and describe the research (Carspecken, 1996; Myers, 2007) which is to be conducted in a natural setting (Creswell, 1998). The interpretive methods in IS aim to understand how information systems influence the business processes they support (Orlikowski & Baroudi, 1991; Walsham, 1993). The research question framed for this study seeks to understand how the ISEA applies spoken language technology to capture elite athlete injury data; thereby obtaining a holistic and in-depth understanding of the influences of ISEA on the injury management business process. Further, the aim is to interpret these influences in the light of previous theories. The emphasis of the research is on the relationships between the social factors and the organisation. Klein and Myers (1999) argue that interpretive studies enable the researcher to gain deeper insights into IS development, to understand the “how” and “why” the application influences the organisational members and the business processes of the organisation.

Klein and Myers (1999) suggest that field studies include interpretive in-depth case studies (Walsham, 1993), and the case study research method is particularly well suited to IS research, as the object of the study is the IS in an organisation (Myers, 2007). An interpretive case study obtains organisational members’ perspectives of reality (Klein & Myers, 1999). This aligns well with the views of Carroll and Swatman (2000), who state case studies research is well suited to in-depth studies of people, organisations, such as the ESC, and/or events such as an IS in their organisational setting (Benbasat, Goldstein, & Mead, 1987; Walsham, 1995). Creswell (1998) also agrees that case study research is appropriate for investigations into a program, event, activity, team or individuals, and in general where a range of topics are to be explored.

Important this research considers the ESC injury management information system from two perspectives: 1) its structure and functioning; and 2) its organisational
context (Flynn, 1998). Hence, this research describes the spoken language HCI and its influences on the business processes, to determine the “what” and “how” of the HCI to achieve both organisational and individual user effectiveness and efficiency (Carey, et al., 2004). The IS researcher’s perspective affords emphasis to managerial and organisational contexts by focusing on the analysis of tasks and outcomes at a level that is relevant to organisational performance and effectiveness (Zhang et al., 2005). This suits an interpretive epistemological position as it is concerned with “the understanding of reality and asserting that all such knowledge is necessarily a social construction and thus subjective” (Walsham, 1993, p.5). Interpretive researchers start with “the assumption that access to reality (given or socially constructed) is only through social constructions such as language, consciousness and shared meanings” (Myers, 2007, p.4).

The research area under investigation is bounded; has contextual material about the research area; and has extensive material from multiple sources of information to provide an in-depth picture about the research area; which are necessary criteria to satisfy, for case study research (Creswell, 1998). Further, the research involves an in-depth study (Benbasat et al., 1987) of an information system (Myers, 2007), and occurs in the natural setting of an organisation (Benbasat et al., 1987; Darke, Shanks, & Broadbent, 1998; Yin, 2002). Hence, this study fulfills many of the attributes associated with interpretive case study research, making the case study an appropriate choice of research method.

### 3.3 THE RESEARCH PROCESS

This section describes the structure of the research; the role of the researcher; the choice of participants; the methods of data gathering, management and control of the research; and the methods of data analysis; and quality assurance. These are now discussed.

#### 3.3.1 THE STRUCTURE OF THE RESEARCH

The research followed a set procedure and series of planned activities (Neuman, 1994) to answer the research questions (Stake, 1995). The research process is summarized in Figure 3.1 below.
Figure 3.1 - Structure of the research

The two strands of enquiry: 1) spoken language human computer interfaces; and 2) injury management, with a specific emphasis on its application in elite sports; established the basis for input into the first step of the research process. This entailed an in-depth review of the literature pertaining to speech-enabled applications and injury management. The literature review established a snapshot of the current research in spoken language technology, its relevance to business, and identified areas for ongoing research. Further, the literature review provided sources of definitions and the concepts central to this research.

A key output of the ‘Analysis of Relevant Literature’ activity is the conceptual framework for this research study as described in Section 2.6. The conceptual framework for spoken language injury management information systems is central to the case study analysis and involves input from both the ‘Description of ISEA’ and ‘Evaluation of the Implemented ISEA’ research activities. The two strands of enquiry defined in the conceptual framework established the need for the research processes of ‘Description of ISEA’, which is detailed in Chapter 4, and ‘Evaluation of the
Implemented ISEA’, which is detailed in Chapter 5. The research evidence was collected through interviews, documents and observation (Carspecken, 1996; Myers, 2007), and conducted in the natural setting (Creswell, 1998) of SpeechNet and the ESC. Using interpretive methods to analyse the data collected, issue-relevant meanings emerged (Stake, 1995). Several unexpected outcomes emerged from this study, which are discussed in Chapter 6. Lastly, a revised conceptual framework is proposed in Chapter 6, based on the findings of this research.

### 3.3.2 The Researcher’s Role

The researcher was directly involved in the development of ISEA. The researcher was not an employee of the ESC but worked for SpeechNet who were commissioned by the ESC to undertake the ISEA development project. From the ESC’s perspective, the researcher is an “outside observer” (Walsham, 1995, p.77) as the researcher’s role “preserves more distance from the personnel in the field organizations... [and is considered by ESC personnel] not as one of themselves” (Walsham, 1995, p.77). Being an outside observer is fundamental to evaluating the implemented ISEA and determining its influence on the injury management business process. Implicit in being an outside observer is to seek the interviewees’ voices, and not that of the researcher. As Walsham (1995, p.77) states, “the merit of this approach is that the researcher is seen as not having a direct personal stake in various interpretations and outcomes, and thus personnel will often be relatively frank in expressing their views”. However, being an outsider often means access to confidential documents and or commercially sensitive information is restricted (Walsham, 1995) which may impact on data analysis and render the research incomplete. This possible limitation to the research has been minimised as a direct consequence of the researcher’s involvement with the development of ISEA. The researcher was a member of the SpeechNet ISEA development project team. Hence, within the research context of describing the ISEA technology and ISEA development activities, the researcher is an “involved researcher” (Walsham, 1995). The dual researcher roles overlap emanating from the key job roles of business analyst and project manager that the researcher performed in the ISEA development project. As a business analyst, the researcher immersed himself in the ESC organisation, uncovering the business problems in the organisation and made recommendations on IS solutions in conjunction with key ESC personnel.
As the project manager, the researcher obtained a first hand account of business process improvements and other cultural and organisational issues from steering committee meetings and other management meetings. Essentially, the researcher obtained insights into both operational and management issues, and obtained an in-depth understanding of business pressures and drivers for change in the organisation beyond the IT application. This insider view (Walsham, 1995) included having access to confidential information, being in a privileged position of trust, and resulting in awareness of sensitive issues (Walsham, 1995) within the ESC and Association.

The dual research roles of involved researcher and outside observer align respectively with the two strands of enquiry: 1) spoken language human computer interfaces; 2) injury management; hence both roles contribute to the success of this research. The first strand of enquiry describes the ISEA technology and development process. As an insider the researcher is able to undertake an in-depth analysis of the development team processes and the ISEA technology. In contrast to this, the second line of enquiry is seeking the ESC’s view of the implemented ISEA and its influence on the ESC injury management business process. This lends itself to an outsider perspective as it is investigating the viewpoints of ESC personnel.

While the experiences discussed with the interviewees in this research cannot be assumed to be the same as those of the researcher, the past work experience of the researcher as an IT professional and exposure to ISEA development and the business area of injury management, ensured that the interviews could be conducted from a common knowledge baseline or level of communication, and this served as a valuable means of informing the research as the themes unfolded. Due to the common baseline of understanding, the interviewees were relaxed and at times recounted quite technical details that would not have been possible if the researcher had not had the same level of understanding of the subject matter. This shared level of understanding encouraged the interviewees to speak more candidly as the interviews progressed.
3.3.3 DATA GATHERING

(a) Choice of Participants

The two strands of enquiry are distinct and required research participants to be sourced from two different organisations. The SpeechNet participant (ISEA software engineer) was invited to add value to the contributions of the researcher’s descriptions and interpretations of the ISEA development process and technology, and validate in some instances the researcher’s interpretations of the ISEA technology components. Interviews with the SpeechNet software engineer were primarily through face to face meetings and via e-mail questions. The researcher had access to technical documentation, ISEA software source code, and other materials collected over the life of the project. The ISEA development project team existed for over a two year period from project inception, proof of concept and full development to post-implementation improvements. Hence, the researcher collected primarily first-order data (Walsham, 1995) from SpeechNet. As the ISEA project manager, the researcher had access to all project management documentation, project reports and presentation materials, steering committee notes produced by SpeechNet and correspondence between SpeechNet and the ESC. The analysis was therefore based on factual information with interpretations facilitated by the researcher’s direct participation in meetings and report writing. Hence, the researcher was able to analyse the data from multiple perspectives, and uncover “hidden meanings” (Hanisch, 2004; Thanasankit & Corbitt, 2002) and unravel complex intertwined conceptual structures (Walsham, 1995). The researcher’s reflections on ISEA and on the ISEA project are considered in-depth, insightful and based on good theory (Walsham, 1995). Hence the interpretations are based on ‘thick descriptions’ (Walsham, 1995) which provide a true representation of the data collected.

The second strand of enquiry, which evaluated the implemented ISEA in the ESC, was based on information from participants within the ESC. The participants were invited from a cross section of staff involved in the management of injuries of elite athletes at the ESC. The participants were chosen for their relevance to the research questions (Glaser & Strauss, 1967). Importantly, participants were selected from all the business areas associated with injury management at the ESC which included:
1) physical performance;

2) strength and conditioning;

3) training;

4) management;

5) medical (general practitioners);

6) rehabilitation; and

7) physiotherapy.

The SpeechNet and ESC participants are summarised in Table 3.1. As SpeechNet and ESC are small organisations with readily identifiable job roles, individual interviewee numbers are not elaborated in Table 3.1, to ensure participant anonymity in subsequent chapters.

Table 3.1 - SpeechNet and ESC participants

<table>
<thead>
<tr>
<th>Company</th>
<th>Interviewee</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESC</td>
<td>Training services manager</td>
</tr>
<tr>
<td></td>
<td>Head trainer</td>
</tr>
<tr>
<td></td>
<td>Senior medical officer</td>
</tr>
<tr>
<td></td>
<td>Physiotherapist</td>
</tr>
<tr>
<td></td>
<td>Physical performance manager</td>
</tr>
<tr>
<td></td>
<td>Strength and conditioning coach (rehabilitation)</td>
</tr>
<tr>
<td></td>
<td>Training services assistant</td>
</tr>
<tr>
<td>SpeechNet</td>
<td>Software engineer</td>
</tr>
</tbody>
</table>

(b) Process of Data Gathering

Interviews were conducted at the ESC and at SpeechNet during normal business working hours and were typically less than an hour in length.

All participants interviewed were invited and their participation was voluntary. The interviews were conducted between January 2008 and March 2008 at the ESC and at SpeechNet during normal business working hours. Interviews were 30 to 60 minutes in length. The interviews were informal and semi-structured with non-directive, open-ended questioning (see Appendix A for sample questions). The interviews were not
taped as there were concerns regarding the sensitivity and confidentiality of personal athlete medical data, which could result in the respondents being inhibited when being taped (Walsham, 1995). A further concern of the researcher was to ensure information relating to personal medical data of elite athletes was not inadvertently recorded as part of the interview process. To protect the identities of individual athletes whose names were provided in examples by the interviewees, pseudonyms were used in place of the athlete’s actual name in the researcher’s written notes. This is not considered a limitation to this research, as specific personal medical records are not of interest to this research. The research seeks to understand the injury management business process and the ESC’s use of the improved speech-enabled application in supporting this business process.

The researcher contacted each company to formally invite them to participate in this research. The ESC required general manager level approval for this research as a large cross section of ESC staff were required to ensure meaningful and complete research, and also to gain authorisation to interview medical consultants to the club. Each company involved in the research nominated potential staff who could contribute to the research. Each potential participant was then invited directly via email or phone call by the researcher. This prevented the participant from feeling coerced to participate in the research, as there is no management control between the researcher and the participants. As there were enormous time pressures on the availability of interviewees, the ESC assigned the training services assistant to coordinate the scheduling of interview times with each interviewee. Each potential participant was provided details of the research and its aims and was required to complete a consent form before the interviews commenced.

No ESC participant had a vulnerable or a dependent relationship with the investigator. However, during the development of ISEA, the researcher was the manager of the software engineer who participated in this research. Hence, the SpeechNet interview questions were designed such that they in no way reflected on the work performance of the software engineer and did not compromise the research outcomes due to this dependent relationship. The only focus of the SpeechNet interview questions was to investigate the technology components of ISEA, and the general systems development processes adopted by the ISEA project team. This research required an in-depth
insight into the use of artificial intelligence specifically in the area of natural language understanding technology in ISEA. To achieve this insight, and to ensure the researcher’s interpretations of the data collected were correct, it was necessary to interview the software engineer who was intimately involved in the detailed technical design and coding of the natural language understanding algorithms. This ensured an unbiased view of the collected SpeechNet data and importantly a credible source to validate the researcher’s interpretations of the data.

Very detailed notes were taken during the interviews and written up within 48 hours of the interview. When necessary follow-up e-mail and phones calls were used to clarify interview statements.

Approximately three months after completing the final interview, an interim research report including a Microsoft PowerPoint presentation was prepared and provided to the ESC for review. The researcher met the ESC shortly after the interim report was provided, to receive feedback. Hence, the report was a valuable deliverable for this research as it provided the means to validate the researcher’s initial interpretations of the data collected from the interviews conducted at the ESC.

Other empirical data was collected at the ESC using techniques such as participant observation and written data sources such as e-mail, memos and organisational and Association policy documents, and field notes. All participants were kept anonymous including their interview notes. All interview notes and other data collected from the participants is protected from unauthorised access.

3.4 DATA MANAGEMENT AND CONTROL

The nature and importance of confidentiality is well understood, and was of prime consideration throughout this study. All interview material is locked in a filing cabinet. Access to data is limited to the researcher and the senior supervisor. Data analysis is securely stored and under control of the researcher. In all reported results, within the University or through external publications or presentations, individuals and the specific organisations in which the study was conducted were made anonymous. To ensure the privacy of the participants are protected, the researcher maintained a separate list of the participant’s names and details and cross referenced
this with a single number on the interview notes. The list is kept in a separate locked location from the storage of the actual interview notes and only the researcher has access to the list. Pseudonyms (Leedy 1997; Neuman 1994) were used in written notes and the write-up of these notes. Any other documentation related to this research is kept in a locked filing cabinet.

3.4.1 DATA ANALYSIS

Interviews were conducted at the ESC and at SpeechNet during normal business working hours and were typically less than an hour in length. Data were transcribed within 48 hours of the interviews taking place with annotations added regarding categorical aggregations, direct interpretations, patterns and naturalistic generalisations (Stake, 1995). Hence, analysis of the data commenced immediately following each interview and documented formally. As the interviews progressed, a number of themes emerged (Stake, 1995). The analysis documents were subsequently structured around these themes, and the relevant data from each interview were progressively added to each theme. The researcher then commenced constructing an argument around each interviewee’s response in relation to the theme. This provided a rich set of data from which further analysis could be undertaken. Participants were interviewed from a broad cross section of ESC staff involved in injury management.

Interviewing various organisation layers within the ESC provided a holistic view of the injury management business area. Doctors for example, have both a management and operational perspective with one important difference. They belong to a fraternity which share knowledge across their discipline outside of the ESC and have professional standards to which they must adhere, and which are stipulated and regulated by external bodies and/or government. Hence, doctors possess a position of power in relation to the well-being of an athlete which supersedes their manager’s authority. Other interviewees were clearly operational with their degree of influence being limited to one or a small number of key sub-processes of the injury management business process.

This research adopted an interpretive case study (Neuman 1994; Stake 1995) research method using one case study in one elite sporting club. As Yin (2002) states, a single case study as in this research, is generalisable to theoretical propositions. In using the
interpretive case study research method, the researcher considered “the development of concepts, the generation of theory, the drawing of specific implications, and the contribution of rich insight” (Walsham, 1995, p.79) during the data analysis stage of this research. The researcher sought through the interpretation of the data, the emergence of issue-relevant meanings, and naturalistic generalisations or lessons learned that could be applied in the broader context (Stake, 1995).

Several data collection and analysis approaches were investigated for this study and both hermeneutics and semiotics modes of analysis were selected. Using natural language as the basis of the HCI requires a detailed analysis of the type of language that is used in the problem domain. The language was investigated from several perspectives including, words and their domain meanings, structure of phrases for data capture input language, and mapping of input phrases to target database schema. Content analysis (a form of semiotics (Myers, 2007)) was used as the data analysis technique to uncover the above. The technique aligns well with this aspect of the research, as the intention and meaning are discoverable in the frequency with which words, phrases, idioms or ideas occur in a text and the meanings can be captured in a set of predefined content variables and drawing inferences from this text (Truex, 1996). Krippendorf (1980) further supports this, defining content analysis as a research technique for making replicable and valid references from data to their contexts. Myers (2007) agrees that semiotics is primarily concerned with the intended meaning (Price & Shanks, 2005) of words, and these can be assigned to primary conceptual categories. Myers (2007, p.1) further states, “the importance of an idea is revealed in the frequency with which it appears in the text”.

The researcher drew on more than 5 years of ESC injury tracking data and other artefacts from the development of the speech-enabled HCI application including, software programs, templates, requirements analysis documentation, paper records of medical consultations, electronic documents and spreadsheets of consultation and treatment notes, and electronic records stored in the InjuryTracker™ database. The InjuryTracker™ database repository was large in size and provided a comprehensive source of data. The repository consisted of 1727 notes of medical visits, over 7000 treatment notes that included specific modalities of treatments and 706 injury descriptions.
The exploratory and interpretation components of this study used a hermeneutics mode of analysis. Using this method provided the opportunity to undertake an iterative analytical approach known as the hermeneutic circle (Lee, 1994). The idea of a hermeneutic circle refers to the dialectic between the understanding of the text as a whole and the interpretation of its parts, in which descriptions are guided by anticipated explanations (Gadamer, 1976, p. 117). As Myers (2007, p. 1) states:

“If hermeneutic analysis is used in an information systems study, the object of the interpretive effort becomes one of attempting to make sense of the organization as a text-analogue. In an organization, people (e.g. different stakeholders) can have confused, incomplete, cloudy and contradictory views on many issues. The aim of the hermeneutic analysis becomes one of trying to make sense of the whole, and the relationship between people, the organization, and information technology”.

Hence, using an hermeneutics analysis mode has significance for this study, as the research area poses many organisational perspectives in terms of the business drivers and competitive positioning of the IS in the organisational context, which need to be uncovered and analysed.

3.4.2 QUALITY AND INTEGRITY OF RESEARCH

To ensure the quality and integrity of the research the researcher used member checking and triangulation, and adhered to the interpretive case study research principles as defined by Klein and Myers (1999).

(a) Member checking

Member checking is recommended by Stake (1995) to verify the accuracy of the data (Creswell, 1998). As part of the analysis of the data and to ensure rigour and relevance in the research process, the researcher invited the participants to review the detailed interview and field notes made by the researcher. The researcher was proactive in obtaining feedback from the participants. Approximately three months after completing the final interview, an interim research report was prepared and discussed with ESC participants and management. The researcher maintained ongoing
discourse with the SpeechNet software engineer to validate the data and interpretations of data collected.

(b) Triangulation

The procedure of triangulation was employed to search for convergence of information during the analysis step of this research. As the interviews progressed, a number of themes emerged (Stake, 1995), which were further analysed to confirm that the findings were not merely intuitions, but were well founded on theory and in-depth analysis (Creswell, 1998; Stake, 1995).

(c) Principles of interpretive research

Interpretive research principles as defined by Klein and Myers (1999) were adopted as guiding principles for conducting this research study. Table 3.2 below aligns the principles outlined by Klein and Myers (1999) to how they were applied in this research.

*Table 3.2 - Application of Interpretive Research Principles (Source: adapted from Klein & Myers, 1999)*

<table>
<thead>
<tr>
<th>Klein and Myers (1999)</th>
<th>This Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principle of the hermeneutic circle</td>
<td>The exploratory and interpretation components of this study used a hermeneutics mode of analysis.</td>
</tr>
<tr>
<td>Principle of contextualisation</td>
<td>Several themes emerged as a direct result of adopting a hermeneutics mode of analysis. The data analysis was structured around these themes ensuring the context of the data was maintained.</td>
</tr>
<tr>
<td>Principle of interaction</td>
<td>The interviews were conducted using open-ended interview questions. This enabled the explanation and extension of responses by participants. The researcher’s familiarity with the business subject areas of IS development and injury management, provided a deeper understanding of the environment, the judgement and opinions of the participants. There was congruence between the interviewees for the key findings of this study. Where there were differences of opinion, these were highlighted and the rationale behind the differences discussed. The procedure of triangulation was employed to search for convergence of information.</td>
</tr>
<tr>
<td>Principle of</td>
<td>The conceptual framework developed was based on a</td>
</tr>
<tr>
<td><strong>abstraction and generalisation</strong></td>
<td>theoretical underpinning gained from the literature. Several theoretical models were used to analyse the data and to develop arguments to support the generalisations. Subsequently, the conceptual framework was refined to reflect the research outcomes. Hermeneutics analysis, triangulation, content analysis and the general principles of interpretive research were used as a guide to interpret and code the findings.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Principle of dialogical reasoning</td>
<td>The researcher was aware that the interpretations of the data may not support the known literature. However, the data analysis provides opportunity for new theory development.</td>
</tr>
<tr>
<td>Principle of multiple interpretations</td>
<td>Both member checking and triangulation ensured that bias was not imposed more than acceptable for interpretive research.</td>
</tr>
<tr>
<td>Principle of suspicion</td>
<td>While considered, this was not of concern for this study. The ESC has a very open culture and encourages staff to freely discuss their strengths and weaknesses. They continually assess their work performance. Hence, the research was seen as an opportunity to improve the injury management business process, and importantly, to identify areas for improvement. The researcher was an ‘involved researcher’ at SpeechNet; therefore fully aware of the operational and political environment.</td>
</tr>
</tbody>
</table>

This chapter established the set of criteria to meet and the actions of the researcher engaged in the research process. The research was underpinned by the selection and execution of the most appropriate research method (Trauth, 2001; Yin, 2002) and conducted using a set plan (Neuman, 1994) and is therefore considered valid research (Trauth, 2001; Yin, 2002).

### 3.5 Conclusion

The aims of this chapter were to:

1) describe the research approach and design of this study;

2) demonstrate that the chosen research methodology, an interpretive case study, results in a valid research approach for this study (Trauth, 2001; Yin, 2002); and

3) demonstrate that the research followed a set procedure or plan (Neuman, 1994) including the collection of data and information (Stake, 1995) to
understand the context of information systems and the processes whereby “the information system influences and is influenced by the context” (Walsham, 1993, p.4-5).

This research is exploratory (Neuman, 1994; Yin, 2002) and adopts an interpretive case study (Neuman 1994; Stake 1995) research methodology. The research was conducted in a natural setting (Creswell, 1998) and sought to understand how ISEA applies spoken language technology to capture elite athlete injury data; thereby obtaining a holistic and in-depth understanding of the influences of ISEA on the injury management business process operating at the ESC. It was argued that the interpretive case study research method is a valid approach for this research as it involves field studies (Klein & Myers, 1999) which include the study of a few people, an organisation, and event (Carroll & Swatman, 2000) to build theory from practice (Benbasat et al., 1987; Walsham 1995).

Necessary for the support of generalising to theoretical propositions is an in-depth description of the case study (Creswell, 1998). Hence, Chapter 4 presents an in-depth description of the ISEA development approach and technology, and Chapter 5 provides an in-depth description of the evaluation of the implemented ISEA. The interpretive case study commences with describing the improved speech-enabled application, which is now discussed.
Chapter 4 DESCRIPTION OF THE IMPROVED SPEECH-ENABLED APPLICATION (ISEA)

4.1 INTRODUCTION

ISEA was developed by SpeechNet, (a research and development IT company) to improve the efficiency of injury data capture. By using speech recognition software and integrating this with SpeechNet’s natural language understanding technology, it was envisaged that improvements in productivity would be achieved, resulting in significant reductions in the effort required to capture key injury data.

The researcher performed both the key roles of business analyst and project manager in the ISEA development project. As a business analyst, the researcher was principally involved in: uncovering and describing the business problems to be solved by ISEA; determining and documenting the detailed user requirements; designing the ISEA technical architecture solution; and system testing design and execution. Further, the researcher performed the language modelling study, generated the customised language model, and was directly responsible for the speech recognition improvement activities discussed in this chapter. The researcher was the principle management interface between SpeechNet and the ESC, and was accountable for all project deliverables. As the project manager, the researcher performed the tasks of: project planning and reporting; commercial contract negotiation; steering committee reporting, and ISEA demonstrations both at the ESC and Association levels. Through these roles, the researcher obtained insights into both the operational and management aspects of the project and obtained an in-depth understanding of the business pressures and drivers for change in the ESC organisation beyond the information technology application itself.

This chapter provides a detailed description of ISEA and the system development processes involved in developing ISEA. Importantly, the systems development process provides an insight into the ISEA technology components required when developing speech-enabled applications. The chapter commences by describing the business problem to be solved, as defined by the ESC.
4.2 THE PROBLEM TO BE SOLVED

The following correspondence between the ESC and the Association explains well the problem to be solved by ISEA:

“The [ESC] has used an injury management system called InjuryTracker™ for three years. A Canadian software package which cost less than $3,000. While a generic program, InjuryTracker™ supplies most of the details a club needs to ensure it keeps good records of its medical and rehabilitation programs. However, data entry is very time consuming and is therefore a costly activity for a club. The [ESC] on average has spent 15 hours per week to update the records from information supplied by the medicos, physiotherapists, head trainer, specialists, investigative procedures” (ESC to Association proposal, 20 September 2006, p.2).

InjuryTracker™ is an off-the-shelf shrink-wrapped software package, developed using 1980’s technology. Data entered via InjuryTracker™ input screens is stored in dBASE files (*.dbf). InjuryTracker™ utilises the Borland Data Base Engine to interact with these dBASE files. At the end of 2006, Presagia (the developers and owners of InjuryTracker™) withdrew customer support for InjuryTracker™ (ESC to Association proposal, 20 September 2006), encouraging their customers to move to a new modern replacement of InjuryTracker™ called Presagia Sports™. Presagia Sports™ is a modern web-based platform utilising a hosted centralised database delivery model that provides data capture and management of athlete health and fitness information (Presagia, 2008). While the club could see benefits of migrating to a modern web-based platform, the cost to do so was not financially justifiable, particularly considering that InjuryTracker™ met the current needs of the club. The ESC viewed an InjuryTracker™ replacement with a similar HCI, would not resolve the key problems of time and effort required to capture injury data.

Prior to ISEA, manual injury data entry through InjuryTracker™ consumed approximately 15 hours of effort per week. Resourcing this activity from existing staff, whose time is already over-allocated to other critical functions at the club, posed resource management challenges for the ESC. Further, the need for this data to be
timely was at odds with the available resources to capture the data electronically. A point ESC highlights in a report to the Association:

“In an endeavour to reduce this effort the club sourced and investigated a couple of off-the-shelf voice response software packages [which] did not meet the needs of the club” (ESC to Association proposal, 20 September 2006, p.2).

The Association and individual elite sporting clubs have considered many alternatives to reduce the effort associated with entering injury data and to improve the quality of this data. In doing so:

“Clubs have purchased computer software with improved computer user interfaces and pre-defined paper forms/templates. These resulted in minor improvements in productivity but the problem still remains. Significant time and resources are required to enter the data” (ESC to Association Medical Officers Conference, 15 November 2007, p.2).

Clearly, ISEA needs to resolve these time and human resource problems, by reducing the time and effort to capture and record key injury data. Interestingly, an InjuryTracker™ replacement is not the focus at this time even though it is a legacy application (Applegate et al., 2009). The researcher recalls on numerous occasions ESC professional staff emphasising that the problem is not the injury management application, it is the recurring need for substantial resources to capture injury data in a timely way. Not addressing this issue translated to low user acceptance of the injury management system, and therefore a reluctance to use the system. This fact is well supported from internal meeting notes, which document feedback from a recent physiotherapist association general meeting. The topic under discussion related to a proposed introduction of a new system for physiotherapists to capture treatment data electronically. The physiotherapist states that:

“The system needs to be very user friendly and add no more time to their processes” (SpeechNet notes, 27 August 2007).

This, together with several other key aspects, were considered critical success factors for the new system that
“must be met otherwise they will not accept it” (SpeechNet notes, 27 August 2007).

From the ESC's perspective, the intention for using ISEA is for doctors and other professional staff to dictate directly into the system, thereby removing the need for paper records. That is, written notes of the medical consultations would no longer be generated. A point the ESC highlights to the Association when discussing the benefits of ISEA:

“Data capture process [is] streamlined. [There is a] move to paperless records” (ESC to Association presentation, 19 January 2007).

ESC viewed the move to paperless records as a key user requirement for ISEA. Figure 4.1 summarises the ESC injury data capture process prior to ISEA, and the proposed injury data capture with ISEA. Figure 4.1 illustrates that paper records are replaced with audio files in the ISEA solution, and that the audio files are processed automatically by ISEA.

![ESC process before ISEA](image)

**ESC process before ISEA**

**Proposed ISEA process**

*Figure 4.1 - ESC injury data capture process before ISEA verses proposed ISEA process (Adapted from SpeechNet to ESC presentation, 19 October 2005)*
Interestingly, at an ESC Innovation Committee meeting (which includes the ESC CEO, directors of the club, and other industry specialists), where the researcher and ESC staff presented ISEA, the CEO suggested using the audio recording of the medical consultation as the only injury record. That is, not to perform further processing of the audio file. It was pointed out, and he understood very quickly, that performing data queries on audio files requires listening to each audio file sequentially, which is a very time consuming process. In other words, the data are not in a suitable format for database searches and reporting.

With this background in mind, ISEA is now described.

### 4.3 ISEA DESCRIPTION

ISEA provides a user interface that allows medical staff to capture data in a way that reflects the data collection requirements in their natural setting (Creswell, 1998). In this way, ISEA provides a flexible and dynamic user interface that does not enforce a set process, and is not constrained by the data structures of the target software application (that is, InjuryTracker™). Instead, ISEA aims to integrate data capture with the business processes. To provide this dynamic and flexible HCI, ISEA uses both speech recognition and natural language understanding technologies in the user interface. Specifically, the inclusion of natural language understanding in ISEA provides an alternative to a fixed sequence of input screens as is common for data entry graphical user interfaces. The ISEA HCI aims to allow the user to interact with ISEA in the same way people communicate naturally. The ISEA user interface is explained through a detailed comparison between the InjuryTracker™ manual data entry process, and the equivalent transaction entered using ISEA’s natural language interface in Section 4.3.1.

ISEA consists of three software modules:

1. Module-1; provides audio capture, and speech to text transcription;
2. Module-2; interprets, validates and corrects the output text of Module-1; and
3. Module-3; updates the InjuryTracker™ database with the transaction data generated from Module-2.

All three modules are executed in sequence.
Medical and other professional staff use a predefined language template as a guide for entering data. The template guides the user with the syntax and vocabulary that can be used to describe a medical consultation using spoken language. A commercially available speech recognition package called Dragon Naturally Speaking™ (DNS), is used to transcribe the spoken language discourse (that is, audio transcripts) of the medical consultation into text (SpeechToText), which is then parsed (processed) by ISEA to interpret, understand and correct the input injury data (SpeechToText). However, where data provided by a user cannot be deciphered, and/or the data are ambiguous, ISEA prompts the user to verify and/or correct the problem data. This step is essential as it facilitates generating data of a high level of quality before the data are uploaded into the InjuryTracker™ database (InjuryTracker_DB).

Module-1 and Module-2 are interdependent and interrelated. Module-1 turns the spoken word into text (SpeechToText), a process known as speech-to-text processing. Module-2 undertakes natural language processing of the SpeechToText generated from Module-1 to interpret, understand and correct the input injury data. To do this, Module-2 requires an understanding of the user language (UL) spoken when capturing consultation data. To improve speech recognition, DNS also requires an understanding of the UL vocabulary and grammar, to accurately interpret the words spoken. Poor speech recognition accuracy implies the generation of low quality SpeechToText. Low quality SpeechToText will impact on the quality of data being generated by Module-2, as Module-2 will have as input low quality input data from Module-1. Similarly, a poor understanding of the UL in terms of vocabulary, grammar and meaning in Module-2 implies poor interpretation and understanding of the SpeechToText. This results in serious implications for ISEA. If the data generated are of low quality, this will translate into low quality data being uploaded into InjuryTracker_DB. Essentially, this implies the data would be unreliable and therefore would impact on its effectiveness in decision-making. An understanding of the UL is therefore central to the processing of injury data in both Module-1 and Module-2. Module-2 defines the UL to be used by Module-1. Hence understanding and defining the UL is a fundamental activity in the development of ISEA. Once defined, the UL will also impact on how Module-3 maps the output from Module-2 to InjuryTracker_DB tables and fields. Consequently, the UL and its interpretation have an impact on all three modules.
Taking into account these impacts and addressing the complexities of the interdependence and interrelationships between all 3 modules required the adoption of a suitable systems development approach, which at its core defines the UL. This is discussed in Section 4.3.2. However, prior to the discussion, Section 4.3.1 provides a demonstration of injury data entry using InjuryTracker™ in comparison to ISEA for the same sample medical transaction.

4.3.1 DEMONSTRATION OF ISEA USER INTERFACE VERSUS INJURYTRACKER™

Through a demonstration of application screenshots, this section aims to provide the reader, a visual overview from a user’s perspective of the differences between using a speech interface compared with using a standard application graphical user interface. The demonstration compares the steps involved in using both the ISEA user interface and InjuryTracker™ to enter details associated with a player medical consultation. Of importance, the demonstration highlights the time difference in recording the same consultation data through both modes of data entry. It should be emphasised, that while the medical consultation is fictitious, the data entry process is real, and reflects the actual processing that is required by a user to enter the data. In both cases, the target database associated with InjuryTracker™ (that is InjuryTracker_DB) is updated with medical consultation data. Further, the demonstration provides an insight into the differences between these two quite distinct ways of entering data into the same database repository, and highlights some advantages of using a spoken language interface.

Several key fields uniquely identify a particular medical consultation. These are:

1) player’s name;
2) Doctor’s name; and
3) the date of consultation.

For the sample medical transaction: the player’s last name is James, and first name is Jimmy; and the Doctor’s last name is Doctorwho and first name is Kaynine. James has an appointment with Doctorwho on 19 January 2009 with regards to a suspected
injury that occurred during a training session on the 17 January 2009. The training session was held at the Melbourne Cricket Ground. The weather was fine and the ground’s surface was the usual normal grass surface. After examining James, Doctorwho diagnosed that James had strained his left adductor, which likely occurred as a result of kicking the ball. The extent of the damage to the adductor was unclear; hence Doctorwho’s recommendation is to undertake further tests and subsequently arranged an MRI of the adductor. In the meantime, to reduce further damage to the strain, Doctorwho recommends that icing and compression should continue to be applied to the adductor.

To record James’ medical consultation with Doctorwho via InjuryTracker™, the following steps are undertaken. Note, the steps in the data entry process and the corresponding InjuryTracker™ screenshot(s) are shown following each step description.

The following commands are provided as though presented in a user manual, while the descriptions are provided to explain the events in the process. This is relevant as it illustrates the complexity of ISEA and how effective it is for data entry.
STEP 1 – Select athlete.

COMMAND: Select athlete ‘Jimmy James’ from InjuryTracker™ <Name> list.

Once player Jimmy James has been selected, the details concerning James’ medical consultancy with Doctorwho can now be entered as follows.

![Image of InjuryTracker™ interface showing selected athlete and encounters tab]

STEP 2 – Enter consultation details.

COMMAND: Select <Encounters> tab.

In InjuryTracker™ the doctor’s patient visit or consultation are known as encounters. To access the InjuryTracker™ data entry forms associated with encounters, the <Encounter> tab is selected.
STEP 3 – Create a new consultation database record.

**COMMAND:** Select <New>.

As this is a new consultation with Doctorwho, a new encounter record is created in InjuryTracker™.

After STEP 3 is performed, a new data entry screen is presented to the user. This screen is used to record general summary details about the consultation. This screen is shown as part of the screenshot for STEP 4.
STEP 4 – Enter encounter details.

The new encounter input screen is used to:

1) enter the details regarding the date of the encounter, which is ‘19 January 2009’;

2) enter the name of physician who performed the consultation, in this case ‘Doctorwho’; and

3) select from a pick list of existing injuries associated with James, which in this case is the existing injury ‘strain of left adductor’.

This is shown in the following screenshot.

However, there is a problem with this data entry. There is no existing injury of ‘strain of left adductor’ for James. As it is a new injury it will not appear in the injury drop
down list. This example highlights a poorly designed user interface resulting in slowing down the data entry process. In this case, the data entry of the medical consultation cannot continue until the Doctor creates a new injury record for the player. This problem is fairly common at the ESC as many doctors may consult the same player on the same day, and therefore not know whether the new injury has been created in InjuryTracker_DB. The reason for multiple doctors consulting (at different times) for the same player injury is due to short consultation times for visiting doctors. Doctors are not full-time staff at the ESC. Often further tests are required to diagnose a player’s injury, and the results from the tests may not be returned before the original doctor’s session at the club has finished. As there is an immediacy associated with diagnosing elite athlete’s injuries, the next doctor to consult at the club will continue with the diagnosis of the injury and determine the subsequent treatment.

**STEP 5 – Enter injury details.**

**COMMAND:** Select <Injuries> tab on the InjuryTracker™ main form.
The details concerning the new injury can now be entered. The data entry forms for this are shown as part of STEPS 6, 7 and 8.

**STEP 6 – Create a new injury database record.**

**COMMAND:** Select the <New> control button located on the bottom right hand side of screen.

Selecting <New> results in a new data entry screen being displayed as shown below in STEP 7. The new injury input screen has 3 tabs which relate to different data entry screens used to describe distinct aspects of the new injury. For this example, both <Incident> and <Injury> tabs are used to enter data. The <Incident> tab is selected to enter information about the incident. The <Injury> tab is selected to describe the injury.
STEP 7 – Enter incident details.

COMMAND: Select the <Incident> tab.

The <Incident> tab is selected so that the data pertaining to the incident can be entered. Some default fields such as <Date> of incident are pre-filled with today’s date (the date of data entry) which is mostly different from the day when the injury occurred, and <Position> which also may need to be changed. For the sample consultation, the date is the ‘17 January 2009’, the segment is ‘training’, the surface is ‘grass – normal’, and the weather is ‘fine’. The incident occurred on the ‘MCG’ (Melbourne Cricket Ground).
InjuryTracker™ provides users with pre-defined field level pick lists to assist with data entry and facilitate data integrity for key fields. A further benefit is that it removes the need for users to remember the valid codes/text for key fields. However, as the system has evolved over many years, so has the number of valid data values for key fields. As a result, pick lists have become very large and ambiguous, adding further time for users to select the correct entry. The following incident input screen provides an example of the <Segment> pick list to demonstrate this point. Users may need to scroll through many items before they locate the correct value for selection.

The completed InjuryTracker™ new incident form is shown in the following screenshot.
The incident has now been entered. However, there are many fields that have no data entered but still require user checking to ensure all required fields have been entered.

**STEP 8 – Enter injury details.**

**COMMAND:** Select <Injury> tab at the bottom of the current screen.

On selecting the <Injury> tab the InjuryTracker™ data entry form for injury details is presented. The sample injury data can now be entered. The injury type, body part and mechanism are selected from a pick list of valid values. Select ‘Strain’ for type of injury, ‘Adductor’ for body part and ‘Kicking’ for mechanism of injury. Click ‘left’ on radio button to indicate that the injury is on the left hand side of the body. Click on ‘1st occurrence’ radio button to indicate this is the first time this injury has occurred.

The incident and injury have now been entered.

**COMMAND:** Click <OK> control button.

This saves the information and returns to the InjuryTracker™ main form. This form is equivalent to STEP 6, with the exception that now the injury details are displayed at the bottom of the InjuryTracker™ main form, as shown following the STEP 8 screenshot.
STEP 9 - Enter encounter details.

Now that the injury details have been entered, STEP 2 and STEP 3 can be executed to create the new encounter record, followed by STEP 4 to enter the new encounter
details. To do this, select the existing injury ‘strain of left adductor’ from injury pick list. Type in the encounter note ‘Referred for MRI. Continue icing and compression’. Then click on the <OK> control button to save the data entered and return to InjuryTracker™ main form. The screenshot above shows STEP 9 and the InjuryTracker™ main form below is presented once the <OK> is selected. Notice, that the InjuryTracker™ main form (with <Encounters> tab selected) now contains extra information relating to encounters.

![InjuryTracker™ main form](image)

Entering the sample consultation data into InjuryTracker™ takes 2 minutes 15 seconds for an expert user.

In contrast, the user’s spoken language to enter the same details for the sample consultation is:

```
```

To dictate this takes approximately 50 seconds.
The sample consultation reflects very well the challenges faced by speech-enabled systems to interpret spoken language. Typically spoken language can be incomplete, and not exactly correct. For example, the player’s name in the spoken language is not complete. In this case, ISEA determines that player: James is ‘Jimmy James’. ISEA also accounts for misspelt names by performing automatic spell checking and error correction. The encounter dates do not require the year to be stated, as ISEA determines this automatically. Providing this flexibility in the language has many benefits for the user including:

1) it reduces the amount of data that needs to be spoken;
2) it improves the efficiency of the user interface; and
3) overall makes the HCI discourse more natural for the user.

There are many other functions in ISEA to correct inexact key information provided by the user, such as ‘surface: is normal grass’ instead of the pick list value of ‘grass – normal’.

DNS speech recognition package is used to transcribe the spoken language into text. The user either dictates directly into DNS or records the consultation onto a portable digital recorder. In the latter case, many consultation sessions, usually several hours, can be recorded and the user may, at a more convenient time, use DNS to transcribe in bulk the audio recordings of consultations. DNS transcribes spoken words at rate of approximately 120 words per minute; hence DNS transcribing occurs at a similar rate as people speak (Nuance, 2009). DNS transcribing is a background task requiring minimal interaction from the user. Once DNS has transcribed the text (SpeechToText), it is interpreted and InjuryTracker™ updated with the consultation information. ISEA’s processing of the SpeechToText is an automated activity and is a background task for the user. Apart from starting the ISEA process running, and repairing erroneous input data during the ISEA validation and cleansing process, the user is free to perform other activities.

Following is a demonstration of ISEA using screenshots of the user interaction with ISEA to enter the sample medical consultation. In this demonstration it is assumed that DNS has transcribed the audio recordings of consultations into text, that is
generated SpeechToText. The following screenshot is ISEA’s main form with which users interact to process the SpeechToText.

![ISEA Form](image)

The processing of the SpeechToText follows a series of steps as follows.

**STEP 1 – Select SpeechToText file to be processed.**

Click on the <Browse> control button, and select the appropriate SpeechToText file. The file selected appears to the left in the <File> field. Once selected, a simple pre-parse of the SpeechToText surrounding key words is performed by ISEA to provide a visual representation of the input file. This is provided to help the user ascertain that they have selected the correct file for processing. This is displayed in the STEP 1-A window.
Next the SpeechToText is processed with the ultimate aim of uploading the injury data into InjuryTracker_DB. The user has two options at this stage:

1) process SpeechToText without cleansing the data first (see STEP 2), or

2) run the <Cleanse> function first (see STEP 3) and then execute STEP 2.

These are now explained.

**STEP 2 – Upload SpeechToText into InjuryTracker.**

Click on the <Go> control button to process SpeechToText and upload consultation data into InjuryTracker_DB. This is a background process which usually takes less than 20 seconds for a large number of consultations. However, as this is a background
user task, how long it takes to process does not impact on the user’s efficiency in data entry. When completed a message ‘All done’ is displayed in STEP 2-A window.

Note in this example that the user said ‘surface: is normal grass’ instead of the reference data valid value of ‘surface: Grass – Normal’. In this instance, ISEA corrects this automatically through using ISEA Bestmatch algorithms. Following is a screenshot from InjuryTracker™ of the incident information entered by ISEA in STEP 2. Also note that the incomplete date has been evaluated correctly.
STEP 3 – Cleanse SpeechToText data before executing STEP 2.

For the purposes of describing the sophisticated processing of the ISEA cleanse function, and to demonstrate the user interaction with this interface, a spoken language transaction has been created which contains some errors. The errors are not substantial but are included to highlight how simple mistakes by a user can result in ambiguous text, and to demonstrate cases where speech recognition can introduce errors thereby corrupting key field data. Following is a sample consultation transaction which contains errors.


In this spoken language example the key words ‘end injury:’ are missing. That is, the user has inadvertently not signified in their spoken language that they have completed the description of the injury.
To cleanse this data, click on the <Cleanse> control button (STEP 3-A). Note ISEA detects that it is expecting ‘end injury:’ prior to the ‘encounter note:’ and requests the user to fix this error. The user can directly insert ‘end injury:’ in the ISEA window where the error was detected. ISEA provides basic text editing functionality in this window.
STEP 3-A

Note error is highlighted in red by ISEA

User inserts 'end injury:'

encounter note referred for MRI, continue icing and compression
end encounter
Now execute the cleanse function to process this modified SpeechToText data. This time the SpeechToText passes the cleansing test and is therefore ready for processing by executing STEP 2. This is demonstrated in the next screenshot.

One final example is used to highlight automatic correction and repair of key field data and transaction structure by ISEA.


In this example there are two errors. The first error is due to poor speech recognition accuracy. The player’s name should be ‘James’ instead of ‘Jaemes’. The second is a user error of not saying the word colon after the key word ‘practitioner’.

The following screenshot highlights the outcomes of running the cleanse function on the sample consultation. For this consultation, ISEA will correct the player’s name to
‘James’ and insert ‘:’ after ‘practitioner’. As the input SpeechToText has been corrected and repaired by ISEA, and as there are no further errors, STEP 2 can now be run.

The difference in data entry time between using InjuryTracker™ and using spoken language for the equivalent transaction is significant. This is even more so when the number of weekly data entry transactions are taken into account. During a typical premiership season the ESC captures between 500 to 1000 transactions per week. Using 500 as a baseline for the number of transactions captured per week, this equates to approximately 7 hours of effort for users to enter the data via ISEA compared to almost 19 hours of effort for InjuryTracker™ for the equivalent data entry transaction.

4.3.2 SYSTEMS DEVELOPMENT APPROACH

The project environment (Hanisch, 2004) for ISEA development is complex. While all ESC professional staff involved with the ISEA development fully supported the project, there were significant challenges to overcome when scheduling meeting times
with key ESC staff due to organisational pressures on their time. ESC professional staff work in a ‘pressure cooker’ environment. During the premiership season the business focus is to field a competitive team every week. Matches are typically played on Friday evening, Saturday afternoon and evening, and Sunday afternoon. Special matches are played on ANZAC\textsuperscript{1} day and occasionally on a public holiday Monday. Hence, the day of the week when a match is played, and the subsequent day of the next match can result is less time to prepare the team for the forthcoming match. For example, if the team plays on Saturday afternoon and the next match is on the following Saturday afternoon, this allows 7 days before the next game. However, if the team plays on the Sunday and the next game is on the following Saturday then this reduces the time to prepare by 1 day. That is, 6 days before the next game. At the elite level having fewer days to recover from the previous week’s competition is significant and may impact on the athlete’s preparedness and overall performance for the next game. Time to recover and prepare for the next game is further compounded if the team needs to travel interstate to play. In the interests of ensuring interstate teams arrive on-time to matches, the Association requires all teams who have an interstate match to travel the day before the match. Travelling to Perth, Western Australia further impacts on time between matches. Usually a Perth trip results in the team being away for 3 days for an 80 minute game. To maximise the time available to get the team ready for the next week’s game, the ESC often hold recovery sessions for athletes prior to returning home, and hold review and planning meetings at the interstate airport. Hence, time pressures on ESC professional staff result in considerable planning and scheduling for user intensive project activities such as requirements analysis and review of prototypes.

Through necessity, the ESC has developed a professional business culture to consistently achieve recurring weekly deadlines of fielding a competitive team. A ‘can do’ culture pervades the ESC with problem ownership and a very supportive

\textsuperscript{1} ANZAC Day – 25 April. “It marks the anniversary of the first major military action fought by Australian and New Zealand forces during the First World War. ANZAC stands for Australian and New Zealand Army Corps. The soldiers in those forces quickly became known as ANZACs, and the pride they soon took in that name endures to this day” (ANZAC, 2009).
senior management group. Working as a developer/researcher in this environment was refreshing. Decisions on contracts and project deliverables were obtained with relative ease. Agreements on requirements were achieved quickly. Meeting staff however, was difficult to arrange: not because the staff were unwilling to participate, but due to their unavailability and the urgency of their work. Injuries occurring to players and other unplanned events relating to the pressures of fielding a competitive team can severely impact on the planned activities for the week. Scheduled project meetings were often delayed for several weeks due to these higher priority tasks. However, once the developers had the opportunity to meet ESC staff, the meetings were very productive. If a decision could be made at the meeting, then it was made.

Overall, the availability of professional staff was a key issue for the development of ISEA. However, these impacts were minimised through having an understanding of the ESC business cycle. There are three time periods of the ESC business cycle, which are of significance. These are:

1) Pre-season;

2) Premiershipt session; and

3) Break.

Pre-season commences in November each year and runs through to March of the following year. Pre-season activities revolve around improving the fitness and skills development for the players in preparation for the next premiership season. Between February and March, the Association runs a short pre-season competition. The Premiershipt season commences around the end of March and finishes at the end of September. The Break is in October, which is usually reserved for professional staff annual recreational leave.

Generally, there is very limited access to professional staff during the Premiershipt season; hence this period of the business cycle was avoided for activities such as requirements analysis and other activities that require intensive user participation. The Break is problematic for access to staff as many use this time for recreational leave and are therefore not available. As supported by an ESC to SpeechNet e-mail correspondence:
“The doctors at the ESC have been on 4 weeks leave (end of season). They return on Monday. We were unable to start our business analysis activities before they went on leave. This will hopefully commence next week” (ESC to SpeechNet e-mail, 26 October 2005).

Further, even when professional staff remain working in October, they use this time as an opportunity to attend meetings; attend coaching and medical conferences; undertake training in relation to their field of expertise; and generally allocate the time to complete unfinished tasks from the previous season. Further, during this period, key professional staff are involved in next season player selections, and new player recruitment. Consequently, the Break period is not ideal for user demanding development activities. The ideal time to undertake these activities is the Pre-season period. Taking into account the ESC business cycle during project planning contributes to setting realistic goals and outcomes for the project. The ESC business cycle is illustrated in Figure 4.2.

The project development was broken into two parts:

1) proof-of-concept; and

2) full project development.

The proof-of-concept was developed so

“that the approach can be validated by the ESC and a decision can be made on whether to continue with the full development” (Internal SpeechNet project management documentation, 6 April 2005).
The proof-of-concept approach was necessary as there were considerable technical risks associated with the project. The technical risks identified covered four areas:

1) speech recognition and natural language understanding user interface development;

2) alignment and integration of the technology components with the injury management business process;

3) interfacing with the legacy InjuryTracker™ application’s database; and

4) professional staff acceptance of this type of innovative HCI.

The full project development adopted the Agile (Larman, 2004) systems development method. The Agile method provided development flexibility in allowing frequent experimentation with the language development components of ISEA and close user interaction on the usability aspects of the application. ISEA was innovative and therefore had significant technical risk. Adopting the Agile principles of “incremental delivery” and “customer involvement” (Cockburn, 2002; Sommerville, 2008) were key to minimise the project risks. As stated in SpeechNet correspondence to the ESC:
“SpeechNet will use an iterative development approach for this stage of the project. This means during the 2 months of development work, there will be at least 3 releases of ISEA, which will be considered as operational versions.

The releases will be structured such that a specific data input area will be analysed in-depth and implemented. The functionality to be included in each release will be constrained to ensure a release can be completed within a 2-4 week timeframe.

Adopting this approach means that the [ESC] will be in a position to review project outcomes during the development, and also to provide feedback to make improvements in subsequent releases” (SpeechNet to ESC letter, 20 October 2005).

The requirements were gathered principally at a half-day joint application development (JAD) (Kendall & Kendall, 2005) session, held at the ESC pre-season training camp outside of the city. This was an excellent opportunity for requirements gathering as all medical and other professional staff involved with injury management were available at one location and at the same time.

The focus tasks of the JAD session were to:

1) undertake requirements analysis of data and information requirements of the injury management business process. This also included a study of the injury management business process;

2) undertake an in-depth study of the spoken language requirements for entering injury data through a speech interface;

3) map the spoken language requirements to InjuryTracker™ database fields (SpeechNet internal documentation, 19 December 2005).

Follow-up meetings were held with ESC professional staff to elicit and validate requirements over a period of 3 months.

Subsequent to the requirements gathering phase, the project was structured around the development of the 3 ISEA modules:

1) audio capture and speech to text transcription (Module-1);
2) consultation text interpretation, validation and correction (Module-2); and

3) InjuryTracker™ database update (Module-3).

The ISEA HCI systems design is dependent on understanding and modelling the users’ spoken language vocabulary and grammar to record medical consultations. An in-depth understanding and modelling of the spoken language requirements is necessary before detailed work can commence on each module of ISEA. This is highlighted clearly in Figure 4.3 the ISEA next stage development approach.

![Image of ISEA Development Process Diagram]

*Figure 4.3 – ISEA next stage development approach (SpeechNet project documentation, 20 October 2005)*

As the project manager, the researcher sub-divided the ISEA development project into 3 stages. Stage 1 (S1), Stage 2 (S2) and Stage 3 (S3) relate to Module-1, Module-2 and Module-3 respectively. Stage 1 to Stage 3 reflect the sequence of events involved in ISEA’s processing of medical consultation injury data. Stage 1 captures the spoken language discourse and uses DNS to transcribe this spoken language into text (SpeechToText). Once completed, Stage 2 processes the SpeechToText and generates database transactions for uploading into InjuryTracker_DB. Stage 3 uploads the injury data into InjuryTracker_DB. This is summarised in Figure 4.4.
Requirements analysis uncovered several medical consultation data groupings. These data groupings related to injury, illness, prescription, and medical inoculation. To assist in focusing the development activities and to facilitate an incremental systems development approach, one data grouping was selected for each development increment. The data groupings were prioritised in terms of importance with the highest priority data grouping selected for the first development increment and so on until all data groupings were implemented. Two analysis streams were undertaken for each selected data group. These analysis streams were:

1) elicit the data and information requirements, and undertake entity relationship modelling; and

2) define the spoken language requirements to record a medical consultation, and undertake a language modelling study.

Both of these activities were primarily performed by the researcher as part of his business analyst job role. The activities associated with the first stream commenced during the JAD workshop, as discussed above. On completion of the data and information requirements activity, the language modelling study commenced. The language modelling study required analysis from 3 perspectives:

1) the language structure of a medical consultation;
2) the words and phrases used to describe a medical consultation; and
3) the relationship between words and phrases and InjuryTracker_DB tables and fields.

The language modelling study is now described.

### 4.3.3 LANGUAGE MODELLING STUDY

#### 4.3.3.1 Overview

The vocabulary and grammar associated with injury data capture is very complex. Injury data consists of medical terms including diagnostic data; prescription data relating to dosages and drug names; treatment data, including physiotherapist equipment; equipment settings; techniques; procedures; and ‘free form’ general descriptions of the medical condition and treatments provided to the player. This amounts to significant challenges for the ISEA spoken language technology components to correctly transcribe the spoken words, and for the natural language understanding algorithms to correctly interpret the SpeechToText.

A further challenge for ISEA is to determine automatically whether DNS has correctly recognised the spoken language. This is achieved by identifying key words and phrases in the SpeechToText generated by DNS, so that validation of the data can occur. For example, a doctor’s name can be validated against a reference table containing the names of all doctors registered to provide medical services to the ESC. This assumes, however, that ISEA knows that this particular word in the SpeechToText is a doctor’s name. Hence, to validate the SpeechToText, ISEA applies natural language understanding techniques to identify key words and phrases so that the SpeechToText can be interpreted, understood and validated.

To minimise the risk of low quality injury data due to poor speech recognition accuracy, ISEA adopted a dual approach to improve data quality. Firstly, an in-depth study was undertaken to understand the spoken language and *modus operandi* followed in recording medical consultations. Secondly, the spoken language was structured in the form of a template that is used by medical staff as a guide for recording consultations with players. ISEA uses the language structure as defined in
the template to identify key words and phrases in the SpeechToText. Hence, this template provided ISEA with the means to validate the data from two perspectives:

1) the identification of errors generated as a result of poor speech recognition; and

2) validation of key fields in the SpeechToText.

Thus, ISEA uses the knowledge of the language syntax to correct misrecognitions by DNS. Addressing errors generated as a result of poor speech recognition implies that the interpretation of the SpeechToText can be undertaken with a high degree of confidence, as the data being parsed is considered to reflect correctly what the user said. The language modelling study is now discussed.

4.3.3.2 Language modelling study description

The researcher performed the language modelling study over a period of 3 months. The ESC provided the researcher access to medical consultation and treatment data spanning 5 years. This included paper records, electronic documents and spreadsheets of consultation and treatment notes, and access to the electronic records stored in InjuryTracker_DB. The InjuryTracker_DB repository is large in size, and provided a comprehensive source of data to undertake in-depth language modelling. The repository consisted of 1727 notes of medical visits, over 7000 treatment notes that included specific modalities of treatments and 706 injury descriptions.

A brief preliminary analysis of the source data highlighted that the vocabulary and grammar used by medical staff in documenting player medical consultations is very complex. The source data contained medical terminology and lacked a consistent structure surrounding key words. That is, the descriptions were free form and did not follow a prescribed format. As the following ESC Doctor’s consultation summary notes attest:

“4th April 2005
Has had two weeks of right lower back pain. Left slump leads to back pain. Lumbar-sacral flexion leads to discomfort. Tender L5 and L4 on left side. Diagnosis: probable facet joint of L4 and L5 or L5 and S1 inflammation. Treatment: Feldene, physiotherapy, no overhead or standing weight training”

(ESC internal documentation, 15 July 2005).
“12th March 2005

The above examples highlight many inconsistencies in documenting injuries. For example, in some cases the medical officer records where the injury occurred; other times they do not. Sometimes they clearly identify the diagnosis; other times it is implied in the text written. Often mixed data types are used for the same data grouping. For example, the description for treatment in some instances includes both the treatment details and other information such as date for follow-up consultation.

Analysing the data further identified another dimension to the complexity for the language modelling study. The data stored in InjuryTracker_DB was of low quality due to erroneous input and/or users adopting shortcuts to improve their data entry efficiency. That is, ESC professional staff adopted an approach of summarising the input data and using shorthand notations, including abbreviations, to reduce the typing effort involved in entering data into InjuryTracker™. Specifically:

- numerous abbreviations were used for the same term;
- there were many instances of poor speech recognition accuracy resulting in incorrect information being stored in InjuryTracker_DB;
- the input consultation data was summarised resulting in information loss;
- non-standard abbreviations were used;
- InjuryTracker_DB contained duplicate data; and
- there were many examples of erroneous data stored in InjuryTracker_DB.

As the researcher states in a memo to the ESC:

“No estimate at this time on how difficult the conversion is...... There seems to be many duplicate records in the .dbf files they gave me, which needs to be cleaned up. e.g. the patients file has many duplicate records for a player” (SpeechNet project notes, 16 December 2005).
These problems were addressed, and the data repaired as a precursor to commencing formal language modelling. The repair process began with the extraction of consultation notes from InjuryTracker_DB. The InjuryTracker_DB data were downloaded into a series of Microsoft Excel worksheets. Microsoft Excel was chosen as its data manipulation capabilities were more than adequate for this type of analysis. Further, the ESC were familiar with Microsoft Excel which meant the sharing of information between SpeechNet and the ESC could occur in an efficient manner. Data areas requiring explanation and/or interpretation by the ESC were identified in the worksheets, with suitable annotations to facilitate feedback and correction. An example of a consultation note that was analysed and requiring correction follows:

<table>
<thead>
<tr>
<th>Consultation note:</th>
<th>X-ray review. NAD. Stable joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher comment:</td>
<td>What is NAD?</td>
</tr>
<tr>
<td>ESC response:</td>
<td>Shorthand (both written and verbal) for &quot;No abnormality detected&quot;</td>
</tr>
</tbody>
</table>

Abbreviations and/or specific terms used by medical and professional staff when recording data posed many problems for the language modelling study. Abbreviations are highly ambiguous in the medical domain with many medical professionals using their own abbreviation conventions (Patrick et al., 2007). Hence, an understanding of abbreviations and other terms is necessary for ambiguity resolution and for standardisation of the data. Understanding how these terms and words are spoken is also important for improving speech recognition accuracy. The ESC therefore were asked to include in their feedback how these words would be spoken. As ESC e-mail to the researcher states:

“I've gone through the spreadsheet and been able to answer most of your concerns. A couple of points about them

1. Many sentences are incomplete but would not have been left incomplete in the original record so it appears something has gone awry in transposing them.
2. You will note my increasingly acerbic comments about Dragon as I worked down the list. Most of the problems where there was apparent nonsense or complete no idea of what was written was due to poor word recognition by Dragon. The give away is that most (if not all of them) appeared in sentences which started with a lower case letter because that is the way Dragon would enter them.
3. There are several examples of doctor speak that is used regularly either verbally or in writing. eg NSAIDs, NAD, C3-C4, stress # (L) and (R) etc.
I'll give you a call and make a time to meet and go through what I have returned today. Tomorrow I will go through the spelling and presentation of regularly used medical terms, anatomical terms etc. I will also try to put together a comprehensive glossary for you to use (ESC e-mail to researcher, 6 July 2005).

DNS contributed to many errors in the data stored in InjuryTracker_DB. Not every word was misrecognised, but sufficient to render the statement substantially incorrect or meaningless, as the following examples demonstrate:

<table>
<thead>
<tr>
<th>Consultation note:</th>
<th>Continue set program. Noble work other than to take the ball in front</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher comment:</td>
<td>Is “Noble” correct?</td>
</tr>
<tr>
<td>ESC response:</td>
<td>Should be &quot;No ball work...&quot; You can see here and elsewhere where Dragon has made mistakes and we haven't picked it up at the time</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consultation note:</th>
<th>you an eccentric stretching program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher comment:</td>
<td>Check this phrase</td>
</tr>
<tr>
<td>ESC response:</td>
<td>Bloody Dragon! No idea</td>
</tr>
</tbody>
</table>

Understanding and standardising abbreviations and acronyms; correcting speech recognition errors; understanding terminology and how they are spoken by medical staff; identifying errors relating to poor data entry; and correcting abbreviations used inappropriately; are all examples of the issues which required analysis during the language modelling study. Several examples are now provided:

**Understanding and standardisation of abbreviations**

<table>
<thead>
<tr>
<th>Consultation note:</th>
<th>Treadmill jog for 20/60 and few kicks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher comment:</td>
<td>What is 20/60?</td>
</tr>
<tr>
<td>ESC response:</td>
<td>20 minutes</td>
</tr>
</tbody>
</table>

**Poor quality data due to manual data entry errors**

<table>
<thead>
<tr>
<th>Consultation note:</th>
<th>Will try to train and play but understands that the chance of a recurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher comment:</td>
<td>Seems to be missing information</td>
</tr>
<tr>
<td>ESC response:</td>
<td>should be “Will try to train and play but understands that the chance of a recurrence is high”</td>
</tr>
</tbody>
</table>
Understanding terminology and how it will be spoken

<table>
<thead>
<tr>
<th>Consultation note:</th>
<th>Treadmill Swim today but in isolation because of URTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher comment:</td>
<td>What is URTI?</td>
</tr>
<tr>
<td>ESC response:</td>
<td>URTI Upper respiratory tract infection but always referred to in shorthand as URTI</td>
</tr>
</tbody>
</table>

Abbreviations which lead to data quality problems

<table>
<thead>
<tr>
<th>Consultation note:</th>
<th>Non impact loading. Needs podiatric review by ST. Wednesday and Sunday off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher comment:</td>
<td>What is ST?</td>
</tr>
<tr>
<td>ESC response:</td>
<td>The doctor’s initials</td>
</tr>
</tbody>
</table>

Repairing the data in these areas was an extensive exercise. There were many occurrences of incorrect or inconsistent data.

Considerable discussion with medical and professional staff was essential to determine how particular terms or words spoken should be recorded. For example, if a doctor says ‘URTI’, should ISEA store this as ‘URTI’ in InjuryTracker_DB or should it be stored as ‘upper respiratory tract infection’? Consistently translating and standardising these terms and words is necessary to maintain database integrity, and to facilitate effective reporting including analytics and data mining exercises.

As e-mail correspondence from the researcher to ESC highlights:

“Important to review from the following perspectives:
1. How you will say the words?
2. How you want them to be translated? e.g. say MRI and this is translated to M.R.I.
3. Check spelling particularly of medical terms, abbreviations and medicines.
4. Allowing the speaker (trainer etc) to use both abbreviations and full word text is fine e.g. “physio” or “physiotherapy” (SpeechNet to ESC e-mail, 6 July 2005).

Table 4.1 provides several examples of terms to be standardised and/or agreement reached with medical staff on how these terms are to be spoken.
Table 4.1 - Examples of terms and how they were recorded in InjuryTracker_DB
(Internal SpeechNet documentation, 28 July 2005)

<table>
<thead>
<tr>
<th>Term</th>
<th>Various representations in the data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultrasound</td>
<td>‘u/s’, ‘u/sound’ or ‘ultrasound’.</td>
</tr>
<tr>
<td>Ultrasound 2 W by 6 minutes</td>
<td>‘U/S:2W x 6’ or ‘Ultrasound 2 W by 6 minutes’. This example highlights that the use of ultrasound can include equipment settings such as ‘2 W’ and time period. Each of these components may use abbreviations.</td>
</tr>
<tr>
<td>Overnight</td>
<td>‘o/night’, ‘overnight’ or ‘over night’.</td>
</tr>
<tr>
<td>Rehabilitation</td>
<td>‘Rehab’ and ‘rehabilitation’.</td>
</tr>
<tr>
<td>Light</td>
<td>‘Lt’ or ‘light’.</td>
</tr>
<tr>
<td>Lumbo-sacral</td>
<td>‘L/S’ or ‘lumbo-sacral’. L/S is a section of the back.</td>
</tr>
<tr>
<td>Interferential 0 to 150 by 15 minutes</td>
<td>‘ITF:0-150 x 15’ or ‘Interferential 0 to 150 by 15 minutes’. This example is complex as it contains many abbreviations, and its structure contains several key information components. ‘ITF’ is an acronym for interferential which is medical equipment used for physiotherapy treatments. ‘0 to 150’ is a setting of the interferential and the ‘by 15 minutes’ denotes how long the treatment is provided.</td>
</tr>
<tr>
<td>Inductomag 4 Hz by 10 minutes</td>
<td>‘IMag:4Hz x 10’ or ‘Inductomag 4 Hz by 10 minutes’. The inductomag is also medical equipment used for physiotherapy treatments. This example highlights the use of abbreviations for key terms. ‘IMag’ is an abbreviation for Inductomag. The phrase is structured around equipment type, value setting (abbreviation ‘Hz’ used for ‘hertz’) and time period.</td>
</tr>
<tr>
<td>Recovery massage</td>
<td>‘RMas’ or ‘recovery massage’.</td>
</tr>
<tr>
<td>Stretching mobilisation</td>
<td>‘S/Mob’ or ‘stretching mobilisation’. This example highlights the use of ‘/’ to signify that the abbreviation contains two words.</td>
</tr>
<tr>
<td>Injection</td>
<td>‘inj’ or ‘injection’.</td>
</tr>
</tbody>
</table>

As a consequence of this extensive phase of the language modelling study, the medical terms, abbreviations, and general language of consultation notes were well understood. The rules required to repair InjuryTracker_DB data were also well documented. The next step of the language modelling study was to apply the repair rules to InjuryTracker_DB data.

The repair process impacts significantly on the technical solution and delivery of ISEA and in particular ISEA’s speech recognition and natural language understanding technology components. For this reason, a formal agreement of the repair rules was sought. Once agreement was reached, the process of applying the repair rules to InjuryTracker_DB commenced. The researcher extracted key tables and fields from
InjuryTracker_DB into a set of comma separated files. These files were opened in Microsoft Excel and the repair rules applied to create a new dataset REPAIRED_DB. REPAIRED_DB contained many tens of thousands of sample medical data specific to the elite sporting industry.

The next stage of the language modelling study analysed REPAIRED_DB to uncover and model the data and data structures used in spoken language discourses for medical consultations. In association with medical staff, simulations of spoken language discourses to capture medical consultation data were performed. As a result of this iterative process, a language template was developed. The language template, an important deliverable of the language modelling study, is used by medical staff as a guide when constructing spoken language to record medical consultations. Hence, the language template aims to replicate how medical staff record information during a real-life consultation. Table 4.2 details the ISEA language template.

Once formulated, the language template was used as the language framework guide to generate spoken language discourses from REPAIRED_DB data. Subsequently, the generated spoken language discourses were processed using DNS specialist tools to create a customised injury management language model (IMLM). Section 4.3.7 provides a detailed description of the speech improvement project, and an in-depth discussion of IMLM and how it is used to improve speech recognition accuracy.

The ISEA software modules are now described.

*Table 4.2 – ISEA language template* (Internal SpeechNet documentation, 27 March 2006)

<table>
<thead>
<tr>
<th>New treatment for player:</th>
<th>[Given Name Last Name]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practitioner:</td>
<td>[Given Name Last Name ]</td>
</tr>
<tr>
<td>Treatment date:</td>
<td>[January 3 2006]</td>
</tr>
<tr>
<td>Treatment time:</td>
<td>[                    ]</td>
</tr>
<tr>
<td>Treatment duration:</td>
<td>[                    ]</td>
</tr>
<tr>
<td>Existing Injury:</td>
<td>[                    ]</td>
</tr>
<tr>
<td>Treatment reason:</td>
<td>[                    ]</td>
</tr>
<tr>
<td>Ice:</td>
<td>[                    ]</td>
</tr>
<tr>
<td>KinCom:</td>
<td>[                    ]</td>
</tr>
<tr>
<td>Manual Therapy:</td>
<td>[                    ]</td>
</tr>
<tr>
<td>Laser:</td>
<td>[                    ]</td>
</tr>
<tr>
<td>Hot packs:</td>
<td>[                    ]</td>
</tr>
<tr>
<td>Ultrasound:</td>
<td>[                    ]</td>
</tr>
<tr>
<td>Inductomag:</td>
<td>[ ]</td>
</tr>
<tr>
<td>Acupuncture:</td>
<td>[ ]</td>
</tr>
<tr>
<td>Prolotherapy:</td>
<td>[ ]</td>
</tr>
<tr>
<td>Manipulation:</td>
<td>[ ]</td>
</tr>
<tr>
<td>Mobilisation:</td>
<td>[ ]</td>
</tr>
<tr>
<td>Warm-up:</td>
<td>[ ]</td>
</tr>
<tr>
<td>Recovery massage:</td>
<td>[ ]</td>
</tr>
<tr>
<td>Interferential:</td>
<td>[ ]</td>
</tr>
<tr>
<td>Therapeutic:</td>
<td>[ ]</td>
</tr>
<tr>
<td>Rehab:</td>
<td>[ ]</td>
</tr>
<tr>
<td>Modalities:</td>
<td>[ ]</td>
</tr>
<tr>
<td>Treatment notes:</td>
<td>[ ]</td>
</tr>
<tr>
<td>Stretching:</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

**End treatment:**

**New encounter for player:** [Given Name Last Name]
Practitioner: [Given Name Last Name]
Encounter date: [January 3 2006]
Existing Injury: [one line description of injury]
Existing Illness: [one line description of illness]

**New injury:**
- Incident date: [morning/afternoon/evening]
- Segment: [ ]
- Activity: [ ]
- Surface: [ ]
- Weather: [ ]
- Arena: [ ]
- Injury Type: [ ]
- Severity: [ ]
- Body part: [ ]
- Side: [ left, right, bilateral, na (default) ]
- Mechanism: [ ]
- History: [ ]
- Recurrence: [ ]

**Encounter note:** [ ]

**New illness:**
- Onset: [ ]
- Illness type: [ ]
- Illness note: [ ]

**New prescription:**
- Drug: [ ]
- Prescription date: [ ]
- Prescription note: [ ]
- Dispensed by: [ ]
4.3.4 MODULE-1 - AUDIO CAPTURE AND SPEECH TO TEXT

TRANSCRIPTION

Module-1’s HCI provides two alternative audio recording modes for the capture of medical consultation data:

1) Mode-1 - audio capture using a digital recording device; and/or

2) Mode-2 - dictate directly using *Dragon Naturally Speaking™* (DNS) via a computer.

The mode selected by the end-user is based on their own personal preference for entering data.

For Mode-1, medical consultations are captured using a digital recording device. The Sony ICD-BM1 Digital Voice Recorder was selected for this purpose. Adopting this mode to capture spoken language involves a two-stage process. Firstly, the consultation data is recorded onto the digital recording device, and secondly the stored audio data is transcribed into text using DNS. *Dragon Naturally Speaking™* Professional (English) V8.10.000.279 SP1 is the speech recognition package used for ISEA. Additionally, the Sony Digital Voice Editor V2.31 software is used to manage the numerous audio files generated by medical staff. An added benefit of the Sony Digital Voice Editor package is that it connects directly to DNS to transcribe audio files. Mode-1 offers an efficient method to capture many hours of consultation data through speech, leaving the transcription of audio data for a more convenient time.
Mode-2 requires medical staff to dictate directly using DNS via a microphone connected to a Windows based personal computer. As the user speaks, DNS transcribes the spoken language into text (SpeechToText). An advantage of this approach is that it provides a visual representation of the audio data as the user speaks, allowing the user to easily identify and correct misrecognitions as they occur.

The consultation audio recordings from both modes are kept as evidence for potential future reconciliations between ‘what was said’ (a correct account of what was done) and ‘what was recorded in the database’ (interpreted account of the audio data). In the event there is a discrepancy between what is recorded in InjuryTracker_DB, and medical staff recollections of the medical treatment, the audio transcripts become an invaluable source to clarify and perhaps rectify the differences in the data. Injury data discrepancies are currently an area of concern for the Association as the following document excerpt highlights:

“We are finding when players threaten legal proceedings against a Club (normally for poor medical advice) that the player, the doctor and the Club have differing documentation as to what transpired and caused the player’s dissatisfaction” (Association documentation, 26 March 2007).

Hence, in cases of litigation for alleged poor treatment of a player’s injury, an audio file recording of the actual medical consultation could provide a credible contemporaneous source for legal evidence to support ESC and Association claims.

4.3.5 MODULE-2 - CONSULTATION TEXT INTERPRETATION, VALIDATION AND CORRECTION

Module-2 is a core component of ISEA. Using natural language understanding techniques, Module-2 parses the SpeechToText to identify key information sets and field level values. Where possible, each identified field is validated against reference data for correctness and completeness. To facilitate the validation and correction process, Module-2 includes several algorithms (Bestmatch) developed by SpeechNet to identify the best match between SpeechToText field values and reference data in InjuryTracker_DB.
Specifically, Module-2 undertakes:

- syntactic and semantic analysis of SpeechToText;
- validation and correction of primary key data such as doctor’s name and player’s name using Bestmatch and automatic word spelling correction;
- validation, correction and standardisation of reference data using Bestmatch to ensure reference data is standardised for later reporting and analysis;
- injury/illness matching to InjuryTracker_DB. Injury descriptions can use a variety of terms with similar meanings and therefore do not exactly match what is recorded in InjuryTracker_DB. In these instances, Bestmatch is used to identify the best candidate for an existing injury; and
- completion of field entries and derives missing data. ISEA tolerates incomplete input data such as dates and names. For field types which often use the same values such as drug dosages, Module-2 will automatically derive the default values. In addition to this, Module-2 evaluates user input codes which represent treatment modalities, such as ultrasound and specific machine settings.

Following is a set of SpeechToText examples which show the outcomes of Module-2 processing in resolving incorrect and/or incomplete data. The comments in red (annotated boxes) are the corrections made by Module-2. Note the following examples use fictitious data.

**Example 1**

New treatment:
- Player: Ferguson, Brett
- Practitioner: Fielding, Matt
- Treatment date: four January
- Existing injury: tendonitis of left patella
- Massage:
- End treatment:

Example 1 highlights Module-2’s automatic resolution of partially incorrect speech recognition, and incomplete data. While not incorrect, the use of ‘four’ in the date is
not in a suitable form for database entry. Also the year is missing in the date. For this example Module-2 translates ‘four’ to ‘4th’ and inserts the missing year ‘2009’.

**Example 2**

New treatment:
- **Player:** Goode
- **Practitioner:** David, Chris
- **Treatment date:** four January
- **Existing injury:** strain of left lumbar spine
- **Massage:**
- **Stretching:**
- **Manipulation:**
- **End treatment:**

In example 2 the user did not specify the player’s full name. For this case, Module-2 will automatically evaluate the player’s name to ‘Goode, Peter’. Module-2’s processing begins by identifying the key word ‘Player:’ and recognising the word(s) following the colon are the athlete’s name. Subsequently this name is validated against the athlete details reference table. The athlete details reference table contains a list of all players associated with the club. Module-2 then checks what was spoken (i.e. ‘Goode’) against the last name and/or first name in the athlete details reference table. As ‘Goode’ is the last name, the first name associated with this player can be determined. Alternatively, the player’s first name could have been spoken and therefore used to validate against the athlete details reference table to determine the player’s last name. This process works well except in cases where there is more than one player with the same name component (first name or last name). For instance, if the athlete details reference table contained two players with names ‘Goode, Peter’ and ‘Goode, Sam’ the results of validation for ‘Player: Goode’ returns more than one possible candidate for the player and is therefore ambiguous. In this case the ambiguity can only be resolved through user intervention.
Example 3

New treatment:
Player: Roy, Mike
Practitioner Phelps, Kevin
Treatment date: four January
Existing injury: third degree rupture of left ACL
Massage:
End treatment:

Example 3 highlights two areas where Module-2 can repair the input SpeechToText without user intervention. Firstly, a ‘:’ should follow the key word practitioner. This is missing in the SpeechToText. ISEA detects the missing ‘:’ and inserts it automatically so that processing can continue. Secondly, the existing injury used ‘third’ instead of ‘3rd’. For database reporting and comparisons these can be interpreted quite differently. Hence, Module-2 automatically standardises the input data to ‘3rd’.

Example 4

New treatment:
Player: Scott, Phillip
Practitioner: Cross, Chris
Treatment date: four January
Existing injury: soreness of left foot
Massage:
Stretching:
End treatment:

New treatment:
Player: Fisher, Ted
Practitioner: Cross, Chris
Treatment date: four January
Existing injury: tightness of pelvis
Massage:
Stretching:
End treatment:

New treatment:
Player: Booth, Robert
Practitioner: Helpman, Chris
Treatment date: five January
Existing injury: third degree rupture of left ratio
Massage:
Treatment notes: exercises
End treatment:

No colon is corrected automatically
Automatically translates to 3rd degree
Should be “painful”
Should be “mild tightness”
Should be “ACL”
In example 4 there are three scenarios which provide insights into both the power of Bestmatch, and the reasons why such automatic corrections are necessary. In all cases there is a discrepancy between the SpeechToText existing injury description and the description of the existing injury recorded in InjuryTracker_DB. If exact matching were performed by Module-2, then the existing injury would not be found in InjuryTracker_DB and require user intervention to proceed.

In scenario 1 of example 4, the doctor’s recollection of the injury is that the player had ‘soreness of the left foot’. However, although very close in meaning, the existing injury was recorded as ‘painful left foot’. Through statistical analysis, Module-2 determines that the existing injury should be ‘painful left foot’. In scenario 2 of example 4, the doctor was not as descriptive of the existing injury as in the original data capture. The degree of tightness was not included in the follow up visit. Similar to scenario 1, Module-2 through its best match algorithms selects the correct existing injury and repairs the input SpeechToText automatically. Similarly, the existing injury in scenario 3 has incorrect words, but in this case they have occurred due to poor speech recognition accuracy. ‘third degree rupture of left ratio’ should have read ‘third degree rupture of left ACL’. From time to time speech recognition will introduce errors, which may result simply from background noise in the office. However, regardless of the source of incorrect words, Module-2 applies its best match algorithms to the existing injury text. In this case Module-2 successfully finds the correct existing injury and repairs the SpeechToText accordingly.

4.3.6 Module-3 – InjuryTracker_DB Update

By the end of Module-2 processing, ISEA has, through the natural language parsing process, obtained a clear understanding of the consultation data as represented in the SpeechToText, and repaired the SpeechToText data where required. The next stage is to translate Module-2 output data into InjuryTracker_DB tables and fields, so that this data can be uploaded into InjuryTracker_DB.

The researcher’s entity relationship modelling of the InjuryTracker_DB data structure revealed that InjuryTracker_DB database design is based around 6 key database tables:
There are significant differences between the SpeechToText data structures and the way this data is stored in InjuryTracker_DB. These data structure discrepancies are explained through the following example of a typical player consultation with a doctor.

During a consultation the doctor examines the player. The examination identified two new injuries from the weekend’s competition. The player has bruising on the left arm, and a possible fracture of left hand. These injuries incurred by the player were all due to the same incident on the playing field. During the consultation the doctor also examined an existing injury currently under rehabilitation consisting of a tight hamstring on the right leg. As part of the treatment the doctor prescribed a drug to aid in the recovery and to assist with pain management.

In this example there are two new injuries identified, one existing injury examined and one new prescription. ISEA considers this as one consultation transaction. In InjuryTracker™ however, this one consultation results in many database records being created as follows:

- three new encounter (consultation) records are created in the VISIT table. These records are made up as one visit record for each of the new injuries and one visit record for the existing injury. The relationship between these injuries from the one consultation is not referenced in the VISIT table and this information is therefore lost once it is entered into InjuryTracker_DB;
two injury records are created in the INJURY table; and

one prescription record is created in the PRESCRIPTION table.

Before the encounter and prescription records can be created, the injury must exist in InjuryTracker_DB. That is, a sequence in processing medical consultation transactions must be followed when creating records in InjuryTracker_DB. Hence, if there is a new injury, then this record must be created in the INJURY table before the visit record is created in the VISIT table. To align with InjuryTracker_DB processing, Module-3 processes the input data files twice. The first pass parses the input file to identify new injuries, and to create new injury records in InjuryTracker_DB. The second pass parses the input file for visit and other consultation information. These records are subsequently uploaded into InjuryTracker_DB.

User spoken language to record medical consultations is not constrained by pre-defined database names. Hence the SpeechToText contains terminology, key field names, and values that do not match directly with corresponding field and data values in InjuryTracker_DB. The next step in Module 3 processing is therefore to map SpeechToText language to specific fields in InjuryTracker_DB tables. This step required substantial analysis by the researcher as there are many instances where there is no direct data relationship between the natural language used in SpeechToText and tables and fields in InjuryTracker_DB.

Table 4.3 below shows the database schema for the INJURY table and the spoken language of a typical medical consultation. Table 4.3 also shows how the ISEA medical consultation transaction is represented physically in the INJURY table. As is evident from the table, considerable processing of the spoken language is required to generate a database transaction suitable for uploading into the INJURY table.
Table 4.3 – Physical representation of spoken language in INJURY table

<table>
<thead>
<tr>
<th>Physical representation of spoken language in INJURY table</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Database schema for INJURY table</strong></td>
</tr>
<tr>
<td>Physically the INJURY table is implemented as INJURY.DBF which is a dBase file. Following are the field names as they appear in the INJURY table record.</td>
</tr>
<tr>
<td>Injury_No, Patient_No, PatientName, Position, IncidentDate, AM_PM, Discipline, Event, Segment, Season, Activity, Surface, Weather, RuleInfraction, OpposingTeam, OpposingPlayer, Arena, Aggressor, OrchardCode, InjuryType, Severity, BodyPart, Side, Mechanism, Equipment, History, Occurrence, InitialTreatment, Subjective, Objective, Assessment, Plan, DaysOut, PracticesMissed, GamesMissed, Indemnity, RecoveryDate, NumberOfTreatments, TeamEvent_No, MedicalDiagnosis, TournaName, Archived, AddStamp, ModStamp</td>
</tr>
<tr>
<td><strong>ISEA medical consultation as dictated by Doctor</strong></td>
</tr>
<tr>
<td><strong>ISEA processed consultation data ready for INJURY table upload</strong></td>
</tr>
<tr>
<td>ISEA processes the spoken language and maps this to INJURY table fields. In some instances, natural language field values are translated into InjuryTracker_DB field codes. Note the following snapshot of the ISEA uploaded INJURY Table record is in the same field order as the database schema above in this table.</td>
</tr>
<tr>
<td>3421,511,&quot;Smith, Stephen&quot;,281,27/10/2007,,,,238,,,64,75,,,,281,,,227,,1144,L,182,..................,&quot;20071117 09:30:18 TestUpdate&quot;,&quot;20071117 09:30:18 TestUpdate&quot;</td>
</tr>
</tbody>
</table>
Table 4.4 provides an example of the mapping complexity between spoken language to INJURY table fields. Note for each InjuryTracker_DB table there is a similar mapping requirement.

**Table 4.4 - Mapping of spoken language to INJURY.DBF fields**

<table>
<thead>
<tr>
<th>Natural Language Key Word</th>
<th>INJURY Table Field</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Injury:</td>
<td>Injury_No</td>
<td>Signifies a new injury is to be created in INJURY.DBF.</td>
</tr>
<tr>
<td>ISEA Generated</td>
<td></td>
<td>Increment from last Injury_No in INJURY.DBF.</td>
</tr>
<tr>
<td>Player:</td>
<td>Patient_No</td>
<td>An InjuryTracker_DB lookup is required to determine Patient_no for a player. This requires a database query of the PATIENTS.DBF table.</td>
</tr>
<tr>
<td>Player:</td>
<td>PatientName</td>
<td>The player’s name is validated against the PATIENTS.DBF table.</td>
</tr>
<tr>
<td>ISEA Generated</td>
<td>Position</td>
<td>Determined from PATIENTS.DBF.</td>
</tr>
<tr>
<td>Incident date:</td>
<td>IncidentDate</td>
<td>Need to identify morning/afternoon/evening and convert to AM, PM respectively. Where morning/afternoon/evening not specified default to PM.</td>
</tr>
<tr>
<td></td>
<td>AM_PM</td>
<td></td>
</tr>
<tr>
<td>Not used</td>
<td>Discipline</td>
<td></td>
</tr>
<tr>
<td>Not used</td>
<td>Event</td>
<td></td>
</tr>
<tr>
<td>Segment:</td>
<td>Segment</td>
<td>Validated using SEGMENT.DBF.</td>
</tr>
<tr>
<td>Not used</td>
<td>Season</td>
<td></td>
</tr>
<tr>
<td>Activity:</td>
<td>Activity</td>
<td>Validated using ACTIVITY.DBF.</td>
</tr>
<tr>
<td>Not used</td>
<td>Surface</td>
<td>Validated using SURF.DBF.</td>
</tr>
<tr>
<td>Weather:</td>
<td>Weather</td>
<td>Validated using WEATHER.DBF.</td>
</tr>
<tr>
<td>Not used</td>
<td>RuleInfraction</td>
<td></td>
</tr>
<tr>
<td>Not used</td>
<td>OpposingTeam</td>
<td></td>
</tr>
<tr>
<td>Not used</td>
<td>OpposingPlayer</td>
<td></td>
</tr>
<tr>
<td>Arena:</td>
<td>Arena</td>
<td>Validated using ARENA.DBF.</td>
</tr>
<tr>
<td>Not used</td>
<td>Aggressor</td>
<td></td>
</tr>
<tr>
<td>Not used</td>
<td>OrchardCode</td>
<td></td>
</tr>
<tr>
<td>Injury Type:</td>
<td>InjuryType</td>
<td>Validated using INJTYPE.DBF.</td>
</tr>
<tr>
<td>Not used</td>
<td>Severity</td>
<td>Validated using SEVERITY.DBF.</td>
</tr>
<tr>
<td>Body part:</td>
<td>BodyPart</td>
<td>Validated using BODYPART.DBF.</td>
</tr>
<tr>
<td>Side:</td>
<td>Side</td>
<td>Valid values are left, right, bilateral and not applicable. If side: is not stated then default to Not Applicable. Valid values are L for left, R for right, B, N.</td>
</tr>
<tr>
<td>Mechanism:</td>
<td>Mechanism</td>
<td>Validated using MECH.DBF.</td>
</tr>
<tr>
<td>Not used</td>
<td>Equipment</td>
<td></td>
</tr>
<tr>
<td>History:</td>
<td>History</td>
<td></td>
</tr>
<tr>
<td>Occurrence:</td>
<td>Occurrence</td>
<td>Valued values are 1st, 2nd or chronic. These are translated to 1 for first OR 1st, 2 for second OR 2nd or C for chronic.</td>
</tr>
<tr>
<td>Not used</td>
<td>InitialTreatment</td>
<td></td>
</tr>
<tr>
<td>Not used</td>
<td>Subjective</td>
<td></td>
</tr>
<tr>
<td>Not used</td>
<td>Objective</td>
<td></td>
</tr>
<tr>
<td>Not used</td>
<td>Assessment</td>
<td></td>
</tr>
<tr>
<td>Not used</td>
<td>Plan</td>
<td></td>
</tr>
<tr>
<td>Not used</td>
<td>DaysOut</td>
<td></td>
</tr>
<tr>
<td>Not used</td>
<td>PracticesMissed</td>
<td></td>
</tr>
<tr>
<td>Field</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>--------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>GamesMissed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indemnity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RecoveryDate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NumberOfTreatments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TeamEvent_No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MedicalDiagnosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TournaName</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Archived</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AddStamp</td>
<td>Date &amp; time &amp; by whom the record was added.</td>
<td></td>
</tr>
<tr>
<td>ModStamp</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The final step in completing a consultation transaction is to upload the processed SpeechToText into InjuryTracker_DB tables and fields. Ordinarily, uploading data is a relatively straightforward task for modern database management systems. However, this is not the case for InjuryTracker_DB as it is a legacy database platform. Further, InjuryTracker™ has no data import facilities for the 6 key tables mentioned above. This is a significant deficiency of InjuryTracker™, as ISEA required a data import and export facility to efficiently interact with InjuryTracker_DB. Consequently the building or acquiring of an import/export facility was necessary. The option to build the import/export facility by SpeechNet was considered. However, building this software involved obtaining an in-depth knowledge of the dBase development environment and the Borland Database Engine, which was considered an expensive option and not cost justified. As a result, the developers of InjuryTracker™ were approached to build an import/export facility, which they were willing do, but the cost again was prohibitive. An alternative solution was to find a tool that could interact with dBase tables and therefore InjuryTracker_DB tables. After an extensive search by the researcher, DB Commander Pro 2000 was found and subsequently selected as the import/export tool, as it is a powerful tool with many utilities to assist with interacting with dBase file types. In particular, it provided import and export facilities that could be integrated with ISEA programs.

Uploading transaction data into InjuryTracker_DB is achieved by Module-3 making direct import program procedure calls to DB Commander Pro, which then uploads the ISEA transaction data into InjuryTracker_DB.

The ISEA application software modules have now been described. Key to the success of ISEA is obtaining good speech recognition accuracy of spoken language
discourses. The investigation into improving speech recognition accuracy of spoken language is part of the speech improvement project, and is now described.

4.3.7 SPEECH IMPROVEMENT PROJECT

The success of ISEA and management approval for the project was very much dependent on achieving an acceptable level of speech recognition accuracy. As the researcher recounts from discussions held at a project management meeting with the ESC:

“The [CEO ESC] was keen to budget for the whole project and not just the proof of concept. A demonstration of DNS was provided to him which highlighted very poor speech recognition of injury data. Improving speech recognition to an acceptable level became a critical success factor for the entire project. So the first milestone for the project was to demonstrate a substantial improvement in the speech recognition accuracy. Otherwise the project will not proceed beyond that point” (Researcher - internal meeting notes and e-mail, 28 April 2005).

DNS is a sophisticated speech recognition engine providing several options to improve the accuracy of speech recognition. Each option was investigated as part of the speech improvement project to ensure that the best method or combination of methods were employed to achieve the aims of the speech improvement project. The researcher sought professional advice from Voice Perfect Systems. Voice Perfect Systems are the developers of the Australian language models for DNS on behalf of Nuance (the owners and developers of DNS). Their guidance and knowledge in this area were fundamental in arriving at a decision on the final approach that was adopted for the speech improvement project. Understanding the rationale behind selecting this approach requires a detailed knowledge of how DNS speech recognition works, which is now discussed.

4.3.7.1 How DNS speech recognition works

DNS uses both an acoustic model of word phonetics for selecting words which sound similar to the word being spoken, and a user’s voice profile to identify particular nuances of a person’s voice (VoicePerfect, 2008). The user’s voice profile is
generated through training of the speech recognition engine. Training of the speech recognition engine takes less than 5 minutes but further training can be undertaken to improve speech recognition accuracy. The user’s acoustic model is created by comparing each sound a person makes for a given word against a database of over 10,000 possible syllables in the English language (VoicePerfect, 2008).

Associated with the acoustic model is a vocabulary (word list and word combinations/sequences) and associated language model. The language model contains usage and context information about all the words in the vocabulary (VoicePerfect, 2008). Through undertaking a statistical analysis and determining the probability of a word and word combination occurring in an utterance, DNS can predict the most likely candidate for a word where there is ambiguity between similar sounding words in the vocabulary.

DNS determines unigram, bigram, trigram, and quadgram probability of each word, two-word sequence, three-word sequence and four word sequence respectively occurring in the text spoken (VoicePerfect, 2008) to predict the word which has the highest probability of being correct. Injury data has many instances of ambiguity and specialised medical vocabulary, which could lead to poor speech recognition. For example the anatomical name “heart” has a higher unigram probability than the name “Hart”. Both words sound the same when spoken. However, “Mr. Hart” scores a higher bigram probability, which results in “Hart” being selected for the word.

The combination of using an acoustic model and vocabulary and associated language model are important in improving speech recognition accuracy. The acoustic model’s role is to recognise sounds and the vocabulary’s task is to relate this sound to actual words and use the language models to resolve ambiguities (VoicePerfect, 2008).

Another important aspect of DNS is that it allows the user to specify how a spoken form is represented in text. For example

<table>
<thead>
<tr>
<th>Spoken Form</th>
<th>Written Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ten</td>
<td>10</td>
</tr>
<tr>
<td>Interferential</td>
<td>ITF</td>
</tr>
</tbody>
</table>

125
This is useful in the injury management data entry context, as medical staff can use abbreviated terms or acronyms specific to their field, which can then be evaluated into a form suitable for data entry purposes and for key field validation.

Speech recognition accuracy is improved by modifying the language models used by DNS. Every vocabulary has three language model slots. The ‘base slot’ contains the base language model that comes with the DNS product (VoicePerfect, 2008). The ‘user slot’ allows users to create a user language model to improve speech recognition of specific words (VoicePerfect, 2008). The ‘middle slot’ is used for custom language models. Customised language models can be developed for organisations and/or professions (such as medical and legal) that have specialised vocabularies. Language models in the ‘middle slot’ work in conjunction with the user defined language model stored in the ‘user slot’ (VoicePerfect, 2008) and the base language model. Individuals can further enhance the vocabulary used by DNS by creating individual language models in the ‘user slot’ to handle specific language and/or writing styles they require. Further improvements to speech recognition accuracy can be obtained through the training of specific words and phrases using DNS tools.

Generic medical vocabularies developed by Nuance and Voice Perfect were considered for this project. However, the advice from Voice Perfect consultants was that a custom built specialised injury management vocabulary would result in higher speech recognition accuracy, than using generic vocabularies. Voice Perfect’s response when asked whether generic vocabulary packs like “MEDISPEAK™” (developed by Voice Perfect) would be suitable for the ESC, supports this:

“I think that if you have a good text data source from the [ESC] that you will end up with higher accuracy. The Medispeak version is for general practice”

(Voice Perfect to SpeechNet e-mail, 28 April 2005).

The researcher had access to a rich source of injury data that could be used to create a customised language model. The data source for this injury data was REPAIRED_DB, which was generated as part of the language modelling study as described in Section 4.3.3. Based on this, and a detailed understanding of how speech recognition works, the decision was made to develop a customised language model for the ESC.
Creating the injury management customised language model (that is IMLM as discussed in Section 4.3.3) was an iterative process, which required the following three key activities to be performed:

1) create IMLM base data (IMLM-base-data). For DNS, the IMLM represents examples of the vocabulary, grammar and word sequences of spoken language discourses to capture medical consultation information. Hence, the IMLM is a comprehensive collection of modelled spoken language discourses. Through extensive manipulation of REPAIRED_DB and using the language template, REPAIRED_DB data were reengineered into a large dataset of spoken language discourses (IMLM-base-data). That is, processing of IMLM-base-data by ISEA would result in the creation of exactly the same records as currently exist in REPAIRED_DB. Hence IMLM-base-data, while generated, reflects real spoken language discourses;

2) create and upload IMLM into the DNS ‘middle slot’. The researcher used specialist DNS software tools to create IMLM from the IMLM-base-data. Once created, IMLM was uploaded into the DNS ‘middle slot’; and

3) test DNS to determine whether the IMLM resulted in speech recognition accuracy improvements.

To test for improvements to speech recognition accuracy, live data samples of medical practitioner recordings were captured and used as a baseline, against which each iteration of the activities above could be tested. Hence, improvements to speech recognition accuracy could be achieved in a controlled manner. To allow this testing to occur at the SpeechNet office, and to allow testing as each new IMLM were created, the researcher requested that the ESC supply him with the DNS user voice profiles for loading onto the SpeechNet test personal computer. A further requirement was that medical practitioners were not allowed to train DNS beyond the DNS enrolment training of less than 5 minutes. The reason for this restriction was to ensure that user training of DNS did not inadvertently interact with the IMLM being tested and skew the testing results. Removing this type of training from the DNS user profiles ensured only the improvements to IMLM were being tested. In addition,
medical practitioners were provided with a set of medical consultation scripts to record. As explained in an e-mail from the researcher to the ESC:

“Just in summary, what I am needing now is

1) A voice recording of you recording doctors/trainers notes for say 5-10 minutes. We will use this as a test sample baseline for further improvements to speech [recognition accuracy]…Any changes we make can be run against this test sample to ensure we are improving. Note we can create more test sets as the speech quality improves.

2) So that I can do tests at my office, I need a copy of your speech [DNS] user files. This can be done by clicking on Naturally Speaking on the Dragon Bar, then Manage Users, Advanced, Export. Then copy these files to CD” (Researcher e-mail to ESC, 8 September 2005).

The creation of the IMLM was an intensive exercise requiring the analysis of a large corpus of data. This involved approximately 6 weeks work by the researcher to establish an IMLM, which resulted in vastly improved speech recognition accuracy. The implementation of IMLM with no additional training resulted in speech recognition accuracy improvements from approximately 80%-85% accuracy to more than 95% accuracy. Tables 4.5 and Table 4.6 demonstrate several spoken language discourses used for testing IMLM improvements. In all cases the spoken language discourses are from the same medical practitioner. In Table 4.5 DNS is used without the IMLM included, and in Table 4.6 IMLM is included in DNS. Table 4.5 highlights many cases where poor speech recognition accuracy (shown in red text) has resulted in essentially meaningless text being produced. Table 4.6 highlights very clearly the improvements to speech recognition accuracy that occurred as a direct result of IMLM.
<table>
<thead>
<tr>
<th>Test text</th>
<th>DoctorWho’s spoken language after DNS processing - Not using IMLM</th>
</tr>
</thead>
<tbody>
<tr>
<td>new encounter for player: Michael Smith</td>
<td>new encounter for player: Michael Smith</td>
</tr>
<tr>
<td>practitioner: DoctorWho</td>
<td>practitioner: DoctorWho</td>
</tr>
<tr>
<td>encounter date: 17 may 2006</td>
<td>in candidate: 17 May 2006</td>
</tr>
<tr>
<td>new injury:</td>
<td>new injury:</td>
</tr>
<tr>
<td>incident date: 14 may 2006 afternoon</td>
<td>incident date: the 14th of May 2006 afternoon</td>
</tr>
<tr>
<td>segment: fourth quarter</td>
<td>segment: fourth-quarter</td>
</tr>
<tr>
<td>activity: tackling</td>
<td>activity: clean</td>
</tr>
<tr>
<td>surface: soft grass</td>
<td>surface: soft ground</td>
</tr>
<tr>
<td>weather: indoors</td>
<td>Where that: in doors</td>
</tr>
<tr>
<td>arena: Telstra dome</td>
<td>arena came on Telstra die</td>
</tr>
<tr>
<td>injury type: strain</td>
<td>in injury time: strain</td>
</tr>
<tr>
<td>severity: mild</td>
<td>severity: mild</td>
</tr>
<tr>
<td>body part: abdominal muscle</td>
<td>body can't Klong abdominal muscle</td>
</tr>
<tr>
<td>side: right</td>
<td>side: right</td>
</tr>
<tr>
<td>mechanism: contact with player</td>
<td>mechanism: contact with player</td>
</tr>
<tr>
<td>history: no previous problem</td>
<td>history: no previous problem</td>
</tr>
<tr>
<td>end injury:</td>
<td>in injury:</td>
</tr>
<tr>
<td>encounter note: injury occurred during tackle.</td>
<td>encounter note: injury and care during tackle.</td>
</tr>
<tr>
<td>investigation: ultrasound scan revealed small tear in internal oblique muscle deep in right side of abdomen.</td>
<td>investigation: hot sound can revealed small care in into a bleak muscle deep in the right side of abdomen.</td>
</tr>
<tr>
<td>treatment: rest and physiotherapy with regular icing initially followed by graded return to playing.</td>
<td>treatment read and physiotherapy with regular-initially followed by a graded return to plane</td>
</tr>
<tr>
<td>end encounter</td>
<td>end in counter</td>
</tr>
<tr>
<td>new encounter for player: Ian Singer</td>
<td>how you encounter form player: Ian Singer</td>
</tr>
<tr>
<td>practitioner: DoctorWho</td>
<td>practitioner: DoctorWho</td>
</tr>
<tr>
<td>encounter date: 17 may 2006</td>
<td>encounter date: 17 May 2006</td>
</tr>
<tr>
<td>existing injury: sprain of left posterior cruciate</td>
<td>existing injury: spraying of left host area cruiseship</td>
</tr>
<tr>
<td>encounter note: ongoing management. Persistent left knee effusion and loss of 30° of flexion and 5° full extension. Continuing with non weight bearing on left knee further three weeks.</td>
<td>encounter night: ongoing management. Is and left me a fusion with a loss of 30° of flexion and 5° and fall extension. Continuing with nonwhite bearing on left me for further three weeks.</td>
</tr>
<tr>
<td>end encounter:</td>
<td>end encounter:</td>
</tr>
<tr>
<td><strong>Test text</strong></td>
<td><strong>DoctorWho’s spoken language after DNS processing - Using IMLM</strong></td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>new encounter for player: Michael Smith</td>
<td>new encounter for player: Michael Smith</td>
</tr>
<tr>
<td>practitioner: Doctorwho</td>
<td>practitioner: Doctorwho</td>
</tr>
<tr>
<td>encounter date: 17 May 2006</td>
<td>encounter date: 17 May 2006</td>
</tr>
<tr>
<td>new injury:</td>
<td>new injury:</td>
</tr>
<tr>
<td>incident date: 14 May 2006 afternoon</td>
<td>incident date: the 14th of May 2006 afternoon</td>
</tr>
<tr>
<td>segment: fourth quarter</td>
<td>segment: fourth quarter</td>
</tr>
<tr>
<td>activity: tackling</td>
<td>activity: tackling</td>
</tr>
<tr>
<td>surface: soft grass</td>
<td>surface: soft grass</td>
</tr>
<tr>
<td>weather: indoors</td>
<td>weather: indoors</td>
</tr>
<tr>
<td>arena: Telstra dome</td>
<td>arena: Telstra dome</td>
</tr>
<tr>
<td>injury type: strain</td>
<td>injury type: strain</td>
</tr>
<tr>
<td>severity: mild</td>
<td>severity: mild</td>
</tr>
<tr>
<td>body part: abdominal muscle</td>
<td>body part: abdominal muscle</td>
</tr>
<tr>
<td>side: right</td>
<td>side: right</td>
</tr>
<tr>
<td>mechanism: contact with player</td>
<td>mechanism: contact with player</td>
</tr>
<tr>
<td>history: no previous problem</td>
<td>history: no previous problem</td>
</tr>
<tr>
<td>end injury:</td>
<td>end injury:</td>
</tr>
<tr>
<td>encounter note: injury occurred during tackle.</td>
<td>encounter note: injury and care during tackle.</td>
</tr>
<tr>
<td>investigation: ultrasound scan revealed small tear in internal oblique muscle deep in right side of abdomen.</td>
<td>investigation: Optus out of can revealed small tear in internal oblique muscle deep in right side of abdomen.</td>
</tr>
<tr>
<td>treatment: rest and physiotherapy with regular icing initially followed by graded return to playing.</td>
<td>treatment: rest and physiotherapy with regular icing initially followed by graded return to playing.</td>
</tr>
<tr>
<td>end encounter</td>
<td>end encounter</td>
</tr>
<tr>
<td>new encounter for player: Ian Singer</td>
<td>new encounter for player: Ian Singer</td>
</tr>
<tr>
<td>practitioner: Doctorwho</td>
<td>practitioner: Doctorwho</td>
</tr>
<tr>
<td>encounter date: 17 May 2006</td>
<td>encounter date: 17 May 2006</td>
</tr>
<tr>
<td>existing injury: sprain of left posterior cruciate</td>
<td>existing injury: sprain of left Posterior cruciate</td>
</tr>
<tr>
<td>encounter note: ongoing management. Persistent left knee effusion and loss of 30° of flexion and 5° full extension. Continuing with non weight bearing on left knee further three weeks.</td>
<td>encounter note: ongoing management. Persistent left knee effusion with loss of 30° of flexion and 5° of full extension. Continuing with non weight bearing on left knee for further three weeks.</td>
</tr>
<tr>
<td>end encounter:</td>
<td>end encounter:</td>
</tr>
</tbody>
</table>
4.4 GENERIC IT ARCHITECTURE MODEL

Incorporating spoken language technology, such as ISEA, in business systems requires a sophisticated technical architecture. ISEA’s IT architecture involves many complex systems development processes specific to speech-enabled applications and is a “pipeline structure consisting of a speech recogniser and domain-specific language understanding modules” (Jeong & Lee, 2008, p.2-12) with additional modules to cleanse the transcribed spoken language prior to language understanding. All modules are tightly integrated with InjuryTracker_DB. ISEA implemented a “tightly coupled architecture [to] reduce propagation of errors and improve performance” (Ostendorf et al., 2008, p. 64-65).

Extrapolating from ISEA’s IT architecture model and emerging from the research, a generic IT architecture model has been constructed for speech-enabled systems (Figure 4.5). This model includes the additional modules developed to improve speech recognition accuracy, post speech recognition correction, and the techniques used to improve the performance of language understanding. Improvements to speech recognition accuracy and language understanding were achieved by tightly integrating these modules with the injury database of record. Implementing an IT architecture that integrates the data entry business process with the speech recognition engine, the natural language understanding components of the application, and the database of record is a new area of enquiry for spoken language systems. The new generic speech-enabled application IT architecture model shown in Figure 4.5 is now explained.
The speech-enabled application has several information technology components as follows:

1) speech recognition software which translates user spoken language discourse into text (SpeechToText). This is represented in Figure 4.5 as the rectangle ‘Speech Recognition’ to the file ‘SpeechToText’;

2) validate and correct SpeechToText. This is represented in Figure 4.5 as the rectangle ‘Cleanse SpeechToText’ to the file ‘Corrected SpeechToText’. The cleanse function uses the data from the domain database of record to validate and resolve ambiguities with the SpeechToText. This is represented in Figure 4.5.
4.5 as the arrow between the ‘Domain Database of Record’ and the rectangle ‘Cleanse SpeechToText’;

3) natural language understanding of the corrected SpeechToText. This is represented in Figure 4.5 as the rectangle ‘Natural Language Parser’. The natural language parser uses the data from the domain database of record to validate and resolve ambiguities with the corrected SpeechToText. This is represented in Figure 4.5 as the arrow between the database ‘Domain Database of Record’ and the rectangle ‘Natural Language Parser’;

4) generate database records for uploading into the domain database of record. This software component requires information from the domain database of record to generate the database records from the output of the language understanding parser. This is represented in Figure 4.5 as the rectangle ‘Database Record(s) Generation’, and the arrow between the database ‘Domain Database of Record’ and the rectangle ‘Database Record(s) Generation’; and

5) upload the database records into the domain database of record. This is represented in Figure 4.5 as the arrow between the rectangle ‘Database Record(s) Generation’ and the rectangle ‘Update Domain Database of Record’ and the arrow between the rectangle ‘Update Domain Database of Record’ and the database ‘Domain Database of Record’.

The user performs three key activities in executing the speech-enabled application. Users:

1) generate the spoken language discourse for processing by the speech-enabled application. Speech recognition software transcribes the spoken language discourse into text (SpeechToText), which is represented in Figure 4.5 as ‘User Input’ and ‘Speech Recognition’ rectangles respectively. The language template is used to guide the user to construct the spoken language discourse, which is represented in Figure 4.5 as the ‘Language Template’ document;

2) validate and correct the SpeechToText by executing the cleanse function of the speech-enabled application. This is represented in Figure 4.5 as the
rectangle ‘Cleanse SpeechToText’. In this process the SpeechToText is validated and corrected from two perspectives:

a. user input errors. These include missing data and/or incorrect data, and incorrect use of the language template.

b. speech recognition errors. These can occur due to environmental issues such as background and/or as a direct result of poor speech recognition accuracy.

3) resolve input data ambiguities. Natural language understanding of the cleansed SpeechToText can result in ambiguous data. This can occur as a result of a simple data entry oversight such as an incomplete reference data. For example, an injury incident may state the weather is ‘fine’. However, in the weather reference table there are three possible valid values for weather: ‘fine and mild’, ‘fine and cold’, or ‘fine and hot’. User interaction with the speech-enabled application, and in particular the natural language understanding algorithms, is required to resolve this ambiguity. This is represented in Figure 4.5 as the rectangles ‘User Interaction’ and ‘Natural Language Parser’.

The language template is an important document as it is used:

1) as a guide in constructing the user’s spoken language discourse. This is represented in Figure 4.5 as the arrow from ‘Language Template’ to ‘User Input’;

2) as a reference to structure the SpeechToText so that it can be validated and corrected by the cleanse process. This is represented in Figure 4.5 as the arrow from ‘Language Template’ to ‘Cleanse SpeechToText’; and

3) by the natural language parser to understand the SpeechToText, which is represented in Figure 4.5 as the arrow from ‘Language Template’ to ‘Natural Language Parser’.

The domain database of record contains considerable organisational information which is used by the speech-enabled application. Links to the domain database of record are necessary, for the following reasons:
1) so that validation and correction of user input can occur. This is represented as the arrow from the database ‘Domain Database of Record’ to the rectangle ‘Cleanse SpeechToText’;

2) to facilitate natural language understanding of the corrected SpeechToText. This is represented by the arrow from the database ‘Domain Database of Record’ to the rectangle ‘Natural Language Parser’;

3) so that database transactions suitable for uploading to the domain database of record can be created. This is represented by the arrow from the database ‘Domain Database of Record’ to the rectangle ‘Database Record(s) Generation’;

4) to generate the language template. Language modelling is performed on the domain database of record plus other artefacts associated with the problem domain to generate the language template. This process is represented in Figure 4.5 as the arrow between the rectangle ‘Language Modelling’ and document ‘Language Template’;

5) to create the customised language model to improve speech recognition accuracy. This is a two stage process as follows:

   a. Stage 1 reengineers the domain database of record based on the language template to generate the customised language model. This process is represented in Figure 4.5 as the arrow from the document ‘Language Template’ to the rectangle ‘Generate Customised Language Model’, and the arrow from the database ‘Domain Database of Record’ to the rectangle ‘Generate Customised Language Model’.

   b. Stage 2 loads the customised language model into the speech recognition engine. This is represented in Figure 4.5 as the arrow from the database ‘Customised Language Model’ to the rectangle ‘Speech Recognition’.

The generic speech-enabled IT architecture model highlights that business IT solutions employing spoken language in the HCI require a sophisticated technical
architecture. Many complex systems development processes specific to speech-enabled applications are involved and these are now discussed.

4.5 THE ISEA DEVELOPMENT PROCESS

This research encompassed a detailed analysis of the project processes involved in developing ISEA. Of interest to the research is whether the inclusion of speech in the HCI, impacts on the activities performed as part of the system development processes. Emerging from the research is that speech-enabled application development requires additional processes to address the spoken language (speech) components of the application. It is evident from the generic IT architecture model (Figure 4.5) there are many processes that are specific to speech-enabled applications development.

The systems development models defined in the literature (Bangalore & Johnston, 2003; Dubinsky et al., 2007; Dybkjær & Bernsen, 2002) do not provide an adequate software engineering framework to address the special needs of speech-enabled applications. Thus, this research proposes a new systems development model which extends the current systems development models as described in the IS literature. The proposed model, entitled the “speech systems development model” (SpeechDM), is shown in Figure 4.6, and is now described.
The SpeechDM systems development process commences with the construction of a proof-of-concept. This is an important preliminary step in speech-enabled application development projects as the proof-of-concept provides the basis to:

1) evaluate the appropriateness of speech technology for solving a given business problem;

2) determine the technical feasibility of the speech-enabled application in delivering the expected business outcomes; and

3) demonstrate the capabilities of speech interfaces specifically surrounding speech recognition accuracy in the user business domain.
The proof-of-concept was a necessary first step in the project before the ESC made a commitment to undertake the full development, as the following memorandum confirms:

“The success of [ISEA] is dependent on the speech recognition accuracy being substantially improved... The proof-of-concept is to better understand the injury management requirements and the business process surrounding this information and to provide the [ESC] a working prototype of how the final application will function in the operational environment... At this point the [ESC] will be in a position to verify that the aims of the project will be achieved” (SpeechNet to ESC correspondence, 15 April 2005).

The proof-of-concept scope provided a prototype with sufficient functionality for the ESC to determine whether the application of spoken language technology results in the productivity improvements sought by the club. As SpeechNet states in the statement of work for the proof-of-concept project:

“The proof-of-concept will allow a trainer et al to record their voice data about an injury/treatment onto a portable digital recorder (such as a SONY ICD-BM1). This voice data will then be translated by Dragon Naturally Speaking. The text file generated by Dragon will then be analysed and interpreted, and information loaded into the InjuryTracker™ database.

For the proof-of-concept a limited set of language will be used to demonstrate the capability of the system. The full development (if approved) will extend the language capabilities and other features of ISEA. It should be emphasised that the language that can be used for the proof-of-concept will be very structured and inflexible. The full version will move towards more free format language” (SpeechNet statement of work, 6 April 2005).

The ISEA proof-of-concept was presented in a demonstration to ESC management in October 2005, and the full development project then approved later in October 2005.

SpeechDM adopts an iterative development approach for systems development. The classical incremental development phases of analysis, design, build (Avison & Fitzgerald, 2003; Beck, 2000; Cockburn, 2002; Larman, 2004; Sommerville, 2004),
are encapsulated in ‘Development Activities’ in SpeechDM. This is represented in Figure 4.6 as the blue cyclical path, which is similar to traditional iterative development methods, cycling through analysis, design, build and user review. Each iteration through this cycle results in small improvements to the previous application increment. The process of implementing small but frequent improvements (Sommerville, 2004) continues until the user requirements have been fully developed. At this point the application is ready for operational rollout into the business area (Sommerville, 2004), which is represented in Figure 4.6 as the black arrow from ‘User Review’ to ‘Final Version,’ which is the exit point for SpeechDM. The exit point of SpeechDM indirectly signifies that the user has formally accepted the application for operational rollout.

A significant finding of this research is that there are systems development process dependencies between the language understanding algorithms and the spoken language used to interact with the HCI. Language modelling outcomes directly impact on the requirements of the language understanding algorithms in the speech-enabled application and vice versa. The iterative cyclical path through ‘Development Activities’ and ‘Language Modelling’ depicts this relationship between the spoken language and the language understanding algorithms, and is represented in Figure 4.6 as the orange cyclical path.

The user plays a key role in speech-enabled application development projects. Consistent with other iterative development methods, users define and validate user requirements, review prototypes and application increments (Beck, 2000; Cadle & Yeates, 2008; Cockburn, 2002). The users’ involvement in these activities is represented in Figure 4.6 as the blue cyclical path. Additionally, users are required to define and review the spoken language used to interact with the speech-enabled application HCI. The impact of these activities is in two areas:

1) language structure and vocabulary used in spoken language discourses. Represented in Figure 4.6 as the activity ‘Language Modelling’; and

2) the alignment of this language structure and vocabulary, to
a. the language template which is used as a guide for spoken language discourses; and

b. the generation of the customised language model used to improve speech recognition accuracy;

These are represented in Figure 4.6 as the activities ‘Language Template’ and ‘Customised Language Model’ respectively.

Hence, the user reviews the outcomes of several cyclical paths shown in Figure 4.6 as the blue, green, and pink cyclical paths.

The modelling of spoken language dialogues results in the generation of and improvements to the language template. That is, changes to language structure and vocabulary, as a result of language modelling, must be applied to the language template. Similarly, changes to the language template resulting from user feedback from speech HCI simulations, may require language modelling. The process is cyclical and iterative and is represented in Figure 4.6 as the pink cyclical path. The cyclical process continues until the outcomes of the language modelling process and development activities are in sync with the language template. This highlights that there is a complex interaction between many cyclical paths in SpeechDM and that these processes are iterative. Language modelling is a key activity in SpeechDM and can result in many iterations of several cyclical paths concurrently.

The ‘Language Template’ process is a significant junction point in the model. It represents the bridge between the:

1) natural language processing algorithms in the application,

2) user spoken language dialogue used in the HCI; and

3) the customised language model to improve speech recognition accuracy.

Hence, the language template provides a fundamental link between how the speech-enabled application processes spoken language and defines the spoken language used to interact with the speech-enabled HCI.
4.6 CONCLUSION

This chapter described the ISEA application from both a technology and systems development process perspective. The chapter commenced by describing the business problems to be solved, and the business drivers for the ISEA development project. The business problems highlighted the three areas to be addressed are:

1) poor speech recognition accuracy is a barrier for the effective use of speech recognition as a user interface mode for data entry;

2) the need for timely access to injury data; and

3) data capture of medical consultations needs to occur in an efficient manner and result in a reduction in the resources required to enter this data.

To set the scene and provide an understanding of speech interfaces, a comparison between spoken language interfaces and graphical user interfaces was demonstrated. The demonstration used several injury data scenarios to compare keyboard data entry using InjuryTracker™ and for the same injury medical consultation using the ISEA speech interface. This introduced several issues surrounding natural language processing and how ISEA dealt with these issues when processing spoken language.

The chapter then provided a detailed description of the ISEA software components. Emerging from this, the researcher constructed a new generic IT architecture model for speech-enabled applications. The model highlights that incorporating spoken language technology in business systems requires a sophisticated technical architecture, and involve many complex systems development processes specific to speech-enabled applications. Following this, the systems development approach adopted by the ISEA development project was described, resulting in a new model (SpeechDM) emerging from the research. A detailed account was provided of the processes involved in developing speech-enabled applications, where at its core is the use of speech recognition and natural language understanding technology. SpeechDM extends the theory surrounding iterative systems development models to include the additional processes required to develop speech-enabled applications. Speech-enabled systems require additional activities to be performed as part of the systems development project. These include:
• undertaking a language modelling study to understand the vocabulary and grammar used in spoken language discourses so that natural language understanding can be performed;

• mapping of natural language to database tables and fields;

• improvement to speech recognition accuracy which included the creation of a customised language model; and

• generation of a language template to assist users in phrasing spoken language to describe a medical consultation, and to improve natural language understanding of the spoken language.

The ISEA description in this chapter is from the developer’s perspective. This study now turns to an analysis of the user’s perspective of ISEA. Chapter 5 provides an evaluation of the implemented ISEA through interviews conducted at the ESC. The interpretation and themes from the interviews are now discussed.
Chapter 5 EVALUATION OF THE IMPLEMENTED IMPROVED SPEECH-ENABLED APPLICATION (ISEA)

5.1 INTRODUCTION

This chapter presents an evaluation of the implemented ISEA. At the time of the interviews (which forms part of ISEA’s evaluation), the software had been operating for approximately 18 months, covering two premiership seasons (see Section 1.2 for explanation of premiership timeframes). This is significant as the interview data is based on extensive user experience of ISEA, and covers two iterations of the ESC business cycle. ESC participants in this research either directly used ISEA in their work, or managed/interacted with professional staff, who use ISEA. Hence, early experiences with ISEA were still fresh in the participants’ minds, and ISEA had been implemented for sufficient time to enable serious reflection on its influence over their daily work.

Interviewees provided substantial information covering their experiences with ISEA and its business implications. This provided an opportunity to evaluate ISEA from several perspectives. Importantly, the analysis considers both the spoken language technology and IS implications of introducing speech-enabled applications into an elite sporting club. Hence, the analysis provides insights into the link between spoken language technology and its support of business processes (in this case injury management), and business outcomes.

The chapter is structured according to the analysis themes:

1) the users’ perspectives of ISEA and spoken language technology; and

2) the injury management process ISEA supports.

The chapter commences with a background covering the participants’ views of the ESC in relation to other clubs in the Association; and how ISEA is used in the work environment.
5.2 BACKGROUND

The ESC belongs to a professional league association, which comprises 16 clubs inclusive of the ESC. To facilitate teams competing on an equal basis, the Association caps total player payments per year for a club to:

“approximately $A6.75 million” (ESC memo, 27 June 2006).

Capping salaries is perceived as necessary to ensure wealthier clubs are unable to use their financial resources to attract the best athletes, and render the poorer clubs uncompetitive. The ESC is perceived as a financially sound and very competitive club in the Association. They are well resourced with both staff and money to position them as one of the top clubs in the competition. Having the organisational capability to execute their business strategy is essential to ensuring the club’s competitive position to contest the premiership. All clubs in the Association have similar demands in fielding a competitive team, but some do not have the capability to deliver equally. As stated in an internal ESC memo:

“The lesser resourced clubs - and there are quite a few - have the same demands but not the same budget or personnel. At least one club doesn't have a doctor attend the club at all for the first 6-8 weeks of pre-season training and all encounters [doctor consultations] have to be at his private practice and claimed through the health system. Others do not have physiotherapists on site as we do. Therefore they [doctors] are not in the position to spend time on anything other than scant basic records.... We [ESC] are one of the better resourced clubs” (ESC memo, 27 June 2006).

The ESC’s strong financial position has allowed them to fund a dedicated onsite medical team to attend to player injuries. Having a medical team onsite at the club has established a work environment where medical staff have time available to collect important injury data to the necessary level to facilitate athlete injury management.

The collection of injury data is an onerous task. In a typical month during the premiership season, the medical team attends to,
“on average 82 new reported injuries, 12 illnesses, 189 physician consultations, 381 treatments and 28 tests” (ESC memo, 27 June 2006).

ISEA was developed and implemented to improve the data collection efficiency of this important injury data. ISEA went live on 16 June 2006 at the ESC, as stated in the following excerpt from a SpeechNet letter to the ESC.

“I am pleased to say that all work associated with the [ISEA] full development project has been completed. [ISEA] has now been implemented and is ready to use” (SpeechNet to ESC letter, 16 June 2006).

The SpeechNet project team were acutely aware of staff availability issues in implementing a new system during the premiership season. Hence, ISEA was progressively rolled out into the business area over a period of several weeks to account for user availability and to facilitate a smooth transition in adopting a new innovative speech interface. As this excerpt from the SpeechNet implementation plan states:

“The aim is to progressively automate the injury data collection process over a period of 4-6 weeks. Considering the urgency associated with tasks within the medical group and therefore their availability for other non-medical tasks, the suggestion is to use [ISEA] for 10% of the Injury data for week 1, 10% for Week 2, 20% for Week 3, 50% for Week 4. This will reduce the workload on the medical staff while they become familiar with the [ISEA] process, and also provide a more controlled environment to tune the application and data entry process. At the end of week 4 a decision can be made on whether to capture all injury data using speech or to continue with a slower uptake” (SpeechNet implementation plan, 12 June 2006).

Post implementation, some minor enhancements to ISEA were undertaken to improve the user interface ‘look and feel’ and the natural language understanding components of the application. The changes included:

1) upgrades to the ISEA graphical user interface to improve the handling of input files;
2) tuning of Bestmatch for selection and validation of existing injuries;

3) modifications to the language template and natural language understanding algorithms to enhance spoken language flexibility, and provide better business process integration; and

4) introduction of a cleanse function to address poor user input and speech recognition errors (SpeechNet to ESC memo, 19 September 2006).

At the time of the first interview in January 2008, ISEA was used continuously for capturing injury data. The interviewees’ (users’) experiences with ISEA and the innovative spoken language interface are now presented.

5.3 USERS’ PERSPECTIVES OF ISEA

5.3.1 SPEECH RECOGNITION

Poor speech recognition accuracy still remains a common problem with speech-enabled applications (De Mori et al., 2008; Gilbert et al., 2008; Jeong & Lee, 2008; Ostendorf et al., 2008). The ESC clearly supports this view, as their key business driver for the development ISEA was to improve speech recognition accuracy. Prior to ISEA, the ESC experienced very poor speech recognition accuracy, as this excerpt of an e-mail from the ESC to the researcher highlights:

“You will note my increasingly acerbic comments about Dragon as I worked down the list. Most of the problems where there was apparent nonsense or complete no idea of what was written was due to poor word recognition by Dragon” (ESC E-mail to researcher, 6 July 2005).

The acceptance and subsequent success of these types of applications in the operational business environment lay heavily on achieving good speech recognition accuracy (Alapetite, 2008). The ESC stipulated good speech recognition accuracy as a critical success factor for the ISEA development project. As highlighted in SpeechNet and ESC meeting notes:

“The [CEO ESC] was keen to budget for the whole project and not just the proof-of-concept. A demonstration of DNS [Dragon Naturally Speaking] was
provided to him which highlighted very poor speech recognition of injury
data. Improving speech recognition to an acceptable level became a critical
success factor for the entire project. So the first milestone for the project was
to demonstrate a substantial improvement in the speech recognition accuracy.
Otherwise the project will not proceed beyond that point” (SpeechNet and
ESC meeting notes, 28 April 2005).

As De Mori et al. (2008) state, if the confidence in the transcribed spoken language is
low due to poor speech recognition accuracy, then it follows that there is low
confidence in specific words in the transcribed spoken language. Hence, natural
language understanding of low quality transcribed spoken language will directly
impact on the quality of InjuryTracker_DB injury data. Further, the user’s confidence
in this data for decision-making will be low. That is, from the user’s perspective, poor
speech recognition accuracy renders the injury data unreliable.

Some words are phonetically similar yet quite different in meaning. For example,
words such as ‘Hart’ and ‘heart’ are phonetically the same but are very different in
meaning. In this example, ‘Hart’ is a person’s last name while ‘heart’ is the
anatomical name for an organ in the human body. Both have specific and different
meanings in the context of the medical problem domain, which need to be
distinguished to ensure the correct word is selected. This ambiguity of meaning and
spelling of phonetically similar words can result in the selection of the wrong word
choice by the speech recognition engine; for example, the athlete’s last name being
transcribed as ‘Heart’.

As the business domain becomes more complex, as in the case of transcribing medical
records, the probability of misinterpretation increases substantially. Alapetite (2008)
found that the language used in the medical domain resulted in poor speech
recognition accuracy in some instances as low as 20% for free form text. Other types
of speech recognition errors originate from incorrect interpretation of the spoken
utterance. These could be due to noise in the work environment (Lewis & Powers,
2002); poor training of the speech recognition engine; and/or disfluencies such as ‘uh’
and repetitions of data (Alapetite, 2008; Ostendorf et al., 2008); and other incorrect
speech from the user. A key challenge for spoken language systems is being robust to misrecognitions (De Mori et al., 2008; Jeong & Lee, 2008; Ostendorf et al., 2008).

To increase the confidence level in the data ISEA generates, user-spoken language is constrained in terms of structure (for example, how an injury can be described), and vocabulary. While free form text could be used for descriptive input text fields in ISEA, key data entry fields (such as injury type and severity), were restricted to improve the extraction of meaning; hence the accuracy of the transcribed text (Gilbert et al., 2008). The restrictions to language and grammar (Gilbert et al., 2008) of the spoken language were formalised through the generation of a semi-structured English language template which provided a “reference semantic frame” (Jeong & Lee, 2008, p.11) as an aid for users during data entry.

Hence, the ISEA language template is used as a guideline to construct spoken language to document medical consultations. However, some interviewees expressed expectations that computers should be able to recognise their speech in the same way as their colleagues. As Interviewee-1 recalls of comments made to him by ESC doctors:

“the ideal solution is just talk normally and it all goes in” (Interviewee 1).

Interviewee-3 suggests when asked whether spoken language, which is constrained by the language template, is a barrier to using ISEA?

“Yes, until we can speak the same as writing free hand notes it will be a limiting factor” (Interviewee-3).

Interviewees directly involved with data capture concur that improving speech recognition and language understanding components would result in more people using the application directly. Interviewee-2 recounts:

“If it is a simpler speech interface I would use it. If it were simplified further then I would definitely use it. Having to follow a template with specific words and colons is a problem ” (Interviewee-2).

It is interesting to note, that interviewees did not raise issues surrounding speech recognition accuracy. Rather, their concern is the requirement to use structured
spoken language. However, SpeechNet implemented the structure to improve speech recognition and natural language understanding accuracy, as that was the critical success factor for the project. Alapetite (2008, p.450) supports this approach, stating there is a need in “finding a balance between a large and therefore expressive grammar (and vocabulary) and a smaller one but with higher recognition rates”. Alapetite (2008) goes further to state that by restricting the vocabulary and grammar of the spoken language, the HCI language is simplified and easy to learn, thereby improving user proficiency in using spoken language (Alapetite, 2008). Ensuring a high level of data quality is important, as data related to medical consultations “serves as a legal document and must therefore contain a log of all important events and actions, second, it may also provide information for the patient medical record” (Alapetite, 2008, p.449) and third it is a repository of “the medications given, what has been done, thus supporting decision-making” (Alapetite, 2008, p.449).

While the language template is perceived by some interviewees as restrictive, SpeechNet did not view adopting this approach as too onerous, because “many clinical information systems enforce standard semantics by mandating structured data entry” (Patrick et al., 2007, p.219), and the interface is, in reality, easy to use. Interviewee-7 supports this saying that the issue is more about allocating time to become familiar with the semi-structured language. Interviewee-7 states:

“it is more about learning it and using it. Once they get used to it, it’s fine”
(Interviewee-7).

This is further supported from an excerpt from a user feedback memo to SpeechNet:

It is quite an easy program to use, after you get used to the way of speaking into the computer (ie. Saying all the colons etc). It is pretty good at picking up different medical terms/injuries/body parts, and if it can't pick up something then it's easy to train that specific word. [ISEA] itself seems to be a user friendly program and once I learned how to use it I haven't had many problems with it (ESC to SpeechNet memo, 15 May 2007).

The language template provided a balance between flexibility in spoken language to describe a medical consultation and the quality of the data captured. Using a language
template to guide the user in data entry is a powerful tool to improve the performance of natural language understanding, and was deliberately constructed for this purpose by the ISEA developers. The ISEA natural language understanding algorithms use the language template to identify “lexical sequence information [which] provides cues related to syntactic and semantic constraints” (Ostendorf et al., 2008, p.60) to find “sentence and clause boundaries” (Ostendorf et al., 2008, p.60). Words (De Mori et al., 2008) and or other markers such as punctuation can be used as signs to identify sentence boundaries (Ostendorf et al., 2008). Ostendorf et al. (2008) support the approach of using domain specific language cues, as defined in the language template, to improve the natural language understanding of the spoken language. Similarly, Interviewee-8 states that ISEA:

“uses structured input fully intended for computer processing to relational database records. [ISEA] asks users to make a compromise to their language in order to increase parsing accuracy” (Interviewee-8).

To further improve the performance of natural language understanding, ISEA incorporated a colon ‘:’ as a marker for key word(s) identification and to provide structure and context to the spoken language. Experiments have shown that including markers in this way has enabled natural language parsers “to identify a name that it had previously missed, or to correct a name boundary error” (Ostendorf et al., 2008, p. 66). In addition to looking for signs and markers (De Mori et al., 2008) in text, ISEA requires the users to insert the markers (in this case the colon); hence, removing word ambiguity and identifying key words to designate sentence boundaries (Ostendorf et al., 2008). Being able to ‘tag’ a word with the colon marker allows the language understanding parser to clearly understand the context and meaning of this word; and to make assumptions about the data that follows. For example, in the text ‘Player: Peter Smith’, the word ‘Player:’ signals to the language understanding parser that the text following is the player’s name, which can then be validated.

Hence, ISEA requires the user to record information using a language template to constrain the grammar and vocabulary of spoken language, and use a colon marker to signal to the natural language parser that a particular word in the text is a key word. The colon is used as the tagging character, as it is rarely used in natural spoken
language discourses of medical consultations. Spoken language is usually devoid of punctuation characters (Ostendorf et al., 2008); hence, saying the word ‘colon’ is deliberate, providing high certainty that it identifies a key word, (which is the desired effect); so its use is not ambiguous. As Interviewee-1 states:

“Having colons is not natural” (Interviewee-1).

When parsing spoken language discourses it is important “to integrate information related to the whole dialog context” (De Mori et al., 2008, p.56). Doctors’ consultation notes, for example, can contain key word signs such as:

Peter’s new injury to the hamstring is painful and causing considerable discomfort. Minimise training drills which affect this area.

In this example, does the word sequence ‘new injury’ signal the beginning of a new injury transaction? No; that is not the intention of the doctor in this case. In spoken language discourses, the consultation note is used as a general free form text field and is not intended for the purpose of defining the injury. To determine this, the ISEA natural language parser identifies the beginning and end sentence boundaries (Ostendorf et al., 2008) of the consultation note. In this example, ‘new injury’ is not marked with colon and is present within the bounds of the consultation note. Hence, it is assumed part of the free form text within the consultation note, and is therefore discounted as a key word(s).

By combining a number of techniques to enhance natural language understanding, ISEA has been successful in post speech recognition error correction. As supported by interviewees when questioned whether speech recognition is a good user interface for data entry:

“It is good and should persist with it” (Interviewee-7);

“positive – much more efficiency” (Interviewee-1).

However, Interviewee-7 suggests further improvements to the spoken language interface to allow InjuryTracker_DB updates as the user speaks. Interviewee-7 suggests the interface would be improved,
“if [ISEA] updates InjuryTracker™ as you go” (Interviewee-7).

Currently, ISEA batch uploads many medical consultations into InjuryTracker_DB, a requirement which stemmed from the need to process medical consultations captured on digital recorders. However, Interviewee-7 views there would be improvements in usability and efficiency if ISEA allowed real-time data entry into InjuryTracker_DB. That is,

“seeing it in front of you that it is going in ok” (Interviewee-7),

rather than a data view of what will be uploaded into InjuryTracker_DB.

5.3.2 QUALITY OF DATA CAPTURE

Analysis of spoken language discourses of the medical consultations in ESC highlights many examples of low quality input data including:

1) errors generated due to poor speech recognition accuracy;

2) incorrect use of the language template. For example, missing key words, missing colon markers for key words, and incomplete transactions structure; and

3) incorrect data spoken by the user.

Section 4.3.7 provides several examples which highlight these areas of low quality input data.

The ISEA Cleanse function (Cleanse) aims to correct automatically erroneous user input data. The researcher recalls a conversation with a key ISEA user prior to the introduction of Cleanse, who says:

“another case of pilot error” (Personal communication between SpeechNet and ESC).

The ISEA user highlights that their spoken language input contained errors which originated from them, and not ISEA’s processing of this data. The recurring 'pilot error' problems were the business driver for the Cleanse enhancement to ISEA. From
the user’s perspective, Cleanse accounts for their poor spoken language input. There are cases where Cleanse cannot repair the input data. To address this, Cleanse provides a graphical user interface for manual input data correction. Cleanse’s automatic and manual error correction features has improved the quality of the input data as Interviewee-1 states:

“Records are better” (Interviewee-1).

Prior to Cleanse, poor quality user input data impacted on ISEA processing and therefore the injury data uploaded into InjuryTracker_DB. The researcher examined many examples of erroneous user input, highlighting that spoken language systems cannot assume user input data is correct. Hence, functionality such as Cleanse is an essential component for spoken language systems. The Cleanse function has improved the usability of ISEA and increased user confidence in the data generated by ISEA. A view expressed by ISEA users, who were having difficulty in processing medical consultation data and then used Cleanse to process this data:

“They have worked. These have been entered ... and going well” (ESC to SpeechNet e-mail, 11 August 2006)

“I created another file and put it through the Cleanse and GO functions and everything worked without a hitch. On checking, all the [player] details have been entered into Injury Tracker OK” (ESC e-mail to SpeechNet, 30 November 2006).

The ESC users highlight that by running the troublesome input data through Cleanse the input data were repaired and successfully uploaded into InjuryTracker_DB.

Interviewee-1 and Interviewee-7 use ISEA regularly to record medical consultations. Other interviewees have not embraced the new technology to the same extent. Interviewee-3 suggests this is a broader issue, as they are not comfortable with new technology, in general, particularly when they use handwritten notes as their prime method for recording medical consultations.

“Pendulum is swinging. Younger staff are used to computers. Every night I am in the study working on the computer but I still don't like them and I am
really unfamiliar with them. Younger people are brought up with computers. I’d rather spend time on seeing more patients rather than consuming time to learn how to use computer. What we need now is different to what we need in 10 years time” (Interviewee-3).

The age of the medical staff also appears to be a barrier to the effective use of applications such as ISEA. Many interviewees highlighted that younger professionals were more willing to use technology to support their job activities; to the extent that younger staff questioned why these tools were not used. Interviewee-7 supports this, saying it is:

“Easier for younger guys because they have been using computers” (Interviewee-7).

The impact of “time and pressure” (Interviewee-1)

results in a lack of resources to both capture injury data and/or directly use tools such as ISEA to facilitate this process. There is a desire to use the application, but the resources to do so are not available. There are many competing demands on professional staff. Interviewee-1 emphasises this point:

“The users who have the most reason to enter the data are not having time to do it” (Interviewee-1).

The lack of time to collect injury data in systems is a key concern of the club. Currently many professional staff are casual and/or required on an ad hoc basis. As Interviewee-1 highlights through an analogy of the degree of resource pressures to deal with the number of incidents to be attended to by medical staff:

“Currently it is like a casualty ward rather than a professional practice” (Interviewee-1).

Due to time pressures on medical staff, support staff transcribe handwritten medical notes and use ISEA to enter this data.
The ESC is embarking on a major re-development of its facilities which includes a medical clinic. Doctors will be employed full-time by the ESC to facilitate

“social... [and] communication” processes (Interviewee-3)

between professional staff. The aim is to create a work environment which addresses conflicting priorities, freeing up time to allow medical staff to capture the medical consultation data the club requires. As Interviewee-1 states:

“Doctors and physios will eventually become full-time. If not going to another practice they will make more time. Better communication between doctors and physios etc”. [Communication] is currently via a verbal report as they can walk next door. Eventually they will have meetings with computers and used more as they get younger people involved who are familiar with computers” (Interviewee-1).

There is a prevailing view by medical staff that there will be a transition from written notes to data being captured electronically only, and to use speech to capture the essence of the consultation rather than ticking boxes on a graphical user interface. As Interviewee-3 highlights:

“Eventually they will go [written notes] I think. You need to ask the appropriate questions from legal/medical perspective. These notes can be electronic. Need to write down what was actually said and not tick boxes in a list” (Interviewee-3).

Timeliness of information is important to the club. Interviewee-6 emphasises this point:

“1-2 days to key into InjuryTracker™ diminishes data value. There needs to be immediacy” (Interviewee-6).

For the ESC, there is a direct link between timeliness of data capture and value of the data, because timely data is essential for decision making. Rather than being concerned with poor data content due to “long periods of recall leading to recall bias” (Finch, 2006), the ESC requires immediate timely data to select a competitive team for the next match. Decisions surrounding an athlete’s availability to play are made
early in the week (Mondays), with final player selections occurring on Thursdays. The information regarding injured players is required by trainers and coaching staff preferably immediately once the doctor consults with players. As Interviewee-7 highlights:

“Doctors generate reports. The Doctor has a report and presents it at the PPT. All know on Monday what is going on” (Interviewee-7).

The PPT is the ‘Physical Performance Team’ meeting. ESC requires the player injury information on Mondays, which is the first normal business day after the weekend’s competition. The immediacy of the data for decision-making purposes has resulted in the ESC adopting alternative methods for data collection. As Interviewee-6 states:

“We only take snapshots currently because [we] haven’t got time to collect all the information for assessment” (Interviewee-6).

These snapshots are ‘pulled together’ into a document called ‘Player Lists’. As Interviewee-2 points out:

“Player lists of player injuries is generated by [staff member] [who] generates list by talking to doctors, physios etc and then presents this at the PPT” (Interviewee-2).

The Player Lists are highly summarised providing a snapshot (as Interviewee-6 states above), of player injuries and other information about the player. It is not a detailed account of medical consultations. Tools such as ISEA that reduce the effort involved in capturing injury data and improve the timeliness of injury data are considered essential to delivering effective injury management. As Interviewee-1 states:

“[ISEA] is a very vital tool...The club really can’t operate without it” (Interviewee-1).

ESC and Association documents agree and make specific reference to the business benefits of ISEA. The ESC and Association said:

“ESC developed [ISEA] which allows rapid entry of injury data using speech, timely input of medical data resulting in up to date player injury management,
...[and] resulted in labour savings of 75-80% “ (ESC to Association document, 4 September 2006);

“We have viewed the ESC voice recognition component which cuts down hours of data entry into minutes” (Association to Executive document, 26 March 2007);

“[ISEA results in] timely recording of this information... [and] avoid[s] summary paper notes being generated” (Injury management working party document, 31 Aug 2007).

Before ISEA was implemented, the ESC allocated 0.5 FTE (full-time equivalent) to manually key injury data into InjuryTracker™. Using ISEA for data entry substantially reduces this effort. ESC and Association documentation supports this:

“[Before ISEA] manual data entry required approx 0.5 FTE for ESC” (Injury management working party document, 31 August 2007)

“[ISEA] resulted in labour savings of 75-80%” (ESC to Association document, 4 September 2006);

“With [ISEA] this effort has been reduced to approx 2 hours per week” (Association medical officers’ conference, 15 November 2007).

The analysis described in this section supports that incorporating spoken language technology in the HCI, can deliver business outcomes in terms of productivity improvements, and importantly, the timeliness of data capture. Interviewees voiced that ISEA is a vital tool for injury data capture without which the club cannot operate. Hence, it is from this perspective that the injury management process, which uses the data captured by ISEA, is now analysed.
5.4 INJURY MANAGEMENT

5.4.1 IMPORTANCE OF INJURIES AT ESC

Consistently interviewees made reference to the athlete’s injury as the key area under investigation and the primary purpose of the injury management process. As interviewees state:

“player gets new injury” (Interviewee-5);

“[injury] assessment by medical group” (Interviewee-6);

“correct handling of injuries when they occur” (Interviewee-1).

Hence, the key aim of the injury management process is to effectively diagnose and treat a player’s injury to ensure their earliest return to competition at the elite level. Broadly, ESC views a player as a ‘performing business asset’ with the injury management process endeavouring to maximise the output of this asset. As one interviewee states:

“The theory of injury management is the same in any business. That is, measuring performance out of assets – if not performing take remedial action” (Interviewee-1).

The ESC employs sports scientists and other professional staff to assist in determining and collecting player performance measurement data. Understanding the condition of a player through a comprehensive measurement program is paramount in determining remedial action, so that a player can perform at their optimal level. Performing at the elite level is however problematic in terms of health and fitness. Training too hard or performing at their optimum level can result in injury and/or illness. As interviewees recount:

“A footballer is the F1 in racing and the worker the VW. Because F1 is operating at 100%, it has a tendency to break down. Not many F1 cars finish the race. F1 cars are not reliable” (Interviewee-1);
“Training harder leads to being better but can also lead to injury”
(Interviewee-6).

Interviewee-1 has drawn an analogy between an elite athlete, and a Formula 1 racing car to demonstrate that athletes are no different to machines when operating at 100% capacity. Operating at, or near, their physical limit increases the probability of breakdowns, and in the elite athlete’s case, injury. Bahr (2008) supports this claim when stating that, as activity moves from a brisk walk to competitive sport, the probability of incurring an injury increases significantly.

Chalmers (2002) considers an injury is any intentional or unintentional damage to the body, and a sport’s injury as the athlete’s inability to continue participation. Further, Chalmers (2002) states that an injury requires medical treatment at a specifiable level of severity, which may range from first aid through to hospitalisation. Roberts-Yates (2006) supports this view that injuries require some form of intervention to enable the injured person to recover. However, contrary to Chalmers (2002), a sporting injury does not necessarily imply injured athletes cannot continue to participate in the sporting event. In practice, it is often the case that athletes continue playing/competing even though they have an existing injury or have become injured during competition. Notably, on occasions their performance may deteriorate due to the injury, and/or they continue even though they are in considerable pain. Interviewees did not put such constraints on the athlete’s inability to participate. As Interviewee-2 states:

“Some players have been able to play 1 or 2 quarters with corky [sic]”
(Interviewee-2).

Interviewee-2 highlights that even though the athlete is injured, they may continue to play even if this is for part of the match. Note the term ‘corky’ is the vernacular for a bruised muscle that results in bleeding into the muscle (SSM, 2009).

The ESC’s scope for injury is inclusive of “damage to the body” (Chalmers, 2002, p.22), and is extended to include illnesses and other ailments sustained by the athlete that impact on their performance. Interviewee-1 agrees saying, the term ‘injury’ in ‘injury management’ is not limited to injuries alone, but includes:
This broader view of injury is consistent with workers compensation agencies which view a work-related injury, as an injury or disease which prevents the injured worker to perform to their pre-injury work capacity (WorkCoverTAS, 2008). This perspective on pre-injury work capacity has relevance for the injured athlete at the ESC, as the aim of injury management is to return the athlete to pre-injury performance capacity and to:

“get players [back] on [the] park to play” (Interviewee-4);

however,

“sometimes an assessment will be made that the player is not ready to return” (Interviewee-6).

5.4.2 Definition of Elite Athlete Injury

Resulting from incomplete and contrary definitions concerning injuries within the literature, and based on ESC interviewees’ responses, I have developed a new definition for an elite athlete’s injury. The new definition reflects its context within elite sporting clubs and the injury management process. The definition I propose for an elite athlete injury is:

“The intentional or unintentional damage to the body, illness or other ailment, regardless of its origin, resulting in a condition which prevents an athlete performing at the elite level; and requiring intervention to remedy the condition”.

This definition accounts for the broader scope of the term injury to include illnesses and other ailments as supported by WorkCoverTAS (2008) and ESC interviewees. The definition also recognises the elite level performance requirements before returning to competition. Interviewee-6 clearly highlights this point:

“a player can be made ready to play in most cases but their performance level is not there yet” (Interviewee-6).
That is, even if the athlete is ready to play, their performance level is not at the competitive level required. Hence, further conditioning of the athlete is required before they can return to competition.

Further, the site and/or circumstance where the athlete sustained their illness/injury does not limit their access to any treatment they receive through the ESC. Elite athlete injuries can occur as a result of formal training sessions, during on-field competition or generally performing normal off-field activities outside of the club’s working environment. The broader perspective of injury takes into account illnesses, such as influenza, and other ailments that cannot be directly attributed to ESC’s work environment. Further, the researcher’s analysis of InjuryTracker_DB injury data and medical consultation notes, highlight explicitly many examples of injuries that occurred both as a result of work and non-work related activities. Where the injury occurred and/or originated from is clearly identified in the InjuryTracker_DB field ‘SEGMENT’, which is one of many fields used to describe the injury incident. The valid values for SEGMENT are pre-defined in the InjuryTracker_DB reference table SEGMENT.DBF. Examples of valid SEGMENT values are 1st Quarter; pre-game; off-field; practice session; training; outside activity; not football related; off-season conditioning; and during the game. Overall there are approximately 50 valid values for SEGMENT. Hence, InjuryTracker_DB records clearly demonstrate athlete injuries also occur outside the work environment.

This is a significant departure from most workplace environments where organisations are predominately concerned with injuries that are sustained as part of employees’ work-related duties. Workers compensation organisations define an injured worker as “a worker who has sustained a work-related injury” (WorkCoverTAS, 2008, p.5). Hence, when the injury is sustained outside work-related duties, the person rather than the organisation is responsible for treating the injury. ESC elite athletes are considered as

“The club’s performing assets” (Interviewee-1)

and it is this aspect which distinguishes them from other workers. The elite athlete must be ‘fixed’ as other assets, and returned to full capacity to ensure the ESC can perform effectively as a business. The club selects elite athletes because they are
either the best at what they do, or can be developed to be the best. As the West Coast Eagles AFL football team sports science manager, Glenn Stewart, attests “you can’t just go out and get another Chris Judd; you have to look after the one you’ve got” (Madden, 2008, p.1). Glenn Stewart is inferring that the elite athlete Chris Judd has unique qualities which cannot be easily replaced.

Injury management requires input from a cross-section of professional staff (including the player) to determine the player’s injury, ongoing treatment, and rehabilitation. These activities are all necessary to facilitate the player’s earliest return to the competitive level. As Interviewee-3 states:

“Injury management involves a number of people. [Including] the doctor, physios, dieticians, coach, trainers and the players. Everyone is involved in the injury” (Interviewee-3).

Interviewees agree that the doctor is a key person in this process. The doctor has the final ruling on the player’s well-being, including the types of exercises, intensity of exercise required for rehabilitation, and whether the player should return to training. The doctor must also provide approval before the player returns to competition. As Interviewee-5 and doctor medical notes highlight:

“There is a hierarchy. The doctor sits at the top of the tree” (Interviewee-5);

<table>
<thead>
<tr>
<th>Excerpts from doctor consultation notes in InjuryTracker_DB</th>
</tr>
</thead>
<tbody>
<tr>
<td>clear to normal training this week however may need to modify</td>
</tr>
<tr>
<td>clear to train and play.</td>
</tr>
<tr>
<td>clear to train outside tomorrow by having easy run throughs.</td>
</tr>
<tr>
<td>cleared for football training. May need to modify the amount.</td>
</tr>
<tr>
<td>cleared for full activity</td>
</tr>
<tr>
<td>cleared for full running program on Saturday. Restricted skill work</td>
</tr>
<tr>
<td>cleared for full training</td>
</tr>
<tr>
<td>cleared for swimming program today.</td>
</tr>
</tbody>
</table>

Regardless of the type or circumstances of the injury, in all cases, the player must visit the doctor, who assesses the player’s medical condition and provides a diagnosis. Often players require a more thorough assessment by the doctor. This follow-up visit may occur the day following the game. Further, delays in the diagnosis can occur if an X-ray or other tests are required. In some cases, the doctor recommends that the player is treated overnight to stabilise the condition and to
minimise the recovery time. By commencing treatment immediately after the injury has occurred, it is believed that the player’s injury recovery time can be reduced, thereby allowing a speedier return to competition. As Interviewee-2 states:

“After the game a player who has [an injury] problem will see the doctor. He can then stay overnight [for] icing [of the injury]. Therefore the player can play next week because of preventative measures” (Interviewee-2).

Fielding a competitive team every week requires adherence to very tight timeframes. ESC professional staff operate in a high pressure environment where timely decisions are required to enable selectors and coaching staff to develop game day strategies. A player’s availability for the next match is critical information for game day planning and training programs for the week ahead. Hence, the timing of business process activities to obtain this information is a crucial component of the injury management process. Team selection for competition typically occurs on Thursdays with matches played on the weekend. Hence, training programs for players are set early in the week. Mondays are a pivotal point for training program planning. During the development of ISEA, the researcher recounts that professional staff repeatedly emphasise the importance of Mondays, many saying:

“we are flat out on Mondays, no point in even trying to speak to me on Mondays” (Interviewees).

To demonstrate this, a Monday morning clinic for one doctor,

“will have around 20 player consultations in a 2 1/2 hour period” (Interviewee-1).

Interviewee-2 concurs, saying:

“Mondays, all players see the doctor” (Interviewee-2).

The researcher recalls that these consultations occur before 9:30 am and reports are generated and presented at the Physical Performance Team (PPT) meeting, which is held shortly after the doctor consultations.
Additional information pertaining to the player is gathered from professional staff so that a complete assessment of the player’s condition can be determined. Once the player’s condition is known, the player’s subsequent availability for the upcoming weekend’s game can be determined. As Interviewee-2 states:

“Doctors generate reports. The Doctor has a report and presents it at the PPT. All know on Monday what is going on. [staff member] will liaise with all to get the info’” (Interviewee-7).

The PPT is the formal communication forum to inform professional staff, including the coach, about a player’s condition and to share information relating to the player’s treatment and expected recovery outcomes. As the interviewees recall:

“The coach comes to Monday’s PPT. He is there for the player listing. He wants to know what cattle will be on the field” (Interviewee-2);

“The coach being there brings accountability and allows for greater degree of challenges and debate” (Interviewee-6).

5.4.3 INJURY PREVENTION

Injury prevention is a key area in the injury management process. Hence, injury management at the ESC commences before an injury occurs. The ESC broadly defines injury management as the

“prevention of the injury and correct handling of injuries when they occur” (Interviewee-1)

and includes diagnosis, treatment and rehabilitation. The interviewees’ responses to describing the injury management process are:

“Prevention, diagnosis, treatment and rehabilitation” (Interviewee-1);

“[When] player gets new injury [they are referred to] doctor and forwarded to physio and rehab coach [for treatment]” (Interviewee-5);

“Assessment, diagnosis, management plan” (Interviewee-4).
Prevention of the injury is a key activity of the injury management process as the “easiest injury to manage is the one that doesn’t occur” (Interviewee-1).

Prevention is performed from two perspectives;

1) from an individual athlete’s perspective, with maintenance programs to reduce risk of an injury occurring/recurring, and to improve performance; and

1) from a general analysis through data mining and analytics of the injury data, including measurements of all athletes across the club, as part of a managed injury prevention strategy.

As Interviewee-6 states it:

“Provides opportunity to do data mining. Ability to perhaps identify trends and common things for a review at the end [of season]. Predict things” (Interviewee-6).

Players are screened at regular intervals to assist in determining whether they are at risk of injury. An in-depth screening occurs annually for all players at the end of the premiership season. Many interviewees expressed the importance of player screening saying:

“[Player screening occurs] every 1 to 2 months to see where the guys are at [and to determine] improvement on last few years [performance]” (Interviewee-7);

“There is an end of year screening for all players. 45 minutes doctor, 1 hour physio for each player” (Interviewee-3);

“At end of year or session they have an intense assessment from the doctor and physio and other staff as required” (Interviewee-1);

“We need to predict injuries by looking at each player. We do a screening of the player and plan a training program. If injury occurs, it is investigated and appropriate treatment given. Also we need to ensure appropriate aerobic fitness is maintained while the player is being treated. There needs to be
proper injury management, and ongoing treatment. Continue rehab and make sure player is doing the training” (Interviewee-3).

Professional staff develop a comprehensive maintenance program for injured players, to improve their fitness and to facilitate their early recovery from injury. There is an onus on players to follow this maintenance program. As Interviewee-2 emphasises:

“Ongoing there is maintenance with the player, which is part of being able to play injury free. It is up to the player to follow the maintenance program. Each player has a maintenance program. For example [to] strengthen and address weaknesses” (Interviewee-2).

ESC professional staff monitor the player’s adherence to the maintenance program. If the player is not performing to the required level, the coach is informed and can request further monitoring. As Interviewee-1 recounts a meeting with the coach:

“The coach asked how many injuries and treatments a [player] has had... Player is then told as a result of this look after yourself as they have missed physio sessions as these treatments are being tracked” (Interviewee-1).

Importantly, even when a player is considered ready to return to competition, they do not exit the injury management process. Maintenance programs are developed to reduce the risk of injuries recurring, and to assist the player to lead a normal life once they retire from competitive sport. As Interviewee-3 states:

“After the player returns, there is an ongoing maintenance program. We are also interested in their future health. So they can play tennis when they are over 40. [That is] looking after them in the longer term. We will look at factors that may contribute to injury” (Interviewee-3).

Significant resources are allocated to analysing how injuries may be prevented. The researcher recounts an example from ESC about their approach to preventing the high occurrence of knee injuries. Analysis of the previous season’s injury data revealed a high incidence of knee injuries occurring for a particular competition round. Further analysis determined that the round coincided with an increase in training intensity. By modifying the training program and implementing slight changes, they were able to
reduce the incidence of knee injuries for that round in the next premiership season. This reinforces that preventative measures can contribute to reducing injuries to players. Injury prevention was a recurring theme in interviews, as several interviewees recall:

“Physios do [injury] prevention class and rehab [sic] has weights classes to strengthen them up” (Interviewee-7);

“[ESC has] thorough injury prevention process” (Interviewee-5);

“We assess areas of potential weakness [obtained from] physio screening, previous history of injuries, and weight room observations” (Interviewee-6).

Injury prevention is a key business driver for injury data capture at the ESC. Understanding the areas which are affecting a player’s performance means new strategies and approaches can be developed and employed to reduce the risk of injuries occurring. Interviewee-2 highlights this point:

“[The coach] has mandated that once you roll an ankle it is strapped” (Interviewee-2).

ESC’s analysis of injury data from the previous year revealed many instances of recurring ankle injuries, which impacted either player availability or reduced working to their optimal level. As a preventive measure, the coach mandated that players who have rolled their ankle previously, require ankle strapping before all training sessions and games. Notably, the results to date are encouraging demonstrating that interventions can prevent injuries and result in reductions of injury incidences. As Interviewee-2 continues:

“This has worked” (Interviewee-2).

Injury prevention is an additional business function performed at the ESC to minimise the risk of injuries. Parallels can be drawn between the TRIPP model (p. 40) and the injury prevention activities undertaken by the ESC. TRIPP Stage 1 requires an in-depth understanding of the injury problem with respect to how the injury occurred; a description of the injury; and its severity (Finch, 2006). At the ESC, the information is collected as part of the injury management process.
Interestingly, this was a key business driver for the development of ISEA, which has the specific aim to improve the efficiency of data capture. Hence, injury management provides the information for Step 1 of van Mechelen’s (1996) model and Stage 1 of TRIPP models. It is relevant and significant; as both Chalmers (2002) and Finch (2006) state that injury prevention has suffered from poor data collection. Similarly, before ISEA, ESC perceived that poor injury data quality was a barrier for effective injury prevention. Interviewees state:

“We only take snapshots currently because [we] haven’t got time to collect all the information for assessment” (Interviewee-6);

“People can’t do their jobs without the information” (Interviewee-1).

InjuryTracker_DB is the repository for injury data at the ESC, and is one of many sources of data used to facilitate injury prevention. By integrating injury prevention with the injury management process, the data necessary to move to Stage 2 of TRIPP is provided by the injury management process.

There is evidence from interviewees that suggests the ESC’s injury prevention activities align well with the TRIPP model. Specifically through

“data mining” (Interviewee-6)

and preventative measures, such as the previous example, where ankles are now

“strapped” (Interviewee-2);

hence, the ESC has established aetiology and mechanisms of injuries; introduced preventative measures; and provided ongoing assessment of their effectiveness (Finch, 2006; van Mechelen, 1996). From the research data, there is evidence that the ESC developed implementation strategies of the interventions to ensure their effectiveness on the field (Finch, 2006). Physical performance assessment and medical screening business processes feed information back into the injury prevention process.

New ways to prevent injuries or illness is an ongoing priority at ESC. For example, from casual discussions with the ESC, the researcher recalls that all ESC professional
staff and players are required to have an influenza inoculation at the start of the season.

Further, significant resources are allocated to analysing how injuries can be prevented. Understanding the areas which are affecting a player’s performance means new strategies and approaches can be developed and employed to reduce the risk of injuries occurring and/or recurring.

5.4.4 DIFFERENTIATION BETWEEN ATHLETES AND OTHER WORKERS

When a player leaves the club due to de-listing, retirement or moving to another elite sporting club, there is a mandatory and comprehensive exit medical screening of their health condition. As Interviewee-3 states:

“When the player leaves the club there is an exit report. We can send an exit report to other clubs including X-rays etc so that the new medical team knows what the medical records of the player are. Although there are some issues there. Some players do not want the new club to know about certain problems. We are working through this” (Interviewee-3).

It is interesting that although the player is made aware of their current medical condition through the exit screening, they are reluctant to share this information with future employers, even though it may benefit them in the longer term. However, medical professionals have a duty of care to ensure the health of the player is not compromised when they leave the club. This occurs even though there is no formal ongoing business relationship between the player and the club. As Interviewee-3 says:

“We have a good relationship with the other medical teams across the [Association]. There are physio and medical officers conferences and teleconferences every 2 months” (Interviewee-3).

Hence, the Association views knowledge sharing between medical professionals across all clubs as important, and it should be an ongoing regular and frequent activity.
When a player leaves the ESC there may, in some instances, be an ongoing relationship with the player for payments related to treating an injury. These payments relate to injuries incurred at the club. As Interviewee-1 states:

“If an injury occurred whilst playing football, then that player can claim prescriptions relating to this injury after they have left the club. [However, the injury] needs to be related back to something that occurred or a medical position on how long it will take to fix” (Interviewee-1).

The player exit screening process has evolved significantly, and has primarily been driven by potential player litigation against the club for poor treatment of injuries (AFL, 2005). As Interviewee-1 emphasises:

“At end of year or session they have an intense assessment from the doctor and physio and other staff as required. Also they have exit medical which is mandatory. The players association requires this as well. It shows the condition of players when they leave the club. This process has developed significantly over the last 5 to 6 years due to litigation or fear of litigation and payments of injuries” (Interviewee-1).

The ESC injury management system has developed into a mature business process which is transparent to players and medical practitioners. In this way, the ESC can demonstrate that they have followed due process in treating player injuries; hence reducing the risk of players claiming poor treatment and subsequently seeking litigation to obtain compensation from the club or Association for poor treatment.

The player has a significant role in the injury management process and can influence the decision to return to competition. As Interviewee-1 states:

“The elite athlete wants to be fixed tomorrow” (Interviewee-1).

This is not something most injured workers need to be concerned about. Elite athlete teams are competitive on and off the field. There are a limited number of positions on the team, and as such, there are many athletes vying for the same positions. Being injured can mean the athlete is unable to play and/or not selected to play due to their injury. Elite athletes may perceive this as contributing to an early end to their career,
as another elite athlete could take their position on the team permanently. A point Maddin (2008, p.1) emphasises: “players don’t want to come off the field. If they come off, then someone else will come on and might do really well and threaten their spot”.

Hence, there may be real pressure applied by the player on the medical team to use inappropriate methods and treatments for an injury. As Interviewee-1 suggests when referring to a player requesting an MRI scan for an injury because another player with technically the same injury had an MRI scan:

“He had a L3 and had a scan. When will I have a scan?” (Interviewee-1).

The player’s intention is to recover from the injury sooner, and/or even mask the extent of the problem so they can return to competition sooner. As Interviewee-1 continues:

“This is different to a normal person who will take/wants to take extra time. The sports person may hide things to get back on the field. Sports people do not want to get injured as someone may take their spot” (Interviewee-1).

Either way, this is not a good situation for the club, as an injured player is unlikely to perform at the elite level. However, in some instances a player may provide additional information which could influence the decision about whether they can return to competition. As Interviewee-6 recounts:

“Sometimes an assessment will be made that the player is not ready to return. We made decision that he required another week of full training before returning to play. But after discussion with the player who provided other information on his condition on Tuesday, we did a re-assessment and he is now playing” (Interviewee-6).

There are influences

“from all levels of the business” (Interviewee-1)
on the injury management process that cause significant tension between players, professional staff, and management. Supporters and the media also put pressure on the ESC and even directly on the player themselves. For example, the statement

“Get rid of him, he is always injured” (Interviewee-1)

has been touted by the media.

Apart from the ongoing well-being of the player through the management of their current season’s injuries, the injury information captured is used in the team selection process for next year’s premiership season. The researcher’s observations as part of his role in the SpeechNet ISEA development project revealed the management perspective of player injury information. Many summary reports of the player’s medical condition are generated at season end, and used as input into next season player selections and player contract negotiations. Interviewee-2 supports this stating:

“InjuryTracker™ [injury data is used] to review certain players. [It has an] impact on player contracts” (Interviewee-2).

Players who have incurred injuries and deemed unable to perform at the elite level are likely to be de-listed or traded for other registered players in the Association. Players are mindful that their past and present injuries may impact on future contracts and are unwilling to share this information with other clubs in the Association. As Interviewee-3 highlighted previously:

Some players do not want the new club to know about certain problems” (Interviewee-3).

The injury management process therefore plays a significant role in the business of the club. Firstly, the role is to ensure the club’s players perform at their optimal level; and secondly to select a player that fulfils the competition aspirations of the club.

The aim of workers compensation bodies and normal commercial businesses is to minimise costs associated with the injured worker. To achieve this aim, they develop an injury management plan which includes determining whether compensation is to be paid, and if so, how to minimise workers compensation claims (WorkCoverTAS, 2008). The business drivers for the injury management plan are to:
1) facilitate the earliest return to work for the injured worker;

2) be cost efficient in undertaking this work;

3) result in lower costs to employers and the workers compensation system; and

4) cease compensation when no further improvement in function is attainable

(WorkCoverTAS, 2008; WorkCoverSA, 2008).

Analysing this further suggests that in workers compensation claims the worker’s injury is the focus and not the injured worker. Once the injury is considered ‘fixed’, the worker returns to their employment (WorkCoverSA, 2008) and exits the injury management process (WorkCoverSA, 2008).

Injured workers require intervention for injuries sustained and proactive management with rehabilitation to return safely to the work environment (Roberts-Yates, 2006). WorkCoverSA (2008) and WorkCoverTAS (2008) describe this as the injury management process, which consists of the following 5 steps:

1) clinical assessment of the injury;

2) diagnosis of the problem;

3) establishment of a treatment plan;

4) rehabilitation; and

5) return to work (WorkCoverSA, 2008).

The findings of this research indicate that the elite athlete is monitored continually. Further, monitoring is not restricted to athletes with injuries, but is inclusive of all ESC elite athletes. As these statements from Interviewees emphasise:

“Players have screenings/test in place to detect if the player is ready to return to play. These are compared against their best and is discussed with doctor and physio” (Interviewee-6);
“Assessing areas of potential weakness... obtained from physio screening, previous history of injuries, weight room observations [to] see potential weaknesses” (Interviewee-6);

“GPS information, training, weight training, screening, testing of fitness, player feedback” (Interviewee-6);

“Dieticians” (Interviewee-3);

“Performance measurement is part of the injury management process” (Interviewee-6).

This is consistent with other peak elite sporting organisations such as the Australian Institute of Sport (AIS), which states that besides clinical services such as medicine and physical therapies, nutrition and performance analysis are important components in developing the elite athlete (AIS, 2009). Understanding the condition of the athlete through a comprehensive measurement program is paramount to determining remedial action so that the athlete can be developed to perform at their optimal level.

Performing at the elite level is, however, problematic in terms of health and fitness. Training too hard and generally performing at the optimum level can act as a catalyst for injuries and/or illnesses (Bahr, 2008; Chalmers, 2002). Striking a balance between fitness and performance, and the athlete’s well-being is necessary to minimise risk of injury. Hence, the ESC performs similar activities to traditional injury management, plus additional activities to assist the athlete to reach and maintain an elite performance level.

5.5 PERFORMANCE AND INJURY MANAGEMENT AT ESC

Elite athlete injuries assume a special role in the business process, beyond simply treatment. For example, the treatment for an illness, such as a cold may be medication and rest. However, treating an injury requires a multi-disciplinary approach (Cumps et al., 2008) involving many professional staff such as doctors, physiotherapists, and trainers. As Interviewee-3 highlights:
“Injury management is a multi-disciplinary approach...[and] involves a number of people [including] doctor, physios, dieticians, coach, trainers and the players” (Interviewee-3).

From the research, it emerged that the business functions of injury management: diagnosis; treatment; and rehabilitation are part of a complex and sophisticated business process to manage, develop and maintain an elite level of performance in their athletes. This is a significant departure from the traditional concept of injury management, where the injury is the key focus.

In the literature, injury management is perceived as a sequential process with a clear beginning and end (WorkCoverTAS, 2008). However, ESC athletes do not exit the business process as in workers compensation systems. The ESC adopts a proactive approach to injury prevention and injury identification through regular medical screenings of the athletes. For elite sporting clubs, while managing an injury is important, it is only one of several business functions relating to managing an athlete’s physical well-being and performance. Interviewees consider the functions of injury management are:

“performance measurement” (Interviewee-6);

“prevention” (Interviewee-3);

“assessment, diagnosis” (Interviewee-4);

“treatment and rehabilitation” (Interviewee-3);

“screen players to find weaknesses and avoid soft tissue injuries” (Interviewee-4).

Hence, the ESC business process is not sequential as the athlete’s condition is continually assessed through a number of interdependent and interrelated business functions. As the interviewees’ recall and as discussed previously (Section 2.6), the key process areas performed are:

1) physical performance assessment;
2) injury management;

3) injury prevention; and

4) athlete medical screening – which adopts a proactive approach to determine an athlete’s medical condition.

The injury management key process area includes: 1) athlete’s assessment, 2) diagnosis, 3) treatment, and 4) rehabilitation, which are grouped here to reflect the relevant theory surrounding workers compensation injury management, (which states injury management consists of clinical assessment of the injury; diagnosis of the problem; establishment of a treatment plan; and rehabilitation (WorkCoverSA, 2008)). The injury prevention key process area aligns with the van Mechelen (van Mechelen, 1996) and TRIPP (Finch, 2006) models.

The key process areas of physical performance assessment, and athlete medical screening emerged from the research data. Each key area is a set of business functions in its own right, occurring frequently at the club. Hence, I argue that in elite sporting clubs, the injury alone is not the focus of attention; rather the athlete is the focus. The change in focus supports a multi-disciplinary approach for athlete performance management, which is not limited to an athlete’s injury, but includes all aspects of the athlete’s physical and mental well-being to perform at the elite level.

As evidenced from the research data, a multi-disciplinary approach is a key requirement of the business process, which extends beyond the medical discipline area of injury management. Hence, this research proposes a new model that incorporates injury management, but goes beyond to include other processes to support the athlete to perform at the elite level. As the term injury management is a subset of the business process, I propose a new model entitled ‘elite athlete performance management model’ (PERFORM) to reflect the business process performed by the ESC. PERFORM reflects the overall aim of the ESC to manage the elite athlete’s performance. PERFORM is shown in Figure 5.1, and is now explained.
PERFORM demonstrates the multi-disciplinary approach (Cumps et al., 2008; Dennis, 2006; Finch, 2006) for elite athlete performance management by combining the key processes being performed at the club under the umbrella of performance management. The model is divided into the four key process areas outlined previously as:

1) physical performance assessment - represented in the model as the aqua cyclical path;

2) injury management - represented as the orange cyclical path;

3) injury prevention - represented in the model as the green cyclical path; and

4) athlete medical screening - represented in the model as the pink cyclical path.

To facilitate knowledge sharing and the multi-disciplinary approach to problem solving, the ESC established the physical performance team (p.154). Interviewee-3 emphasises the PPT’s role at the ESC:
“[The] PPT allows us to throw things around to come up with a management program for the player. The PPT meetings are absolutely vital” (Interviewee-3).

Hence, the point of intersection of all four process areas in Figure 5.1 is the physical performance team. It is at this point that the multi-disciplinary approach is enacted through the sharing of information generated from each process area.

### 5.6 Conclusion

ISEA applies the spoken language understanding techniques of: restricting language and grammar of spoken language input (Gilbert et al., 2008); a reference semantic frame to find sentence boundaries (Jeong & Lee, 2008, p.2:11; Ostendorf et al., 2008); and signs and markers to identify key words (De Mori et al., 2008) and additional techniques developed by the ISEA development team to improve both speech recognition accuracy and natural language understanding. The additional techniques were:

1) the development of a language template to guide the user in the formulation of spoken language discourses to capture injury data;

2) inclusion of a user inserted colon marker (De Mori et al., 2008) in spoken language to identify key words and sentence boundaries (Ostendorf et al., 2008);

3) incorporation of a cleansing function to validate and correct the transcribed spoken language (SpeechToText) before full processing of the spoken language; and

4) generation of a customised language model to improve speech recognition accuracy.

Interviewees agree that ISEA’s application of spoken language understanding techniques resulted in improvements to both speech recognition accuracy and language understanding. As a result, interviewees also agree that the productivity improvements sought by the club were achieved. However, several interviewees voice
that even though the techniques improved speech recognition accuracy and language understanding of spoken language, having to use the language template was restrictive and impacted on ISEA’s usability. Their preference is to use more flexible language, moving towards a solution that allows them to speak normally in the same way they write free hand notes. Clearly, this is the ultimate aim of computer science research into spoken language understanding, as discussed in Chapter 2. Interviewees who use ISEA regularly suggest a differing opinion, stating that they find the ISEA user interface easy to use. Several interviewees suggest that younger ESC staff are more willing to use new technology solutions such as ISEA, and spend the necessary time to learn these systems. Most interviewees highlight that the lack of time to learn and use ISEA is a barrier to its widespread adoption.

Based on theory and ESC interviewee responses, the researcher created a new definition for an elite athlete sport injury. The definition reflects its context within elite sporting clubs and the injury management process. Emerging from the ESC interviewees’ perspectives of the term ‘injury’, this new definition accounts for the broader scope of ‘injury’ to include illnesses and other ailments, and recognises the elite level performance requirements before players can return to competition.

From the analysis, it emerged that the business functions of injury management: diagnosis; treatment; and rehabilitation are only one part of a complex and sophisticated business process to manage, develop and maintain an elite level of performance in their athletes. This is a significant departure from the traditional concept of injury management where the injury is the focus. ESC athletes do not exit the business process. Instead, each athlete’s condition is continually assessed through a number of interdependent and interrelated business functions. Interviewees consider the business functions performed cover four key process areas:

1) physical performance assessment;

2) injury management;

3) injury prevention; and

4) athlete medical screening.
Each key area is a set of business functions occurring frequently at the club. While interviewees perceive that the athlete injury is the focus of the business process, the research uncovered that this is not the case. Rather, the *athlete* is the focus. This change in focus supports a multi-disciplinary approach for athlete performance management, which is not limited to an athlete’s injury, but includes all aspects of the athlete’s physical and mental well-being to perform at the elite level. From the interviewees’ accounts, a multi-disciplinary approach is an essential requirement of the business process, which extends beyond the medical discipline area of injury management and includes all four key process areas. Hence, the research proposed a new model entitled elite athlete performance management model (PERFORM) that incorporates all four key process areas, necessary to support the athlete to perform at the elite level.

Interviewees consider that ISEA is a vital tool for injury data capture, and therefore influences athlete performance management. In analysing these influences, knowledge sharing, community of practice and competitive advantage emerged as unexpected outcomes of this research. These unexpected outcomes are now discussed in Chapter 6.
Chapter 6 Unexpected Outcomes Emerging From This Research; And Conceptual Framework Revisited

6.1 Introduction

This chapter reports on the unexpected outcomes from the research data analysis and then revisits the conceptual framework proposed in Section 2.6 (p.45). A revised conceptual framework highlighting the research findings is then presented.

The practice of knowledge sharing between professional staff, and the injury management process providing potential for competitive advantage both on and off the field, emerged as two unexpected outcomes from the research. Of interest therefore is whether ISEA influences competitive advantage, and if so, from where does this competitive advantage emanate? It has been established in Chapter 5 that a key outcome of ISEA is the timely capture of injury data. Timeliness used in association with data capture is an emotive word signifying ‘importance’. Specifically, timeliness suggests that the ESC were unable to perform a specific function effectively prior to ISEA. According to Awad and Ghaziri (2004), timely data capture allows for effective knowledge transfer and is therefore an enabler for knowledge sharing, which is a source of competitive advantage (Argot & Ingram, 2000). Hence, how significant the influence of timely injury data is on the ESC is investigated.

The analysis of the unexpected outcomes commences with an assessment of the literature pertaining to knowledge transfer and knowledge sharing. This provides theoretical underpinning from which an in-depth analysis of the influences of ISEA on knowledge sharing at the ESC can be explored. Specifically, the analysis considers the role of the physical performance team (PPT) and the ways in which it behaves as a ‘Community of Practice’ to facilitate knowledge sharing, and ISEA’s support of that role. I argue that ISEA facilitates knowledge sharing, as it allows timely capture and transfer of important injury knowledge required for elite athlete performance management. The argument is developed further to consider whether elite athlete performance management is strategic to the club, and whether this leads to competitive advantage.
ISEA captures knowledge. Or does it? To answer this question a broad level of understanding concerning the knowledge management literature is required, and is now discussed.

6.2 OVERVIEW OF KNOWLEDGE TRANSFER AND SHARING THROUGH COMMUNITIES OF PRACTICE – A THEORETICAL PERSPECTIVE

The terms ‘data’ and ‘information’ are well defined in the literature (Davenport & Prusak, 2000; Laudon & Laudon, 2004; Turban et al., 2008) and provide a context in which to build the theory surrounding knowledge and knowledge management. Data are the raw facts collected with no meaning attached (Shelley, Cashman, & Rosenblatt, 2008). For example, data is the recording of each product item sale to customers in a database. Information results from the processing of the raw facts (data) to obtain some meaning (Shelley et al., 2008). An example of information is an aggregation of product item sales for the month for the purposes of re-ordering more supplies. The information gathered facilitates decision-making, in this case identifying the goods in the store that need to be replenished. Knowledge, however, is far more complex to define, particularly as it is not always explicit but often resides in people’s minds. From an IS perspective “knowledge is neither data nor information” (Awad & Ghaziri, 2004, p. 32) but is “information combined with experience, context, interpretation and reflection” (Davenport, 1998, p.43). Knowledge is the “know-how” (Awad & Ghaziri, 2004, p. 32) to apply to decisions and actions (Davenport, 1998). Knowledge exists in one or more of the following components. Facts about a domain; Procedural rules that should be followed for a specific event problem; and Heuristic or rule of thumb based on experience (Awad & Ghaziri, 2004). Davenport and Prusak (2000, p.5) define knowledge as a “fluid mix of framed experience, values, contextual information, expert insight that provides a framework for evaluating and incorporating new experiences and information”.

The complexities of defining knowledge are not new. Plato, one of the great philosophers in his dialogue the ‘Meno’, distinguishes between a person who has an opinion of the directions to the town of Larissa; from another who provides the same directions, but has actually made the journey and having been there (Plato, 308BC). The difference between knowledge acquired ‘second hand’ and from someone with
direct experience of the knowledge, is significant according to Plato. As Cahn, Eckert, and Buckley (2004, p. 1) state, “for Plato… one who has knowledge of anything must have knowledge of the form of the thing in question, not just empirical familiarity with it”. As this definition has it roots in deep philosophical reasoning and argument, there may be a tendency to lose sight of the practical aims of business knowledge management. Organisations are focused on capturing the knowledge, of the directions for example, and sharing this knowledge so it can be used. Arguing whether the knowledge is from actual personal experience of travelling to the town is not important to an organisation. Knowledge, regardless of the original source, can be used to enhance an organisation’s intellectual capital and performance (Jashapara, 2004). Knowledge is the ability to turn information and data into effective action and is therefore driven into practice (Awad & Ghaziri, 2004) regardless of its original source.

While a database may be described as a collection of data items and tables (Shelley et al., 2008), a knowledge base will contain the extra and enriched new information derived from “experience, context, interpretation and reflection” (Davenport, 1998, p.43). IT can be used as a “vehicle for knowledge transfer” (Awad & Ghaziri, 2004, p. 32) which is the process by which knowledge is captured, codified and deployed in a format acceptable to the user and at the time needed (Awad & Ghaziri, 2004). Knowledge transfer is a prerequisite for knowledge sharing, which is making available what is known through an exchange of knowledge between individuals (Awad & Ghaziri, 2004); hence supporting the collaboration and communication between organisational members (Ju, Li, & Lee, 2006).

Knowledge management is considered a contributing factor to an organization’s competitive advantage (Awad & Ghaziri, 2004; Ju et al., 2006; Voelpel & Han, 2005). An organisation’s inability to capture knowledge and learn from experience often determines organisational success or failure (Awad & Ghaziri, 2004; Ju et al., 2006). Managing and sharing knowledge can be achieved through communities of practice (Lave & Wenger, 1991). According to Wenger (2004), members of these communities share a passion for something they know how to do, and they regularly interact for the purpose of improving their discipline. Hanisch and Churchman (2008, p.420) contend that
“informal interaction occurs in groups and is prompted by, and in turn contributes to, shared organisational discourses. These discourses contribute to both the identity of the group and its organisational members, and help them to give meaning to their work, thereby enabling them to develop and improve their discipline”.

Hence, the community develop a common set of values and behaviours (Hanisch & Churchman, 2008).

Central to community of practice theory is the notion that more experienced members (or those with expertise) will share freely their knowledge with less experienced members through social interactions (Ardichvili, Maurer, Li, Wentling, & Stuedemann, 2006; Lave & Wenger, 1991. For a given problem, there is a need to share knowledge with professionals from different disciplines. In this research, an example is, doctors sharing knowledge with physiotherapists and vice versa. The aim is not for physiotherapists to become medical doctors. Rather, the aim is to share knowledge necessary to enable physiotherapists to determine appropriate injury treatments. Communities of practice are closely aligned to business strategy and competitive advantage as organisations need to manage the existence of a community of practice as part of a systematic and strategic approach to promote the effective management of intellectual capital, and as a means of maintaining long-term organisational memory (Dubé, Bourhis, & Jacob, 2005). Knowledge management is a strategic activity (Wenger, 2004). Interestingly, theory suggests excessive organisational intervention in communities of practice is a barrier to effective knowledge sharing (Dubé et al., 2005). McDermott (2000) states autonomy and independence for innovation are essential for long-term survival of the community of practice.

However, the ESC’s business strategy is not to change the game of the competition; rather the strategy’s aim is to play the existing game better (Mazzucato, 2002). To achieve this aim, the primary focus of strategic management is on intra-organisational dynamics, such as information flows and knowledge creation (Mazzucato, 2002), and it is from this position that the execution of the strategy is investigated further.
6.3 Knowledge sharing through PPT as a community of practice

The need for information and the subsequent knowledge sharing at the ESC is consistent with other businesses that increasingly perceive knowledge as central to their success (Hildreth, Kimble, & Wright, 2000). The PPT is central to knowledge sharing between professional staff at the ESC. The PPT’s aim is to improve the management and treatment of an athlete’s medical condition, and in so doing, accomplish an elite performance level so that ultimately the athlete can return to on-field competition. The PPT is not merely a normal business committee, such as a project review meeting. It has been constructed as a vehicle for knowledge sharing between professionals. Through the PPT, ESC professional staff are “bound together by a common purpose and an internal motivation” (Kimble & Hildreth, 2005, p.103) around sharing knowledge specific to a particular problem domain (Awad & Ghaziri, 2004) to improve their discipline (Hanisch & Churchman, 2008). Interviewees support this view as the reasoning behind the establishment of the PPT:

“Injury management is based on knowledge of what causes injuries...It is dependent on a number of individuals including the players. You need the right people for diagnosis [and] transfer of information between various professionals...Performing at the elite level requires better communication and information for treatment. Communication is vital to provide better service” (Interviewee-1);

“Some people can’t do their jobs without the information. So currently doctors and physios will collaborate on a player’s condition. This is different from normal Johnny who will be referred to a physio somewhere else” (Interviewee-1);

“Injury management is very good. The communication between the doctors, physios, trainers, rehab is very good. Player lists of player injuries is generated by [staff member] [who] generates list by talking to doctors, physios etc and then presents this at the PPT” (Interviewee-2).
These statements highlight several key points and re-enforce sentiments by other interviewees at the ESC. Firstly, the PPT is a group of professionals at the club that meet regularly (twice a week) to share information on the player’s condition including treatments, stage of rehabilitation and to jointly propose solutions for particular injury problems. The PPT is central to communication and knowledge sharing between the professional staff at the club. Secondly, the ‘Player Lists’ document is vital for knowledge sharing as it contains details of the health and condition of each player. Interviewees recall:

“The Player Lists report is in place by lunchtime Mondays” (Interviewee-2);

“Player Lists of player injuries is generated by [staff member]. [Staff member] generates list by talking to doctors, physios etc and then presents this at the PPT” (Interviewee-2);

“Monday’s PPT is very important. Plays massive role. One doctor sends e-mail around about what is in Player Lists” (Interviewee-4).

Data collection is currently spread across the club using many different applications from paper documents; spreadsheets; word-processed documents; and specialist tools, such as GPS tracking software and database applications, such as InjuryTracker™. A point emphasised by interviewees, stating:

“[It is] hard to extract data out of InjuryTracker™ like graphs. What we have done is create a massive spreadsheet ... [which includes] how many games players missed due to injuries and what type of injury” (Interviewee-7);

“Everyone captures [their own] information” (Interviewee-7);

“We record all the information we need to record. The way we record is the challenge. There are too many systems. We have handwritten notes, software, [and] spreadsheets. There needs to be an integrated way – need [a] database” (Interviewee-6).

Professional staff members require information to perform their work. They collect information that is relevant to their specific job activities. While InjuryTracker™ is used as a repository of medical consultation and treatment data, other information
relating to areas such as diet, rehabilitation, and training details are stored elsewhere. The ESC does not have a central repository and/or integrated database architecture to facilitate access to all relevant information pertaining to the player. The information is brought together in the ‘Player Lists’. Hence, to facilitate knowledge sharing, additional information is gathered from professional staff and from myriad systems, and consolidated in the ‘Player Lists’ document. ‘Player Lists’ is an important document as it is used as the basis for assessing a player’s condition. As Interviewee-2 points out:

“At the PPT we will discuss how the player’s injury is or how the player is progressing. How is [player’s] program going. He is at 70% and can go to next level” (Interviewee-2).

The PPT provides the forum for professional staff to comment on the ‘Player Lists’ information in a non-threatening environment. Doctors are central to the injury management process, usually having the final say concerning player treatments. However, the PPT creates a work environment where the views of all professional staff regarding player treatments are encouraged, valued and considered. As Interviewee-2 states:

“The doctors give a lot of direction but I will give advice. They acknowledge my comments” (Interviewee-2).

The PPT is therefore a forum for professionals to undertake a complete assessment of the player’s condition; to determine their subsequent availability for the upcoming weekend’s game; and to determine their ongoing treatment to return to pre-injury work capacity.

There is concern that the knowledge shared may be incomplete, and therefore lead to questioning the professional’s expertise. Players, for example, will compare their treatment with the treatment of other players who have a perceived similar injury. As Interviewee-1 states a player will question their treatment in the following way:

“A little knowledge is a dangerous thing. He had a L3 strain and had a scan. When will I have a scan?” (Interviewee-1).
In some cases to fully diagnose an injury, additional tests such as X-rays or MRI scans are necessary. However, they are not always required despite a player believing they should receive the same treatment as others. Incomplete information and the possibility of misinterpretation of information can lead to unnecessary tension between players and professional staff at the ESC, as Interviewee-1 recounts:

“Someone has collected we have these hamstring problems. The doctor’s version needs to be shared and respected by physios. If doctors say it would be due to bike program then [person-2], arks up (sic). If you don’t know what they are doing then the information leads to misinformation. We cannot work in isolation” (Interviewee-1).

The above highlights the many different role types at the ESC with somewhat conflicting business objectives. Trainers and fitness coaches will push players to their maximum to build strength and aerobic fitness. Doctors and other medical staff are focussed on the well-being of the player, attend to their injuries, and if possible suggest preventative measures to reduce the occurrence/recurrence of injuries. Where training methods could lead to injury, this can result in conflict between medical and coaching staff. Evidence-based assessment (Fowler & Lee, 2007) of the situation therefore becomes important in resolving this conflict.

ESC professional staff collect information specific to their field, but when sharing information they are selective and only share data and knowledge at the appropriate level of detail. The level of data granularity depends on how the data will be used. As Interviewee-1 says:

“A doctor saying to the physio the [player] has a sore back is not the right thing. The doctor will give the physio sufficient information to treat the player [and the] physio will give general information to rehab and trainer” (Interviewee-1).

Hence, the level of detail communicated will vary depending on the intended use of the data, and to whom the data is communicated. For example:

“Orthopaedic surgeons get in-depth details from the doctor. Physios may get less and so on to rehabilitation, trainers and player” (Interviewee-1).
However, information suitable for all levels must be captured and stored so that knowledge can be shared between all levels of professional staff. As Interviewee-1 goes on to say:

“It all needs to be there in the database, so they can get the detail if needed… [Usually the] dietician doesn’t need to know about swimming program. But this might be necessary in 1% of cases” (Interviewee-1).

Knowledge sharing and therefore the need for knowledge transfer and a knowledge repository is important to ensure that injury management remains effective, and continues to be available as a reference source even if professional staff leave the ESC. As Interviewee-1 highlights:

“If someone leaves [the ESC] it shouldn’t fall apart. Knowledge sharing is needed” (Interviewee-1).

A theory of sharing and managing knowledge is ‘Communities of Practice’ (Lave & Wenger, 1991). Communities of practice are recognised as important to the social fabric of knowledge (Wenger, 2004), and are described as social structures which enable knowledge to be shared by practitioners. The strength and value of the community is derived from the group recognising common knowledge, energy and a commitment to shared understandings and vision of a way forward for their discipline and practice (Hanisch & Churchman, 2008). In this way, the PPT demonstrates the traits of communities of practice where members of the PPT share, develop and diffuse learning, knowledge and practice (Lave & Wenger, 1991), and create “value by improving the performance of their members when they apply their knowledge in the performance of their job” (Wenger, 2004, p.5).

Hence, I argue that the PPT behaves as a community of practice as its members are a group of professionals who are involved in solving a particular problem surrounding an athlete; who interact regularly to solve this problem; and strive to learn how to perform their work activities better through knowledge sharing (Wenger, 2004). The PPT also aligns with the three fundamental characteristics of communities of practice that Wenger (2004, p.3) defines:

1) ‘domain’ (area of knowledge);
2) ‘community’ (the people with shared interest in the work); and

3) ‘practice’ (the work being performed by the people).

Effective elite athlete performance management requires information from a variety of sources relating to the elite athlete’s condition. By behaving as a community of practice around a common problem (Wenger, 2004), the ESC PPT were able to determine better ways to improve work practices (Wenger, 2004). As Interviewees state in support of this:

“More communication than IT...[staff member] has rehab list and discussed at Monday’s PPT” (Interviewee-3);

“At [opposition club] they are old school. They don’t strap shoulders and knees. They have the doctor and bits and pieces. Here, everyone knows what is going on. The PPT is key to process. There is two way communication” (Interviewee-2).

An organisation’s ability to learn through knowledge sharing directly influences organisation-wide improvements in efficiency, productivity and innovation; and change adeptness (Finger & Woolis, 1994; Scott-Ladd & Chan, 2004) contributes to attaining a competitive advantage (Scott-Ladd & Chan, 2004). Learning is therefore a cornerstone for competitive advantage (Scott-Ladd & Chan, 2004), and the role of the PPT is to ensure project-specific learning does not remain either local or incidental, and the knowledge is made available to all concerned, synthesized and integrated, remembered and distributed (Wenger, 2004). Changes in knowledge and performance of a group are significant measures of knowledge transfer (Argote & Ingram, 2000). That is, it is not important what knowledge has been transferred, but whether it has resulted in performance improvements. For this reason, I argue that the PPT is a community of practice and is a critical component of PERFORM (p.175), and without this PERFORM does not function effectively as a business process. The PPT as a community of practice is the link between all parties involved in PERFORM. In this way professional staff are developed and become more valuable to the ESC, making it difficult for competitors to imitate; hence, resulting in a source of competitive advantage (Argot & Ingram, 2000).
Knowledge transfer is a prerequisite for knowledge sharing (Awad & Ghaziri, 2004) supporting collaboration and communication between organisational members (Ju et al., 2006). ISEA is a vehicle for knowledge transfer, as its main function is to capture, codify and deploy knowledge (Awad & Ghaziri, 2004) in a valid way so that it can be used to solve a particular problem about an elite athlete injury. The term ‘valid’ is used cautiously here. As Awad and Ghaziri (2004) emphasise, valid does not mean that the result will be correct, but the process to form the recommended approach follows logically from facts and rules using inference procedures. That is, the doctor in recording details about a medical consultation with an elite athlete has applied their expertise, which includes their “ability to reason and to make deductions” (Awad & Ghaziri, 2004, p.32) to diagnose the injury and to capture this information in the knowledge base to facilitate knowledge sharing. ISEA improved the timeliness (Awad & Ghaziri, 2004) of data capture allowing for effective knowledge transfer and is therefore an enabler for knowledge sharing. As supported by ESC and Association documentation saying ISEA resulted in:

“Rapid entry of injury data using speech” (ESC to Association document, 4 September 2006);

“Timely input of medical data resulting in up to date player injury management“ (ESC to Association document, 4 September 2006);

“Voice recognition component which cuts down hours of data entry into minutes” (Association to Association Executive document, 26 March 2007);

“Timely recording of this information” (Injury management working party document, 31 August 2007).

Knowledge sharing occurs as part of the PERFORM business process and can be a source of competitive advantage (Argot & Ingram, 2000). Interviewees support that knowledge sharing is fundamental to delivering a best practice process:

“Best practice means sharing data between involved parties is essential” (Interviewee-1).
However, competitive advantage through knowledge sharing is dependent on PERFORM providing an advantage that is not easily replicated by competitors (Jessup & Valacich, 2006). Hence, the analysis now considers PERFORM’s impact on business strategy, and therefore its strategic positioning within the ESC.

6.4 COMPETITIVE ADVANTAGE THROUGH PERFORM

Since the early 1980s, considerable research attention has focused on the strategic role of IS and their potential for creating competitive advantage (Ives & Learmonth, 1984; McFarlan, 1984; Parsons, 1983; Piccoli & Ives, 2005; Porter & Millar, 1985). It is now widely accepted that IS can be used to create efficiency improvements, differentiation, and channel domination (Jessup & Valacich, 2006; Sethi & King, 1994; Turban et al., 2008) thereby enabling a competitive advantage. Strategic systems are argued to be the tools that raise entry barriers, increase bargaining power with suppliers and customers, offer new products and services, or change the rules of the competition (Bhatt & Grover, 2005). Even though competitors may duplicate a technology innovation, relative advantage can be created and sustained where the technology leverages some other critical resource. However, in his controversial article “IT Doesn’t Matter”, Carr (2003) argues that IT is ubiquitous, increasingly inexpensive, and accessible to all organisations. As such, Carr (2003) asserts that IT cannot provide differential competitive advantage, because it is scarcity, not ubiquity that creates the ability to generate supernormal rents. The underlying assumption behind Carr’s (2003) paper is that contemporary IT management believe the business value of IT is in its possession (Peppard, 2007). The danger with Carr’s (2003) perspective is that senior managers would therefore assume a defensive and utilitarian posture with respect to IT (Bhatt & Grover, 2005).

In response to Carr’s (2003) assertions, some researchers have framed the discussion in terms of IT capabilities, and argue that managing IT is a capability that can create uniqueness and provide organisations a competitive advantage (Bhatt & Grover, 2005; Peppard, 2007). Kettinger, Grover, Guha and Segars (1994) describe a number of complementary resources, such as size, structure, and culture that could make it difficult for competitors to copy the total effect of the technology. Further, changes to
the business processes or business activities may provide an advantage that is not easily replicated (Jessup & Valacich, 2006). This view is supported by interviewees:

“We look for best practice to deal with and treat injuries and how to prevent the injury... getting players back sooner is a competitive advantage” (Interviewee-1).

“All clubs will be doing similar things. The key difference is how you address the injury” (Interviewee-3).

Rottenberg (1956) claims that the ‘game’ is the product with revenues derived from its play. This perspective has evolved to include team performance as an important output which influences the revenue generation capability of the product (that is the ‘game’). As Cairns, Jennet and Sloan (1986, p.11) explain, team performance is “expressed as a percentage of matches won”. Further, “the higher the home team's expected quality, the greater its probability of success...Higher expected quality attracts consumers not only because of its relationship to probability of success but also because consumers prefer watching better teams” (Cairns et al., 1986, p.21). Hence, a club’s financial success is reliant on establishing an organisational capability to develop a quality team through best practice processes with the ultimate aim of fielding a ‘winning team’. Interviewees agree, and were unequivocal in stating that the injury management process is strategic to the ESC. They viewed injury management was tied closely to the business and financial success of the club. In support of this, interviewees state:

“[Injury management is] strategic to success” (Interviewee-3);

“Injury management is strategic” (Interviewee-2);

“Injury management is strategic from club’s point of view” (Interviewee-1);

“The [ESC General Manager] sees injury management as strategic” (Interviewee-6);

“It is a priority” (Interviewee-7);

“Definitely results in competitive advantage” (Interviewee-5).
The ESC operates in a competitive environment with all clubs positioning themselves to attract new members (supporters) and sponsors from the same market pool. Winning on the field improves a club’s ability to attract more members and sponsors, which leads to financial success (Stewart et al., 2005). A view also expressed by Interviewees:

“The teams are so close and even. The clubs all find ways to improve competition...Injury management is important because players are assets and performing assets” (Interviewee-1);

“Keeping player on the park, to attract more sponsors and in the longer term the club will be more successful” (Interviewee-3).

Clubs generally consider injury management as strategic to their success on and off the playing field. In some cases if the injury management goals are not achieved, clubs have sacked their entire injury management staff and recruited new staff to replace them. Interviewee-1 emphasises:

“If clubs don’t get the results in injury management then they will make changes. A number of clubs do and to solve problem is to get rid of the people (doctors, physios etc) and start again” (Interviewee-1).

Interviewee-1 highlights further the importance of injury management and the associated injury data, recalling:

“A trainer last year accepted a job at another club. While he was informing [Manager], his PC and access were removed. This highlights the club believes this data is of strategic value” (Interviewee-1).

Hence, fielding a competitive and ‘winning team’ is central to providing financial sustainability to support the strategic objectives of the club and to develop a competitive advantage. Interviewee-2 highlights that a ‘winning team’ strategy requires good coaching, an effective recruitment program for new elite athletes, and injury management. Interviewee-6 states:
“There are three areas that are strategic to the club. Good coaching; recruitment, that is players we bring in; and injury management” (Interviewee-6).

Conversely, poor on-field competition outcomes can result in declining club supporter memberships and spectators. That is “individuals are attracted by improved prospects of success but as the result becomes less and less uncertain, some will lose interest in the contest” (Cairns et al., 1986, p. 6). In a notable case, the Association forced two clubs to merge due to poor on-field performances by one of the clubs. As Stewart et al. (2005, p.109) state, “the merger between Fitzroy and Brisbane is the clearest example of the AFL’s efforts to ensure the long-term future of the Brisbane AFL licence”. Stewart et al. (2005) highlight the business drivers for the AFL club merger were to improve the competitiveness and financial viability of the merged club; and to resolve Fitzroy’s inability to field a competitive team. A low supporter and spectator base can impact on a club’s ability to attract a major sponsor (Cairns et al., 1986). This is similar to other elite sporting codes, such as tennis, where successful on-field/on-court outcomes usually result in higher levels of sponsorship. The implication here is that the strategic positioning (Applegate et al., 2007) of the ESC is dependent on developing business strategies that result in not only maintaining their current supporter base but also drive membership growth and significant sponsorship deals.

The ESC views the activities they perform at the club as a differentiator from other clubs and this leads to their competitive positioning on the field, as Interviewee-3 supports:

“On the medical side we share information like techniques with colleagues. Techniques like dealing with faulty shoulders. ‘Player management’ from injury perspective is the difference. How they are screened, encouraged, and not pushed too hard” (Interviewee-3).

Business process (Jessup & Valacich, 2006), structure and culture (Kettinger et al., 1994) are key aspects at play at the ESC, and are important differentiators between the elite sporting clubs in the Association. The ESC’s organisational structure and culture promotes a multi-disciplinary approach (Cumps et al., 2008; Dennis, 2006; Finch, 2006) where professional staff including medical, physiotherapy, rehabilitation
and other professional staff share knowledge through the PPT. Further, Interviewee-3 highlights that ‘player management’ distinguishes the ESC from other clubs in the Association. This broadly suggests that the business process at the club is the differentiator from which ESC achieves competitive advantage.

I argue that PERFORM is the process to which Interviewee-3 refers as ‘player management’, and which supports the ESC’s ‘winning team’ business strategy. Further, while it has been established that the injury is the focus of traditional injury management (WorkCoverTAS, 2008), ‘player management’ implies that the athlete is the focus, and that adopting this perspective leads to competitive advantage. While injury management contributes to developing a ‘winning team’, competitive advantage is achieved through adopting a holistic approach surrounding the athlete’s performance.

Emerging from the research is that involvement of the whole community of professional staff in elite athlete performance management is far more important than the individuals in the process realised. PERFORM reflects the end-to-end business process performed at the ESC, and to be effective requires a multi-disciplinary approach (Cumps et al., 2008; Dennis, 2006; Finch, 2006). As the name suggests, elite athlete performance management, focuses on the broader management of the athlete’s performance, rather than on a specific injury of the elite athlete. Being able to determine

“this is your performance” (Interviewee-6)

for an elite athlete and acting on this information is fundamental to the club’s capability in fielding a competitive team. As Interviewee-6 states:

“a player can be made ready to play in most cases but their performance level is not there yet” (Interviewee-6).

That is, even if the elite athlete is ready to play, their performance maybe considered as sub-optimal intensity to compete at the elite level, implying an athlete’s poor performance level can risk the team’s chances of winning. So, while injury management is important to the overall well-being of the athlete, and their attainment of a ‘ready to play’ status is relevant, it is the athlete’s performance that is critical to
the success of the team’s performance on the field. Although subtle, this difference between the *injury* as the focus of the business process, and the athlete’s *performance* as the focus, is critical to supporting the strategic need of the ESC to field a ‘winning team’. The shift in focus to an athlete’s performance changes the nature of the business process and its strategic importance to the club. The ESC either, intentionally and/or inadvertently, adopted an innovation strategy (Porter & Millar, 1985) which resulted in the creation of the PERFORM business process. Hence, in pursuit of a ‘winning team’, the ESC, through athlete performance management, aims to gain a profitable and sustainable position against their competitors, thereby achieving a competitive advantage (Porter & Millar, 1985).

The ESC has undergone organisational change to establish a business process that is better than its competitors to obtain an on-field competitive advantage and ‘winning team’, and has created a business process, that is PERFORM, which is of strategic importance (Mazzucato, 2002). Hence, PERFORM has a high impact on the ‘winning team’ business strategy; exists as a direct result of executing the ‘winning team’ strategy; and is fundamental in achieving the goals of this strategy. The organisation’s capability to execute this strategy is complex, expensive, requiring several work discipline areas and functional groupings of staff. Hence, PERFORM has both high impacts on business strategy and high impacts on business operations and is therefore positioned strategically within the ESC (Applegate et al., 2007; McFarlan, 1984).

ISEA’s strategic positioning is now analysed, with respect to its support of the PERFORM strategic business process and the ESC business strategy of fielding a ‘winning team’.

### 6.5 STRATEGIC POSITIONING OF ISEA

ESC professional staff have various degrees of understanding of the importance IT plays, or could play, in support of the PERFORM process. While ISEA supports the injury management process, it is one of many standalone applications that support components of PERFORM. Interviewees expressed that PERFORM is not well supported by systems, and that the current systems and databases were not integrated. As Interviewee-6 emphasises:
“There are too many systems... There needs to be an integrated way”
(Interviewee-6).

Interviewees suggest the integration of systems and databases is an area which needs improvement to facilitate knowledge sharing across the key process areas of PERFORM. In support of this Interviewee-1 states:

“The results from [staff member] needs to be available to doctors. Particularly as players are putting in their own data... Need to link various things. E.g. [staff member] has a program on how players feel. The conditioning guy has a program which are not linked to InjuryTracker™ and other systems...Communicating through a common database [is needed]”
(Interviewee-1).

This lack of systems integration and inability to access the information easily, appears to be the reasoning behind the disparity between the interviewees’ perceptions of the strategic importance of PERFORM, and not the systems that support this process. Interviewees consider that current IT are tools to support the business process, and not of significant importance to the club. Interviewees consider:

“IT is supporting the operation only” (Interviewee-2);

“Computerised is not now. But once it is up and running [it] will be important for the club” (Interviewee-3).

Interviewee-3 raises an interesting point. ‘Computerised is not now’, suggesting that the ESC has missing components to its IT architecture, but once these have been addressed then IT will become important to the club. That is, the organisation must identify, through strategic planning, the investment in resources, such as IS and technologies to help achieve competitive advantage (Jessup & Valacich, 2006; Turban et al., 2008). Interviewee-2 agrees:

“If [the] club has the system and practice” (Interviewee-2).

Interviewee-2 infers that once the system(s) support the end-to-end PERFORM business process, that is ‘the practice’, then these systems will become very important to the club. This is not to say that existing systems are unimportant to the
ESC. On the contrary, the ESC does rely on many applications to support their job functions. A point Interviewee-2 emphasises when asked what would be the impact on the ESC business process if InjuryTracker™ were removed? Interviewee-2’s reply to this question is:

“Getting rid of InjuryTracker™ would throw them out of wack ... IT is beneficial. It is used for statistical needs and to review certain players. [It has] impact on player contracts” (Interviewee-2).

Interviewee-3 supports this view:

“It would cause problems. We would be unable to look up injuries and player ages from previous years. Much easier to do it with software rather than paper” (Interviewee-3).

Lack of an integrated suite of applications for PERFORM has lead to a piecemeal IT architecture. To bridge the gap in data integration, paper-based systems and basic office automation tools still form a vital component in knowledge transfer. However, the effort and duration to manually piece together the various sources of data, impacts on the value of this data, and therefore the importance of the IT which support PERFORM. As Interviewees highlight:

“The IT systems are a form of keeping good records. Making it easier to take notes and to get access to the notes. IT is support currently but if it could improve data capture, quicker and easier then maybe strategic” (Interviewee-3).

“Currently IT is more support ... IT, however, needs to move to being strategic” (Interviewee-1).

As established previously, PERFORM is positioned strategically (Applegate et al., 2007; McFarlan, 1984) within the ESC. However, interviewees clearly state that in general, PERFORM is not well supported by systems due to poor systems integration; myriad disparate systems; and reliance on manually generated paper-based reports such as ‘Player Lists’ as the source of data for knowledge sharing. For this reason I argue, that overall the systems have a low impact on business strategy and a low
impact on business operations, and are therefore as a whole not strategic to the ESC (Applegate et al., 2007; McFarlan, 1984). Interviewees agree stating that the IT are supporting PERFORM only, but should be positioned strategically where there is an organisational commitment to use IT to enable both core operations and core strategies (Applegate et al., 2007). However, ISEA’s business requirements scope is constrained to injury management alone, and therefore its strategic positioning needs to be considered in isolation to the other systems involved in the support of PERFORM. ISEA impacted on injury management in several key areas. Informants at ESC consider that ISEA:

1) results in significant labour savings of between 75 - 85%;

2) provides rapid data capture of injury data;

3) is a vehicle for knowledge transfer;

4) improves the timeliness of injury data; and

5) is an enabler for knowledge sharing of injury data.

Further, ISEA’s influence extends beyond injury management and includes impacts on each of PERFORM’s three key process areas. While ISEA does not support these key areas directly, the injury data captured by ISEA is an essential input into these process areas. As noted in Chapter 5, injury prevention is a fundamental business driver for injury data capture. Similarly, injury data is used in the key process areas of physical performance assessment and athlete medical screening. Currently, as there is a lack of an integrated database environment, player injury details are extracted from InjuryTracker_DB and combined with other information in Player Lists. Hence injury data forms a vital component to physical performance assessment and athlete medical screening. As Interviewees highlight:

“Player lists of player injuries is generated by [staff member]” (Interviewee-2);

“[injury] assessment by medical group” (Interviewee-6);
“The theory of injury management is the same in any business. That is, measuring performance out of assets – if not performing take remedial action” (Interviewee-1);

“We do a screening of the player and plan a training program. If injury occurs, it is investigated and appropriate treatment given” (Interviewee-3).

Hence the scope of influence of ISEA extends beyond injury management and its importance to PERFORM spans all key process areas.

The timely capture of injury data as a result of ISEA and its impact on knowledge transfer is significant to ISEA’s strategic positioning. Fundamental to the success of PERFORM is knowledge sharing which is reliant on timely access to InjuryTracker_DB injury data. As Awad and Ghaziri (2004) state, timeliness of data capture results in effective knowledge transfer and is an enabler for knowledge sharing. Technology that supports information flows and practitioner involvement, facilitates the coordination of the management of knowledge (Wenger, 2004), thereby connecting “a strategic need to the daily work of the community members” (Wenger, 2004, p.4). According to Jessup and Valacich (2006), using IT to automate or improve processes has advantages, but using IT to support the organisation’s strategy enables the organisation to gain or sustain a competitive advantage. Hence, ISEA through support of injury management, provides timely access to information; enables sharing of knowledge with respect to the athlete’s performance, and in particular injury related performance; and is therefore a key pillar for achieving a competitive advantage. Through ISEA, the ESC has used IS and technologies, in this case speech recognition and language understanding, to achieve competitive advantage (Jessup & Valacich, 2006; Turban et al., 2008). ISEA has a high impact on the business operations of injury management; has a high impact on the strategic PERFORM business process; and is therefore positioned strategically within the ESC (Applegate et al., 2007; McFarlan, 1984). Interviewee-1 summaries the strategic importance of ISEA well by saying ISEA:

“is a very vital tool...The club really can’t operate without it” (Interviewee-1).
6.5.1 SUMMARY

Emerging from the research is that the PPT behaves as a community of practice, which promotes a multi-disciplinary approach (Cumps et al., 2008; Dennis, 2006; Finch, 2006) for athlete performance management. The PPT is central to knowledge sharing between professional staff at the ESC. By acting as a community of practice, the ESC community were able to determine better ways to improve work practices (Wenger, 2004) and this contributed to obtaining a competitive advantage (Scott-Ladd & Chan, 2004). For this reason, it was argued that the PPT is a critical component of PERFORM, and without this, PERFORM does not function effectively as a business process. The research established that ISEA is a vehicle for knowledge transfer, as its main function is to capture, codify and deploy knowledge (Awad & Ghaziri, 2004). Further, ISEA provided timely knowledge transfer and therefore is an enabler for knowledge sharing (Awad & Ghaziri, 2004).

Central to the ESC’s financial success is the establishment of an organisational capability to develop a quality team through best practice processes with the ultimate aim of fielding a ‘winning team’. Winning on the field improves a club’s ability to attract more members and sponsors, which leads to financial success (Stewart et al., 2005). Thus, fielding a competitive and ‘winning team’ is essential to supporting the strategic objectives of the club, and to develop a competitive advantage.

The research uncovered that the athlete’s performance, and not athlete injuries, is critical to the success of the team’s performance on the field. Although subtle, this difference between the injury as the focus of the business process, and the athlete’s performance as the focus, is vital to supporting the strategic need of the ESC to field a ‘winning team’. The shift in focus to an athlete’s performance changes the nature of the business process and its strategic importance to the club. Hence, in pursuit of a ‘winning team’ the ESC, through athlete performance management, aims to gain a profitable and sustainable position against their competitors, and therefore achieve a competitive advantage (Porter, 1985). Through PERFORM, the ESC has undergone organisational change to establish a business process that is better than its competitors to obtain an on-field competitive advantage and ‘winning team’, creating
a business process, which is of strategic importance (Mazzucato, 2002). Hence, the research established that PERFORM is strategic to the ESC.

ISEA, through the use of speech recognition and natural language understanding, resulted in significant labour savings and enabled rapid data capture of injury data. As a direct consequence of this, ISEA improved the timeliness of injury data capture. The timely capture of injury data and its impact on knowledge transfer is significant to ISEA’s strategic positioning. ISEA, through direct support of injury management, provided timely access to information and enabled sharing of knowledge with respect to the athlete’s performance. As a result, ISEA’s influence extended beyond injury management and spanned all of the four key process areas of PERFORM. Through ISEA, the ESC has used IS and technologies, in this case speech recognition and language understanding, to achieve competitive advantage. ISEA supports the PERFORM strategic business process through timely knowledge transfer, enabling knowledge sharing through the PPT, which results in competitive advantage. Hence, ISEA is of strategic importance to the ESC.

The reporting of the research analysis is now complete. It is appropriate at this point, to revisit the conceptual framework proposed in Figure 2.8 (p.45) in light of the research findings.

6.6 REVISITING THE CONCEPTUAL FRAMEWORK

The research findings firstly confirm and then extend the conceptual framework described in Section 2.6. Figure 6.1 represents the revised conceptual framework for this research based on the analysis of the findings. The rectangles in green highlight the changes to the original conceptual framework that emerged from the research findings.

A key outcome of the research is that the influences of ISEA on injury management were more important than first envisaged. The influences are represented in Figure 6.1 as the blue arrow. Significantly, interviewees highlight that the timeliness of injury data, and more specifically timeliness in terms of ‘ready to use’ injury data, have considerable impacts on the effectiveness of injury management and PERFORM. To be effective, knowledge transfer needs to be in a format acceptable to the user and at
the time needed (Awad & Ghaziri, 2004). Hence ISEA, through timely knowledge transfer, enabled knowledge sharing through the PPT. The research found that the timeliness of injury data defined in the literature did not reflect the issue at play at the ESC. Finch (2006) states poor injury data quality occurs if there are significant delays in data collection, due to recall bias. However, for the ESC, timeliness relates to the availability of the data to enable knowledge sharing. As Interviewee-6 suggests:

“1-2 days to key into InjuryTracker™ diminishes data value. There needs to be immediacy” (Interviewee-6).

Figure 6.1 – Revised conceptual framework

Hence, the research has identified that in addition to the need for high quality data, particularly for ongoing analytics, the data value is dependent on its timely availability. This dual role perspective of timeliness is represented in Figure 6.1 as the
green rectangles ‘Timeliness to Improve Recall of Injury Data’ and ‘Timeliness to Use Injury Data’.

The study’s research design was based on an original premise that the business process under investigation was injury management. This occurred as a direct result of the ESC identifying injury management as the business process operating at the club. However, emerging from the research is that the ESC business process extends beyond injury management, and includes the additional key process areas: injury prevention; physical performance assessment; and athlete medical screening. Hence, the research constructed the new business process model PERFORM. This is represented in Figure 6.1 as the green rectangle ‘Elite Athlete Performance Management Business Process’. While ISEA supports injury management, it also indirectly supports the other key process areas of PERFORM.

Timeliness of injury data resulted in effective knowledge transfer, enabling knowledge sharing, which led to competitive advantage. While ISEA enabled knowledge sharing of injury data, it was the PPT which provided the forum allowing knowledge sharing to occur. These are represented in Figure 6.1 as the green rectangles ‘Community of Practice’, and ‘Knowledge Sharing’. Importantly, elite athlete performance management as part of the elite athlete performance management IS led to competitive advantage, which is represented in Figure 6.1 as the green line between the green rectangle ‘Elite Athlete Performance Management Information System’ and the green rectangle ‘Competitive Advantage’.

ISEA through improvements to speech recognition accuracy and natural language understanding provided a HCI, which resulted in timely injury data capture. Through adopting an IS perspective, when incorporating spoken language technology in the HCI, ISEA delivered business outcomes in terms of productivity improvements and importantly the timeliness of data. By combining and integrating a number of technology methods in the software, ISEA improved speech recognition accuracy, improved natural language understanding of spoken language discourses, and overall increased user confidence in the accuracy of the data. Hence, ISEA influenced both the enablers for high quality injury data and timeliness of this injury data. This is represented in Figure 6.1 as the green rectangle ‘Integrated Technology Methods’.
The literature did not provide an adequate software engineering framework to address the special needs of speech-enabled applications. In Section 4.5, the systems development approach adopted by the ISEA development project team is described, and from this emerged the speech systems development model (SpeechDM) shown in Figure 4.6 (p. 135). SpeechDM provides a detailed account of the processes involved in developing speech-enabled applications, where at its core is the use of speech recognition and natural language understanding technology. In Figure 6.1, SpeechDM is shown as the green rectangle ‘Speech Systems Development Model’.

The revised conceptual framework demonstrates that speech-enabled applications can lead to competitive advantage. But to do so, they need to deliver business outcomes in terms of timely knowledge transfer.

### 6.7 CONCLUSION

This is an important chapter as it converges the data analysis from Chapters 4 and 5, examining the user’s perspective and ISEA in relation to its structure and functioning (Flynn, 1998), but goes further and considers ISEA’s organisational context (Flynn, 1998).

Applications such as ISEA are not standalone IT tools. They are part of an information system supporting a critical business function created as part of executing business strategy, with the prime purpose of creating value for all stakeholders (Applegate et al., 2007). ISEA operates in a business environment where the ESC’s business success is tied to fielding a ‘winning team’.

The research uncovered that the athlete’s performance and not the athlete’s injuries is critical to the success of the team’s performance on the field. Athlete performance management is vital to supporting the strategic need of the ESC to field a ‘winning team’. Through incorporating speech recognition and natural language understanding in the HCI, ISEA improved the timeliness of injury data capture. This is significant from an organisational context, as it has enabled knowledge sharing necessary for effective elite athlete performance management. In this way, ISEA has directly supported the strategic objectives of fielding a ‘winning team’.
The research analysis outcomes are reflected in the revised conceptual framework which highlights ISEA’s influence in terms of timely injury data, that is ‘ready to use’ injury data, and its impact on competitive advantage.
Chapter 7 CONCLUSION

7.1 INTRODUCTION

This research has explored the influences of speech recognition and natural language understanding technologies on an elite sporting club’s injury management business process, with specific interest on whether these influences can lead to business efficiencies. Consequently, the research design is from an IS perspective, incorporating an in-depth analysis of the ISEA technology and the business process supported by this technology. An IS perspective ensured the research was not merely an in-depth evaluation of spoken language technology, but provided a holistic view of the end-to-end system from development, implementation through to and including operation in the work place. The research focus is the application of technology to support the business in achieving clearly defined business outcomes.

The research was undertaken across two strands of enquiry:

1) spoken language human computer interfaces, which described how the speech-enabled software was developed to solve the business problems; and

2) injury management, with a specific emphasis on its application in elite sports, which also included an evaluation of the impact of the implemented speech-enabled software on the injury management business.

The research was conducted over several years (2007 to 2009) and included reflecting on the researcher’s involvement in the software development project to construct ISEA, which occurred between April 2005 and December 2006. The findings of the research are now discussed.

7.2 KEY FINDINGS OF THE RESEARCH

The research identified that the elementary use of speech recognition, as a tool for business applications did not result in satisfactory business outcomes; and very poor speech recognition accuracy impacted on user acceptance of speech interfaces and their feasibility for use in business systems. These were the underlying business drivers behind ISEA’s development. ESC staff expressed that while using speech
recognition to dictate directly into application input forms is generally faster than typing, re-work to correct poor speech recognition erodes very quickly these productivity gains. The research data clearly highlights that ISEA successfully improved speech recognition accuracy.

Emerging from the research, it was found that by removing the obstacle of poor speech recognition accuracy, ISEA became an enabler for business solutions necessary to achieve competitive advantage. The research uncovered that the success of ISEA is not that it improves speech recognition accuracy. The speech improvement accuracy is a peripheral benefit of ISEA. The main benefit for ESC is that ISEA integrated speech recognition and natural language understanding in a purpose built injury data capture application, achieving substantial labour savings and enabling rapid data capture of injury data. The additional benefit of rapid data capture resulted in timely data, which changed the value of the data to the ESC. ISEA’s application of spoken language technology allowed timely data capture which provided effective knowledge transfer, enabling knowledge sharing (Awad & Ghaziri, 2004) to achieve competitive advantage (Argot & Ingram, 2000). For the ESC this is significant to ISEA’s strategic positioning within the organisation.

Central to the ESC’s financial success is the establishment of an organisational capability to develop a competitive team through best practice processes, with the ultimate aim of fielding a ‘winning team’. Contrary to interviewees expressing that injury management provides this capability, the research identified that injury management alone is not strategic to the ESC. The research uncovered that the athlete’s performance and not the athlete’s injuries is critical to the success of the team’s performance on the field. Although subtle, this difference between the injury as the focus of the business process, and the athlete’s performance as the focus, is vital to supporting the strategic need of the ESC to field a ‘winning team’. The shift in focus to an athlete’s performance changes the nature of the business process and its strategic importance to the club.

The strategic process PERFORM, which encompasses injury management, emerged from the research. PERFORM supports the business need to field a competitive and ‘winning team’, and is therefore key to support the strategic objectives of the club.
Further, I argue that the PPT is a community of practice (Wenger, 2004), which is central to the effectiveness of the PERFORM business process. The PPT behaving as a community of practice provided the multi-disciplinary approach (Cumps et al., 2008; Dennis, 2006; Finch, 2006) necessary for athlete performance management, and is central to knowledge sharing between professional staff at the ESC. By acting as a community of practice, the ESC PPT was able to determine ways to improve work practices (Wenger, 2004) and this contributed to obtaining a competitive advantage (Scott-Ladd & Chan, 2004). I argue that PERFORM is a foundation model which identifies best practice elite athlete performance management. The research determined that ISEA supports the PERFORM strategic business process through timely knowledge transfer, enabling knowledge sharing through the PPT, which results in competitive advantage. Hence, the research found that ISEA is of strategic importance to the ESC.

ISEA demonstrated that IT has the potential to enable the achievement of competitive advantage (Ives & Learmonth, 1984; McFarlan, 1984; Parsons, 1983; Piccoli & Ives, 2005; Porter & Millar, 1985). ISEA’s support of PERFORM further demonstrates that delivering value through IT is an organisation-wide endeavor, requiring IT and business process integration which ultimately sees the creation of business value (Peppard, 2007). Indeed the use of IT in the ESC is not to automate a business function to reduce costs, but instead delivers business value through its support of a business function. Put simply, the research found the answer to the research question, “How does the development and implementation of speech-enabled software influence the injury management business process of an elite sporting club?” is:

**Performance. Performance. Performance.**

ISEA enabled knowledge sharing (Awad & Ghaziri, 2004) necessary for the management of athlete performance. Knowledge sharing through the PPT acting as a community of practice (Wenger, 2004) is critical to PERFORM which has been established to improve team performance. A high performing team means a winning team (Cairns et al., 1986), which results in successful business performance (Stewart et al., 2005). The challenge for the ESC is to achieve this performance across all levels.
7.3 Research Contributions

The thesis makes contributions broadly to theory three ways:

1) spoken language understanding;

2) its application in the development of business spoken language systems; and

3) to elite athlete performance management.

Hence, considering both the technology used in ISEA, and the business process that ISEA supports, this study contributes to knowledge surrounding the influences of spoken language systems on organisational business processes in practice. The contribution of this research is therefore significant to several research knowledge areas:

1) information systems health informatics;

2) software engineering best practice associated with spoken language systems development;

3) sports science relating to elite athlete performance management;

4) information systems; and

5) computer science in the areas of spoken language technology and spoken language understanding.

This thesis assessed whether speech recognition and natural language understanding improvement techniques (discussed in Section 2.3), can be applied to an existing speech-enabled application to improve its performance in an operational business environment. Specifically, this research considered the application of spoken language technology to capture elite athlete injury data in an elite sporting club, which has not been documented in the literature previously. The objective of the research was not to test computer algorithms which purportedly improve speech recognition accuracy, or natural language understanding techniques, but to ascertain whether these technologies can be applied to a real business system.
The research contributions are:

- a conceptual framework proposed in Figure 2.8 (p.), and then refined and described in Section 6.6 Figure 6.1 (p.). The conceptual framework considers the key enablers; inhibitors; and other influences associated with the application of spoken language technology; to capture elite athlete injury data within the business context of an elite sporting club. This has not been documented in the literature previously. Hence, the research adds to the theory of the application of spoken language systems to support elite athlete performance management. The theoretical model defined describes and organises the key concepts and their relationships, providing a basis for ongoing research in this research area;

- there is considerable research on the intricacies of technology components associated with speech recognition and natural language understanding. This research has documented a generic IT architecture model which emerged from the investigation into ISEA, and is described in Section 4.4 Figure 4.5 (p.). The generic IT architecture model contributes significantly to the body of knowledge in relation to the technical design of speech-enabled business systems. The model provides a baseline for future research into speech-enabled systems design;

- speech recognition and natural language HCI can influence business process and lead to unexpected outcomes. Typically, spoken language understanding and spoken language technology research is focused on technology improvements, and not to investigate the use of this technology for business process improvements and/or provide opportunities to improve a business’ strategic positioning. This research identified that the ISEA improved the timeliness of injury data capture and facilitated knowledge sharing at the ESC. This increased the value of the injury information, and resulted in ISEA forming part of the strategic IS solution for the ESC;

- software engineering best practice for speech-enabled systems development is immature and not well described in the literature. Current research literature mainly considers the techniques to validate spoken language dialogues rather than adopting a holistic view of the end-to-end systems development of business systems. Development methods that consider business systems integration with
spoken language and speech recognition as a mode for HCI are not described. An outcome of this research is the speech systems development model (SpeechDM), described in Section 4.5 Figure 4.6 (p.), which was constructed from practice as performed during the development of ISEA. SpeechDM builds on the theory associated with iterative system development methods. I argue, that SpeechDM is a significant contribution to the systems development methods body of knowledge as it has for the first time documented the processes involved in spoken language systems development;

• the term injury and more specifically elite sporting definitions in the literature do not align with practice in the ESC. Hence, this research constructed from both theory and from interviewee data a new definition of elite sport injury. The new definition of injury, for the first time looks beyond the injury itself, and places the definition within a business context of elite athlete performance management. The new elite sport injury definition is described in Section 5.4.2;

• the research identified that injury management alone is not strategic to the ESC. Even though injury management is important to the club, injuries and injury management are not strategic. Of significance is that a new process, PERFORM, described in Section 5.5 Figure 5.1 (p.), emerged from the research focusing on the ongoing performance management of the elite athlete. An unexpected outcome from this research is that the athlete’s performance, and not the injury, is strategic to the ESC and that PERFORM (which includes injury management) leads to a competitive advantage. Further, the research uncovered that the PPT which behaves as a community of practice, is central to the function of PERFORM, and is critical to its support of the strategic directions of the club. The PPT provides the forum for a multi-disciplinary approach for athlete performance management. I argue that PERFORM is a foundation model for the management of elite athlete performance management, which can be tested at other elite sporting organisations. Hence, PERFORM contributes to best practice elite athlete performance management; and

• This research identified that the elementary use of speech recognition packages did not result in satisfactory outcomes for business and in particular the ESC.
Before the development of ISEA, the interviewees’ research data highlighted significant user frustrations with speech recognition. Poor speech recognition still occurred even after many hours of user training of the speech recognition engine. Interviewees attributed this to the complex nature of medical data vocabulary and grammar. Without improvements to speech recognition accuracy, SLT is not considered a feasible technology solution for business applications particularly where data quality is paramount. High quality data is necessary for legal requirements and for analytics. Speech recognition accuracy at a suitable level was therefore a critical success factor for speech-enabled applications.

7.4 SUMMARY OF THIS RESEARCH

The aim of the research was to describe how the business processes of injury management are influenced in an elite sporting club as a result of the introduction of a speech-enabled software application. The research went beyond experiment and isolated components of a system. Rather, the research investigated the end-to-end development, implementation and operation of a complete speech-enabled system; which is in full operation at the ESC; and which provides support to the critical injury management process of the ESC. The research question framed to address this aim is:

“How does the development and implementation of speech-enabled software influence the injury management business processes of an elite sporting club?”

The sub questions associated with this are:

a) What are the components of a speech enabled software application?

b) What are the processes involved in developing a speech enabled software application?

c) How has the speech-enabled application influenced the data capture of injury data?

d) How does the implementation of the speech-enabled software application influence the injury management business process?
These research sub-questions are now discussed to determine how they have been addressed in this study.

**7.4.1 WHAT ARE THE COMPONENTS OF A SPEECH-ENABLED SOFTWARE APPLICATION?**

The objective of this question was to understand the relationship between business outcomes and the technology components of ISEA.

A detailed review of SLT literature was undertaken and the components of the ISEA were analysed with reference to the relevant SLT theory. It was found that ISEA applied the spoken language understanding techniques identified from theory of: restricting language and grammar of spoken language input (Gilbert et al., 2008); a reference semantic frame to find sentence boundaries (Jeong & Lee, 2008, p.2:11; Ostendorf et al., 2008); and signs and markers to identify key words (De Mori et al., 2008). Additionally this research uncovered new techniques which contribute to the theory surrounding spoken language research. The additional techniques identified were: the development of a language template; the inclusion of a user inserted colon marker (De Mori et al., 2008) to identify key words and sentence boundaries (Ostendorf et al., 2008); incorporation of a cleansing function to validate and correct the transcribed spoken language; and generation of a customised language model to improve speech recognition accuracy.

The key components of ISEA were analysed and described in Section 4.3. The components identified included: language modelling; customised language model; speech recognition; cleanse spoken language; natural language parser; database records generation; and domain database of record. From the analysis of these components a new generic IT Architecture model was constructed from theory and practice for speech-enabled applications and is described in Section 4.4. The research has answered the sub-question.
7.4.2 What are the processes involved in developing a speech-enabled software application?

The objective of this question was to understand the processes involved in developing speech enabled applications when applied to business. Specifically, understanding this would provide an insight into whether the method used is important in terms of achieving a successful outcome. Further, if a model could be developed it would be useful for practitioners involved in speech enabled systems development.

Section 4.5 provided an in-depth analysis of the system development processes involved in speech-enabled systems development. A new systems development model, SpeechDM (Figure 4.6) emerged from the research, which is an extension to the iterative/evolutionary systems development lifecycle models, and includes the additional steps required for developing speech-enabled applications. Hence, the processes involved in speech-enabled systems development were analysed and documented, and the sub-question has been addressed.

7.4.3 How has the speech-enabled application influenced the data capture of injury data?

Evaluating ISEA against the business objectives as defined by the ESC, identified that ISEA influences the injury management process from several perspectives. Improvements in speech recognition accuracy as a result of the development of a customised language model lead to general acceptance of spoken language and therefore speech recognition as a feasible HCI mode. Good speech recognition coupled with the ISEA’s post speech recognition error correction, cleanse function, Bestmatch algorithms and data normalisation lead to simplifying the users’ interaction, and made it easier for users to interact with the ISEA spoken language HCI. These influences are described in Section 5.3 and Section 6.5. Hence, the sub-question has been addressed.
7.4.4 How does the implementation of the speech-enabled software application influence the injury management business process?

To address this question, the research commenced with understanding the injury management process currently operating at the ESC. From this analysis the research identified that injury management is one part of an extensive elite athlete performance management business process operating at the club. A new business process, PERFORM (Figure 5.1), emerged from this research and is described in Section 5.5.

From a hermeneutics study of the data emerged several unexpected outcomes, centring on knowledge transfer, knowledge sharing, communities of practice, competitive advantage and strategic information systems. Section 6.5 analysed the influences of ISEA on the injury management process and more importantly PERFORM. Hence, the sub-question has been addressed.

7.5 Methodological contribution

The main methodological contribution from this study emanates from the dual roles of the researcher as a practitioner involved in the development of ISEA and as the researcher of this study, and the influence this has on the research methodology selected for this study. The dual roles of practitioner and researcher occurred over two distinct and separate time periods as follows:

1) **Time period 1 - ISEA development and implementation.**

   Prior to the commencement of this study, the researcher was employed as a practitioner in the SpeechNet ISEA development project team, to “change the existing conditions” (Davison, 1998, p.3-11) within an organisation, but not to develop theoretical knowledge (Mathiassen et al., 2009; Mumford as cited in Trauth, 2001; Baskerville & Wood-Harper, 1998). That is, as a practitioner, the researcher performed similar activities to action researchers (Mathiassen et al., 2009) with the notable exception of the requirement to develop theory, which is a key component of action research (Mathiassen et al., 2009; Mumford as cited in Trauth, 2001; Baskerville & Wood-Harper 1998);
2) **Time period 2 - commencement of this research.**

At the initiation of this study ISEA had been developed, implemented and in operation at the ESC for 18 months. Hence, there were no action research elements (Davison, 1998) associated with the development activities performed during time period 1. Had this study commenced at time period 1, then the opportunity to undertake action research would have arisen.

Of particular interest is that these dual roles influenced the data gathering components of the research. From the ESC’s perspective, the researcher is an “outside observer” (Walsham, 1995, p.77) which is fundamental to evaluating the implemented ISEA and in determining its influence on the injury management business process. Whereas, within the research context of describing the ISEA technology and ISEA development activities, the researcher is an “involved researcher” (Walsham, 1995). Having this insider view provided access to confidential information and other first-order data (Walsham, 1995) which informed the hermeneutics analysis through rich descriptions which assisted in uncovering “hidden meanings” (Hanisch, 2004; Thanasankit & Corbitt, 2002).

**7.6 LIMITATIONS**

From an in-depth description of one case study, the researcher has successfully generalised to theoretical propositions (Creswell, 1998). However, the researcher considers that constraining the study’s scope to an organisational setting of one elite sporting club and for one speech-enabled application is a limitation.

Restricting the research to one case study may not have fully explored the “complex relationship between IS and their social, political and organisational contexts” (Cecez-Kecmanovic, 2001, p.141). The interpretive researcher’s assumption is that access to reality is through social constructions (Myers, 2007). While this study’s social constructions involved a large cross-section of professional staff who participate in injury management, this is from one club’s, and from one sporting association’s perspective, therefore representing one sphere of influence (Hanisch & Corbitt, 2007). Further, interpretive methods in IS are “aimed at producing an understanding of the context of the information system, and the process whereby the information system influences and is influenced by the context” (Walsham, 1993, p.4-5). Limiting the
research scope to one case study context diminishes its value in relation to how the theoretical propositions can be applied generically to speech-enabled applications and elite athlete performance management within and beyond the ESC Association. However, the exploratory single case study can be used as the basis from which multiple-case studies can build theory, test theory and extend theory (Benbasat et al., 1987).

Extending the research scope to investigate several case studies of speech-enabled applications, across different business contexts and therefore across a diverse range of business processes would contribute to further validating and developing the theoretical speech systems development model (SpeechDM) and the generic speech-enabled application IT architecture model. A key finding of the research is that spoken language technology results in timely data capture which increased the value of the data collected. Therefore it is important to understand whether the ESC is an isolated example where spoken language technology has been used in this way, or is this common in practice. Regardless of this, the findings suggest that the timeliness of data can be applied to different business problems and theory needs to be further developed surrounding the key business drivers for applying spoken language technology to business problems. Hence, a cross-case analysis would explore the extent to which the application of spoken language technology in business produces business value rather than cost reductions through productivity improvements.

The PERFORM theoretical model has not been tested and validated outside of the ESC. The researcher views broadening the research scope to include other elite sporting clubs within the Association, and more widely against other elite sporting organisations is necessary to validate PERFORM as a foundation model for elite athlete performance management. The immediacy of data is viewed as an enabler for knowledge sharing which needs to be investigated to determine how other clubs deal with this need currently. A cross-case analysis would provide an in-depth understanding of the influences of knowledge sharing on the business processes associated with fielding a competitive team, and would further validate PERFORM as a foundation model for elite athlete performance management.
7.7 IMPLICATIONS FOR PRACTITIONERS

The research provides significant outcomes for practitioners in the discipline areas of IS, medical, sports science and the professional areas involved in the development of elite athletes. Specifically, the research outcomes can be applied in practice for the business functions of:

1) systems design of speech-enabled business applications;

2) speech-enabled systems development project management; and

3) elite athlete performance management.

The research found that the techniques defined in the literature to improve speech recognition accuracy and natural language understanding can be successfully applied to spoken language systems used for the specific purpose of data capture. Further, adopting an IS perspective when incorporating spoken language technology in the HCI, delivers business outcomes in terms of productivity improvements, and importantly, the timeliness of data capture. An important outcome of this research for practitioners is that the techniques used in ISEA were implemented across many integrated software components, and the design of this application summarised into a generic speech-enabled application IT architecture model. Specifically, the model describes the additional modules required to improve both speech recognition accuracy and the performance of language understanding. The generic IT architecture model highlights to practitioners that business IT solutions which use spoken language in the HCI require a sophisticated technical architecture. The IT architecture model has been constructed as a blueprint for the design of speech-enabled applications, and would be useful for practitioners.

The ISEA project team adopted formal software engineering practices for the development of ISEA, which resulted in the speech systems development model (SpeechDM) emerging from the research. SpeechDM extends the theory surrounding the iterative systems development models, which are widely used by today’s IS practitioners. The research found that speech-enabled applications require additional systems development processes to be undertaken by users and developers to define and review spoken language requirements, and to define and review the natural
language understanding of this spoken language. These processes have not previously been discussed in the literature within the context of a comprehensive speech-enabled systems development model. Hence, SpeechDM which was constructed from practice, provides practitioners a project development framework for planning of speech enabled system development projects.

The research has for the first time constructed a comprehensive model of the business process involved in elite athlete performance management, in this research entitled ‘PERFORM’. This is a foundation model from which practitioners can develop best practice management of elite athlete performance. The practitioner implications of PERFORM extend beyond a set of business functions, to include a community of practice to facilitate knowledge sharing. The link between speech-enabled applications and effective knowledge transfer is important for practitioners to understand; particularly as knowledge sharing is considered a contributing factor to an organisation’s competitive advantage (Awad & Ghaziri, 2004; Ju et al., 2006; Voelpel & Han, 2005). Hence, the ESC’s implementation of the PPT which acts as a community of practice to facilitate knowledge sharing is very relevant for application in business.

7.8 FUTURE RESEARCH

The threat of litigation from players due to poor duty-of-care was raised in ESC and Association documents as a business driver for retaining the information pertaining to athlete injury management. Hence, it would be of interest in future research to determine the influences of the ‘litigation threat’ business driver on the ‘winning team’ business strategy, and on the business process of elite athlete performance management. As evidenced in the research, where training methods could lead to injury, there may result conflict between medical and coaching staff. Trainers and fitness coaches will push players to their maximum to build strength and aerobic fitness. However, doctors and other medical staff attend to player injuries, and where possible, suggest preventative measures to reduce the occurrence of injuries. Future research could consider the processes involved in striking the balance between on one hand, the degree athletes are pushed physically and mentally in pursuit of the ‘winning team’ strategy, and on the other hand consider when is pushing too hard
breaching duty-of-care policies and potentially increasing the risk of injuries and possible subsequent player litigation.

There are many professional staff involved in the injury management business process, each of whom collect various information about the player’s medical condition. Much of this information is formalised in official medical records. Some information collected is considered the intellectual property of specific professional staff members. Hence, the data ownership of medical information involves many stakeholders, each having different rights to the information. Interestingly, at no time during the development of ISEA or during the research, were formal ESC data ownership governance policies raised. However, there was a general understanding by all professional staff to keep medical information very confidential. I argue that data ownership is a potential area of conflict in the future, as more information is collected and as the need for evidence-based assessment (Fowler & Lee, 2007) continues to mature.

Additional information is collected as part of a player medical assessment and includes an assessment of the player’s ability to perform at the elite level. I argue providing access to this information (including the player) is an emerging issue for the ESC. Of particular interest is: what constitutes the medical record? Is it restricted to the Doctor’s notes of the consultation, or is it the electronic record of the consultation as stored in the club’s database of record such as InjuryTracker_DB? The answer to this question is not straightforward, particularly as many staff members can modify electronic records legitimately at any time. Athlete data is enriched with both medical and non-medical data including objective and subjective data. The injury data therefore has moved beyond a medical professional’s notes, for instance a doctor’s personal notes of a consultation, to a corporate repository of athlete information. An issue for the ESC therefore is: to what information should the player have access? That is, should the player have access to all the information pertaining to their medical condition, including subjective and objective assessments, and other additions to this information stored in the corporate repository? In an organisational context this could become difficult to manage, particularly as over time the source of the specific data may not be known. Hence, knowing what
constitutes a correct medical record for a player is often unclear. A point emphasised by the Association:

“We are finding when players threaten legal proceedings against a Club (normally for poor medical advice) that the player, the doctor and the Club have differing documentation as to what transpired and caused the players dissatisfaction. Sometimes the doctor has left the Club, and is unable to assist the Club in defending the claim” (Association documentation, 26 March 2007).

Data ownership in elite sporting organisations is unclear and therefore could result in conflict in the future. As the information needs increase for elite athlete performance management and subsequently shared between medical staff and professional staff, data ownership policies will become increasingly important. Of significance, moving forward for the club are the following questions: ‘what constitutes the statement of record for an athlete’s injury, where is this stored, and who has access to this information?’ This is an important area for future research which needs to be considered from multiple stakeholder perspectives.
REFERENCES


Research & Development, 44(7), 963-974.


APPENDIX A

Research Tools

A. Table of research questions and tools.
B. Interview documents.

A. TABLE OF RESEARCH QUESTIONS AND TOOLS

<table>
<thead>
<tr>
<th>Main Research Question</th>
<th>Content of Sub-questions</th>
<th>Data Collection Method</th>
<th>Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>How does the development and implementation of speech-enabled software influence the injury management business processes of an elite sporting club?</td>
<td></td>
<td>• Interview with software development organization. • Document analysis.</td>
<td>Interview documents and notes. Publicly available government papers and research papers.</td>
</tr>
<tr>
<td>Data capture and speech-enabled technology</td>
<td></td>
<td>• Interview with software development organization. • Document analysis.</td>
<td>Interview documents and notes. Publicly available government papers and research papers.</td>
</tr>
<tr>
<td>Process of current Injury management and how the speech-enabled software supports this process</td>
<td></td>
<td>• Interview with elite sporting club staff. • Document analysis.</td>
<td>Interview documents and notes. Publicly available government papers and research papers.</td>
</tr>
<tr>
<td>IS Competitive advantage</td>
<td></td>
<td>• Interview with elite sporting club staff. • Document analysis.</td>
<td>Interview documents and notes. Publicly available government papers and research papers.</td>
</tr>
<tr>
<td>Policy implications</td>
<td></td>
<td>• Interview with elite sporting club staff. • Document analysis.</td>
<td>Interview documents and notes. Publicly available government papers and research papers.</td>
</tr>
</tbody>
</table>

B. INTERVIEW DOCUMENTS

- Interview with software developer
- Interview with elite sporting club

(See next page)
APPENDIX A

INVESTIGATOR
Mr Brian Hanisch

INTERVIEW WITH SOFTWARE DEVELOPMENT COMPANY

(For investigator use)

Organisation ...........................................................................................................

Interview date .............. Interview time ...............

Participant ....................... Gender ...........

Contact email (if required) .................................................................

Structured Questions

1. Job title:
2. Role in organization:
3. Year of experience in current role
4. Years of experience in software development:
APPENDIX A

Discussion Questions

1. Describe the speech-enabled software that was developed and how it supports the injury management business process.

2. What were the business drivers for the development of the speech-enabled software? Do you consider that the speech-enabled software satisfies the needs of these business drivers?
   a. If so, how?
   b. If not, why not?

3. What are the software components of the speech-enabled software?

4. Describe the software development process used to develop the speech-enabled software. Could this be applied as a general systems development methodology for speech enabled applications?

5. Which components of the software were the most difficult to develop? Explain why?

6. Could the speech-enabled software be adapted to other business and/or application areas?
   a. If so, explain how this could be achieved? Explain which components of the speech-enabled software would need to change.

7. Describe the key challenges when developing the speech-enabled software.

8. In terms of developing speech-enabled software, are there any mandatory steps, tasks, types of participation or any other aspects of the project which are required to ensure a successful project?
   a. If so, describe these.

9. Do you think there are usability issues associated with speech technology?
   a. If yes, how do you think these can be overcome?

10. Has the use of the speech-enabled software resulted in improvements in productivity?
    a. If so, by how much? Do you think this can be improved further? Explain how.

11. What do you see as the advantages of speech technology?

12. Are there any disadvantages of speech technology?
    a. If so, how can they be overcome?

13. How do you think speech-enabled software will evolve? Could this be applied to the current speech-enabled software?

14. Do you see any reasons why workers would not want to use speech technology?
    a. If yes, please elaborate.

Notes
(For investigator use)

Organisation

Interview date

Interview date

Participant

Gender

Contact email (if required)

Structured Questions

1. Job title:
2. Role in organization:
3. Year of experience in current role
4. Years of experience in health care sector:
APPENDIX A

Discussion Questions

1. Why is injury management important to the elite sporting club?
2. What injury management information is important for your business area?
3. Does the current injury management system satisfy these information needs?
   a. If not, describe how it could meet these needs.
4. Describe the injury management business process and key people/groups involved in this process.
5. What were the business drivers for the development of the speech-enabled software? Do you consider that the speech-enabled software satisfies the needs of these business drivers?
   a. If so, how?
   b. If not, why not?
6. Has the speech-enabled software impacted on the injury management business process?
   a. If so, explain how.
7. Do you consider that the speech-enabled application resulted in productivity improvements in the data entry of injury and treatment data? If so;
   a. Has this lead to other opportunities in terms of how this data is used? Would these opportunities result in competitive advantage? Explain why/why not?
   b. By how much? Do you think this can be improved further? Explain how.
8. Do you see any usability issues associated with using speech technologies?
9. Are there areas where the speech-enabled software could be improved?
   a. If so, describe these and rank importance.
10. What enhancements to the speech-enabled software would you consider could improve the efficiency of data entry and interactions with the injury management system?
11. Are there barriers to wide spread adoption of the speech-enabled software within the business?
   a. If so, what are these?
12. If the speech-enabled software was removed would this cause problems?.
   a. If so, describe the problems.
13. Do you think there are perhaps better software alternatives for data entry?
   a. If so, describe these alternatives.
14. Are there any other concerns you would have in using speech technologies for data capture?
   a. If yes, please explain further.

Notes
APPENDIX B

LIST OF PUBLICATIONS
