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# **In Search of Ergonomics Expertise**

by

Claire A. Williams

Doctoral Thesis

Submitted in partial fulfillment of the requirements  
for the award of  
Doctor of Philosophy of Loughborough University

May 2008

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## **Abstract**

In order to achieve the title 'Registered' or 'Certified', ergonomists undergo lengthy training and certification processes to demonstrate their membership of the profession. However, there has been little study to date on what skills, in particular, are required to be expert as an ergonomics advisor. There is some opinion that the 'softer' skills (such as active listening and empathy) which are key to client-advisor relationships do not generally form part of ergonomics taught courses, whereas the 'harder' knowledge content and technical skills do.

Furthermore, in some ergonomics arenas (particularly in the physical domain) other non-ergonomist professionals such as Health and Safety Advisors, Occupational Health Advisors and Physicians, Physiotherapists, Occupational Therapists, and Specialist Furniture Suppliers, also apply ergonomics principles. Rather than the tertiary ergonomics education of the ergonomists, many of these other professionals will undertake short course ergonomics training or learn 'on the job'. This begs the question 'will they all be delivering the same 'product', containing the same message, of the same quality and with the same goals?' In other words, are there qualitative and quantitative differences in ergonomics expertise between ergonomists and others in the field?

These two areas of 'what knowledge, skills and attributes constitute ergonomics expertise' and 'what expertise differences exist between ergonomist and non-ergonomist ergonomics advisors' form the basis of the research reported here.

These broad competence questions matter because ergonomics advisors in the physical domain deal with issues of health and safety. Their performance matters both ethically (Corlett, 2000) and in business terms (Wilson, 2000; Oxenburgh & Marlow, 2005).

An initial focus group study was undertaken from which the knowledge, skills, attributes and other factors (KSAOs) for high-level performance as an ergonomics advisor were derived. This highlighted having practical (not just theoretical) knowledge; taking a holistic/systematic approach; being observant/perceptive and having good communication skills were deemed the important characteristics for high level performance as an ergonomics advisor. A second study used the IEA's ergonomics competencies to ascertain areas of confidence in ergonomics research

and practice amongst ergonomists and others. This study demonstrated that ergonomists were more confident across the breadth of ergonomics competencies than their non-ergonomists colleagues. It also demonstrated that both groups lacked confidence in the making, implementing and evaluation of recommendations.

A more in depth focus group investigation of the knowledge, aims, approach and activities of ergonomists and other professionals using ergonomics was then undertaken. This study underlined differences between ergonomist and non-ergonomist groups but established a breadth of ergonomics understanding across all groups.

Finally, groups of both ergonomists and other professionals participated in an objective study to measure expertise via consistency and discrimination ability when undertaking Upper Limb Disorder (ULD) risk assessment judgements. The Cochran-Weiss-Shanteau (CWS) expertise index was used to determine which professionals behaved most like judgement experts. The response of the participants to the presence of specific risk factors was also analysed. In both sets of analysis, the ergonomists performed more 'expertly' than the other participants, though all groups responded to an increase in risk by increasing their likelihood of ULD ratings. Almost all respondents reacted especially to the presence of psychosocial risk factors.

Overall, these findings support the view that even short course training can provide a broad understanding of physical ergonomics issues, allowing for the identification of risk factors in workplace scenarios, however, this is not sufficient to allow for consistency in risk assessment judgements. The lack of confidence reported by all groups in making, implementing and evaluating recommendations, as well as the importance of softer skills such as communication and perception are important considerations for the future design of all ergonomics training.

Whilst differences have been demonstrated between ergonomists and other professionals, further work is required to determine who is best placed to carry out the various tasks which make up ergonomics advising.



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## **Publications**

Aspects of the work presented in this thesis have been published or accepted for publication in the following peer-reviewed journals and conference proceedings.

### **Journal Papers**

Williams, C., Haslam, R. & Weiss, D. (2008) The Cochran-Weiss-Shanteau Performance Index as an indicator of Upper Limb Disorder Risk Assessment Expertise, *Ergonomics* 51:8, 1219 -1237

### **Conference Papers**

Williams, C. & Haslam, R. (2006). *Ergonomics advisors - a homogeneous group?* In: Contemporary Ergonomics 2006, (Edited by P.D.Bust), Taylor & Francis: Great Britain, The Ergonomics Society Annual Conference 2006, Cambridge, UK, pp. 117-121.

Williams, C. & Haslam, R. (2006). *Ergonomics by non-Ergonomists – danger, threat or opportunity?* In: Proceedings of IEA2006 Congress, Pikaar, R.N., Koningsveld, E.A.P. & Settels, P.J.M. (eds), Elsevier, International Ergonomics Association Triennial Congress, Maastricht, The Netherlands, 2006, ISSN: 0003 6870, [CD-ROM].

Williams, C. & Haslam, R. (2006). *Core Competences in Ergonomics – Do we have them?* In: Proceedings of IEA2006 Congress, Pikaar, R.N., Koningsveld, E.A.P. & Settels, P.J.M. (eds), Elsevier, International Ergonomics Association Triennial Congress, Maastricht, The Netherlands, 2006, ISSN: 0003 6870, [CD-ROM].

## **Abbreviations used in this thesis**

CWS	Cochran-Weiss-Shanteau Index
EOP	Ergonomically oriented professional
FS	Furniture supplier
HAS	Health and Safety Advisor
HSE	Health and Safety Executive
IEA	International Ergonomics Association
MSD	Musculoskeletal Disorder
NIOSH	National Institute for Occupational Safety and Health
OCRA	Occupational Repetitive Actions
OHA	Occupational Health Advisor
Physio	Physiotherapist
PRE	Professionally recognised ergonomist
QEC	Quick Exposure Checklist
RULA	Rapid Upper Limb Assessment
TUC	Trades Union Congress
ULD	Upper limb disorder
WAC	Washington State Ergonomics Rule

# Chapter 1 - Introduction

## 1.1 Problem Statement

The International Ergonomics Association (IEA) explains that 'Ergonomists contribute to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people' (IEA, 2008a). Ergonomists will engage in a number of activities to make this contribution and the UK's Ergonomics Society lists these potential activities under 'areas of competence' on its website. For example, the list includes 'training for management and staff'; 'expert witness work'; 'design and layout of displays and controls'; 'design of control rooms'; and 'risk assessment' (Ergonomics Society, 2008a). Likewise, the Board of Certification in Professional Ergonomics in North America (BCPE) outlines the different activities in which ergonomics professionals may engage in its 'scope of practice'. These include activities such as workstation analysis; walkthrough surveys; task analysis and statistical techniques (BCPE, 2004).

To support these activities, the IEA and other bodies outline competencies (made up from various knowledge, skills and abilities) which are deemed 'core' for ergonomists to have (IEA, 2001). However, there is some opinion that some of the knowledge, skills and abilities which lead to successful performance as an ergonomics advisor, and which are considered 'core competencies' by the IEA (IEA, 2001), are not necessarily taught on ergonomics programmes (Kirwan, 2000; Whysall et al., 2004; Shorrock & Murphy, 2005; Shorrock & Murphy, 2007). For example, the 'softer' skills (such as active listening and empathy) which are key to client-advisor relationships do not generally form part of ergonomics taught courses. How necessary a part of ergonomics expertise these skills are has not been the focus of much research to date.

The situation is further complicated by the fact that in some ergonomics arenas, particularly in the physical domain, professionally recognised ergonomists or PREs, (Karwowski, 2000) are not the sole applicers of ergonomics principles. In the UK, professions applying ergonomics principles to address musculoskeletal disorders will certainly include ergonomists, but will also include Health and Safety Advisors, Occupational Health Advisors and Physicians, Physiotherapists, Occupational Therapists, and Specialist Furniture Suppliers. These individuals, labelled

'ergonomically-oriented professionals' or EOPs (Karwowski, 2000) may work from within an organisation, or alternatively they may be called in from outside the organisation, in a consultancy type of role.

In a broad sense, these different professionals could be considered 'ergonomics advisors' if an ergonomics advisor is anyone who is called on to give advice and information pertaining to ergonomics. Rather than the tertiary education of the 'Registered' or 'Certified' ergonomists (BCPE, 2004; Ergonomics Society, 2008c), many of these other professionals will undertake only short course ergonomics training or learn 'on the job'.

The existence of both ergonomist and non-ergonomist 'ergonomics advisors' begs the question, 'will they all be delivering sound advice, containing the same message, of the same quality and with the same goals?' In other words, are there qualitative and quantitative differences in expertise between ergonomists and other ergonomics advisors? Some authors believe there are differences and that these matter (Karwowski, 2000; Macdonald, 2006) whilst others feel this 'protectionism' should have no part in the professional development of ergonomics (Ahasan & Imbeau, 2003).

These two areas of 'what constitutes ergonomics expertise' and 'what differences exist between ergonomist and non-ergonomist ergonomics advisors', form the basis of the studies reported here. This thesis details the research undertaken to examine the characteristics of 'high-level' performers (experts) amongst ergonomics advisors and identify any differences between what MacDonald (2006) describes as non-ergonomists 'doing ergonomics' and 'the work of professional ergonomists'.

These broad competence questions matter because ergonomics advisors in the physical domain deal with issues of health and safety. Their performance matters both ethically (Corlett, 2000) and in business terms (Wilson, 2000; Oxenburgh & Marlow, 2005).

## **1.2 Personal Background**

I have been working as an Ergonomics Consultant since 1996, providing advice to industry about how to manage Musculoskeletal Disorder (MSD) risk. Over the course of these 12 years, I have begun to question my own expertise, and that of colleagues more and less qualified than I. Issues around whether ergonomics interventions

work; why they work; what it takes to make them work and who is capable of being successful, have become important to me.

My questions became paramount in 2003, when I was promoted to Head of Ergonomics in an established occupational health consultancy. At this time I became responsible for assuring the quality of mine and other's work, and for facilitating the professional development of my ergonomics colleagues. It is against this back-drop, that I came to the research described in this thesis.

### **1.3 Research Aims**

This research aimed to further current understanding of what it means to be 'expert' as an ergonomics advisor and to highlight any differences between EOPs and PREs engaged in ergonomics practice. Specifically, the objectives were to:

- Identify the characteristics which ergonomists cite as important for high-level performance in their domain.
- Examine the extent to which the IEA's ergonomics competencies are held by ergonomics advisors.
- Determine any differences between EOPs and PREs, highlighted by the IEA's competency listing.
- Ascertain the breadth of ergonomics knowledge and activities which characterise PRE and EOP, physical (musculoskeletal) ergonomics advisors.
- Identify any differences in judgement expertise between PRE and EOP physical (musculoskeletal) ergonomics advisors, on one specific task.

### **1.4 Potential Benefits**

It is posited that furthering current understanding of what it means to be 'expert' and what differences exist between Ergonomists and others in ergonomics practice should provide useful information for:

- the content and methods of ergonomics training
- assessing the usefulness and application of the IEA's competency listing
- determining the potential activities and roles for ergonomists and non-ergonomists

### **1.5 The Research Paradigm**

'An old story tells about three baseball umpires bragging about their abilities.

The first one says "I call 'em as I see 'em!"

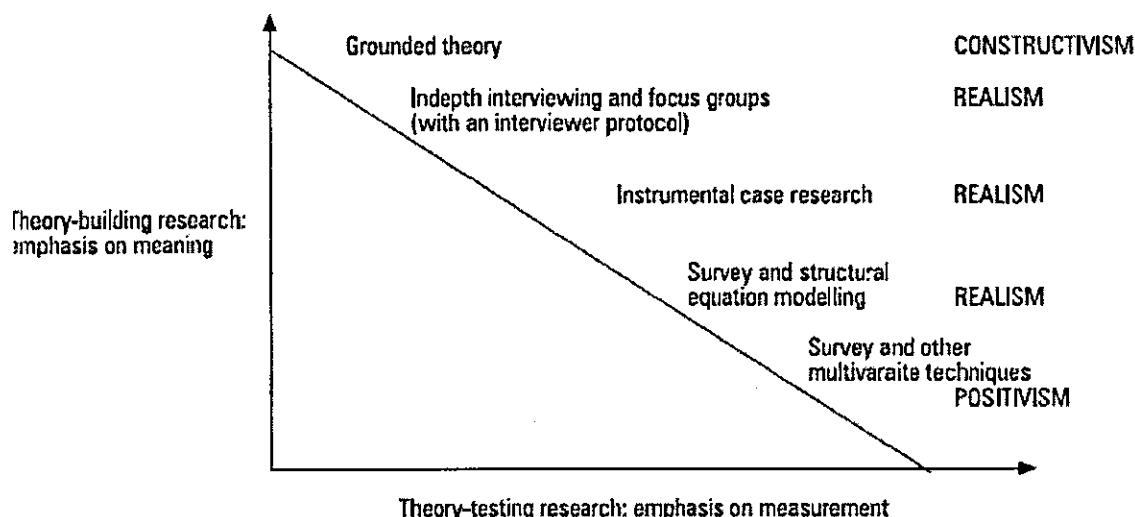
The second one says "Well, I call 'em as they *are!*"  
 And the third one says "Shoot, they ain't *anything* till I call 'em!"  
 The first is a critical realist, the second a direct realist, and the third is a subjective idealist.'

(Boeree, 1999)

Critical Realism is the basis on which the scientific investigation of this PhD has been constructed (Bhaskar, 1978). The ‘basic belief system’ (Guba and Lincoln, 1994) that has guided the work is that there is a reality to be observed which is ‘real but fallible’ (Krauss, 2005). In other words, it is maintained that there exists an objectively knowable reality, whilst acknowledging the important impacts of perception and cognition on that reality.

### 1.5.1 Mixed methods research strategy

Mixed methods research has been defined as ‘the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study’ (Johnson and Onwuegbuzie, 2004). The mixed methods approach of both qualitative and quantitative enquiry is commensurate with the critical realism philosophical standpoint (Healy and Perry, 2000) as represented in Figure 1.1 below.



**Figure 1.1: A representative range of methodologies and their related paradigms** (Healy and Perry, 2000)

## **1.6 Ethical Issues**

This research complied with the requirements outlined by the Loughborough University Ethical Advisory Committee. The Committee's Ethical Clearance Checklist was completed for each study. All participants gave informed consent before taking part.

## **1.7 Structure of this Thesis**

This thesis is made up from 8 chapters, which are briefly summarised below. The rationale for the studies and the progression from one to the next is presented in Table 1.1.

Chapter 1 (this introduction) outlines the problem statement and aims for this work, the research paradigm used and the nature of this thesis.

Chapter 2 is a review of the literature concerning the study of expertise generally and more specifically the investigation of expertise amongst those involved with ergonomics. The terms 'expert' and 'expertise' are explored along with the related concepts of 'competence' and 'competencies'. The relationship between expertise, competence and competencies is then examined, before reviewing the literature covering all of these areas specifically in relation to ergonomics advisors.

Chapter 3 presents a focus group study which garnered the opinions of a number of experienced ergonomists about what characteristics make for a good (as opposed to a bad) professional in their field, and if any further characteristics define what it is to be expert.

Chapter 4 reports the results and findings of an international questionnaire study, which used the IEA's core ergonomics competencies as a basis to identify areas of practice in which ergonomics advisors felt high or low confidence.

Chapter 5 outlines a further focus group study with PRE and EOP ergonomics advisors working in the physical (musculoskeletal) domain. Similarities and differences in their ergonomics knowledge and activities are examined and the potential implications are discussed.



Chapter 6 presents an empirical assessment of judgement expertise, where written scenarios describing workplaces were used to elicit judgements from participants regarding the likelihood of staff complaining of Upper Limb Disorders. The Cochran Weiss Shanteau Expertise Index (Weiss & Shanteau, 2003) combines two important attributes of expert judgements (consistency and discrimination) into one value, as a way of differentiating between more and less 'expert' judgements.

Chapter 7 examines the data from the Chapter 6 in more detail, looking not just at the consistency and discrimination of the judgements made, but at the nature of the cues which elicited the judgements.

Chapter 8 reviews and synthesises the findings from all of the other chapters and outlines the conclusions which can be drawn. A discussion regarding the limitations of the work contained in this thesis along with the contribution that the research makes to existing knowledge and suggestions for future research also form part of this chapter.

**Table 1.1 : Rationale behind the studies and their progression**

	Study design	Specific study aims	Findings which led to the next study
<b>Part 1 – studies with ergonomics advisors from any ergonomics discipline and any country</b>	<b>Study 1 (Chapter 3)</b> Focus Group study with ergonomists to garner their views on ergonomics expertise.	Identify the characteristics which ergonomists cite as important for high-level performance in their domain.	Generated a list of knowledge, skills attributes and other factors (KSAOs) for ergonomics advisors. These form the building blocks of competencies and could be used to generate a list of competencies. As a list of competencies already exists ( the IEA's), the next study will further examine expertise by ascertaining which of the IEA competencies Ergonomists have.  The view from this first study (that ergonomists are different from non-ergonomists working in the domain) meant that both these types of ergonomics advisor would be invited to participate in the next study. Further, the differences between academics and consultants brought out by this first study will also be further explored in the next.
	<b>Study 2 (Chapter 4)</b> Questionnaire study with ergonomists and other professionals rating their confidence in the IEA ergonomics competencies.	Examine the extent to which the IEA's ergonomics competencies are held by ergonomist and non-ergonomist ergonomics advisors.  Determine any differences between Ergonomists and non-ergonomists highlighted by the IEA's competency listing.	This study demonstrated quantitative, self-report differences in core competencies, between ergonomists and a range of other professionals who engage in ergonomics. It also demonstrated a confidence difference between ergonomists from different countries. Both this and the study reported in Chapter 3 garnered opinion from Ergonomics advisors from any specialism. The next two studies (Part 2) will build on the findings from these first two, but will sample participants from one location (the UK), and one specialism (physical (musculoskeletal) ergonomics) to reduce the variables.  The next study (Chapter 5) will investigate further the differences between ergonomists and other professionals engaged in ergonomics (demonstrated in this study), using focus groups to look for some of the KSAOs identified in Chapter 3 by examining participants' ergonomics knowledge, aims, approaches and activities.

Study design	Specific study aims	Findings which led to the next study
<b>Study 3 (Chapter 5)</b> Focus group study with ergonomist and non-ergonomist physical, ergonomics advisors.	Ascertain the breadth of ergonomics knowledge and activities which characterise PRE and EOP, physical (musculoskeletal) ergonomics advisors.	<p>In each of the areas examined in this study (knowledge, approach, aims and activities) the ergonomists were more comprehensive than the other groups. One definer of an expert is having 'adequate domain knowledge' (Shanteau, 1992) and though the ergonomists had more, this study alone does not answer for their knowledge adequacy, nor does it determine inadequacy amongst the other professions (who covered fewer but none-the-less the majority of the themes). If the number of activities undertaken can be seen as a proxy for the number of skills attained, then the Ergonomists also behaved more like experts by that measure. However, their performance ability in any of the activities was not tested.</p> <p>Having demonstrated some subjectively reported expertise, an objective measure of performance is required to test the findings. The results from this study therefore informed the development of the next, which undertakes objectively to measure the performance of some of these different professional groups in one specific ergonomics activity. The fact that all of the groups attested to carrying out industrial assessments sanctioned the development of industrially based scenarios about which judgements could be made. This study will be the subject of Chapter 6.</p>
<b>Studies 4 and 5 (Chapters 6 and 7)</b> Quantitative, objective measure of judgement expertise using the CWS expertise index with ergonomist and non-ergonomists.	Identify any differences in judgement expertise between PRE and EOP physical (musculoskeletal) ergonomics advisors, on one specific task.	<p>In the 4th study, the combination of judgement consistency and discrimination into one index affords the conclusion that ergonomists are quantifiably different from other ergonomics advisors in their judgement performance in the specific context of ULDs. In this study higher CWS was linked with higher ergonomics training level, but not with longer experience in Occupational Health and Safety.</p> <p>The 5th study (Chapter 7) uses the same data to see whether participants increased their judgement of likelihood of staff complaining of a ULD in line with the increase in risk factors.</p>

A summary diagram outlining the thesis structure can be found below (Fig 1.2). This diagram will be used at the start of each chapter with the relevant chapter highlighted.

### **Chapter 1 – Introduction**

- Problem statement
- Research aims
- Research Paradigm
- Thesis Structure

### **Chapter 2 - Literature review**

- Establishing the nature of expertise and how it is identified and measured
- Establishing the nature, extent and findings of previous work examining expertise amongst ergonomics and allied professionals

### **Chapter 3 – What characterises good and expert Ergonomics Advisors?**

- 3 Focus groups (n = 26) with Ergonomists
- Model building of features of good and expert ergonomics practice

### **Chapter 4 – The self reported competencies of Ergonomics Advisors**

- 217 competency questionnaires from 6 national ergonomics conferences
- Establishment of areas of high and low confidence across the breadth of IEA ergonomics competencies.
- Relationship of competence and expertise

### **Chapter 5 – The Knowledge and Activities of Ergonomics Advisors**

- 8 Focus groups (n = 55) with Ergonomists and other professional groups engaged in ergonomics advising
- Template analysis and model building of ergonomics expertise from knowledge and activities differences

### **Chapter 6 – The decision making expertise of Ergonomics Advisors - part 1**

- ULD risk assessment task undertaken by 58 PREs and EOPs and a control group of 148 students
- Establishment of comparative expert performance using the CWS index of expertise

### **Chapter 7 – The decision making expertise of Ergonomics Advisors - part 2**

- Investigation of the content of risk assessment decisions
- Relationship of decision content and expertise

### **Chapter 8 – Discussions, Implications and Conclusion**

- Discussions and implications of findings from all studies
- Limitations
- Recommendations for further research
- Conclusion

**Figure 1.2: Thesis Summary Diagram**

### **Chapter 1 – Introduction**

- Problem statement
- Research aims
- Research Paradigm
- Thesis Structure

### **Chapter 2 - Literature review**

- Establishing the nature of expertise and how it is identified and measured
- Establishing the nature, extent and findings of previous work examining expertise amongst ergonomics and allied professionals

### **Chapter 3 – What characterises good and expert Ergonomics Advisors?**

- 3 Focus groups (n = 26) with Ergonomists
- Model building of features of good and expert ergonomics practice

### **Chapter 4 + The self reported competencies of Ergonomics Advisors**

- 217 competency questionnaires from 6 national ergonomics conferences
- Establishment of areas of high and low confidence across the breadth of IEA ergonomics competencies.
- Relationship of competence and expertise

### **Chapter 5 – The Knowledge and Activities Ergonomics Advisors**

- 8 Focus groups (n = 55) with Ergonomists and other professional groups engaged in ergonomics advising
- Template analysis and model building of ergonomics expertise from knowledge and activities differences

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- Investigation of the content of risk assessment decisions
- Relationship of decision content and expertise

### **Chapter 8 – Discussions, Implications and Conclusion**

- Discussions and implications of findings from all studies
- Limitations
- Recommendations for further research
- Conclusion

## **Chapter 2 – Literature Review**

### **2.1 Introduction**

This chapter provides a review of the published literature concerning the study of expertise generally and more specifically the investigation of expertise amongst those involved with ergonomics. The terms expert and expertise are explored along with the related concepts of competence and competencies. The relationship between expertise, competence and competencies is then examined before reviewing the literature covering all of these areas specifically in relation to ergonomics advisors.

#### **2.1.1 Search strategy, search terms and search criteria**

The objective of the search strategy was to identify relevant literature from the field of expertise, as well as more specifically the literature from the ergonomics field pertaining to expertise. The 5 questions being addressed by the literature review were:

1. What is an expert?
2. What are the characteristics of experts?
3. How might expertise be identified?
4. How does expertise relate to competence?
5. What literature is there pertaining to expertise and competence amongst ergonomics advisors?

The initial search to answer the first 4 of these questions was undertaken in the Loughborough University on-line Library Catalogue, using the title search term 'expertise'. References from the catalogue were excluded if they were only about one, specific, non-ergonomics type of expertise (e.g. sports or music expertise) but were included if they covered expertise in general.

Further searches were then undertaken in the on-line Library Catalogue using the title terms 'expert' and 'competence assessment'. References were excluded under 'expert' if they were concerned solely with one area (as above) or if they dealt exclusively with expert systems. Competence Assessment references were also excluded if they dealt only with one specific, non-ergonomics profession.

Having identified key authors and references in the expertise and competence assessment fields from these search strategies, further works by key authors were also then sought out, along with references from the bibliography of these main references.

### **Database searches**

In order to look at the specific field of ergonomics expertise (Question 5 in the search strategy), the *Ergonomics Abstracts* database was searched using the following search terms:

- 'expert' NOT 'system' AND 'ergonomic' (with stemming)
- novice AND 'ergonomic' (with stemming)
- practitioner AND ergonomic (with stemming)
- 'ergonomist'
- 'ergonomists'

Articles were only included from peer reviewed publications where some form of experimental study had been undertaken to examine expertise amongst ergonomics advisors. Articles which were opinion pieces or where qualification criteria were discussed were excluded from this part of the literature review (reported in section 2.7). These were used in other parts of the literature review, however, alongside that from the University Catalogue search.

## **2.2 Experts**

This section reviews the various definitions of 'expert' in the literature and outlines how the term has been understood over time. The focus then moves to outlining the characteristics that have been linked with experts in order to develop the definitions presented.

### **2.2.1 What is an expert?**

As long ago as Plato, individuals with exceptional knowledge in a specific domain were known as experts, and given status beyond those without that knowledge:

"I observe that when a decision has to be taken at the state assembly about some matter of building, they send for the builders to give their advice about the buildings, and when it concerns shipbuilding they send for the shipwrights.....but if anyone else tries to give advice, whom they



don't regard as an expert, no matter how handsome or wealthy or well-born he is, they....jeer at him and create an uproar..." (Plato, 1991, pp 11-12, cited in Ericsson, 2006a)

More recently, in her concept analysis of the term expert, Jasper (1994) summarised a number of dictionary definitions as follows (Table 2.1):

**Table 2.1: Summary of dictionary definitions of expert**

- 
1. A person who has skill and/or knowledge, gained by experience
  2. One whose special knowledge or skill cause him to be regarded as an authority
  3. One skilled in the study of handwriting (expert witness)
  4. Destitute or devoid of, free from (Obsolete usage)
  5. Proved or approved by test
  6. Highest classification given to a member of the military for skill in the use of arms
- 

**Sources:** Oxford English Dictionary (1961), Webster's International Dictionary (1963), Cassell's Compact Dictionary (1963), Collin's Concise Dictionary (1988), Roget's Thesaurus (1962)

From these definitions a number of attributes of experts are made manifest. These include; the attainment of a high level of performance; having skills and knowledge, gained from experience; being a reliable authority; and having status. 'Expert', as a proper noun, denotes an individual at the top of his or her field. Ericsson (2006a), a highly regarded researcher in the expertise field, cites the wikipedia definition by way of summary:

'an expert is "someone widely recognized as a reliable source of knowledge, technique or skill whose judgement is accorded authority and status by the public or his or her peers. Experts have prolonged or intense experience through practice and education in a particular field"

(Wikipedia (2005) cited by Ericsson (2006a) page 3)

Having defined the term 'expert', the following section outlines the characteristics of experts associated with these definitions.

### **2.2.2 Characteristics of experts**

There are numerous catalogues of the features of experts in the literature (for example Chi et al, 1988; Stevenson 1998; Alexander, 2003; Dunphy 2004). Many of

these features have been identified by research in the psychology domain. One such list is presented by Chi et al (1988) in their comprehensive text, *'The nature of expertise'* (Table 2.2).

**Table 2.2 : Characteristics of Experts Chi et al (1998)**

- 
1. Experts excel mainly in their own domains
  2. Experts perceive large meaningful patterns in their domain
  3. Experts are fast
  4. Experts have superior short-term and long-term memory
  5. Experts see and represent a problem in their domain at a deeper level than novices
  6. Experts spend a great deal of time analyzing a problem qualitatively
  7. Experts have strong self monitoring skills
- 

This list builds on the characteristics of experts from the definitions presented in section 2.2.1 (the attainment of a high level of performance; having skills and knowledge, gained from experience; being a reliable authority; and having status). It proposes that the high performance level referred to in the definitions is, in addition, domain-specific and results from superior memory, superior pattern recognition and superior qualitative analysis. It also introduces a more 'behavioural' characteristic of experts, namely their ability to and proclivity to self-monitor.

Abdolmohammadi and Shanteau (1992) expand the list of 'behavioural' characteristics of decision making experts to include amongst others; the ability to communicate; self-confidence; creativity and the ability to handle adversity (see table 2.3 for a full list). All of these features emerged originally from observations made by Shanteau (1987) over the course of several studies of experts in different domains. They then grouped the characteristics into 3 categories: 'cognitive'; 'presentation' (or 'style') and 'strategic'.

The cognitive or 'thinking' characteristics included 'current knowledge', 'knows what's relevant' and 'experience'. The 'presentation' or 'style' characteristics included 'assumes responsibility', 'self-confidence' and 'communication'. The 'strategic' characteristics included 'creativity', 'problem simplification' and 'makes exceptions'.

**Table 2.3: Attributes of expert decision makers (from Abdolmohammadi and Shanteau (1992))**

Attribute	Description
Adaptability	Experts adjust their decision-making strategies to fit the current situation. They are responsive to changes in conditions of the on-going problem situation.
Assumes responsibility	Experts accept responsibility for the outcomes of decisions, successful or unsuccessful. They are willing to stand behind their decisions.
Creativity	Experts can find novel or unique solutions to difficult problems. They are capable of generating new approaches to established problems as necessary.
Communicates expertise	Experts can convince others that they have specialized knowledge. They can effectively communicate their ability to make decisions to others.
Current knowledge	Experts have an extensive knowledge base. They make a special effort to keep up with the current facts, trends and developments.
Experience	Experts use past experience to make decisions more or less automatically. Their background and experience produces decisions without obvious effort.
Knows what is relevant	Experts, based on experience, can readily distinguish relevant from irrelevant information in a problem. They use only what is relevant; they ignore what is not.
Makes exceptions	Experts know when to follow established decision strategies and when not to. They do not have just one way to solve problems.
Perceptive	Experts are able to extract information from a problem that others cannot see. Their decision making ability is enhanced by insightful recognition and evaluation of confusing situations.
Problem selectivity	Experts use foresight and planning in selecting which problems to work on and which problems not to work on. They tackle those problems that they can effectively handle or resolve.
Simplification	Experts know how to use a divide-and-conquer approach with complex problems. They work on parts to get a better understanding of a complex problem.
Self confidence	Experts have a strong belief in their ability to make good decisions. They are calm and self-assured while making decisions.
Stress tolerance	Experts are able to make decisions under high stress situations. They continue to be effective problem solvers even as conditions effectively worsen because of high levels of pressure.

When the list in Table 2.3 was presented to groups of auditors for their view on the relative importance of each attribute, Abdolmohammadi and Shanteau found that the cognitive traits (what an expert knows and how he/she thinks) were deemed the most important. The presentation (or outward image) traits and the strategic traits were of lesser importance (Abdolmohammadi and Shanteau, 1992).

The lists of expert characteristics presented above (Chi et al, 1998; Abdolmohammadi and Shanteau, 1992) add to the picture of an expert painted by the definitions. In addition to the attainment of a high level of performance; having skills and knowledge, gained from experience; being a reliable authority; and having status, further positive attributes such as being fast at problem solving; using pattern recognition skills and being creative have resulted from the psychological studies of experts.

However, this characteristic 'excellence' has often been unsupported by the Judgement and Decision Making (J/DM) literature. The poor performance of experts in this body of literature will be the subject of the next sub-section.

### **2.2.3 Experts and poor performance**

Although the cognitive scientists have recognised different and superior characteristics in experts (as outlined in tables 2.2 and 2.3), the decisions these experts have made, have not always stood up to the scrutiny of the J/DM researchers. Whilst traits such as confidence, speed and pattern recognition have been viewed as strengths by some (Chi et al, 1998; Abdolmohammadi and Shanteau, 1992) they have been deemed weaknesses by others.

Experts have been criticised as being overly confident; missing important detail by focussing too quickly on the main features of a problem; being inflexible and even inaccurate (Chi, 2006a). Shanteau (1988) gives an overview of the J/DM literature, which in summary has found expert judgements wanting, in that they have:

- lacked validity
- lacked reliability
- been deficiently calibrated
- used limited information

- used simplistic models
- relied on heuristics
- been prone to bias

Some authors (Spiro et al, 1996) propose that these shortcomings may be a function of the expert's 'world view'; the intense structuring of problems which characterises the traditional expert and which lowers the cognitive load required of them, in fact leads to an over-simplification of a problem which cannot take into account important deviant information. They describe experts of this type as belonging to 'World One' which is characterised by inflexibility. They propose there is another type of expert, belonging to 'World Two' who is characterised by cognitive flexibility. These experts do not over-simplify complex problems because they have more than one mental model from which to analyse, and furthermore they are capable of processing outside of their mental models, thereby being able to deal with deviant information. Therefore, these authors would suggest that the poor performance described above emanates from the individual experts not being the right 'type'.

By contrast, Shanteau (1992) proposes that this apparent incompetence is in fact a function of the task characteristics of the domains being studied, rather than a failure of the experts themselves. He explains that, except for nurses, physicians and auditors (where both good and poor expert performance has been reported), the literature for the level of performance exhibited by experts in a given domain is either good or poor. These domains are listed in Table 2.4 below.

He goes on to explain that the reason behind this split is in part because of the task characteristics associated with the domains of the experts:

*"domains with competent performance involve static objects or things (Shanteau, 1987). That is, the experts are being asked to evaluate and make decisions about stimuli that are relatively constant; consequently, judges are faced with a stationary target. Where poor performance is observed, the stimuli are dynamic and generally involve human behaviour. Because experts are being asked to evaluate and decide about what is effectively a moving target, they do less well."*  
(Shanteau, 1992)

**Table 2.4: Domains in which good and poor expert performance has been observed**

<b>Good Performance</b>	<b>Poor Performance</b>
Weather forecasters	Clinical psychologists
Livestock judges	Psychiatrists
Astronomers	Astrologers
Test pilots	Student admissions
Soil judges	Court judges
Chess masters	Behavioural researchers
Physicists	Counsellors
Mathematicians	Personnel selectors
Accountants	Parole officers
Grain Inspectors	Polygraph (lie detector) judges
Photo interpreters	Intelligence analysts
Insurance analysts	Stock brokers
Nurses	Nurses
Physicians	Physicians
Auditors	Auditors

(Shanteau, 1992)

He expands on this with an explanation of the characteristics of tasks which make for good and poor performance (Table 2.5). His conclusion is that expert performance is dependent not only on the attributes of the expert, but also on having the type of task domain in which it is possible to perform expertly. Spiro et al (1996) would argue that a cognitively flexible expert would perform expertly even where the domain characteristics predicated against it.

**Table 2.5: Task characteristics associated with good and poor performance in experts**

<b>Good Performance</b>	<b>Poor Performance</b>
Static stimuli	Dynamic (changeable) stimuli
Decisions about things	Decisions about behaviour
Experts agree on stimuli	Experts disagree on stimuli
More predictable problems	Less predictable problems
Some errors expected	Few errors expected
Repetitive tasks	Unique tasks
Feedback available	Feedback unavailable
Objective analysis available	Subjective analysis only
Problem decomposable	Problem not decomposable
Decision aids common	Decision aids rare

(Shanteau, 1992)

## 2.2.4 Section summary

This section began with a presentation of dictionary definitions of 'expert' which linked the term with the attainment of a high level of performance; having skills and knowledge, gained from experience; being a reliable authority; and having status.

Further characteristics of experts were proposed by the summary list from Chi et al. (1988) outlining that expertise is domain-specific and results from superior memory, pattern recognition and qualitative analysis. The 'behavioural' characteristics of experts were introduced by the Chi et al. list, and expanded on by the work of Shanteau (1987 & 1988) and Abdolmohammadi and Shanteau (1992), to include cognitive, presentation and strategy traits. All of the characteristics presented underlined the superior performance of experts.

By contrast, the occurrence of poor performance by experts reported in the J/DM literature was explained by Shanteau (1992) as being a function of the task domain; where the domain was complex and dynamic it was impossible for experts to behave consistently. The same situation was explained with recourse to Spiro et

al's (1996) model of the cognitively flexible and inflexible expert; the latter performing poorly in dynamic, complex environments but the former being capable of dealing with the uncertainty. Rather than requiring the right type of task, their model proposes expert performance required the right type of expert for the task.

In conclusion, this section can be summarised by Shanteau's (1992) 'Theory of expert competence', which is made up from five components summarised as follows:

- a sufficient knowledge of the domain
- the psychological traits associated with experts
- the cognitive skills necessary to make tough decisions
- the ability to use appropriate decision strategies
- a task with suitable characteristics

## **2.3 Identifying expertise**

Expertise 'refers to the characteristics, skills, and knowledge that distinguish experts from novices and less experienced people' (Ericsson, 2006a). Section 2.2 above ended with a discussion about the need for a suitable domain in which experts can behave 'expertly' and listed four other characteristics of experts, namely:

- a sufficient knowledge of the domain
- the psychological traits associated with experts
- the cognitive skills necessary to make tough decisions
- the ability to use appropriate decision strategies

The process of identifying these characteristics has meant that expertise has been a focus for various disciplines for over a century. Some of the methods used for identifying the expert traits were mentioned in passing in section 2.2. The purpose of this section is to expand on the ways these characteristics have been identified, so as to understand their provenance and review the various methods used in the literature for investigating expertise.

The section will be divided into several sub-sections; the first four (2.3.1- 2.3.4) will deal with each of the four expert characteristics in turn, examining how a picture of expert behaviour has been built up over time by discussing some exemplar studies.



This is not an exhaustive review of the enormous field of expertise investigation. The subsequent part (2.3.5) summarises the various methods used in the study of expertise. The final sub-section (2.3.6) will expand on how experts have been selected to take part in these studies. This has generated other ways of identifying experts in addition to looking for the four characteristics outlined in 2.3.1 - 2.3.4.

### **2.3.1 A sufficient knowledge of the domain**

Experts have a more extensive knowledge than novices in their particular domain. This was observed by Plato (see section 2.2.1) and has been demonstrated by knowledge tests of, for example, physicians (Johnson et al, 1981) and taxi drivers (Chase, 1983). In both of these examples, when experts were given familiar tasks (presenting the possible variants of disease diagnoses for the medics, and generating variant routes between two places for the taxi drivers) both expert groups generated far more variants than their novice colleagues; demonstrating their more extensive domain knowledge. This expert level of domain knowledge is thought to take in the order of ten years to acquire (Hoffman et al, 1995) and it has been proposed to contain between 10,000 and 100,000 'bits' of knowledge when compared with a novice's 1000 (Chase & Simon, 1973 a and b) .

In addition to knowledge tests elucidating a broad knowledge base, other investigations have used sorting tasks to demonstrate that experts' knowledge is not only wider ranging but is also represented differently from novices'. For example, Chi et al (1981) asked physics experts and novices to sort physics problems into categories, using any category headings they chose. The experts sorted the problems according to the Principles of mechanics, whereas the novices used concrete but superficial features of the problem description by which to group them.

Similar differences in the nature of knowledge representation have been demonstrated using interviews about aquaria with school-children, teachers and aquaria experts. Novices focussed on 'concrete' structures within the aquaria; 'I know there are rocks...', whereas the more expert participants integrated these structures with both functional and behavioural information; 'you have rocks...certain kinds of fish like to breed in the rocks....' (Hmelo-Silver and Pfeffer (2004). Similar work has been undertaken with historians (Wineburg, 1991) and engineers (Weld, 1983).

As well as breadth and representation differences, the concept of experts having 'complete' knowledge compared to the partial knowledge of novices has been proposed (Chi, 2006b). Chi argues that a study by Alberdi et al (2001) using a familiar task for physicians demonstrates the concept of 'complete' knowledge. In this study, physicians were asked to view traces on a computer of five physiological measures (e.g. oxygen levels and heart-rate). Changes in these measures occurred for 'key' events like developing a pneumothorax, and also occurred as a result of smaller events. The expert clinicians picked up both 'key' and 'small' events, whereas the novices noticed only the 'key' events. The experts also detected and ignored artefacts, unlike their novice colleagues. Chi (2006b) argues that these differences demonstrate the more complete knowledge of the experts; a concept related to greater knowledge but not equivalent to it.

### **2.3.2 The psychological traits associated with experts**

In section 2.2.2, various psychological traits associated with experts were put forward (Table 2.3, Abdolmohammadi and Shanteau, 1992). As described in that section, the traits were proposed as a result of observations when working with experts in a number of studies (Shanteau, 1987; 1988). These were then validated in further studies and their relative importance judged by a ranking exercise with members of the auditing profession (Abdolmohammadi and Shanteau, 1992).

### **2.3.3 The cognitive skills necessary to make tough decisions**

In the mid 19<sup>th</sup> century, Sir Francis Galton set out the tenet that exceptional performers are born not made, in that certain people have innate capabilities, which mean they will out perform those without them. He used observation techniques to demonstrate that individuals who made eminent contributions in areas as broad as science, music and politics came from a small number of families. His conclusion was that, just as stature was heritable, so were other physical traits like brain size, which in turn allowed for the higher intellectual capacity required for expert performance (Galton 1869/1979 cited by Ericsson, 2006a).

This premise persisted into the 20<sup>th</sup> century until the work of de Groot in the 1940s (1978) and others, whose studies focussed extensively on chess players. De Groot in particular demonstrated that, rather than being dependent on superior intellectual capacities (heritable or otherwise), master chess players relied heavily on pattern recognition. He did so by asking both masters and competent club players to 'think aloud' as they chose moves in chess games (de Groot, 1978) noting that the

experts formed a rapid impression of the current situation from which they then retrieved potential moves from their memory.

Simon and Chase (1973) used familiar though simulated tasks to demonstrate that master chess players could remember almost entire chessboards whereas novices could only remember the position of around 4 pieces. However, they showed that if the pieces were arranged randomly (a contrived task), the masters could only recall between 5 and 7 pieces; only marginally better than the novices. This suggested that the masters did not have an innately superior memory, but rather could divide the game board into meaningful chunks, and need only remember 4 or so of those chunks. They were, in fact, remembering a similar number of 'chunks' as the novices but the expert's chunks were more complex, containing more information.

In addition to this 'chunking' which aids recall, differences in perception between novices and experts have also been demonstrated. Lesgold et al. (1988) used both familiar and contrived tasks to show that expert radiologists could see cues and relationships between cues on X-rays which their novice colleagues did not see. Each participant was interviewed and was also asked to draw on the X-ray film to highlight the problem areas as they saw them. The experts highlighted more areas than their novice colleagues. Similar perceptual differences have been demonstrated in weather forecasters (Hoffman, Trafton and Roebber, 2005).

### **2.3.4 The ability to use appropriate decision strategies**

Through the 1960s and 70s, investigation into the nature of expertise gained new impetus from Artificial Intelligence (AI) research and Expert Systems development (Hoffmann, 1992) which perpetuated through the 80s and 90s. The emphasis for this work was on understanding how people process information and problem solve, with the aim of replicating these processes either artificially or in non-experts. In addition to using the novice-expert differences approach (examining what has been termed *relative* expertise (Chi, 2006a)), this AI and expert systems work examined the experts' performance in isolation (otherwise known as *absolute* expertise (Chi, 2006a)).

Using think aloud protocols, Patel and Kaufman (1995) demonstrated differences in decision strategies between expert and novice medics. Experts tended to work forward from the data presented, to end with a diagnosis, whereas less proficient clinicians started with a hypothetical diagnosis and worked backwards to see if the

data fit their hypothesis. The same feature has been demonstrated with geneticists (Smith and Good, 1984) and physicists (Simon and Simon, 1978).

Shanteau (1988) argues that other decision making strategies open to and employed by experts include ‘making adjustments to initial decisions’ and ‘learning from past decisions’. Both of these strategies were demonstrated by participants in work by Rolo and Diaz-Cabrera (2005) who used a verbal protocol technique during a field study and a questionnaire in a simulated task study, to glean information from participants.

### 2.3.5 Summary of methods used for identifying expertise

In sub-sections 2.3.1 – 2.3.4, the various methods employed in the literature for identifying expertise and expert traits were highlighted. Hoffman et al (1995) have grouped the techniques used for eliciting knowledge from experts into three broad categories; analysis of the tasks that experts usually perform (such as the field study of Rolo and Diaz-Cabrera, 2005); various types of interviews (such as those of Hmelo-Silver (2004) about aquaria); and contrived tasks which reveal reasoning processes without explicitly asking about them (such as the problem sorting study with physicists, Chi et al, 1981). These are summarised in Table 2.6 below:

**Table 2.6: Methods used for identifying expertise**

Category	Procedures
Familiar task activities	Task analysis, unobtrusive observation, simulated familiar tasks
Interviews	Unstructured, structured (probe questions, test cases, first-pass knowledge base)
Contrived techniques	Event recall, think aloud problem solving, creative problem solving, decision analysis, scaling tasks, sorting tasks, rating tasks, constrained processing tasks, limited information tasks, graph generation tasks

### 2.3.6 Selecting experts in order to study expertise

In order to study expertise in any of the domains or ways described above, experts had first to be identified. Examining how experts have been identified sheds more light on the nature of expertise. For example, Hoffman (2006) outlined a ‘proficiency scaling’ procedure for the purpose of identifying experts with examples from the weather forecasting domain (Table 2.7).

**Table 2.7: The proficiency scaling procedure outlined by Hoffman and Lintern, 2006**

Method	Yield	Example
<b>In-depth career interviews about education, training, etc</b>	Ideas about the breadth and depth of experience; estimate of hours of experience	Weather forecasting in the armed services, for instance, involves duty assignments having regular hours and regular job or task assignments that can be tracked across entire careers. Amount of time spent on actual forecasting or forecasting-related tasks can be estimated with some confidence (Hoffman, 1991)
<b>Professional standards or licensing</b>	Ideas about what it takes for individuals to reach the top of their field	The study of weather forecasters involved senior meteorologists of the US National Atmospheric and oceanographic Administration and the National weather service (Hoffman, 1991). One participant was one of the forecasters for space shuttle launches; another was one of the designers of the first meteorological satellites.
<b>Measures of performance at the familiar tasks</b>	Can be used for convergence on scales determined by other methods	Weather forecasting is again a case in point since records can show for each forecaster the relation between their forecasters and the actual weather. In fact, this is routinely tracked in forecasting offices by the measurement of 'forecast skill scores' (Hoffman & Trafton, 2006).
<b>Social Interaction Analysis</b>	Proficiency levels in some group of practitioners or within some community of practice (Mieg, 2000; Stein, 1997)	In a project on knowledge preservation for the electric power utilities (Hofmann & Hanes, 2003) experts at particular jobs (e.g. maintenance and repair of large turbines, monitoring and control of nuclear chemical reactions etc) were readily identified by plant managers, trainers, and engineers. The individuals identified as experts had been performing their jobs for years and were known among company personnel as "the" person in their specialization: <i>"If there was that kind of problem I'd go to Ted. He's the turbine guy."</i>

From Hoffman and Lintern, 2006

As can be seen from table 2.7, performance at familiar tasks forms part of the process for identifying experts (row 3), just as has been described above for demonstrating their characteristics. However the purpose of the performance testing recorded above (section 2.3.1) was to elucidate the processes behind the superior performance, whereas here, it is the performance itself which is important in identifying the expert; this performance testing is therefore a level above the cognitive traits which have been examined above.

In addition to their superior performance, Hoffman introduces the idea that experts can be identified by the nature and duration of their training and education (row 1); by their achievement of standards outlined by their profession (row 2); and by acclamation as experts by their social group (row 4). He thereby introduces 3 more methods of identifying expertise.

In their review on the subject, Shanteau et al (2002) add to Hoffman's methods as well as those reported in sections 2.3.1. - 2.3.5 for identifying experts. Along with the approaches, however, they also highlight the problems with each method of expert identification. These are summarised in Table 2.8 below. As this table shows these authors add 'years of experience in a domain' (row 1); 'consistency' (row 4); and 'consensus' (row 5) to other methods already discussed.

In response to the limitations of the methods for identifying experts listed in the problem column (Table 2.8), Weiss and Shanteau (2003) propose an objective measure of expertise based on the characteristics of the judgements the 'would-be' experts make. They explain that experts must be both consistent and discerning in their judgments, and that consistency and discrimination are therefore attributes of experts worth measuring:

"We propose the ratio of discrimination over inconsistency as an index of expertise. *Discrimination* refers to the judge's differential evaluation of the various stimuli within a set. *Consistency* refers to the judge's evaluation of the same stimuli similarly over time; inconsistency is its complement. The ratio will be large when a judge discriminates effectively, and it will be reduced if the judge is inconsistent." (Weiss & Shanteau, 2003)

**Table 2.8: Traditional Approaches to identifying experts (summarised from Shanteau et al., 2002)**

Approach	Detail	Problems
Experience	Individuals with many years of experience are deemed 'experts' whilst those with few years are labelled 'novices'.	Whilst experts do almost always have many years of experience, it is not the case that all people with a lot of years of experience in a domain, are experts.
Certification	Many professions give accreditation or titles as people progress through their career.	Often more related to time in service than skill. 'Ratchet-up effect' means that people only move up the accreditation track, never down, and there is therefore no measure of maintenance of a skill.
Social Acclamation	Ask professionals within a field to identify the experts in their domain.	'Popularity effect' means that someone widely known will be deemed expert more readily than a more expert but less known individual.
Consistency	An expert should judge the same situation with the same result every time – i.e. they should be internally consistent.	A person could be consistent and yet wrong – perhaps by using a simple but inaccurate rule by which to judge.
Consensus	Experts in the same domain should agree with each other.	Consensus can occur from incomplete decision making, such as demonstrated in <i>groupthink</i> . Many experts may agree but be wrong.
Discrimination	Experts should identify and respond to small differences that a non-expert may not even perceive.	It is often the case that non-experts will distinguish between different cases based on an irrelevant difference, making them seem more discerning.
Behavioural characteristics	Various studies have identified shared characteristics of groups of experts in a given domain (e.g. perceptiveness, stress tolerance, communication skills etc.) The presence of these characteristics could be used as a way of identifying experts.	Testing for some of these characteristics is difficult at best. If it were possible, the tests would have to be domain specific and normalised for the domain. Furthermore, the traits might also be present in non-experts to significant degrees.
Knowledge tests	Often used to see what a proposed expert knows, as good domain knowledge is a prerequisite to expertise.	Knowledge is not enough. Knowing how and which knowledge to apply to a given situation is also an important feature of expertise.

They have called this ratio the Cochran-Weiss-Shanteau (CWS) index and have used it in a number of different situations including; to discern between expert and novice financial auditors and personnel selectors (Shanteau et al., 2002); to demonstrate the improvement in performance with training, in occupational therapists (Weiss et al., 2006); and to highlight the differences in discernment and consistency amongst medical doctors diagnosing heart disease (Weiss & Shanteau, 2003).

### **2.3.7 Section summary**

This section has given an overview of how the expert traits outlined in section 2.2. have been identified. Study methods from each of the three knowledge elicitation categories described by Hoffman et al (1995) have been used in the history of expertise study. These include the analysis of the tasks that experts usually perform; various types of interviews; and contrived tasks which reveal reasoning processes without explicitly asking about them.

The section concluded with a review of the methods used for identifying experts (rather than individual traits they exhibit), which included social acclamation, qualification and training level, duration of experience and consensus with other experts. Due to the limitations of these definers, Shanteau et al developed an empirical method of identifying experts; namely the Cochran-Weiss Shanteau index (Shanteau et al, 2002). This identifies and combines judgement discrimination and judgement consistency into one 'expert' index, allowing those displaying more expert tendencies to be discerned from those displaying less.

## **2.4. Professional Expertise and Competence**

Many of the psychological studies reviewed above (section 2.3) involve professionals. These have included investigating, for example, medics, auditors, and weather forecasters, examining what they do as a way of understanding the characteristics of experts. In these psychological studies, the tasks which make up a job are of interest as a vehicle for studying expert behaviour; the motivation for the studies is, for the most part, to understand expertise generically rather than to understand the optimal performance of the specific jobs. For example, the work reported on auditors by Abdolmohammadi and Shanteau (1992), produced overall expert traits, rather than information on optimal auditing performance. These studies



demonstrate there is enough commonality between the different domains to elicit a common theory of expertise (Ericsson, 2006a), and that was their purpose.

By contrast, the 'competency' literature which emanates from the industrial and occupational psychology domains, as well as the human resources and management science disciplines, also deals with expertise, but with the aim of understanding expert performance in a particular work setting. The following sections will discuss professional expertise and competency, exploring what is meant by key terms and reviewing how this area has developed differently in different countries.

#### **2.4.1 Professions and performance**

'Professions are essentially the knowledge-based category of occupations that usually follow a period of tertiary education and vocational training and experience' (Evetts et al., 2006). It has been said that professions effectively 'institutionalise expertise' (Abbott, 1988) and, in sociological terms, create two groups; experts and 'laypersons'. These groups are split not only by expertise but also often by prestige and power; that 'status' referred to at the start of this review in section 2.2.1.

Even within a professional group, however, there will be those who are more or less expert at their job. Ericsson (2006b) explains that most professionals, having worked in their domain for a number of years, 'reach a stable, average level of performance, and then they maintain this pedestrian level for the rest of their careers' (page 683). However, he goes on to explain that some carry on to 'the highest level of professional mastery'. Indeed, as far back as the Middle Ages, craft guilds identified various stages through which crafts people would progress, as their skill and experience increased (Table 2.9, Hoffman, 1998). This progression explains what an individual at any level can do in professional terms.

More recently, an exemplary performer has been described as 'best-in-class'; an expert (Rothwell & Lindholm, 1999). A fully-successful or 'good' performer has been described by these authors as 'an experienced worker who is not best-in-class'.

Human resources, psychology and ergonomics professionals have distinguished between the different levels of performance by endeavouring to identify the behaviours associated with each level (Byham & Moyer, 1996; Burke, 2005). These behaviours have been termed competencies. The next section will discuss what competencies are and what competence means in this context.

**Table 2.9: Terminology of the ‘craft guilds of the Middle Ages**

<b>Naivette</b>	One who is totally ignorant of a domain.
<b>Novice</b>	Someone who is new – a probationary member. There has been some (“minimal”) exposure to the domain.
<b>Initiate</b>	Someone who has been through an initiation ceremony – a novice who has begun introductory instruction.
<b>Apprentice</b>	One who is learning – a student undergoing a programme of instruction beyond the introductory level. Traditionally, the apprentice is immersed in the domain by living with and assisting someone at a higher level. The length of an apprenticeship depends on the domain, ranging from about one to 12 years in the craft guilds.
<b>Journeyman</b>	A person who can perform a day’s labour unsupervised, although working under orders. An experienced and reliable worker, or one who has achieved a level of competence. It is possible to remain at this level for life.
<b>Expert</b>	The distinguished or brilliant journeyman, highly regarded by peers, whose judgments are uncommonly accurate and reliable, whose performance shows consummate skill and economy of effort, and who can deal effectively with certain types of rare or ‘tough’ cases. Also an expert is one who has special skills or knowledge derived from extensive experience with sub-domains.
<b>Master</b>	Traditionally, a master is any journeyman or expert who is also qualified to teach those at a lower level. Traditionally, a master is one of an elite group of experts whose judgements set the regulations, standards or ideals. Also, a master can be that expert who is regarded by the other experts as being ‘the’ expert, or the ‘real’ expert, especially with regard to sub-domain knowledge.

(Hoffmann, 1998)

#### **2.4.2 Competent, competence and competency**

‘*Competent*’ is an adjective which suggests someone is capable of carrying out a specific job or task to an adequate, though not expert, level. The compact Oxford English dictionary describes *competent* as:

- having the necessary skill or knowledge to do something successfully.
- satisfactory or adequate, though not outstanding e.g. she spoke quite competent French.

and *competence* as:

- the quality or extent of being competent.

(Compact OED, 2008)

This definition of 'competent' is reflected in the crafts guilds model reported above (Table 2.9, section 2.4.1), where a competent performer or 'journeyman' is a level below an expert, and it is stated that professionals may remain at this competent level all of their lives.

Though these dictionary definitions are straightforward, there is not a consensus in understanding regarding the terms in the professional expertise and professional development setting (Wolf, 1995). The terms *competent* and *competence* have different meanings in this context, and there are further terms such as *competency* and *competencies*. These will be described in the following section.

### **2.4.3 Competence in the professional development field.**

In the UK's professional development arena, *competence* and *competences* are nouns used to label broad capabilities an individual has; they describe a person rather than an activity. By contrast, *competency* and *competencies* are more specific, describing particular activities. Smith (2005) explains that under these definitions, the first view (competences) might lead to describing 'a competent informal educator', the latter (competency) might entail describing 'a competent piece of driving.'

A further contrast is evident between the North American perception and that in the UK. Whereas in the UK, *competence* is the broad term describing a person and *competency* describes the specific skills or activities, in the USA, a *competency* will often relate to a person. *Competencies* are the characteristics and qualities that enable a person to do a superior job, rather than definers of what the job itself is in the USA (Manley & Garbett, 2000). In a recent review of competence within the psychology profession, Kaslow et al (2007) cite the following operational definitions:

'Competencies are complex and dynamically interactive clusters of integrated knowledge, skills and abilities; behaviours and strategies; attitudes, beliefs, and values; dispositions and personal characteristics; self perceptions; and motivations (Mentkowski & Associates, 2000) that enable task performance with myriad potential outcomes (Marrelli, 1998).

*Competence* includes the “habitual and judicious use of communication, knowledge, technical skills, clinical reasoning, emotions, values and reflection in daily practice for the benefit of the individual and community being served.” (Epstein & Hundert, 2002, p27)’

Rodolfa et al (2005) add that ‘Simply having knowledge or skill is insufficient for someone to be considered competent. Rather, there is the implication that competency requires action and in some public way verification of what is achieved by that action. ....In a profession, competency also connotes that behaviors are carried out in a manner consistent with standards and guidelines of peer review.’

The definition of ‘competency’ outlined above describes clusters of a number of different individual factors including knowledge, skills and abilities and a host of other attributes. Identifying these necessary characteristics for different roles is the first stage of ‘Competency modelling’ which will be the focus of section 2.5.

#### **2.4.4 Section summary**

This section has introduced the concept of professional expertise as an area focussed on optimal job performance as opposed to the focus on expert characteristics of the psychology literature presented in sections 2.2 and 2.3. The progression within a profession from ‘naivette’ to ‘master’ (or more commonly today from ‘novice’ to ‘expert’) is an idea which emanates from the middle ages, along with the understanding that professionals can successfully remain at a level below expert for their whole lives. This level is commonly termed ‘competent’, though this and related terms have different meaning in the professional development field. Though there is disagreement in terms between the USA and the UK (the former favouring ‘competency’ and the latter ‘competence’) there is agreement that clusters of individual attributes can be described, and job performance credited to them. These attributes include knowledge, skills, abilities and other characteristics and form the building blocks of competenc(i)es, the identification of which will be discussed in the following section.

## **2.5 Identifying competence**

### **2.5.1 Competency modelling**

As described above a ‘competency’ can be made up from clusters of a number of different individual factors which some authors describe under the headings; Knowledge, Skills, Abilities and Other factors (KSAOs) (Kierstead, 1998; Landy &

Conte, 2007). These headings themselves have been defined by Landy and Conte (2007) in the following way (Table 2.10):

**Table 2.10: Definitions of Knowledge, Skills, Abilities and Other factors**

Term	Definition
<b>Knowledge</b>	" A collection of discrete but related facts and information about a particular domain.....acquired through formal education or training, or accumulated through particular experiences" (Peterson et al., 1999, p.71)
<b>Skills</b>	A practiced act
<b>Ability</b>	The stable capacity to engage in a specific behaviour
<b>Other characteristics</b>	Personality variables, interests, training and experience

Whilst Landy and Conte define them separately, other authors conflate the terms Skill and Ability, determining that they are synonymous (Kierstead, 1998).

'Competency modelling' is the process by which the specific competenc(i)es that are characteristic of high performance and success in a given job are determined (LaRocca, 2007). These are then amalgamated into a framework which can be used to assess the current performance of professionals in a field or to aid their development. Methods for generating competency frameworks will be the focus of section 2.5.2.

### **2.5.2 Collecting information for a framework**

Generating a competency framework begins by collecting information about high and low performance from those currently doing a particular job (Dubois, 1993; Byham and Moyer, 1996; Rothwell and Lindholm, 1999; Wu and Lee, 2007).

A wealth of methods is available which include starting with exploratory focus groups (Dubois, 1993) and then moving on to more involved processes such as critical incident technique (CIT) (Flanagan, 1954) Behavioural Event Interviews (BEIs) or Kelly's repertory grid technique (Kelly, 1955a; Kelly, 1955b.)

In CIT, key stakeholders are asked to describe an incident which occurred whilst carrying out the job of interest. Questions such as 'what happened?'; 'what were you aiming to do?'; 'what do you think made the difference and ensured the right outcome?' are asked, from which key behaviours are identified (Thomas, 2007). These behaviours are then incorporated into the competency framework.

Behavioural Event Interviews (BEIs) are another means by which such frameworks can be generated. Although they are often used to assess individuals against a pre-determined competency framework, they are also useful for framework generation. The focus of the questions in a BEI differs from those in CIT by focusing on the characteristics of the individuals, rather than the nature of the tasks undertaken (Thomas, 2007). Questions such as 'what were you thinking?' or 'what were you feeling?' are asked, in order to generate a list of competencies (Smith and Flanagan, 2000).

Finally, Kelly's repertory grid technique (Kelly, 1955a; Kelly, 1955b) is also a popular method by which to generate key competencies for a particular job, or for an organisation as a whole. In this method, stakeholders are asked to group individuals into threes (based on two being similar, and the third different) on some aspect which the participant feels is important to work performance e.g. 'relates to clients easily – with difficulty' (Thomas, 2007). This effectively generates a number of bi-polar constructs which are useful in the production of a competency framework. Both this and CIT have successfully been used with police officers (McGurk et al, 1992; Wigfield, 1996).

What all these methods have in common is that they elicit knowledge from individuals in a particular profession or organisation which is then used to define the necessary competencies for success (they are the same methods outlined in Table 2.6 in section 2.3.5 with only the motive behind the data collection differing). Examples of the behaviours associated with each competency generally form part of the resultant framework (Hogg, 2007) and are often labelled 'performance criteria' (Wolf, 1995).

### **2.5.3 Competency frameworks in the USA and the UK**

In the UK the generation of competency frameworks has been driven by the desire to ensure 'standards of occupational performance' whereas in the USA, the focus has been on competency development (Fletcher, 1992). Further differences between the two countries' approaches have been described by (Fletcher, 1992) and are outlined

below (Table 2.11). In the UK, the competency standards are very explicit in terms of the required outcome of actual workplace performance. In the USA the focus is on ‘personal attributes’ which the UK System covers with a supplementary set of personal competencies outlining the personal attributes required.

**Table 2.11: Competency-based systems in the USA and the UK**

<b>Type</b>	Criterion referenced competences (UK) (i.e. individuals are judged against the criteria rather than against one another – which would be norm-referenced)	Criterion-validated competencies (USA) (i.e. the criteria have been validated as being representative of real world activities)
<b>Source of competence(i)s</b>	Standards of performance (competences) developed and agreed by industry	Competency clusters developed by research using ‘excellent’ performers.
<b>Aim</b>	Assessment of workplace performance	Learning and development of competence
<b>Definition of competence</b>	Competence = expectations of employment	Competence = personal characteristics
<b>Focus of system</b>	Standards of occupational competence (actual performance at work)	Educational process (competence development)

(adapted from Fletcher, 1992)

Having generated a framework, identifying competence(i)s in individuals is a result of assessing against that framework. Fletcher (1992) suggests that if the aim of any assessment is to assess the outcomes of the workplace activity, the UK approach is best. If one is looking to assess personal effectiveness, the US approach or the UK personal competences model is more appropriate. The next section reviews the literature on competence(y) assessment.

#### **2.5.4 Assessing for competence using competency frameworks**

Leigh et al. (2007) recently generated a review of the competency assessment measures available within the psychology profession, once a competency framework is available. These assessment measures include knowledge tests, task tests and decision making tests. They outline that the important attributes of any competency assessment are its validity, feasibility and fidelity (Leigh et al, 2007).

*Validity* is a measure of how effective an assessment is at actually measuring the specific competency of interest. The limited validity of some types of tests is well explained by Connell et al (2003);

“To take a trivial example, it is possible for four students in an algebra class to get a perfect score on an exam using four completely different competencies: (1) memorizing all the answers from a stolen answer key, (2) graphing the mathematical equations and solving the problems by reasoning from the visual diagrams, (3) manipulating the mathematical formulas directly using the rules of algebra, and (4) copying the answers from one or other of the other three students. If no one gets caught cheating, then all four of these students will end up with the same assessment on the exam, although the underlying competencies being exhibited are qualitatively different.”

*Feasibility* is a measure of the ease with which an assessment can be developed, administered and scored. Finally, *fidelity* refers to how closely an assessment reflects actual behaviours performed by a professional in their practice. For example, in a study of nurses' confidence of their competence, video clips were shown and the nurses were then asked to record what action they would take for each scenario they had viewed (Thorne & Cox, 2005). This approach had the advantage of enabling standardisation of tasks but would measure only what participants say they would do rather than actual behaviours.

Fletcher (1992) explains that competency assessment is about collecting evidence via a number of methods, which include:

- observation of performance
- skills tests
- simulation exercises
- projects or assignments
- oral questioning
- written examinations
- multiple choice question papers

Fletcher argues that only some of these methods provide evidence of job performance (workplace observation); a method used previously with nurses (Smith,



2004). This method is extremely labour intensive and produces findings for a handful of participants (low feasibility as described by Leigh et al, 2007). The assessment methods, along with their strengths and weaknesses as outlined by (Fletcher, 1992) are summarised in Table 2.12 below.

#### **2.5.5 Section summary**

This section began by explaining that the output of a competency modelling exercise is a competency framework. The various methods available for collecting information for a framework were outlined, alluding to the fact that they are the same techniques as those used to identify expertise in section 2.3.5. The difference between frameworks generated in the UK and USA was then reviewed, with a key differentiator being in the purpose for which the framework would be used; the UK's for assessing workplace performance, the USA's for assessing personal effectiveness. In both cases, assessment was the next step, and an outline of the various methods for assessing competencies completed this section. The key attributes of validity, feasibility and fidelity were discussed in relation to the competency measures, and the various strengths and weaknesses of each measure, along with examples of studies which have used them concluded the discussion.

**Table 2.12: Competency assessment methods according to Fletcher (1992)**

<b>Assessment method</b>	<b>Strengths</b>	<b>Weaknesses</b>	<b>Issues</b>
<b>Observation of performance</b>	Provides high quality evidence of performance	Opportunities to demonstrate competence across full range of activities may be limited Assessor-assessee relationship	Need multiple, trained assessors
<b>Skill tests, simulations</b>	Useful where full range of activity not available for observation Can be off-site Conditions can be standardised	Removed from realistic working conditions	Needs for planning and structure
<b>Oral questioning</b>	Can collect evidence across full range of activities Can collect evidence of under-pinning knowledge and understanding and its application in the workplace Can be standardised	Assessors can answer own questions Not sufficient on its own to assign competence Least likely to reflect or represent real working conditions	Trained assessors with effective techniques Largest inferential leap when assigning confidence
<b>Written exam</b>	Useful where knowledge forms a key component of competent performers e.g. information providers Can be standardised	Also assesses ability to write Needs skilled assessors to mark it	Supplementary evidence only - knowing does not mean able to do
<b>Multiple choice question papers</b>	Can be standardised Elicits key knowledge in short time scale	Always 25% chance of correct answer being selected randomly Skilled question designer required	Supplementary evidence only - Knowing does not mean able to do

## 2.6 Expertise and competenc(i)es

Having reviewed the literature on expertise and competenc(i)es and how they have been identified in sections 2.2 – 2.5, the aim of this section is to review the literature which links them.

There are two main theories regarding the link between competencies and expertise presented below. One view is that there are basic competencies and advanced competencies; 'Minimal competencies are required for competent functioning; attainment of aspirational competencies characterizes experts or masters (Kaslow et al, 2007, citing Schon, 1987). A similar delineation is made by Boyatzis (1982), naming those competencies essential for a job as 'threshold' so as to differentiate them from those required for superior performance. In other words, in this view, experts demonstrate different competencies than lower level performers.

An alternative view is outlined by Connell et al (2003) in the following quote:

- "Does individual X (in principle) have the *potential ability* to perform function Y, regardless of whether she can actually do it or not at the present time?
- Has individual X *realized a competence/y* for doing Y, such that she is actually capable of demonstrating it at the present time?
- At what level of *exhibited expertise* in Y is individual X capable of performing at the present time (compared with other members of the same [group] or with members of some other reference group)?"(Connell et al., 2003)

In this example, a competence(y) is the objective demonstration of an ability; an individual can either do something or she cannot. If she can, the quality of performance demonstrated is described as her level of expertise. Implicit in this is explanation is that a competence(y) can be demonstrated at varying levels of expertise; the competencies should all be there for any given professional but the implication is that they may be there to differing degrees depending on the level of expertise the person has.

Sternberg (2005) extends this to describe abilities, competencies and expertise as being all on the same continuum.

'One moves along the continuum as one acquires a broader range of skills, a deeper level of the skills one already has, and increased efficiency in the utilization of these skills.'

He explains

"developing expertise" is defined here as the on-going process of the acquisition and consolidation of a set of skills needed for a high level of mastery in one or more domains of life performance. Experts, then, are people who have developed their **competencies** to a high level; competent individuals are people who have developed their **abilities** to a high level.'

"The novice works toward competence and then expertise through deliberate practice (Ericsson, 1996)....But expertise occurs at many levels. The expert first-year graduate or law student, for example, is still a far cry from the expert professional. People thus cycle through many times, on the way to successively higher levels of expertise." (Sternberg, 2005)

By this explanation, competencies are the combined outworkings of abilities. Expertise is exhibited when these competencies have been honed to a high level. Individuals can become expert at a number of stages along the way (e.g. one can be an expert junior ergonomist but then become a novice senior ergonomist before becoming expert at this level). This model is outlined in Figure 2.1 below.

Sternberg (2005) explains that there are five main elements to the model, all of which are completely interrelated. For example, learning leads to an increase in knowledge, but as knowledge increases ('you begin to know what you don't know'), this encourages further learning. Motivation is at the centre of the model, as it drives the metacognitive skills (problem recognition; problem definition; problem representation; strategy formulation; resource allocation; monitoring of problem solving; and evaluation of problem solving, Sternberg, 1985; 1986) which then activate both learning and thinking skills, enabling expertise to be increased. As knowledge increases, through the extension of thinking and learning, this knowledge then leads to more effective use of these thinking and learning skills.

The context in which all of this takes place affects every aspect of the development of expertise. For example, if a learning experience takes place in English, but the

learner is not proficient in English, this will reduce the level of that learning experience when compared to a highly proficient English speaker.

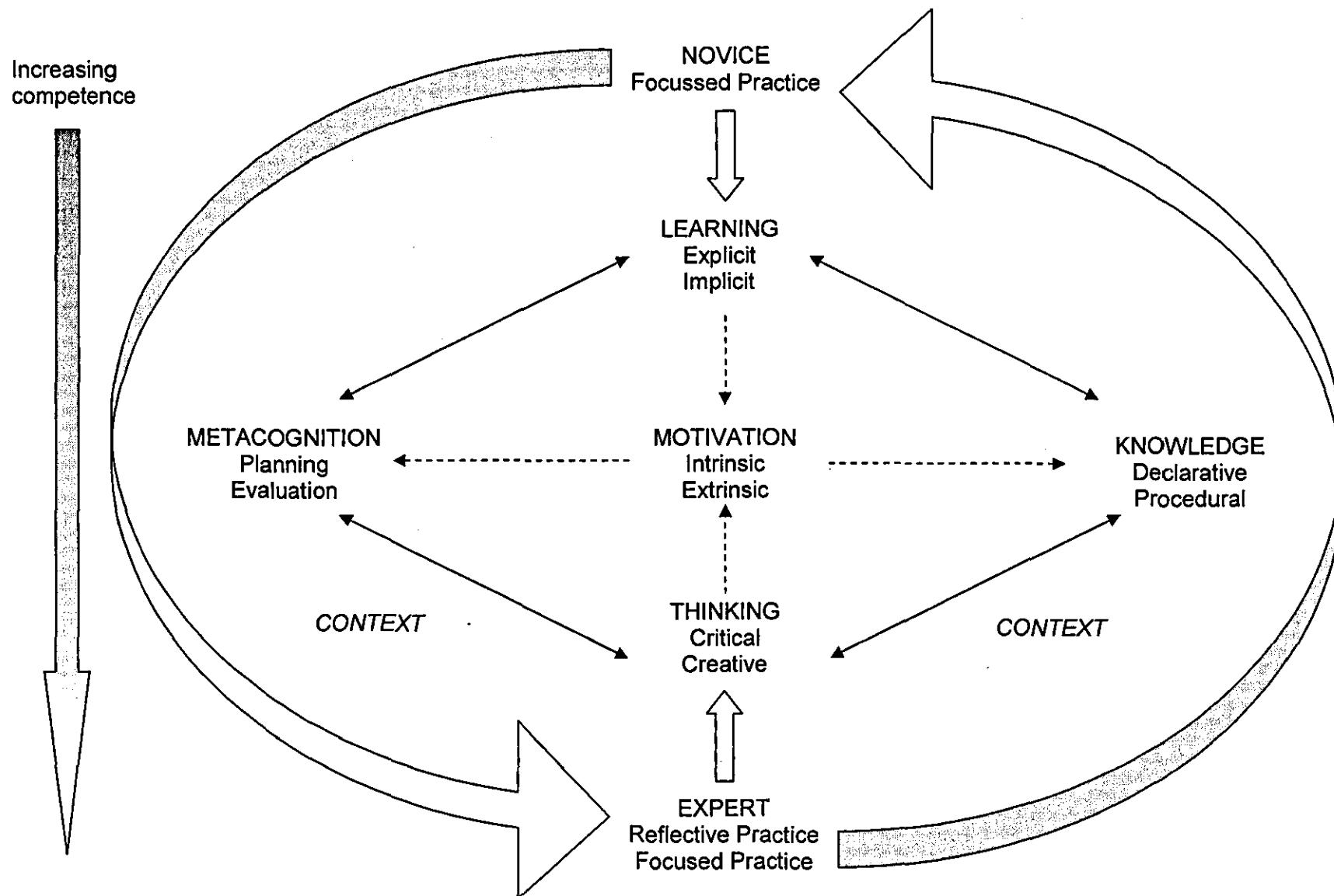
Overall, the key aspects of this model are

- that an individual can constantly cycle through the model via deliberate practice, developing expertise at progressively higher levels
- that abilities are honed to competencies which are developed into expertise.

### **2.6.1 Section Summary**

The aim of this section was to present theories which link the literature on competenc(i)es and expertise presented in sections 2.2 – 2.5. Two theories were presented. The first theory proposes that there are 'minimal' or 'threshold' competencies which allow a job to be performed sufficiently well; and aspirational competencies which are required for expert performance. Therefore an expert exhibits different competencies from others who are not experts.

The second theory puts forward the idea that abilities, competencies and expertise are on a continuum; experts have competencies developed to a high level whereas competent individuals have only their abilities developed to a high level.



**Figure 2.1: The development of abilities into competencies, and competencies into expertise (Sternberg, 2005)**

## **2.7 Expertise and Ergonomics advisors**

The final sections in this review will examine the literature pertaining to expertise and those involved with ergonomics. Articles were only included in this section from peer reviewed publications where some form of experimental study has been undertaken to examine expertise amongst ergonomics advisors (for an explanation of the search strategy see section 2.1.1).

### **2.7.1 Ergonomics Expertise**

Expertise in others, particularly in decision making, is a subject of interest to ergonomists as part of their practice (Farrington-Darby & Wilson, 2006; Piegorsch et al., 2006). However, there is a paucity of studies covering expertise in ergonomists themselves (Piegorsch et al., 2006). Some of the few studies which have examined expertise amongst ergonomics practitioners have looked at expert-novice differences when undertaking different types of ergonomics work. These studies will be the subject of the next section.

### **2.7.2 Expert-novice differences**

Weston & Haslam (1992) investigated the abilities of those with and without formal ergonomics training, to recognise and apply ergonomics principles in design and evaluation activities. The study compared two groups of undergraduates (one group of final year ergonomics students, one group of final year students taking no ergonomics, each with  $n=8$ ) with the performance of three Ergonomics experts (Registered members of the Ergonomics Society of the UK). They found that ergonomics performance improved with ergonomics training when those with and without training were compared with ergonomics 'experts' on two different tasks. In effect, this study compared novices, experts and what others have termed 'advanced beginners' (those with some experience/training in a field) (Dreyfus & Dreyfus, 2004) and found performance to improve with training level. However, potentially due to the relatively small samples, this improved performance was only statistically significant for a minority of the aspects measured. Also of note is the fact that the experts were defined as such by virtue of their Registered membership of the Ergonomics Society, rather than by any empirical measure (see section 2.3.6).

Jones et al. (1999) similarly compared trained and untrained non-ergonomists with ergonomists, for a materials handling risk assessment task. They studied 25 pairs of non-ergonomists in a health care setting, one from each pair having received

training. The performance of each of the 25 trained participants was compared with the 25 without, as well as with that of a trained ergonomist. They found that both non-Ergonomist groups were able to identify hazards, though they were less able to prioritise tasks for assessment. The trained group carried out 'better' assessments than the untrained group (qualitatively and quantitatively for hazards identified and solutions proposed) though this was not statistically significant. Both the non-ergonomist groups proposed fewer solutions than the ergonomist.

A later study by Winnemuller et al. (2004) compared ergonomist assessments of work related musculoskeletal risk factors with those of supervisors ( $n = 37$ ) and workers ( $n=55$ ). In assessing the absence or presence of risk factors, supervisors agreed with the ergonomist 81% of the time, and the workers agreed 77% of the time. Where there was disagreement, the non-ergonomists over-estimated the risks compare to the ergonomist. This study, like that of Weston & Haslam (1992) assumed the ergonomists were correct, and used them as the gold standard.

These three studies demonstrate a performance benefit of ergonomics training. They additionally show a further benefit of being an ergonomist over having had basic ergonomics training. This advantage could come from further training and/or more extensive experience in the domain.

Stanton & Young (2003) examined the reliability ( $n = 8$ ) and validity ( $n= 30$ ) of different ergonomics methods, when employed by novices. They reported that novices could reliably apply certain ergonomics techniques with validity; these techniques included checklists and questionnaires. The more structured technique (Keystroke level model or KLM; (Card et al., 1983)) proved the most valid *and* reliable tool in the hands of novices when carrying out product evaluation and usability tasks. Users of this KLM technique break tasks down into constituent activities e.g. mental operations, motor operations and device operations, and determine response times for each of these operations. These authors suggest that techniques which focus on narrow areas of performance, like the KLM, are likely to prove more reliable and valid because of that.

Previous work by the same research team and reported in Stanton & Young, 2003, had demonstrated that the performance by novices and experts on ergonomics evaluation tasks was dependent on the complexity of the device being evaluated; when evaluating a simpler device than that of the 2003 study, novices performed



better than the 2003 novices (Stanton & Stevenage, 1998); experts, on the other hand, performed better than the 2003 novices, even when evaluating a more complex device (Baber & Stanton, 1996). Clearly, the complexity of the task being undertaken matters, when examining the performance of experts and novices applying ergonomics principles.

### **2.7.3 Differences between experts**

In addition to examining the differences between novices and experts, other work has analysed the objectivity of ergonomics experts' decisions, and the consensus amongst them. Keyserling & Wittig (1988) studied 5 ergonomics experts (designated by being University researchers) and compared their assessment decisions regarding ergonomics stressors, both with one another's and with an objective tool; National Institute for Occupational Safety and Health's (NIOSH) Work Practices Guide for manual lifting (NIOSH, 1981). They found that there was good consensus between their experts (no statistically significant differences across all 4 different stress categories) and with the NIOSH guide (though this finding was tempered due to the lack of comparability between the experts rating categories and the categories of the NIOSH guide). Where there was disagreement, the experts rated the stressors higher than the objective tool.

Further decision making work examined the differences between Ergonomists from different backgrounds (Piegorsch et al., 2006). These authors identified the decision making processes used by Ergonomists from industrial engineering (n = 12) and physical therapy (n = 9) backgrounds, when generating recommendations to prevent and control low back pain. Their aim was to identify the schemata (the abstract form in which people organise and store information from previous experiences) which both kinds of Ergonomists used, to identify if they were similar, in spite of their differing backgrounds.

They found that one model adequately described the decision making of Ergonomists with backgrounds in either discipline (see Fig 2.2). The authors posit that the schema arises from the interaction between practitioner factors and situation factors and this schema then guides the individual through the decision making process (Fig 2.2). The schema contains '*process*' concepts which guide how practitioners do what they do and '*content*' concepts which guide what they pay attention to. The process and content boxes in the model spread across the decision making stages which they influence. Overall, they found that the background of the Ergonomists had less

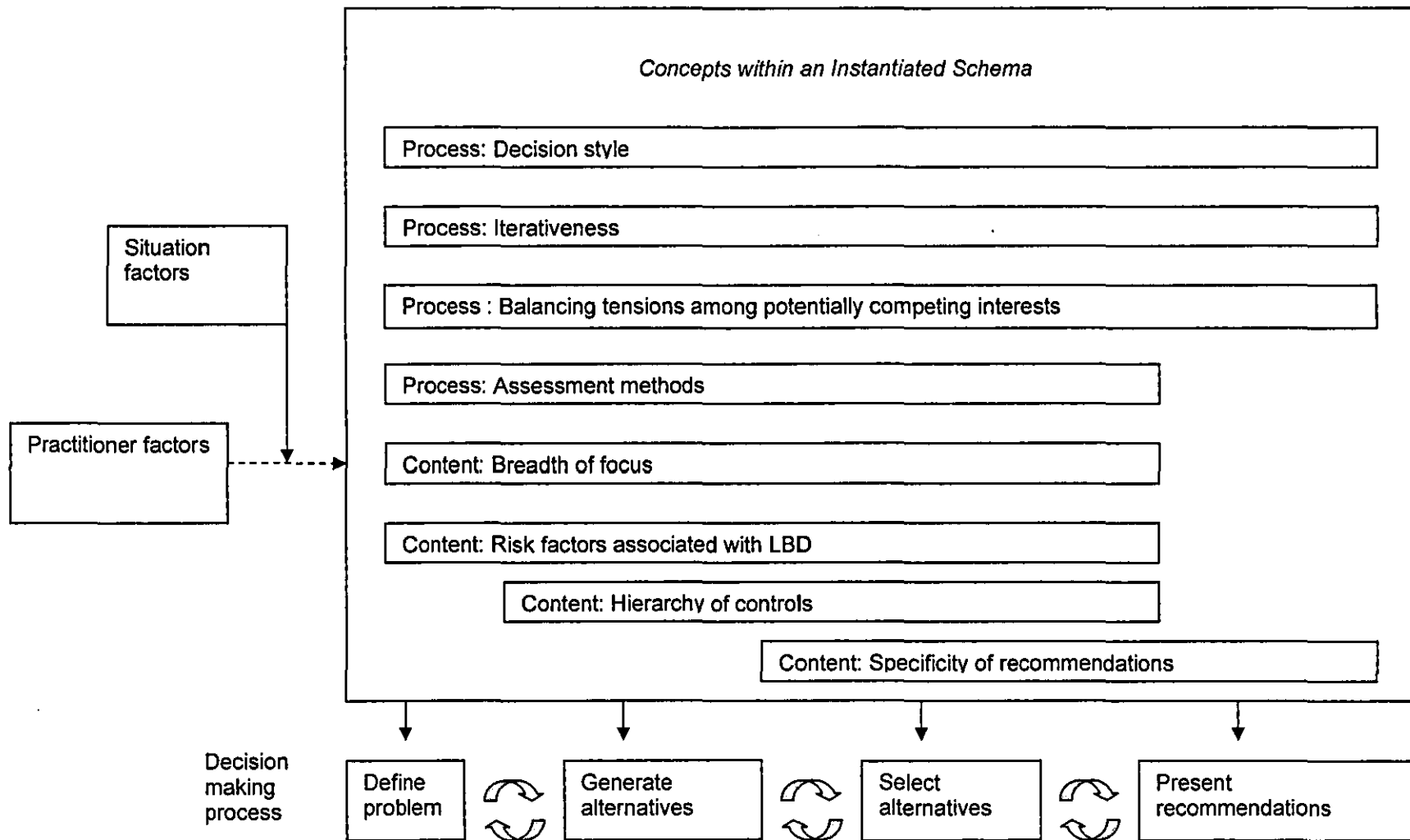
influence on decision making than individual personality traits and the constraints of the practice environment.

Both the Piegorsch et al. (2006) and Keyserling and Wittig (1988) studies demonstrate consensus between ergonomics experts (a traditional definer of expertise, see Table 2.8 in section 2.3.6)

#### **2.7.4 Section Summary**

In this section, a review of the peer reviewed studies on expertise and ergonomics advisors has been undertaken. Two types of studies have been reported; those which compare novice and expert performance and those which compare experts with one another. The first type of study has demonstrated that there is a performance enhancement effect at typical ergonomics tasks which comes from even short course training. This enhancement continues with the more involved training typically required of fully qualified ergonomists, and may also be linked with more extensive experience.

The two studies comparing experts demonstrated consensus between experts in both mental models and decisions made. The first study also found that there was tentative consensus between ergonomics experts and an objective tool. In the majority of the studies, 'experts' were selected based on their qualifications rather than any empirical measure. A critical summary of the literature presented in this section can be found in Table 2.13.



**Figure 2.2: The schema used by Ergonomists from differing backgrounds when dealing with Low Back pain (Piegorsch et al, 2006)**

**Table 2.13 Critical Summary of Peer Reviewed Ergonomics Expertise Studies**

Study (in order of presentation in chapter)	Study design and findings	Sample size	Strengths	Weaknesses
Weston & Haslam, 1992	<p>Comparison of two student groups (one with some ergonomics training) with 3 ergonomics experts, on 2 ergonomics tasks.</p> <p>Find those with training perform better (more like the Ergonomists) than those without.</p>	<p>2 groups of n = 8 and 3 'experts'</p>	<p>Have a control group.</p> <p>Effectively use novices, advanced beginners and experts.</p> <p>Compare on 2 different tasks.</p>	<p>Ergonomists are defined as experts with no empirical measure of their expertise.</p> <p>Small samples.</p> <p>Few statistically significant findings.</p>
Jones et al., 1999	<p>Comparison of trained and untrained non-ergonomists with an ergonomist's manual handling risk prioritisation and assessments.</p> <p>Find all groups could identify hazards but not prioritise. Trained group scored better though not statistically significant.</p>	<p>2 groups of n=25 and 1 'expert'</p>	<p>Have a control group.</p> <p>Random allocation to groups.</p> <p>Qualitative and quantitative assessment of the participants' performance by 2 independent scorers.</p> <p>Expert compared with 2 others for inter-expert agreement (consensus).</p>	<p>Ergonomist is defined as expert with no empirical measure of their expertise, just consensus with others.</p> <p>No statistically significant findings.</p> <p>Manual Handling risk assessment only.</p>
Winnemuller et al., 2004	<p>Comparison of supervisors', workers' and ergonomists' assessments of presence/absence of MSD risk.</p> <p>Find general agreement in assessing the presence/absence of MSD risk factors; where there was disagreement non-ergonomists over-estimated.</p>	<p>37 supervisors, 55 workers, and 1 'expert'.</p>	<p>Multiple work sites and multiple industries were used.</p> <p>Good or excellent intra-rater reliability.</p> <p>Work sampling by ergonomist every minute for 2 hours.</p> <p>Expert compared with one other for inter-observer agreements found to be good or excellent.</p>	<p>ergonomist is defined as expert with no empirical measure of their expertise.</p> <p>Not comparing like with like as ergonomist carried out full analysis and others used questionnaire</p> <p>Questionnaire may have led participants to over-estimate risk due to desire to answer yes to at least one question</p>

Study (in order of presentation in chapter)	Study design and findings	Sample size	Strengths	Weaknesses
Stanton & Young, 2003	<p>Examined novice inter and intra reliability &amp; criterion references validity when using various ergonomics methods.</p> <p>Found novices could reliably apply some techniques with validity (in particular the more structured, narrowly focussed techniques)</p>	n = 30 for validity study and n= 8 for reliability study.	<p>Tested both intra and inter analyst reliability.</p> <p>Tested the validity of the techniques.</p>	There was no expert comparator group.
Keyserling & Wittig, 1988	<p>Comparison of 5 experts' opinions of ergonomic stress in 10 jobs, both with one another and with the NIOSH working practices guide (WPG) for manual lifting.</p> <p>Found good consensus between experts and with the NIOSH guide. Where there was disagreement, the experts rated the stressors higher than the objective tool.</p>	5 'experts'	<p>Compared 'experts' with an objective tool.</p> <p>Collected expert comments to help elucidate reasons behind judgements (qualitative element as well as quantitative).</p>	<p>Differences in scoring system between the experts and the WPG meant difficult to compare.</p> <p>Limited to manual handling assessment.</p>
Piegorsch et al., 2006	<p>Comparison of decision making of Ergonomists from industrial engineering and physical therapy backgrounds.</p> <p>Found both groups made decisions in a way which could be described by the same model.</p>	<p>Industrial engineering background (n = 12)</p> <p>Physical therapy background (n = 9)</p> <p>Total n= 21</p>	<p>Used qualitative and quantitative methods.</p> <p>Recruited participants until saturation was reached.</p> <p>Used follow-up interviews to assure quality of data collected.</p>	<p>Did not use 'live' situations of decision making but relied on recall.</p> <p>Limited to Low Back Disorders field.</p>

The next section (2.8) will move on from these more traditional expertise studies to look at the professional competence literature with regard to ergonomics professionals.

## **2.8 Professional Competence and Ergonomics Advisors**

Identifying the Knowledge, Skills, Abilities and Other factors (KSAOs) for particular jobs and ensuring the match between workers and job requirements is a well trodden path for some ergonomists particularly in the team working field (Marras, 2006; Salas et al, 2005). However, it has much less frequently been the focus for the ergonomists themselves (Hendrick, p 8, in Karwowski and Marras, 1999). This section will review the approaches taken by various professional bodies to specifying professional ergonomics competence, and link this with the general competence literature reviewed above.

### **2.8.1 Competency frameworks in Ergonomics**

A number of professional ergonomics bodies have approaches to defining competence. These include the UK's Ergonomics Society, the US based Board of Certification in Professional Ergonomics (BCPE), the Ergonomics Society of Australia and New Zealand Ergonomics Society as well as the International Ergonomics Association (IEA) and the Centre for Registration of European Ergonomists (CREE).

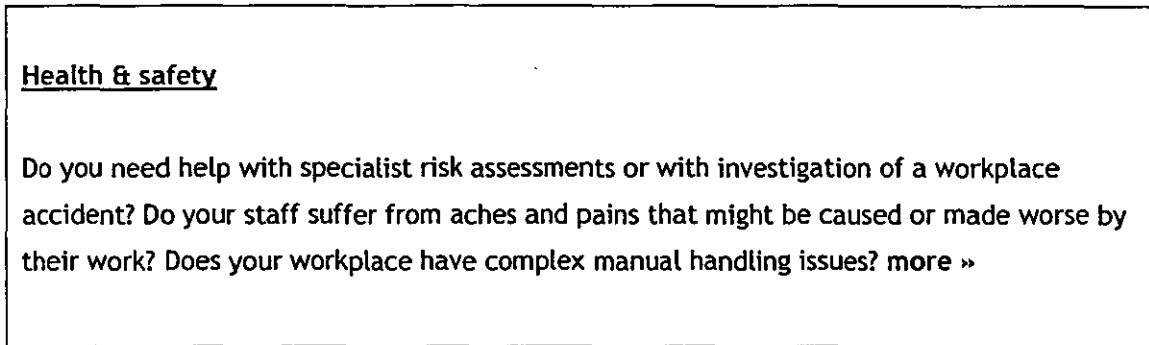
Some organisations have competency frameworks such as those described in section 2.5, including competency units made up from specific elements. Other organisations take an approach which is more 'academic' in nature, outlining the knowledge content required, like a syllabus, and the ergonomics techniques which might be used, rather than the behaviours which might be exhibited by a practitioner in the field. The following sections will examine three different organisations' approaches, as exemplars of extant methods for identifying and assuring ergonomics competence or expertise.

### **2.8.2 The UK's Ergonomics Society**

#### **Seeking expert advice**

The UK Ergonomics Society web site ([www.ergonomics.org](http://www.ergonomics.org)) has two areas which refer explicitly to ergonomics practitioner expertise. The first area is designed for members of the public who are looking for an individual or company to support them

in resolving a particular issue. Consequently, this part of the website lists areas such as computer work; health and safety; training; industrial design and work. As an example, the 'front end' text from this part of the website regarding 'health and safety' is outlined below in figure 2.3 followed by the text obtained by clicking the 'more »' prompt. (Figure 2.4)



**Figure 2.3: The 'Health and Safety' area of the expertise list for the public**  
(Ergonomics Society, 2008a)

As can be seen from Figure 2.4 the 'area of competence' in these lists describes both knowledge and skills. The website then leads enquirers to individuals and companies who have registered as being fully competent in this area via the '[See list of consultancies with this expertise](#)' prompt. Therefore, in this context competence is used meaning 'adequate ability in' an area of practice, rather than a 'competence' in the sense defined in section 2.5.

There are 28 such areas of competence and individuals/companies can select up to 10 of them under which to be registered, having acquiesced to a code of conduct which specifies the need for self regulation to stay within the boundaries of their knowledge and skill. In order to be allowed to select these 10, an individual must be a Registered Member of the Ergonomics Society and companies must have a sufficient number of Registered Members. The requirements for acquiring Registered membership will be the subject of the next section.

### **Health & safety expertise 1**

Are you and your staff aware of all potential risks in your workplace? Risk assessment is a vital part of any health and safety programme but it doesn't stop there. Risks must be reduced and managed. Ergonomists can help you to identify risks and take appropriate action and can help in the education of your workforce.

*Keywords:* risk and cost-benefit analysis; risk assessment and risk management; risk perception; general musculoskeletal risk.

*Area of competence:* Risk assessment: various work situations

See list of consultancies with this expertise

### **Health & safety expertise 2**

Incorrect techniques used in lifting and moving loads can increase the risk of injury to your workers. Ergonomists can help you to assess the manual handling requirements in your workplace and can suggest practical solutions involving staff training, load design, and lifting and moving aids and equipment.

*Keywords:* manual handling assessment and training; manual handling and lifting; manual handling of loads.

*Area of competence:* Manual handling of loads: safety and training

## **Figure 2.4: Options available under health and safety when clicking more »**

(Ergonomics Society, 2008b)

### **Gaining Registered Membership of the Ergonomics Society**

The website explains that Registered membership 'is open to anyone with sufficient education and experience in ergonomics, as specified by the Society.' So education and experience are both cited requirements for Registered membership with the education coming from a 'qualifying' degree or Masters course or from a documented and sufficient alternative route. If an alternative route is taken, the Society defines that the education must cover:

- Anatomy, anthropometry and physiology in human activities
- Environmental stressors(performance shaping factors) and psychophysiology
- Socio-technical systems
- General and organisational psychology
- Survey and research methods



The education must then be followed by three years of full time ergonomics experience for the 'qualifying course' applicants and four years for any taking an alternative educational route. This experience must be documented in a log book and is required to be supervised by a mentor who is already a Registered member of the Society. An example of a log book entry is produced in Figure 2.5 below:

**Log-Book Example 4: Update to safety procedures within large refinery**

**Date: September 2000 – December 2000 85 man days**

**Summary of activity**

Rationalisation of all procedures and working practices within a large refinery's individual assets to ensure the use of standard procedures in all locations.

**Details of personal involvement**

Working as part of a team of consultants and technical authors, I was involved in the development of a standard procedural risk assessment and document control process. I audited some of the occupational health and safety procedures including working with visual display screens, working with asbestos procedures and job safety assessments.

**Details of ergonomics involved**

The review of procedures involved gathering all existing procedures, identifying common aspects, ensuring a note was taken of areas in which procedures had to be carried out differently and a compliance check against the relevant legislation. Ensuring that the appropriate level of guidance was included in each procedure and that information was accessible to the end user.

**Details of professional skills employed**

Compliance with health and safety standards.

Communication with other team members.

Report writing skills to rationalise the procedures to ensure common goals were met.

**Comments on how this activity has benefited your professional development**

The main challenge in this project was to ensure that the final procedures met the requirements for all areas of application. This gave me a good insight into the health and safety legislations and gave me scope to ensure that the procedures were compliant with adequate guidelines and checklists.

**Mentor's comment**

This task was carried out to the complete satisfaction of our client. Patrick interacted well within the team and carried out all tasks within cost and time budgets.

**Figure 2.5: An example of a log book entry**

(Ergonomics Society, 2008c)

As this log book entry outlines, the expertise exhibited by the applicant and recorded here includes specific knowledge (e.g. health and safety standards), ergonomics skills (user centred design of the procedures) and other more generic skills (communication with team members and report writing). The mentor's comments

allude to the demonstration of behavioural characteristics of working to time and being a successful team member.

Finally an applicant must be proposed/referred for membership by two current Registered members.

### **Expertise and competence according to the Ergonomics Society**

In summary, the UK's Ergonomics Society divides the ergonomics domain into fields of practice which it calls areas of competence. Practitioners can select up to ten areas under which to be listed in the database which interested parties can interrogate when seeking ergonomics support. Proof of the practitioner's eligibility comes from their achievement of Registered Status

The process by which Registered Status (certification) is achieved involves most of the traditional methods by which experts are identified as outlined in Table 2.8, section 2.3.6 (Shanteau et al, 2002). It requires completion of tertiary level or equivalent ergonomics courses (education and knowledge tests); a number of years of practice (experience); supervision by a mentor (consensus); completion of a log book (behavioural characteristics); and referral by current Registered members (social acclamation).

### **2.8.3 The Board of Certification in Professional Ergonomics (BCPE)**

#### **Levels of certification**

The BCPE is a non-profit organisation set-up expressly to provide certification for ergonomists. It produces a handbook in which it describes; the operating philosophy; the body of knowledge; the scope of practice; and practitioner experience required of individuals wishing to gain certification in ergonomics (BCPE, 2004). There are two main levels of certification, the higher being the Certified Professional Ergonomist (CPE) the lower being the Certified Ergonomics Associate (CEA). These two levels are described in the following way:

**'CPE:** A career problem solver who applies and develops methodologies for analyzing, designing, testing and evaluating systems. A CPE addresses complex problems and advances ergonomics technologies and methods.

**CEA:** An interventionist who applies a general breadth of knowledge to analysis and evaluation. A CEA reacts to performance, safety, health or quality issues in currently operating work systems.'

By these definitions, the CPE might be viewed as the 'expert' in the craft guilds table (Table 2.9, section 2.4.1) and the CEA as somewhere between the 'apprentice' and the 'journeyman'. The handbook also provides tables of differences in the scope of practice between these two levels both generally and then more specifically in terms of analysis and assessment, intervention and evaluation.

### **The Ergonomist formation model**

The BCPE approach outlines the knowledge (both academic and professional), and the skills required (both academic and professional) for certification, in what it calls the Ergonomist Formation Model (EFM) (Rookmaaker et al, 1992) (Table 2.14). In addition, the handbook outlines the duration of practical experience required for certification (4 years for the CPE, 2 for the CEA) and also 12 items which it describes as the 'behavioural objectives' for the professional ergonomist (taken from Hendrick, 1981). These include the following examples:

- "Sufficient background in the behavioral sciences to respond to ergonomics questions and issues having psychological or other behavioral implications. Implies the equivalent of a strong undergraduate behavioral science minor. "
- "Be able to (a) evaluate and, (b) assist in performing classic man-machine integration, including workspace arrangement, controls, displays, and instrumentation. Implies formal knowledge of ergonomic human-equipment integration technology. "
- "Be able to evaluate the adequacy of applied ergonomics research and the generalization of the conclusions to operational settings. Requires formal knowledge of the basic statistical methods and the principles of experimental design at the introductory level. "
- "Have at least one area of specialized expertise which goes beyond the introductory graduate level of understanding and application. Requires additional coursework or thesis project in a specialized area as covered in the ergonomics topics descriptions."

Though these are termed 'behavioural objectives', these seem to repeat or expand on the knowledge and skills requirements listed in the Ergonomist Formation model (Table 2.14) rather than provide particularly behavioural requirements.

In order to achieve certification, the BCPE requires an individual to have the necessary qualification (e.g. for CPE an MSc in ergonomics/human factors); the necessary duration of experience; documentation of sufficient project involvement; and a pass on the BCPE written exam. The written exam is made up from multiple choice questions and essay type questions where individuals are required to outline their approach to a particular workplace problem. The essay questions require the respondents to specify the data they would collect, methods of analysis which would be undertaken, potential solutions as well as the limitations to be acknowledged.

### **Expertise and competence according to the BCPE**

Just as for the UK Ergonomics Society, many of the traditional methods of identification of experts are employed by BCPE, including knowledge tests, education and experience, and there is a code of professional conduct outlined, just as for the Registered members of the Ergonomics Society.

An important difference in the approach is the detailed outline of the knowledge and the technical skills required of the ergonomics practitioner, and the separation of these between what might be required of 'experts' and 'journeymen' (Table 2.9, section 2.4.1) by defining scopes of practice for both. The requirements are not referred to as competencies (but objectives) and are explicit in terms of the required outcome of actual workplace performance, rather like the UK style competency frameworks described in section 2.5.3. What is lacking (compared with those frameworks) is the supplementary set of personal competencies outlining the personal attributes required.

**Table 2.14: Categories, Topics, Objectives and Points of Reference from the Ergonomist Formation Model ( BCPE 2004 and Rookmaaker, 1992)**

Category	Topics	Objective	Points of reference
Ergonomics Principles	Ergonomics Approach	To recognize the integrated (systems) nature of ergonomics, the centrality of human beings, to use its breadth of coverage and the available knowledge base to adapt the environment to people.	History of work; current developments; paradigms (designing for individuals vs. populations; working in normal vs. extreme circumstances); interaction between society and work.
	Systems theory	To recognize the principles of systems theory and how they apply to ergonomics situations.	Structure and dynamics of systems; human as a system component; system analysis and design (e.g. allocation of functions).
Human Characteristics	Anatomy, Demographics and Physiology	To recognize and measure physical characteristics of people and their responses to their activities and their environments with particular reference to health and performance.	Anatomy; biomechanics and posture; anthropometry; energy and force production; adjustments (stress and strain); individual, gender-related, developmental, racial and cultural variability; chronobiology (e.g. circadian rhythm).
	Human Psychology	To recognize behavioural characteristics and responses and to understand how these affect human behaviour (including health and performance) and attitudes.	Psychophysiological and cognitive aspects of information intake, information handling and decision making; individual motivation; human development.
	Social and Organizational Aspects	To recognize the social dimensions of ergonomics and organizations and to specify systems structures suitable to achieve a good quality of working life performance.	Motivation and attitudes related to needs of individuals and to working in groups; individual and group functioning; socio-technical systems.
	Physical Environments	To understand the human senses and to be able to recognize, measure and specify appropriate levels of and the characteristics of the physical environment to be suitable for human activities.	Climatic environment; visual environment; acoustic environment; vibration; human senses.

Category	Topics	Objective	Points of reference
Work Analysis and Measurement	Statistics and Experimental design	To collect, aggregate, manipulate and evaluate data in a reliable and valid manner.	Descriptive and inferential statistics; probability theory; correlational techniques; estimation and sampling; experimental design; non-parametric statistics.
	Computation and Information Technology	To use (digital) computers, particularly utilize standard packages, for the effective prosecution of ergonomics investigations.	Computation for data collection; computation for calculation; computation for storage, computation for data-base searches, computer-aided design.
	Instrumentation	To use the major measuring instruments, sensors etc., required by the ergonomist to gather data for investigations, design or evaluation of workplaces, procedures or equipment.	Simple and complex equipment; their potential and limitations.
	Methods of Measurement and Investigation	To understand the major methods and procedures of measurement used in ergonomics investigations, and to know when to use them and how to interpret the results.	Simulations (dynamic and static); methods for observing activity and performance; interviews and questionnaires; epidemiological approach; sampling procedures; checklists.
	Work Analysis	To describe and understand the determinants and organization of workers' activities in the field or system.	Activity analysis; task analysis; function analysis; task interdependency; communication and co-operation; the importance of strategies in task execution.
People and Technology	Technology	To understand the factors in the chosen area of application that are relevant to the creation of ergonomic situations; in particular to recognize those aspects of the technology that are flexible/changeable.	Functionality, operation and construction of the technology.
	Human Reliability*	To design and evaluate work situations using 'best practice' in working towards error-free performance.	Accident models; attention, effort and vigilance; error taxonomies.
	Health, Safety and Wellbeing*	To design and evaluate work situations to achieve health and safe work, as well as contribute to quality of work life.	Safety management; occupational injuries and work-related disorders; safety technology; legislation; characteristics of good quality work life.

Category	Topics	Objective	Points of reference
People and Technology <i>continued</i>	Training and Instruction*	To understand the fundamentals of learning, of raining programs and of instruction, and to specify requirements of those programs to achieve successful performance to new or changed work activities.	Learning skills; learning knowledge; assessing job requirements and worker capabilities; designing training programs to bring workers to the level of requirements; designing manuals.
	Occupational Hygiene*	To recognize, measure and cope with the presence of adverse physical and chemical conditions and other major pollutants.	National and International recommendations and requirements; their variations and limitations; measurement, protection, control and monitoring.
	Workplace Design*	To investigate and design workplaces to match the physical and psychological dimensions of their users and to measure their effect on ergonomically relevant dimensions.	Measurement of activities and performance; workspace layout; use of mock-ups/simulations to improve designs; evaluation; compatibility between workplace requirements and human capabilities.
	Information Design*	To investigate and design the major modes of information transfer to the human for effective and efficient performance of the system.	Signal detection; information processing and attention; display characteristics; information overload; stimulus-response compatibility.
	Work Organization Design*	To investigate, design and implement work organizations for effective and efficient performance and good quality of work life.	Co-operative analysis and design of new work systems; basics and applications of work-rest schedules; introduction of change.
Applications	To understand the integrative nature of applying ergonomics, the need for and structure of a specification, and the interactive and iterative nature of work in an applied research or design group', recognizing the practicalities and limitations of applying ergonomics, including the introduction of change.		The applied research/design process is applied in a chosen area such as: consumer products; manufacturing; office work; transport; process industry; health care; automation; architecture; recreation, arts and leisure activities, etc; intervention techniques.
Professional Issues	To recognize the impact of ergonomics on people's lives, the costs and benefits accruing from ergonomics activities, the social and psychological impact of ergonomics investigations, and the professional responsibilities and requirements for the ergonomics practitioner.		Legislation; economics; the ergonomist in the organization; ergonomics and society; role of ergonomist in social settings with different interest groups; ethics; development and marketing of the ergonomics profession.

## 2.8.4 The International Ergonomics Association (IEA)

### Core competency standards

The IEA has produced what it calls 'Core competencies in Ergonomics' (IEA, 2001) in which a competency is described as

*"a combination of attributes underlying some aspect of successful professional performance. "*

It goes on to explain that:

*"An outline of core ergonomics competencies should describe what it is that ergonomists can do in practice."*

(IEA, 2001)

This understanding of competency, with its emphasis on professional performance rather than personal characteristics is therefore akin to the UK style competency framework outlined in section 2.5.3, rather than the USA equivalent. The IEA's competency standards are made up from units, elements and performance criteria which are defined in the following way:

*"Units of competency – which reflect the significant major functions of the profession or occupation.*

*Elements of competency – which describe the identifiable components of ergonomics performance which contribute to and build a unit of competency.*

*Performance criteria - which describe the standards expected of performance in the ergonomist's work. Expressed in terms of outcomes and professional ergonomics performance, they provide the basis on which an expert assessor could judge whether the performance of the ergonomist reached the standard acceptable for professional practice."*

(IEA, 2001)

This structure is identical to that of the National Vocational Qualification (NVQ) system in the UK (Wolf, 1995). There are 41 of the elements in the list which are



grouped into 9 Units (see Appendix B for a summary list of the elements). The Units are described in Table 2.15.

**Table 2.15: The IEA's Units of competency**

Unit	Descriptor
Unit 1	Investigates and analyses the demands for ergonomics design to ensure appropriate interaction between work, product and environment, and human needs, capabilities and limitations.
Unit 2	Analyses and interprets findings of ergonomics investigations.
Unit 3	Documents ergonomics findings appropriately.
Unit 4	Determines the compatibility of human capabilities with planned or existing demands.
Unit 5	Develops a plan for ergonomics design or intervention.
Unit 6	Makes appropriate recommendations for ergonomics changes.
Unit 7	Implements recommendations to improve human performance.
Unit 8	Evaluates outcome of implementing ergonomics recommendations.
Unit 9	Demonstrates professional behaviour.

The first four units (containing 19 elements) describe the assessment and investigation of ergonomics problems, and the recording of the findings there-from. The second four units (containing 17 elements) describe the planning, delivery and evaluation of interventions and recommendations based on the assessments made. The final unit (containing 5 elements) describes various aspects of professional behaviour. An example of each level of the competency standard framework is represented in Table 2.16., using 1 element of Unit 6 as an example, followed through the table in bold.

**Table 2.16: An example of all three levels of a competency standard**

Unit	Elements from Unit 6	Performance criteria for specific element 6.2
<b>6: Makes appropriate recommendations for ergonomics changes.</b>	6.1 Understands the hierarchies of control systems	6.2a Utilizes the systems approach to human-workplace integrated design for new or modified systems and understands design methodology and its use in systems development.
	6.2 Outlines appropriate recommendations for design or intervention	6.2b Applies correct design principles to design of products, job aids, controls, displays, instrumentation and other aspects of the workplace, work and activities and considers human factors in the design of any utility.
	6.3 Outlines appropriate recommendations for organizational management	6.2c Drafts systems concepts for a functional interaction of tasks/technological variants, work means/tools, work objects/materials, work places/work stations and the work environment.
	6.4 Makes recommendations regarding personnel selection	6.2d Develops appropriate simulations to optimize and validate recommendations.
	6.5 Develops appropriate recommendations for education and training in relation to ergonomic principles	6.2e Outlines details of the appropriate concept and develops specific solutions for testing under realistic conditions.
		6.2f Provides design specifications and guidelines for technological, organizational and ergonomic design or redesign of the work process, the activity and the environment which match the findings of ergonomic analysis.
		6.2g Is able to justify recommendations

### **Generation of the competency standards**

As reported in section 2.5.2, generating competency frameworks begins with collecting information about high and low performance from those currently doing a particular job. Specifically, the IEA's list was generated using the following Delphi-style process:

- The Chair of the IEA Education and Training Committee outlined the initial framework.
- Opinion was then garnered from a plethora of experts and federated society members via focus groups, workshops and on-line reviews.
- Consensus was reached and the resultant competency framework was posted on the IEA website in October 2001 (Margaret Bullock, personal communication, 2006)

### **Uses of the competency standards**

The IEA explains that the core competencies could be used in a variety of ways which include 'the development of comprehensive and equitable assessment processes for the evaluation of a person's professional competence.' The standards are presented in two forms; 'summary' and 'full'. The summary version does not include the performance criteria but simply the units and their elements (see Table 2.16). The IEA outlines that 'it is expected that any assessment of an individual or programme would require evidence of competence across these summary elements.' In other words ergonomists should be able to demonstrate their capability in all 41 of the elements which make up the 9 units.

By contrast, with respect to the 'full' version, which additionally includes the performance criteria 'there is no intention that any one ergonomist be expected to meet all these performance criteria in depth for all areas of ergonomics research and application, but they should be aware of all and be competent in a significant number' (IEA, 2000). Unlike the BCPE approach, and to an extent the Ergonomics Society approach, the IEA explain that their competency standards do not represent an outline of certification requirements, though they may help in generating such an outline.

### **Expertise and competence according to the IEA**

Overall, the IEA's competency standards outline what an ergonomics practitioner should be capable of doing. The list covers elements of competency from the initiation to the completion of an ergonomics intervention, and includes some over-

arching professional behaviour competences, in line with the codes of conduct of the other two professional bodies discussed in the previous sections. Of all the bodies discussed here, the IEA's list is the most like the competency frameworks discussed in section 2.5

### **2.8.5 Section Summary**

This section has reviewed the approaches of three professional bodies to defining and identifying ergonomics expertise and competence. The UK's Ergonomics society uses many of the 'traditional' methods for identifying expertise as outlined in Table 2.8, section 2.3.6 (Shanteau et al, 2002). The same is true of the BCPE though in addition, they outline objectives for two levels of practitioner (associate and ergonomist). The objectives the BCPE outlines are explicit in terms of the required outcome of actual workplace performance. In this way the BCPE's list is a move towards the competency frameworks discussed in section 2.5. The IEA's approach is just such a competency framework, with a summary version outlining what every ergonomist should be capable of doing in practice. All three approaches differ but are similar in that they all outline professional behaviours or codes of conduct which sit alongside the specifically ergonomics competencies and expertise they propound.

## **2.9 Chapter Summary and Implications for this Research**

Dictionary definitions of 'expert' have linked this term with the attainment of a high level of performance; having skills and knowledge, gained from experience; being a reliable authority; and having status. The literature (Chi et al, 1988) has added further characteristics of experts, outlining that expertise is domain-specific and results from superior memory, pattern recognition and qualitative analysis. The list of 'behavioural' characteristics of experts has been expanded by the work of Shanteau (1987 & 1988) and Abdolmohammadi and Shanteau (1992), to include cognitive, presentation and strategy traits, with all these features underpinning the superior performance of experts.

By contrast poor performance by experts has also been reported, particularly in the Judgment/ Decision making literature (Chi, 2006a). This poor performance has been explained by Shanteau (1992) as being a function of the task domain and by Spiro et al's (1996) model of the cognitively flexible and inflexible expert; the latter performing poorly in dynamic, complex environments but the former being capable of dealing

with uncertainty. Overall Shanteau's 'Theory of expert competence' proposed that expert performance depends on a sufficient knowledge of the domain; the psychological traits associated with experts; the cognitive skills necessary to make tough decisions; the ability to use appropriate decision strategies; and a task with suitable characteristics. It is reasonable, therefore to look for these features of both the individuals and their domain whilst examining expertise amongst ergonomics advisors.

Studying expertise has involved methods from each of the three knowledge elicitation categories described by Hoffman et al (1995); the analysis of the tasks that experts usually perform; various types of interviews; and contrived tasks which reveal reasoning processes without explicitly asking about them. Methods for identifying experts (rather than expertise) have included using social acclamation, qualification and training level, duration of experience and consensus with other experts. Due to the limitations of these definers, Shanteau et al developed an empirical method of identifying experts; namely the Cochran-Weiss Shanteau index (Shanteau et al, 1992). This identifies and combines judgement discrimination and judgement consistency into one 'expert' index, allowing those displaying more expert tendencies to be discerned from those with less. Both the traditional methods for identifying experts and the empirical method proposed by Shanteau et al (1992) would be useful approaches to take in studying the expertise of ergonomics advisors.

The professional expertise field (as opposed to more general expertise arena) is an area focussed on optimal job performance rather than on expert characteristics per se. The progression within a profession from 'novice' to 'expert' is an idea which emanates from the middle ages (Hoffman, 1998) along with the understanding that professionals can successfully remain at a level below expert for their whole lives. This level is commonly termed 'competent', though this and related terms have different meanings in the professional development fields of different nations (Fletcher, 1992).

There is, however, general agreement that clusters of individual attributes can be described for individuals doing a particular job role and job performance can be credited to these attributes (Byham & Moyer, 1996; Burke, 2005). These attributes include knowledge, skills, abilities and other characteristics (KSAOs) and form the building blocks of 'competenc(i)es'. The identification of these competencies (competency modelling) is often followed by the generation of competency

frameworks (Kierstead, 1998; Landy & Conte, 2007) which are then used to assess individuals within an occupation. The fact that giving ergonomics advice forms part or all of an occupation for many in the domain means that identifying the KSAOs and competencies held by ergonomics advisors would be a useful approach when studying ergonomics expertise.

To date there is only a limited literature examining expertise amongst ergonomics professionals. Previous work identified a performance enhancement effect at typical ergonomics tasks which comes from even short course training (Haslam et al 1992; Jones et al., 1999; Winnemuller et al., 2004). This enhancement continues with the more involved training typically required of fully qualified ergonomists, and may also be linked with more extensive experience. Further studies comparing ergonomics experts demonstrated consensus between experts in both mental models (Piegorsch et al., 2006) and decisions made (Keyserling & Wittig, 1988). This second study also found that there was good consensus between ergonomics experts and an objective tool. Therefore the work carried out in the ergonomics field has identified links between training and improved performance; has demonstrated consensus amongst experts and has shown some ergonomics tools can be both validly and reliably applied in by non-experts. There is wide scope for further study of the nature of expertise amongst ergonomics advisors, examining further differences between novices and experts, as well as using an empirical measure to identify the experts.

In addition to looking at ergonomics expertise reported in journals, this literature review also reported broad differences in the approaches of the professional bodies to defining and identifying ergonomics expertise and competence. The UK's Ergonomics society uses many of the 'traditional' methods for identifying expertise as outlined by Shanteau et al, 2002. The same is true of the BCPE though in addition, they outline objectives for two levels of practitioner (associate and ergonomist, BCPE, 2004). The BCPE list is a move towards a competency framework, when compared to the approach taken by the UK's Ergonomics Society. The IEA's approach is a competency framework, with a summary version outlining what every ergonomist should be capable of doing in practice (IEA, 2001). This competency framework is likely to prove a useful tool for examining expertise amongst ergonomists and others who use ergonomics.

Overall, reviewing the literature has provided methods with which to study and identify expertise as well as characteristics and competencies to look for amongst those who give ergonomics advice.

### **Chapter 1 – Introduction**

- Problem statement
- Research aims
- Research Paradigm
- Thesis Structure

### **Chapter 2 - Literature review**

- Establishing the nature of expertise and how it is identified and measured
- Establishing the nature, extent and findings of previous work examining expertise amongst ergonomics and allied professionals

### **Chapter 3 – What characterises good and expert Ergonomics Advisors?**

- 3 Focus groups (n = 26) with Ergonomists
- Model building of features of good and expert ergonomics practice

### **Chapter 4 – The self reported competencies of Ergonomics Advisors**

- 217 competency questionnaires from 6 national ergonomics conferences
- Establishment of areas of high and low confidence across the breadth of IEA ergonomics competencies.
- Relationship of competence and expertise

### **Chapter 5 – The Knowledge and Activities Ergonomics Advisors**

- 8 Focus groups (n = 55) with Ergonomists and other professional groups engaged in ergonomics advising
- Template analysis and model building of ergonomics expertise from knowledge and activities differences

### **Chapter 6 – The decision making expertise of Ergonomics Advisors - part 1**

- ULD risk assessment task undertaken by 58 PREs and EOPs and a control group of 148 students
- Establishment of comparative expert performance using the CWS index of expertise

### **Chapter 7 – The decision making expertise of Ergonomics Advisors - part 2**

- Investigation of the content of risk assessment decisions
- Relationship of decision content and expertise

### **Chapter 8 – Discussions, Implications and Conclusion**

- Discussions and implications of findings from all studies
- Limitations
- Recommendations for further research
- Conclusion



## **Part 1**

### **Chapter 3- Exploring the KSAOs of ergonomics advisors**

#### **3.1. Introduction**

##### **3.1.1 Outline of research presented in this chapter**

The first research objective of this thesis was to identify the characteristics which ergonomists cite as important for high-level performance in their domain. This chapter presents the findings of a focus group study designed to garner the opinions of experienced ergonomists about what characteristics make for a good (as opposed to a bad) professional in their field, and if any further characteristics define what it is to be expert.

Four characteristics were identified across all groups; having practical (not just theoretical) knowledge; taking a holistic/systematic approach; being observant/perceptive and having good communication skills. Some implications of these findings are discussed, along with their contribution to the overarching research questions.

##### **3.1.2 Identifying expertise**

As discussed in chapter 2, identifying what it is that makes an individual perform well in a specific job role has been an important focus for occupational psychologists for over a century (Landy & Conte, 2007). Performance has been defined within this context as being 'deliberate and purposeful action...in order to achieve a desired output' (Dubois, 2007).

An exemplary performer has been described as 'best-in-class'; an expert. A fully-successful or 'good' performer has been described by these authors as 'an experienced worker who is not best-in-class' (Rothwell & Lindholm, 1999).

As described in Chapter 2, human resources, psychology and ergonomics professionals distinguish between different levels of performance by identifying the behaviours associated with each level (Byham & Moyer, 1996; Burke, 2005). Some authors propose that these behaviours result from a combination of Knowledge, Skills, Abilities and Other factors (KSAOs) which the individuals possess (Kierstead,

1998; Landy & Conte, 2007). Lists of KSAOs have been defined in the literature for managers (Shippmann et al, 1991; Borman and Brush, 1993), for Army leaders (Department of the Army, 1983) medical doctors (Tilson & Gebbie, 2001) and more generally (Fleishmann and Reilly, 1992; Maurer et al, 2003). Having identified the KSAOs, the next step is often to combine them so as to define, amongst other factors, the necessary behaviours (competencies) for superior performance (Byham & Moyer, 1996; Rothwell & Lindholm, 1999; Shippmann et al., 2000; Horey et al, 2004).

This process of identifying KSAOs and subsequent competency modelling generally begins by collecting information about high and low performance from those currently doing a particular job (Dubois, 1993; Rothwell, 1994; Byham and Moyer, 1996; Rothwell and Lindholm, 1999; Wu and Lee, 2007). Identifying KSAOs for particular jobs and ensuring the match between workers and job requirements may be a well trodden path for some ergonomists (Marras, 2006; Salas et al, 2005) however, rarely has it been the focus for the ergonomists themselves (Hendrick, p 8, in Karwowski and Marras, 1999).

An exploration of what ergonomists identify as characterising good, bad and expert performers in the ergonomics arena would be a step towards identifying some of the KSAOs for ergonomics advisors. Such insight would contribute to the understanding of what constitutes an ergonomics expert.

### **3.1.2 Aims of this study**

- To determine the opinion of experienced ergonomists as to 'what makes a good ergonomics advisor?' by asking about good and bad performers.
- To identify whether an 'expert ergonomics advisor' differs from a good one.
- To relate the opinions of the ergonomists to the literature on practice, expertise and competency.

## **3.2 Methods**

### **3.2.1 Design**

The critical realist paradigm adopted throughout this PhD allows for the use of both qualitative and quantitative research methods. Qualitative methods are particularly useful when asking 'in what way' and 'how' type questions (Hancock, 1998), such as

those outlined in the first two aims of this study. It was therefore decided that a qualitative method of data collection would be used for this study.

There are a number of qualitative data collection methods available, notably observation; interviews; focus groups and diaries. The advantages and disadvantages of these methods are outlined in Table 3.1 below:

**Table 3.1 Advantages and Disadvantages of Qualitative Data Collection Methods** (adapted from Taylor, 2008; Powell & Single, 1996; Kreuger and Casey, 2000; Willig, 2001)

Method	Advantages	Disadvantages
<b>Observation</b>	<p>Useful when phenomena cannot be replicated in lab</p> <p>Good ecological validity</p> <p>Gives insight into chronology of events</p> <p>Gives insight into processes</p> <p>One person's view (the observer)</p>	<p>Subjective (to the observer)</p> <p>Time consuming</p> <p>Selective</p> <p>Impact on those being observed</p>
<b>Interviews</b>	<p>Face-to-face therefore rapport can be built</p> <p>Good for sensitive issues</p> <p>Can monitor interpretation of questions (unlike in questionnaires)</p> <p>Flexible</p>	<p>Time and Effort required</p> <p>Self-report therefore relies on ability to describe own experiences and differs person to person</p> <p>Questions are asked which might not normally be asked</p> <p>Cannot assume answers reflect reality</p>
<b>Focus Groups</b>	<p>Face-to-face therefore rapport can be built</p> <p>More data than one-to one interviews in less time</p> <p>Insight into joint constructions &amp; development of meaning and attitude</p> <p>Less artificial and more ecologically valid than interviews</p> <p>Useful where there is little current knowledge about a subject in preliminary stages of research</p> <p>Useful in gleaning several views about the same topic</p>	<p>Less suitable for sensitive subjects due to group nature</p> <p>More difficult to organise than interviews</p> <p>Data transcription and analysis complicated.</p>
<b>Diaries</b>	<p>Allows for participants to use their own words</p>	<p>Time consuming for researcher and participant</p>

Gives temporally ordered data avoiding recall issues	High drop-out rates
Good for intimate or sensitive information	Can sensitize participants to the issues of interest

All of the aims of this study necessitated garnering opinions from ergonomists currently working in the field. Focus groups were the chosen over the other methods outlined in Table 3.1 because they are useful where there is little current knowledge about a subject (Powell & Single, 1996). Whilst there is a breadth of literature outlining the content of what ergonomics professionals should know, there is very little describing other aspects of ergonomics expertise (see Chapter 2).

Furthermore, Kreuger and Casey (2000) outline the usefulness of focus groups at the preliminary stages of research, to enable the identification and conceptualisation of variables which can then be further examined using quantitative methods. It was felt that observation was not appropriate because it was opinions rather than activities which were of interest, and focus groups allowed for access to more people more quickly than one-to-one interviews. The individuals who made up the focus groups were meeting for other reasons, so adding the focus group activity on to their other activities was less disruptive to them than finding the time for an interview. In addition, given that the subject matter was not sensitive, the privacy of one-to-one interviews or diaries was unnecessary.

**3.2.2 Sampling and Participants**

The aim with qualitative research is not to get representative samples via random selection (as in quantitative sampling) but to seek information from specific groups and sub-groups within a population (Hancock, 1998). As described above, the aims of this study involved garnering the opinions of Ergonomists, and therefore Ergonomists were the theoretical population of interest for this work. Therefore, the sampling was necessarily purposive in that it sought out qualified Ergonomists (Hignett, 2005). The obvious place to find groups of Ergonomists was Ergonomics consultancies and therefore three ergonomics consultancies were contacted in the first instance, and asked to take part. Each had a contact known by the researcher. Two of the three consultancies agreed to participate.

Having carried out these 2 focus groups, it became clear that a divide was being drawn between the Ergonomists in consultancies, and what they felt the Ergonomists

in the University setting carried out. A third focus group was therefore sought from a largely research based University workforce which engages in consultancy intermittently. This stratification allowed the opinions from a 'deviant case' sub group of interest to be included.

### **3.2.3 Procedure**

The participants were asked open questions to encourage the group to think about the features and characteristics of good ergonomics professionals. Questions such as 'I want you to think of somebody that you consider to be a good ergonomics advisor; what are they like?' and 'What do you think it is that makes someone good at ergonomics?' were asked. These questions were extended to consider an 'expert' where this had not been touched on during the course of the discussion about 'good'. Care was taken not to confine the discussion simply to ergonomists, but to approach the subject broadly, discussing ergonomics advisors or practitioners. This was so as not to exclude individuals the groups felt were 'good' or 'expert' within the discipline, simply because they were not ergonomists.

Each participant was encouraged to contribute and the moderator regularly summarised the discussion and reflected it back to the participants to verify meaning. The discussions were recorded and notes were taken on a flipchart for the participants to view and challenge, should their views be unrepresented by the record. An additional researcher was present in each focus group to take notes of the key themes discussed and to aid the analysis later on.

### **3.2.4 Analysis**

The focus group discussions were transcribed promptly (Lincoln and Guba, 1995). The initial analysis involved noting the themes which emerged in response to the focus group questions (Dey 1993). Having coded all of the issues forthcoming in each focus group, these were then categorised under the headings 'Knowledge', 'Skills', 'Abilities' and 'Other factors', as defined by Landy and Conte (2007). The validator present at the focus groups then went through his notes and the transcripts and independently identified, coded and allocated the issues to one of the four headings. The two sets of information were then compared; any disparities were noted and discussed, and a final version was agreed.

The data under each of the headings were then summarised and verbatim quotes used as exemplars for each of the themes as recommended by Morgan, Kreuger and

King (1998). The occurrence of the same themes across different groups was noted. Finally, interpretation was undertaken, constructing explanations for the findings via recourse to the transcripts and recourse to the literature.

### **3.3 Results**

The following section presents the findings from this study. A summary of the participant descriptive data is provided (3.3.1) followed by the findings from the focus groups (3.3.2 – 3.3.4). Finally, a table summarising the responses of each of the groups is provided (3.3.5).

#### **3.3.1 Participants**

Table 3.2 outlines the details of the focus group participants including gender, years of experience, job role and ergonomics specialism.

Eight male and eighteen female ergonomists took part ( $n = 26$ ) with a mean age of  $35 \pm 10.1$  years. Their declared specialisms were Occupational Health/ Health and safety ( $n = 14$ ), Physical ergonomics ( $n = 3$ ), Human Factors ( $n = 3$ ), HCI ( $n = 2$ ), Usability ( $n = 1$ ) and General ergonomics ( $n = 3$ ). Their self determined job roles were; ergonomist consultant ( $n=10$ ), ergonomist consultant/trainer ( $n = 9$ ), researcher ( $n = 5$ ), ergonomist consultant/researcher ( $n = 2$ ); all at various levels of seniority.

**Table 3.2: Participants**

Gender	Job title	Qualification	Yrs practice	Specialism
m	Consultant/trainer	BSc Ergs	1 month	Health and Safety
f	Consultant/trainer	MSc Ergs	4 months	Health and Safety
f	Consultant/trainer	BSc Ergs	1 month	Health and Safety
f	Consultant/trainer	BSc Ergs	2 yrs 4 months	Health and Safety
m	Director Consultant/ trainer	BSc Ergs	24 years	Business risk/ Health and Safety
f	Ergonomist/trainer	BSc Psych with Ergs	6 years	Health and Safety
m	Consultant/trainer	B and MSc eng	25 years	Health and Safety
m	Ergonomist	BSc	15 years	Health and Safety
m	Consultant	MIOSH	1 month	Health and Safety
f	Consultant	IOSH Tech	2 years	Health and Safety
f	Consultant	IOSH	5 years	Health and Safety
f	Snr Consultant	MSc Health ergonomics	8 years	Health and safety
f	Director Consultant	BSc Ergs	30 years	Health and Safety, Usability
f	Consultant/research student	MSc in ergonomics	3.5 years	Occupational Health
f	consultant	MSC work design and ergonomics	8 years	Physical
f	Senior consultant	MSc kinesiology and ergonomics	8 years	Physical
f	Consultant/Researcher	PhD ergonomics	6 years	Physical
m	Researcher	MSc ergonomics	10 years	Human Factors/HCI
m	Research fellow	MSC ergonomics	11 years	Human Factors
f	Research project officer	MSc ergonomics	1 year	Human Factors
f	Consultant	MSC HCI	1 month	HCI
m	Consultant	MRES design	3 months	HCI
f	Consultant	MSC HCI and ergonomics	2 years	Usability
f	Consultant/Trainer	BSC ergonomics	6.5 years	Health and safety, Usability, HCI
f	Research Fellow	BSc ergonomics	23 years	General
f	Senior Researcher	PhD ergonomics	20 years	General ergonomics

### 3.3.2 Characteristics of a Good Ergonomics Advisor

In the results section below the group responses are categorised into the Knowledge, Skills & Abilities and Other factors which characterise good performance. A summary of the findings under each of these 3 headings is provided, followed by a section covering the detail.

Where verbatim quotes are included, the participant is identified by the group in which they took part (Gp 1, Gp 2 or Gp 3) and by a participant number (e.g. P1). So the first participant in the first focus group would be identified as follows: **Gp 1 – P1**.

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#### 1. Knowledge

##### **Summary**

In general, the groups did not discuss knowledge content (a list of what ergonomics advisors should know), but the characteristics of the knowledge. In summary, these characteristics included having practical (rather than simply theoretical) knowledge, which was both broad and beyond common knowledge. The need for ergonomics advisors to have knowledge that is scientific, factually correct and integrated was also raised, though there was some discussion about the fact that it was possible to be 'too' scientific, with 'endless statistical analysis' in some ergonomics studies 'missing the bigger picture'.

##### **Detail**

The most common characteristic proposed was that the knowledge should be practical, not just theoretical; this was raised by all three focus groups.

**Gp1- P1** 'well ideally I'd like people in a University setting – professors- to have some practical experience as well.... I think practical experience is important.'

Further, participants proposed that knowledge should be beyond that which is commonly held;

**Gp 1- P 1** 'Someone has to have some sort of introduction to it. You can't just walk off the street and say 'I'm an ice-cream vendor and I do ergonomics''



factually correct;

**Gp 2 – P6** 'And you read what people write and it is factually wrong. There aren't that many facts in ergonomics, and if you get one of the few facts in ergonomics wrong, I think that makes you a bad ergonomist. You know, and that's something that does concern me, particularly if people then design around that.'

and scientifically robust:

**Gp 3 – P2** 'And the flip side of that is the research where it kind of makes out to be quite a big thing when in fact there's five students that have done something.'

Whilst there was the feeling that ergonomics being a scientific discipline was important, there was also an opinion in one group that this could be unhelpful;

**Gp 3 – P1** – 'Focussing on the nitty-gritty and losing the bigger picture – so for example all those studies which have got endless statistical analysis.. and you think well you're just completely off the mark in the first place.'

One participant in another group felt that it was the *appearance* of being scientific rather than science itself which helped in performing well as an ergonomics consultant;

**Gp 2- P7-** 'I went to a place last year.... because some people were complaining of being hot/cold whatever else. And the problem there was political and a really poor management system. But I borrowed x's box of thermal measuring kit, which is a silver flight case ..... And because I walked in there and wagged this air monitor around, and walked around with a stick, it was fantastic. I got all sorts of nonsense out of them. And they genuinely thought this was high science. It was the difference between me going 'there-there, your manager's an arse, which is the root of the problem, and you're a bit flaky,' and being able to go 'you're a bit flaky and your manager's an arse, but there's not much of a draft just here.' And that's kind of bizarre – it was a really challenging thing to have

in your career when you suddenly realise that the addition of a toy makes you legit.'

Two of the focus groups raised the fact that an ergonomics advisors' knowledge should be broad, covering the range of human sciences. They had been presented with the 'domains of specialisation' list from the IEA website before the discussion (IEA, 2006). This lists physical, cognitive and organisational ergonomics.

**Gp 1- P2** 'But I think in terms of the things on the definition list, they do need some, you know their competency needs to be to some level, in each of those specialisations' (*referring to the domains of specialisation from the IEA listing*)

**Facilitator**– 'what would you call those?'

**Gp1 - P2** 'Human sciences really, aren't they? You can't just, you can't just look at the physiological bit and forget the cognitive bit.'

In addition to having knowledge spread broadly across many areas, the ability to link that knowledge together was felt to be important by two of the groups.

**Gp 2- P2** – 'What about, generally being able to link different, I don't know, subjects together? ..... Things like broadly, you could talk about for instance when you're doing the risk assessments, you're looking at maybe the anatomy of somebody, and you should be thinking about what's going on in their head, you should be thinking about the business side - organisational aspects and just interacting with different subjects, and you need to have a broad understanding of all those in order to be able to do that.'

## **2. Skills and Abilities**

### **Summary**

The groups cited a number of skills and abilities, many of which might be deemed 'people skills'. These included communication, putting people at ease and facilitation. In addition, a number of more job-specific skills were discussed; these included

observation, problem solving and solution generation. Finally, a personal ability was also mentioned, namely the ability to learn and adapt.

### ***Detail***

#### **a. Communication**

Each group expressed the need for good communication skills;

**Gp 2- P5** – ‘Just the communication side of things – once you’ve sussed out what the problem is, you’ve then got to communicate it back.

and one group went on to explain this in more depth

**Gp 3- P8** – ‘I was gonna say someone that can um relate ergonomics to the audience’s personal experience. I’m just thinking perhaps in a training context. Giving examples that your audience can relate to which helps enormously in getting your points across.’

In two groups, specifically ‘good listening skills’ as an aspect of communication, were separated out for particular discussion. There was some debate in one group about whether some of these communication attributes could be taught.

**Gp 3- P5**– ‘I think it depends on whether you’re including the people skills. I don’t think that can necessarily be taught. You can be an expert on mice without having to ever speak to somebody.’

#### **b. Observation/Perception**

Each of the groups made reference to the need for a good ergonomics advisor to see beyond what was obvious within a workplace and beyond that which was presented as fact by staff:

**Gp 1- P5** – ‘Observant as well. I think that’s really important.

**P1** .....because you have to be able to hear what people say, but still see what they do. Because what they say isn’t necessarily what they do..’

**Gp 2- P5** – 'I think –perceptive skills, or good perception. In terms of not just the obvious things – I know I keep coming back to this – but um the bigger picture'.

#### **c. Putting people at their ease**

Two groups alluded to the necessity for good ergonomics advisors to put people at their ease so as to aid the communication process:

**Gp 1 – P2** – 'Something that I would say is nothing to do with ergonomics but they need to be able to put the person they are advising or the people they are advising at ease.'

This was linked in one group to having a non-judgemental approach;

**Gp 2- P4** – 'I think you have to be non-judgemental to be able to get the answers that you want. So ask things in a way that lets them know they can answer whatever they want and it's fine.'

#### **d. Solving problems and generating solutions**

Two of the groups noted the importance of problem solving and went on to be explicit about giving solutions.

**Gp 1- P2** – '.....problem solving .... you need to have that competence and experience for knowing well ok, if this is what's wrong, this is how we fix it. And have practical skills.'

Doing so in a consistent and effective way was raised in one group as being a mark of a good ergonomics advisor;

**Gp 3 – P2** 'You know if you're trying to solve a problem and you consistently solve it, effectively.'

#### **e. Ability to learn and be adaptable**

The ability to learn from experience and adapt one's practice accordingly was cited by two of the groups as being important to good ergonomics;

**Gp 2- P7** – ‘And they learn stuff, because clearly you don’t just go and read a book somewhere, there is a degree of.....

**P6** – Experiential learning.’

**Gp 3- P1’**.....someone who can adapt and change and be insightful, as opposed to someone who goes along and does the same thing over and over.’

#### **f. Facilitation**

Facilitation skills to use between different organisational players (for example between the ‘shop floor’ and management) were deemed important by one of the groups.

### **3. Other factors**

A number of additional attributes were outlined by the groups as being important. The first was that the individual should take a holistic (systems) approach to any problem. Though a holistic approach is clearly linked with content knowledge, it was outlined as a process issue. All three groups noted this requirement:

**Gp 2- P7** – ‘And what makes bad ergonomics work is uh an attempt to take something which is fundamentally, as the International Society says, ‘holistic’ and attempt to make it structured.....’

Other individual attributes were noted by single groups. These included being caring; wanting to help; being realistic/pragmatic about the benefits of ergonomics, being passionate and ‘looking the part’.

#### **3.3.3 Insight from considering ‘experts’**

In the results section below, a summary of the findings regarding ‘experts’ is provided, followed by the a section covering the detail.

#### **Summary**

In two of the focus groups, the discussion was extended to include thoughts about how an expert differed from simply a good practitioner. Some participants felt that an expert would demonstrate the attributes of the ‘good’ advisor, but to a greater

degree. Others felt that the nature of ergonomics as an holistic and broad discipline precluded the possibility of their being an 'expert', as this implied too narrow a focus for an holistic approach to be possible. There was also discussion comparing those in academia with consultants, with strengths and weaknesses raised for both sides of the divide.

### ***Detail***

#### **a. More of the same**

One group felt an expert would have more experience than simply a 'good' practitioner:

**Gp1 – P4** 'I'd say experience would come into it.

**Facilitator** – So an expert in terms of experience – what would they have than a good ergonomics advisor ... in terms of experience? They'd have more – is that what you meant?

**P4** – yeah they'd have more experience.....well experience of everything – of facilitating, of communicating of .....

This experience would give them a wider range of solutions on which to call:

**Gp 1- P1** – '– And along with the experience, when they come up with solutions they'll probably have a good idea already of what works and what doesn't work based on the type of person they've met, based on that person's attitude, the environment and think they'd have a good idea... they'd have a good repertoire of solutions for various environments, for various people, various tasks etc.'

The idea that an expert would have better facilitation skills than a good ergonomics advisor was also put forward, with the important point that an 'expert' might facilitate a different outcome than a 'good' ergonomics advisor who was dealing with same situation:

**Gp 1 – P1** – 'I think in terms of facilitating, what a really good or expert ergonomist can do is really help. 'Cause often you go in and let's be honest there's discord between the person doing what they're doing and the management – especially in industrial settings. So being really able to

facilitate that relationship between – so not only you know listening to the end user – but you know facilitating the management.

**Facilitator** – So a good facilitator would be someone who just manages to kind of glean the information potentially from different places as it were, whereas an expert actually moves that relationship on?

**P1** – that's what I'm trying to get at, yeah.

**Facilitator**– I'm just making sure that I understand. So it isn't simply that they get through the process, they actually, there is a different outcome.

**P1** – They actually improve that relationship, so again, at the end of the day they actually improve the business. As well as the person or people they're assessing.'

One further point was that whilst good ergonomics advisors would be effective, experts should be more so:

**Gp 1- P1**– 'I guess maybe following on from what P3 was saying, not only getting feedback but.....when you get to the point where you're getting proven success, so however you want to rate your success to show that your solutions, your problem solving has actually helped that company, so I think you know the more and more you can help people, the greater help you can give people if I can term it like that will also show you have become an expert.'

#### **b. Less not more**

By contrast, one of the groups felt that the term 'expert' was not one that should be used of ergonomists. When considering the list of attributes describing a 'good' ergonomics advisor they felt that an expert would have less, not more, than a good ergonomics advisor. They felt an expert's knowledge would be too narrow and non-applied and that they would have poor communication skills:

**Gp 2 - P7** – 'Because I think expert, depending on how you would define it, the way I would define it is somebody who is quasi autistic, who just has an obsessively deep, narrow specialism.....And probably can't

communicate it. I mean honestly, that was my experience of the ergonomics degree. It was people who were all – you know we talk about silo thinking, all embedded in psychology or vision or whatever else, and actually you learnt nothing from it unless you had someone like, for instance, x, who would say “go and do this stuff” “apply stuff”.’

When this group was challenged about why someone would come to them as consultants if they were not experts, the response highlighted the fact that though they felt the term ‘expert’ was unhelpful, customers nonetheless would expect it of them:

**Gp 2- Facilitator** – ‘So in terms of somebody getting – why would they ask you to come in- if you really aren’t an expert, why would they ask you to come..

**P6** – Because we’re technical...if you go back to the old legal definition, the sort of notion of reasonableness and technical, public and expert domain, I think we operate at a level below public domain, which is, we have a lot of technical knowledge about an awful lot of things and that’s what makes the outside world consider us experts.’

The tension between depth of knowledge and breadth of knowledge was also raised by one group:

**Gp 1- P2-** ‘– They may have that narrower but deeper knowledge. And that could be in different areas.

**P1** – they may be specialised.

**Facilitator**– How does that fit with this competence across the broad range of human sciences?

**P2** – I think they’ve got to have that as well. But say if there was a problem and uh you could see that this plainly doesn’t work, and maybe they need a new mouse, then I’ll phone xxxx –

**Facilitator** – because xxxx knows about mice



**P2** – Yeah – it might be something like that. But I guess you can get too specialised. Because if you're looking at a work situation, you don't know before you go in which might be the important area.'

### **c. The Academic/Consultant divide**

Differences between ergonomics advisors in the academic arena and those in the consultancy arena were raised by all three groups.

#### ***The trouble with academia....***

The consultants felt that academics were not helpful in the consultancy arena because of their lack of practical experience as noted above (section 3.3.2) but that they were useful within the research world:

**Gp 2 -Facilitator** – So in fact, because of our feeling about an expert being really very deeply knowledgeable about one area, it's never going to happen in our field?

**P7** – Pointlessly knowledgeable about.... From an applied point of view. Fabulous from a research point of view...

**Facilitator** – So do you think that expertise, in a sense from what you're saying, you're associating it with academia. Would that be a fair reflection of what you said?

**P7** – Yes.....'

#### ***The trouble with consultants.....***

Those in an academic setting doubted the possibility of expertise existing in the apparently repetitive nature of consultancy:

**Gp 3 – P1** – 'but too practical to me spells consultant rather than human factors specialist because to me an expert is someone who can adapt and change and be insightful, as opposed to someone who goes along and does the same thing over and over'

Interestingly, one of the consultant groups saw the appearance of *not* being an expert as a key business winner for them:

**Gp 2- P7 –...**I can't imagine us having a client who'd go 'tell me more about' ...who wouldn't just say – no 'fix it'. In fact our clients wouldn't employ us if we were experts..

**P6 –** They wouldn't be clients.

**P7 –** The shallowness, or the illusion of shallowness I think is one of the best skills which we can impart.

Though there was some disagreement with that point

**Gp 2- P5 –** 'However, they might see us as an expert in a certain area, because although we might know a lot about a lot of different areas, some people cotton on, and are happy to think of themselves 'we are experts in DSE, or we are experts in manual handling', even though we know that we know a lot more than that.'

### **3.3.4 Insight from considering poor performers**

In the results section below, a summary of the findings regarding 'poor performers' is provided, followed by a section covering the detail.

#### **Summary**

Considering bad advisors raised issues which had already been mentioned when considering good advisors. These included not being solution focussed; not looking at the bigger picture and not being sufficiently qualified. However, a detailed and new discussion area also arose about the fact that even qualified ergonomics advisors could disagree amongst themselves about what the right solution might be in a given situation.

#### **Detail**

##### **a. No one right answer**

One group had a lengthy discussion about how their opinions would differ from those of chair salesmen whom they described by explaining 'as far as we know [he] hasn't got any qualifications or experience, he's just trying to sell the chair.'

**Gp 1 –Facilitator** – 'Right. So what kind of things has he done – what's different about..

**P6** – Well he's told them to set the chair up very different to what we would. He's told them to make sure they've got arms so they can rest on them, whereas we would say don't rest on them, you know, things like that. And heights, you know, tell them to make sure their feet are flat on the floor rather than get to where you need to and get a footrest.

**Facilitator** - OK – so fundamentally different.

**P6** – Yeah fundamental stuff- like if there's a fixed lumbar support, yeah that's the perfect place for you, when it , may not be, but they've got a fixed one, so they're not going to tell you it's in the wrong place.

The discussion went on, however, to acknowledge that opinion would differ amongst their group

**Gp 1 - P2** –'I think we would manage to disagree with each other in this room if we had the same situation, and we individually did an assessment. I think we would spot different things, we would prioritise them differently and we would have different solutions.'

**Facilitator** – ....Why is that level of disagreement ok, whereas the level of disagreement between you and the furniture suppliers say, isn't?

**P6**– We're not just trying to sell the chair. We think, I think we're telling the person the best thing for them, and P2 thinks she's telling them the best thing for them. We're not there just to sell the chair.

**Facilitator**- Sure

**P6** – So we both think we're doing it for the person's good, and to improve their situation, not just to sell the chair.

**Facilitator** — .... I also agree with the fact that it's quite likely that we would come up with different ways forward. Do you not think that is a problem though?

**P2**– I think it is if you were on the receiving end.

**P7**– It depends on how different. If there are small differences, and there are bound to be, because we're all coming from slightly different perspectives, then um

**P1** – But there's always the £1 solution and the £1000 solution, so at the end of the day so long as you think of the fundamentals – you know you're not placing someone in a really awkward posture, you're not affecting them in terms of musculoskeletal physiology etcetera, there are going to be different solutions.....Whereas someone who is just throwing in a chair and not understanding the physiology may actually harm the individual.

### 3.3.5 Summary of findings

**Table 3. 3: Knowledge, Skills, Attributes and Other factors (KSAOs) of a good ergonomics advisor**

		Consultancy Group 1 (n = 11)	Consultancy Group 2 (n = 8)	Research Group 3 (n = 7)
<b>Knowledge</b>	Practical (not just theory) *	•	•	•
	Broad range of Human Sciences†	•	•	
	Scientific†		•	•
	Integrated†		•	•
	Beyond common knowledge†	•	•	
	Factually correct		•	
<b>Skills and Abilities</b>	Communication*	•	•	•
	Observation/Perception*	•	•	•
	Listening†	•	•	
	Problem solving†	•		•
	Solution Generation†	•	•	
	Put people at their ease†	•	•	
	Can learn/ Adaptable†		•	•
	Facilitation	•		
<b>Other factors</b>	Holistic/Systems driven *	•	•	•
	Caring	•		
	Wanting to help	•		
	Realistic/ Pragmatic			•
	Passionate			•
	Looking the part		•	
	Consistent			•
	Effective			•
<b>Key</b>		* = concept mentioned by 3 groups      † = concept mentioned by 2 groups		

### **3. 4. Discussions**

#### **3.4.1 The taxonomies of characteristics**

Asking ergonomists their opinion about what makes a good ergonomics advisor without providing category prompts, provided themes which could usefully be categorised into the 'Knowledge, Skills & Abilities and Other factors' taxonomy (Table 3.3). The characteristics of good ergonomics advisors put forward by the groups are discussed below.

#### **3.4.2 Knowledge, skills, abilities and other factors**

##### **Knowledge**

That knowledge should be practical as well as theoretical was proposed by all three of the groups in the study. Wilson (2000) argues that this underpins the nature of ergonomics as an applied science; 'our field of study is the theory and the practice of understanding people and their characteristics (the human factors) in relation to design'. He also proposes that ergonomics is the only discipline that relates humans to technology, *scientifically* (Wilson, 2000, citing Meister, 1995).

Two of the other characteristics of the knowledge raised by the groups; that it should be factually correct and beyond what is commonly held, are commensurate with the characteristics of experts outlined in Abdolmohammadi & Shanteau (1992). They maintain that exemplary performers in a field should have an extensive and up-to-date content knowledge of their subject.

It is interesting, however, that the groups did not spend a great deal of time listing the content of what a good or expert performer should know, but rather focussed on what they should be capable of doing. This may in part be driven by the nature of the question the groups were asked. They were asked to think about somebody they felt was good at ergonomics and prompted to describe 'what they are like', or 'what makes them good'. These questions may have drawn the groups away from defining an extensive content list for the knowledge required.

##### **Skills and Abilities**

In their paper arguing for the need to teach 'softer' skills to ergonomists, Shorrock and Murphy (2005) outline the similarities between ergonomics consultants and 'helpers'; a term used in counselling. They describe the four factor groupings of the

consultant effectiveness scale (Knoff and Hines, 1995) along with the main associated behaviours, noting that it is process rather than content that supports effectiveness (Table 3.4).

Many of the characteristics outlined by participants in this study are present in the 'Problem-solving skills' factor in the consultant effectiveness scale (marked in bold in Table 3.4). Whilst most ergonomics training programmes will teach the 'harder' ergonomics techniques required for solving problems, Shorrocks and Murphy argue that the softer problem solving skills, identified in this study as marking out good ergonomics advisors, are not part of the training. It is of note, however, that the behaviours denoting the other factors in this scale remained largely unmentioned in this study.

**Table 3.4: The factor groupings and associated behaviours of the consultant effectiveness scale (taken from Shorrocks and Murphy (2005) after Knoff and Hines (1995))**

Factor	Behaviours
Inter personal skills	Respect, trustworthiness, <b>approachability</b> , positive attitude.
Problem-solving skills	<b>Good facilitator, active listening, good rapport builder, good at problem-solving, astute observation.</b>
Consultation process and application skill	Willingness to get involved, evaluation and focus of ideas, active orientation, follow-through, identification of clear goals
Professional practice skills	Maintains confidentiality, trustworthy, clear identity.

Behaviours in **bold** are the themes mentioned in this study

### ***Solution Generation***

The importance of generating solutions is one characteristic not mentioned explicitly in the consultant effectiveness factors (Table 3.4) but which was put forward by two of the groups. As Cornford and Athanasou (1995) point out in their paper on ergonomics professionals, 'What separates the expert from merely the competent performer is that the expert can also tell you how to fix those faults and get things working once more'. Jackson and McKergow (2006) argue that problem-focus, rather than solution-focus is the norm for many arenas of modern thinking, and many technological disciplines have been successful due to their problem focus. However, they go on to state that, 'it is less useful when the issue involves interactions between people' at which point the solution-focus model is more appropriate.

### ***Can learn/ Adaptable***

In their paper on learning and epistemic world views, Spiro, Feltovich and Coulson (1996) argue that individuals whose world view allows them to be flexible in their application of their knowledge will fair better in complex domains. This resonates with the description of a good ergonomics advisor as being 'someone who can adapt and change and be insightful, as opposed to someone who goes along and does the same thing over and over.' These authors argue that individuals with a flexible world view 'account for complex systems with multiple explanatory frameworks'; 'assume phenomena are highly interrelated' and 'apply pre-existing knowledge in a flexible and combinatory manner.' This links in well with the 'holistic' approach issues discussed below.

### ***Facilitation***

Consultants in many fields have been categorised using a continuum, with traditional content 'experts' at one end and 'change agents' or 'process facilitators' at the other (e.g. Schein, 1987; Broberg & Hermund, 2004; Nadler, 2005). The content expert has been viewed as a doctor, with the recipients of the advice, the patients. The facilitator, on the other hand, helps others to help themselves (Broberg & Hermund, 2004; Nadler, 2005). In some participatory ergonomics programmes, the ergonomist may take aspects of both roles, providing scientific information as an 'expert', but empowering and facilitating non-ergonomist team members to generate their own solutions with the information (Devereux & Buckle, 1999; Devereux & Manson, 2008). In this sense, the ability to facilitate is both a mark of an expert and the evidence of relinquishment of that role.



## **Other factors**

### ***Holistic/Systems driven approach***

It is perhaps unsurprising that all three groups highlighted the importance of the holistic, systems driven approach in ergonomics, given that Wilson (2000) states 'The holistic/systems approach is a bedrock of ergonomics practice – it is what provides the strength of ergonomics.' From the work of Spiro et al. (1996), it would seem that as well as an 'approach' or 'technique', holistic thinking is also a fundamental characteristic of the individuals who will tend to excel in complex, multifaceted domains such as ergonomics.

### ***Being passionate, caring, wanting to help***

It is interesting that two of the three groups highlighted motivational drivers such as wanting to help, being caring or being passionate as important for good practice. Byham and Moyer (1996) separate out motivation from behaviour for specific analysis in terms of competencies. They view these motivational dimensions as being important but relatively unteachable, being aspects which an individual brings innately to a job role. This resonates with the view of one of the participants, that some important aspects of being a good ergonomics advisor probably could not be taught.

### ***Being Consistent and effective***

Shanteau and his co-authors (2002) argue that consistency is an important mark of an expert but it is not sufficient, as one could be consistent and yet wrong. Consistency combined with effectiveness however, can be viewed as evidence of expertise in any field, and can be assessed where the gold standard for performance in a domain exists (Shanteau et al., 2002).

### **3.4.3 Academic vs. Consultant**

Stanton (2005) outlines the approach of the ergonomist using the scientist-practitioner model. He explains that as a scientist, the ergonomist should, amongst other activities, develop hypotheses; use rigorous data collection and analysis techniques; and test theories. Conversely, as a practitioner the ergonomist will address real world problems; offer the most cost effective solutions and be required to seek compromises in difficult circumstances. He argues that most ergonomists will work somewhere between these two poles.

The response of the groups in this study suggested that at least one of the consultant groups (Gp 2) felt very firmly at the practitioner pole, applauding the 'shallowness' of their own approach, underlining the need for realism and pragmatism yet at the same time exploiting the opportunity to make clients 'think that you're a scientist' when necessary. The academic group (Gp 3), on the other hand, was alone in being critical of a lack of science in some ergonomics studies, placing them nearer what Stanton calls the scientist pole. These features echo what Shadbolt, (2005) describes as academic vs. practitioner expertise and suggests that academics and consultants may require different KSAOs.

Meister (1992) warns against too broad a split between research and practice, however, explaining that 'much academic writing explains everything but at the same time very little, because one can do nothing with it.' He describes the difference between explanatory knowledge and instrumental knowledge, explaining it is the latter which is needed by the practitioner, and it is often not the latter which is generated by academia; this is perhaps the concept behind the comment that 'experts' are 'pointlessly knowledgeable about' specific areas 'from an applied point of view. Fabulous from a research point of view...'

#### **3.4.4 No one right answer**

Shanteau (1992) explains that experts will tend to be inconsistent or disagree in fields where the 'stimuli are dynamic and generally involve human behaviour.' This, they explain, is due to the fact they are being 'asked to evaluate and decide about what is in effect a moving target'. The participants in this study acknowledged that they would 'spot different things, prioritise them differently and have different solutions.' It was felt that one acceptable reason for the differences in solutions put forward was that different solutions for the same problem could be proposed based on cost.

This was in contrast to the differences cited between ergonomists and the chair salesman, who was reported as giving factually incorrect information and being motivated by the desire to make a sale, rather than by the needs of the user.

#### **3.4.5 Good vs. Expert**

The discussions regarding 'experts' demonstrated a divide in the thinking between the different groups. One consultancy group equated the term 'expert' with 'academic' and had strong views as to why such an individual would not be useful in

their consultancy world. However, this same group acknowledged that the term 'expert' and indeed their 'expertise' was what attracted customers to use them.

The other consultancy group felt that an expert would have all of the attributes of a good ergonomics advisor, but in greater measure, and that the outcomes of their work would be quantifiably different, therefore. This is consistent with the idea of an 'exemplary performer' put forward by Rothwell and Lindholm (1999); they are beyond an experienced worker and are 'best in class'.

### **3.4.6 Limitations**

This study garnered opinion from 26 ergonomists in three focus groups. Some authors have proposed that in order to explore complicated issues in depth, as many as thirty focus groups might be required (Kreuger and Casey, 2000; Fern, 2001). However, the aim of this study was to determine aspects of expertise which could be examined further by other methods, and so the exploratory nature of the work supported undertaking fewer groups (Curtis & Redmond, 2007). It is acknowledged, however, that these findings on their own cannot be generalised.

A further known limitation of focus groups is their potential to be dominated by one vociferous participant at the cost of the opinions of others. Whilst each of the groups had members who were more willing to express opinions than others, care was taken by the moderator to involve each member of the focus group.

Finally, it is also acknowledged that often participants have a desire to conform to expected norms in their focus group answers (Smithson, 2000). However, the areas for discussion in this study were relatively novel, and therefore there is not a pervasive norm to which the groups might feel the need to conform.

### **3.4.7 Further study**

It is common place, having generated a list of KSAOs, to require subject matter experts to rate them for their importance (Maurer, 2002; Rodriguez et al, 2002). This would be an interesting next step in the process for ergonomists with the subsequent step of identifying the competencies emanating from the KSAOs. Given that a list of competencies already exists (IEA, 2001) comparing the KSAOs generated in this study with them would be a useful next step.

### 3.5 Summary and Conclusions

The aims of this study were threefold

- To determine the opinion of experienced ergonomists as to 'what makes a good ergonomics advisor?'.
- To identify whether an 'expert ergonomics advisor' differs from a good one.
- To relate the opinions of the ergonomists to the literature on practice, expertise and competency.

Asking ergonomists their opinion about what makes a good ergonomics advisor provided themes which could usefully be categorised into the 'Knowledge, Skills & Abilities and Other factors' taxonomy. The four characteristics identified across all three groups were; having practical (not just theoretical) knowledge; taking a holistic/systematic approach; being observant/perceptive and having good communication skills. Whilst the first two of these characteristics can be acquired from an academic course with work placement opportunities, the second two are unlikely to form part of a formal ergonomics training course.

The attitudes of the groups demonstrated that the term 'expert' was loaded, with some feeling it had negative connotations, implying an individual with too narrow a focus to be useful as an ergonomist. Discussions suggest there may be differences in the required characteristics for those in academia compared with those in consultancy, with scientific rigour being more important for the former, and meeting the client needs for the latter.

Differences in the recommendations different ergonomists would make and between ergonomists and other professionals working in the field were raised, with the former differences seen as acceptable, and the latter as unacceptable.

In conclusion, this study has provided some answers to the first two of the overarching research questions asked in this thesis; namely, what are some of the features of ergonomics expertise and what are the characteristics of good/expert ergonomics advisors? The next step, having outlined the KSAOs for a specific profession, would be to determine the competencies which emanate from them. The International Ergonomics Association (IEA) has already produced such a list of competencies, so the next chapter will use this list to examine expertise amongst ergonomics advisors further.

### **Chapter 1 – Introduction**

- Problem statement
- Research aims
- Research Paradigm
- Thesis Structure

### **Chapter 2 - Literature review**

- Establishing the nature of expertise and how it is identified and measured
- Establishing the nature, extent and findings of previous work examining expertise amongst ergonomics and allied professionals

### **Chapter 3 – What characterises good and expert Ergonomics Advisors?**

- 3 Focus groups (n = 26) with Ergonomists
- Model building of features of good and expert ergonomics practice

### **Chapter 4 – The self reported competencies of Ergonomics Advisors**

- 217 competency questionnaires from 6 national ergonomics conferences
- Establishment of areas of high and low confidence across the breadth of IEA ergonomics competencies.
- Relationship of competence and expertise

### **Chapter 5 – The Knowledge and Activities Ergonomics Advisors**

- 8 Focus groups (n = 55) with Ergonomists and other professional groups engaged in ergonomics advising
- Template analysis and model building of ergonomics expertise from knowledge and activities differences

### **Chapter 6 – The decision making expertise of Ergonomics Advisors - part 1**

- ULD risk assessment task undertaken by 58 PREs and EOPs and a control group of 148 students
- Establishment of comparative expert performance using the CWS index of expertise

### **Chapter 7 – The decision making expertise of Ergonomics Advisors - part 2**

- Investigation of the content of risk assessment decisions
- Relationship of decision content and expertise

### **Chapter 8 – Discussions, Implications and Conclusion**

- Discussions and implications of findings from all studies
- Limitations
- Recommendations for further research
- Conclusion

## **Chapter 4 – Investigating Expertise using the IEA's Core Competencies**

### **4.1 Introduction**

In the previous chapter the results were presented from focus groups with ergonomists, conducted with the aim of identifying the characteristics of good and expert ergonomics advisors. The most commonly cited characteristics of high level performers from that study were: having practical (not just theoretical) knowledge; taking a holistic/systematic approach; being observant/perceptive and having good communication skills. These and all the characteristics raised in that study were summarised under the headings of knowledge, skills, abilities and other factors (or KSAOs) which are often outlined as being the building blocks of competencies (Kierstead, 1998).

Given the existence of a list of competencies for ergonomics professionals (section 2.8.4) this chapter reports on a study which used the existing list to investigate some of the issues raised by the focus group work (Chapter 3) and to extend the examination of ergonomics expertise to include both ergonomists and other professionals giving ergonomics advice.

#### **4.1.1 Research presented in this chapter**

Two of the research objectives of this research were to:

- Examine the extent to which the IEA's ergonomics competencies are held by ergonomics advisors.
- Determine any differences between EOPs and PREs highlighted by the IEAs competency listing.

This chapter describes the findings from administering a questionnaire (based on the IEA's core competencies) to professionals working in the ergonomics domain. Competency elements in which participants reported high and low confidence are outlined, along with the characteristics of the participants which are associated with them.

This self report, quantitative data suggest that there are confidence differences (across the IEA's competencies) between ergonomists and others who work in the

ergonomics domain. Differences associated with training level, years of experience and nationality are also apparent. The possible implications of these findings are discussed, along with their contribution to the research questions of this thesis.

#### **4.1.2 The IEA competency listing**

This study uses the competency listing from the IEA because, as its name suggests, the IEA is perhaps the most 'over-arching' of all the Ergonomics bodies, being 'the federation of ergonomics and human factors societies from around the world.' This competency list is used as a starting point to look at competencies amongst ergonomics advisors, with a view to evaluating both levels of competence and the usefulness of the competency listing to do this.

There are 41 elements in the competency list which are divided into 9 units as follows:

- Unit 1. Investigates and analyses the demands for ergonomics design to ensure appropriate interaction between work, product and environment, and human needs, capabilities and limitations.
- Unit 2. Analyses and interprets findings of ergonomics investigations
- Unit 3. Documents ergonomics findings appropriately.
- Unit 4. Determines the compatibility of human capabilities with planned or existing demands.
- Unit 5. Develops a plan for ergonomics design or intervention.
- Unit 6. Makes appropriate recommendations for ergonomics changes.
- Unit 7. Implements recommendations to improve human performance.
- Unit 8. Evaluates outcome of implementing ergonomics recommendations.
- Unit 9. Demonstrates professional behaviour.

The first four units (containing 19 elements) describe the assessment and investigation of ergonomics problems, and the recording of the findings there-from. The second four units (containing 17 elements) describe the planning, delivery and evaluation of interventions/recommendations based on the assessments made. The final unit (containing 5 elements) describes various aspects of professional behaviour.

#### **4.1.3. Study aims**

The aims of this study were to:

- Determine the confidence levels of a group of ergonomists and other professionals in each of the IEA's competency units.
- Identify which characteristics of the participant sample are linked with high and low confidence.
- Determine the applicability of the IEA's competencies to the assessment of the expertise of ergonomics advisors.

## 4.2 Methods

### 4.2.1 Design

Questionnaires were selected as the chosen method of data collection because they are useful for obtaining large amounts of data from large samples, relatively inexpensively (Wilson & Corlett, 2005). In the first instance, a questionnaire was designed using the IEA's core competencies, copied verbatim from their list on the website (see Appendix B). For practical reasons, the summary list of elements was used, rather than the full list as this extended to 10 pages.

Gauging competence by asking participants how 'competent' they feel in a particular area has been used previously in expertise studies (Stewart et al., 2000). Using this approach, a small pilot was run (n = 5) using a Likert scale based on competence and a rating scale to ask how important the respondents felt the competence area was (see Fig 4.1). A 7 point scale was selected to elicit opinions from respondents about how competent they felt in each of the IEA's 41 elements, as 7 point scales are more discriminating than 3 or 5 point scales.

<i>How competent are you in....</i>	<i>Personal Competence scale</i>	<i>Importance Rating</i> <i>1=Not at all important</i> <i>5=Critical</i>
<i>1.1 Understanding the theoretical bases for ergonomics planning and review.</i>	<div> 0 1 2 3 4 5 6 </div> <div> Not at all competent Completely competent </div>	<b>5</b>

**Figure 4.1: Example from the Pilot Questionnaire**



Participants in the pilot disliked being asked how 'competent' they were, and recommended they be asked how 'confident' they were that they could 'do' each of the elements.

It has previously been noted that confidence is a less 'loaded' term to use than 'competence' (McColl, 1993). Asking how *competent* participants were, challenged their professionalism and encouraged them to respond with 'desired' responses rather than real ones. Other studies have elicited responses about confidence using Likert scales (Pritchard et al, 2002) so it was felt that this change in terminology should not preclude a Likert scale approach.

Furthermore, a number of studies have shown a positive link between confidence and competence (Leopold et al., 2005; Stewart et al., 2000). Stewart et al. (2000) found a positive expression of confidence was related to a positive expression of competence, for pre-registration house officers. It was confidence, rather than competence which defined whether or not the young medics would actually carry out particular tasks, therefore measuring 'confidence' could legitimately be linked with what these participants could actually do. A number of other studies also support a positive link between confidence (often termed self-efficacy) and competence (Ackerman et al, 2004). It was therefore decided that, in the light of its acceptance by the pilot participants, and its adequacy as a proxy for competence, confidence would serve as the term to use in the questionnaire.

#### **4.2.2 Participants**

The most common opportunity for congregation of ergonomics advisors was thought to be conferences. Therefore, purposive sampling was carried out, by distributing questionnaires into each of the delegate packs at the following conferences; the UK Ergonomics Society, 2005; the Applied Ergonomics, 2006 in the USA; the Association of Canadian Ergonomists, 2005; The Human Factors and Ergonomics Society of Australia, 2005; The Nordic Ergonomics Society, 2005 and The Ergonomics Society of Korea, 2005.

These conferences were selected because they fell in the 10 month data collection period, and because there were willing helpers in attendance to distribute and collect the questionnaires. In addition, English was the main language at all of these conferences except the Korean conference. However, there was the ability to translate the questionnaire into Korean by virtue of a Korean colleague. This

translation was given alongside the English version, should any of the delegates need it. Lack of this translation capacity was the reason for no European societies other than the Nordic and UK conference being targeted.

#### 4.2.3 Procedure

Participants were asked to rate their *confidence* in an element and were then asked to rate each element for its *importance* in ergonomics practice. It was made clear that this importance was a stand alone, rather than a comparative measure.

One element is represented in the example below (Figure 4.2).

<b><i>How confident are you that you....</i></b>	<b><i>Personal Confidence scale</i></b>	<b><i>Importance Rating</i></b> 1=Not at all important 5=Critical
1.1 Understand the theoretical bases for ergonomics planning and review.		<b>5</b>

**Figure 4.2: Example from the Final Questionnaire**

In this example, this respondent feels not at all confident about his/her understanding of the theoretical bases for ergonomics planning and review (shown by circling 0 on the scale) **but** feels that this is a critical element for ergonomics practice (shown by rating it with a 5).

The full questionnaire is available in Appendix B at the end of this thesis.

#### 4.2.4 Analysis

Likert scales are often viewed as interval level data and analysed using parametric tests, particularly where sample size is large, and normal distribution is evident (Jaccard & Wan, 1996). However, a number of authors criticise this approach, given that it is not always fair to assume that the points on the Likert scale are equidistant from one another (Cohen et al., 2000; Jamieson, 2004; Kuzon et al, 1996) but rather

that the data are ordinal. Consequently, the data was therefore analysed using non-parametric tests.

Responses were analysed initially in purely descriptive terms, separating out different groups by, for example, occupation and looking at the median values for their responses, as well as the frequencies for each response category.

The students were then removed from the sample and analysed on their own, leaving the sample of 185 professionals involved with Ergonomics.

Kruskall Wallis tests were used to assess inter-groups differences followed by Mann-Whitney tests to establish where the differences lay. Friedman ANOVAs were used to test for intra-group differences followed by Wilcoxon signed rank tests to identify which units differed. Finally contingency tables were generated in order to use Pearson's Chi Square to test for independence/association of effects.

4.3 Results

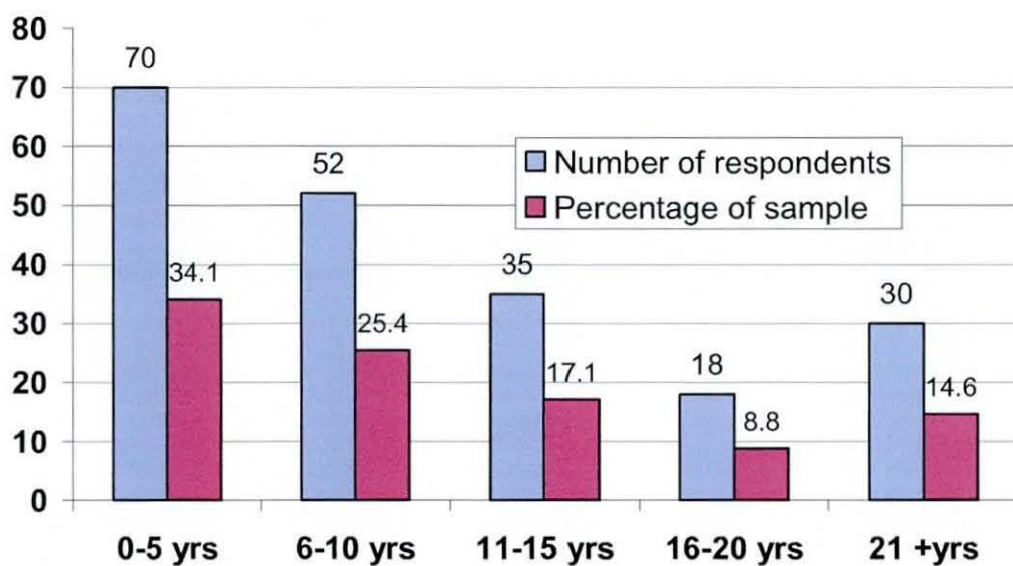
4.3.1 Participants

The return rates and sample proportions are presented below in Table 4.1.

Table 4.1: Response Rate

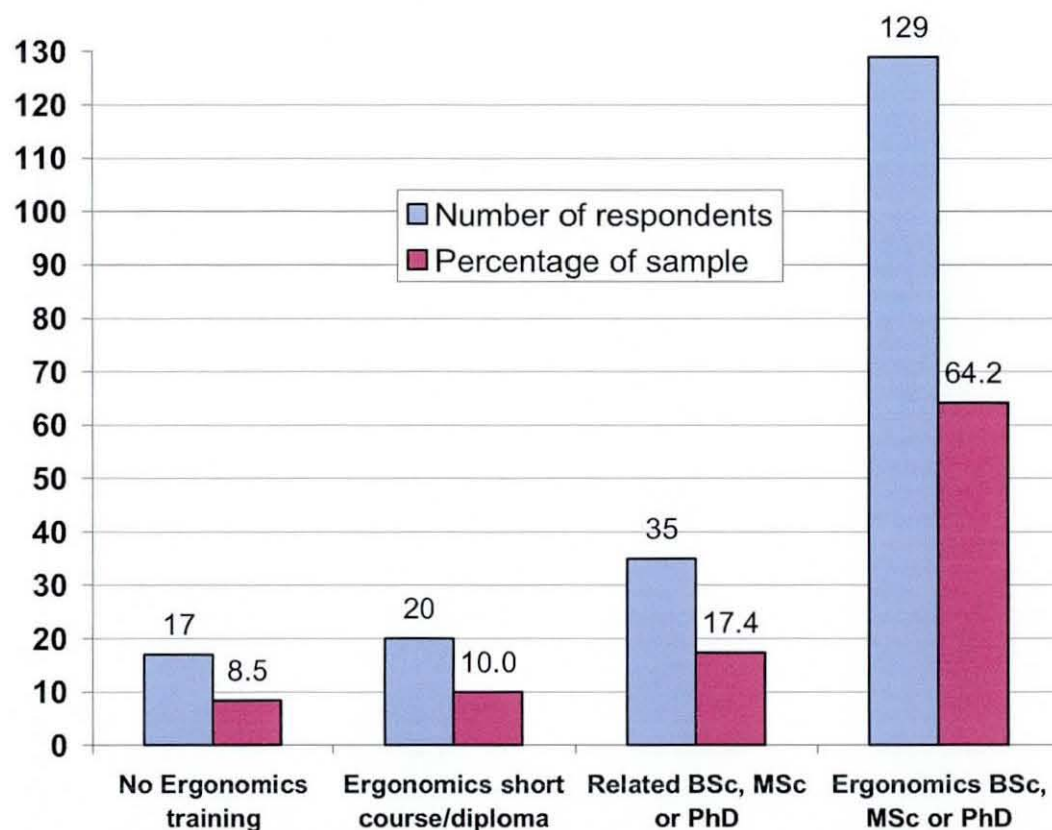
Conference Country	Number of responses (frequency)	Response rate (% of attendees at the conference)	Proportion of the study sample (%)
UK	51	20	23.5
Canadian	48	30	22.1
Korean	42	21	19.4
Australia	32	33	14.7
Nordic	10	15	4.6
USA	34	5	15.7
Total	217		100

The years' of experience in Ergonomics of the sample are summarised below (Fig 4.3).



**Figure 4.3: Years of Ergonomics Experience – Overall Sample**

The respondents had varying degrees of qualification levels in ergonomics as represented below (Figure 4.4).



**Figure 4. 4: Level of Ergonomics Training**

The Occupations of the respondents in the sample are summarised in Figure 4.5 below. Respondents were grouped into practitioners; academics/academics who carried out some consultancy; other professionals and students.

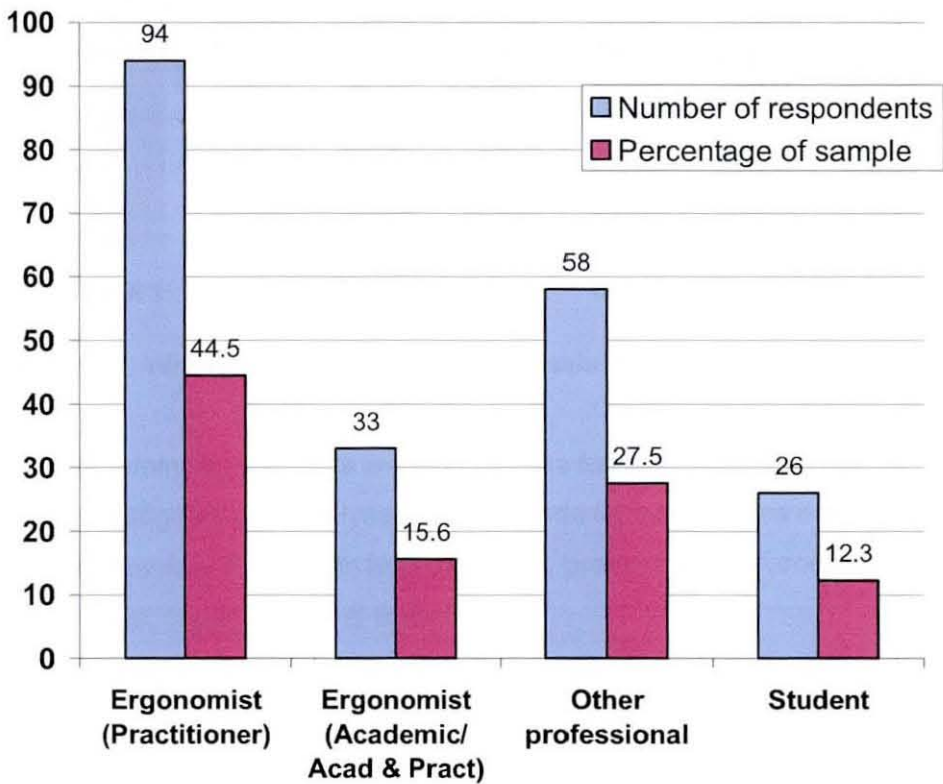


Figure 4.5: Occupations

4.3.2 Importance of the competency elements

The respondents, unlike in the pilot, largely ignored the importance rating part of the questionnaire. It was therefore removed from the analysis.

4.3.3 High and low confidence

Overall there were 41 elements of competency in which respondents were asked to rate their *confidence*, on a 7 point scale (see Fig 4.2). The questionnaire was analysed first in terms of the sample’s median confidence in each of the Units. The whole sample was analysed in this way and then the students were removed so as to focus attention on those already working in the area.



**Figure 4.6: Whole sample and professionals' median confidence**

By way of reminder, the Units were defined as follows:

**Unit 1.** Investigates and analyses the demands for ergonomics design to ensure appropriate interaction between work, product and environment, and human needs, capabilities and limitations

**Unit 2.** Analyses and interprets findings of ergonomics investigations

**Unit 3.** Documents ergonomics findings appropriately.

**Unit 4.** Determines the compatibility of human capabilities with planned or existing demands.

**Unit 5.** Develops a plan for ergonomics design or intervention

**Unit 6.** Makes appropriate recommendations for ergonomics changes

**Unit 7.** Implements recommendations to improve human performance

**Unit 8.** Evaluates outcome of implementing ergonomics recommendations

**Unit 9.** Demonstrates professional behaviour

As Figure 4.6 shows, for the professional sample, the median confidence in 5 units was 5, three were 4 and one was 4.5. In order to test whether there were *significant* differences in the sample's median confidence between the Units, a Friedman's ANOVA was carried out on the professional's data. Median confidence did vary across the nine Units ( $\chi^2(8) = 251.79, p < 0.001$ ).

To test in which units the sample had significantly higher or lower confidence, Wilcoxon signed ranks tests were carried out for median confidence in each unit



compared with the overall median confidence for the sample. A Bonferroni correction was applied where  $\alpha/9 = 0.005$ . Effect sizes ( $r$ ) were calculated using:

$$r = \frac{Z}{\sqrt{N}}$$

Median confidence was significantly lower (than their overall median confidence) for the professional sample on the following units (Table 4.2)

**Table 4.2: Lower confidence units for the Professional sample**

Unit	Description	Wilcoxon	Effect size	Significance
6	Makes appropriate recommendations for ergonomics changes	$z = -7.9$	$r = 0.6$ (large)	$p < 0.001$
7	Implements recommendations to improve human performance	$z = -4.1$	$r = 0.31$ (medium)	$p < 0.001$
8	Evaluates outcome of implementing ergonomics recommendations	$z = -7.1$	$r = 0.55$ (large)	$p < 0.001$

Median confidence was significantly higher for the professional sample than their overall median confidence, in the units represented in Table 4.3.

There was no significant difference between the professionals' overall median confidence and their median confidence in Units 1 and 5.

- **Unit 1.** Investigates and analyses the demands for ergonomics design to ensure appropriate interaction between work, product and environment, and human needs, capabilities and limitations
- **Unit 5.** Develops a plan for ergonomics design or intervention

**Table 4.3: Higher confidence units for the Professional sample**

Unit	Description	Wilcoxon	Effect size	Significance
2	Analyses and interprets findings of ergonomics investigations	$z = -11.3$	$r = 0.87$ (large)	$p < 0.001$
3	Documents ergonomics findings appropriately	$z = -5.91$	$r = 0.45$ (medium)	$p < 0.001$
4	Determines the compatibility of human capabilities with planned or existing demands	$z = -3.5$	$r = 0.27$ (small)	$p < 0.001$
9	Demonstrates professional behaviour:	$z = -3.1$	$r = 0.24$ (small)	$p < 0.01$

#### 4.3.4 What affects Confidence?

When Kruskal Wallis tests were carried out on the Professionals sample, overall median confidence was significantly affected by professional group ( $H(2) = 21.33$ ,  $p < 0.01$ ; ergonomics qualification level ( $H(3) = 15.37$ ,  $p < 0.01$ ; years of experience ( $H(4) = 29.37$ ,  $p < 0.0$ ; and Country ( $H(4) = 9.78$ ,  $p < .05$ ).

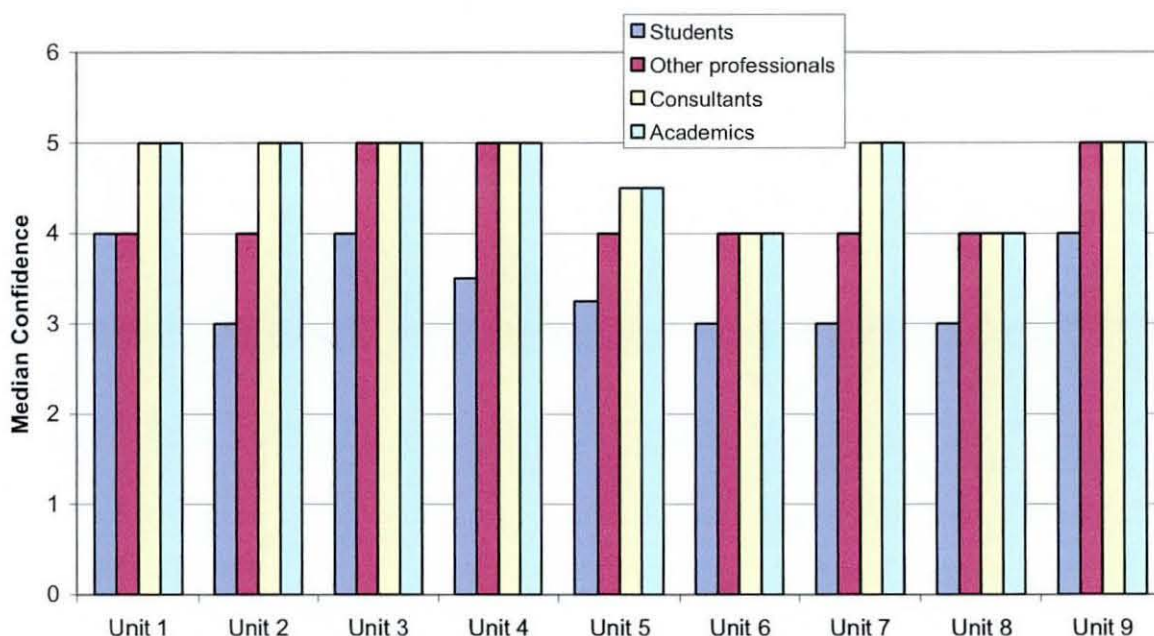
The effects of each of these variables on confidence are reported in four separate sections below. Each section is split into one part describing the effect of the variable on overall confidence (part a) and one part describing the effect on specific units (part b). A summary is provided at the end of each of these sub-sections.

##### 1. Effect of Professional Group.....

###### a. ....on overall confidence

The sample was split into ergonomist practitioners, ergonomist academics/academic practitioners, other professionals and students. The median confidence in each unit for these professional groups is represented in Figure 4.7 below.





**Figure 4.7: Median confidence for each unit for each professional grouping**

The Kruskal Wallis test reported above for professional grouping showed it has a significant effect on confidence. When students are included  $H(4) = 47.75$ ,  $p < 0.01$ . Table 4.4 below demonstrates that the academics had the highest mean rank median confidence and the students the lowest.

**Table 4.4: Mean ranks for median confidence across professional groups**

Group	Overall Median confidence	Mean Rank Median confidence
Students	3.25	53.21
Other professionals	4	81.32
Consultants	5	118.08
Academics	5	124.89

Two Mann Whitney tests were carried out to see whether the differences in Table 4.4 were significant:

Test 1: Other professionals compared to the ergonomists (the ergonomist consultants were chosen for this comparison).

Test 2: Students compared to other professionals.

A Bonferroni correction was applied giving a critical level of significance for the post hoc tests of  $0.05/2 = 0.025$ . There was a significant difference in overall median confidence between ergonomists and the other professionals, ( $U = 1558$ ,  $p < 0.05$  r

= 0.35) as well as between the other professionals and the students ( $U = 483$ ,  $p < 0.05$ ,  $r = -0.3$ ); both effect sizes being 'medium'.

### **Summary**

In summary the students were the least confident, with the non-ergonomist professionals significantly more confident than they, and the ergonomists (consultant and academic) significantly more confident than both groups.

### **b..... on confidence in specific units**

A Friedman ANOVA was carried out for each professional grouping, on their median response to each unit. Where this was significant, post-hoc tests were carried out comparing the Unit median with the overall median confidence for that professional group. Overall, the high and low confidence units for each professional group were in line with those for the overall sample (see section 4.3.3 above). Where they differed, they are reported below.

### **Ergonomist Consultants**

Median confidence did vary for the ergonomist consultants across the nine units (Friedman ANOVA:  $\chi^2(8) = 119.34$ ,  $p < 0.01$ ). Then Wilcoxon signed ranks tests were carried out for all units compared with the overall median confidence for that professional group. A Bonferroni correction was applied where  $\alpha/9 = 0.005$  and effect sizes were calculated in the standard way.

For ergonomist consultants, median confidence differed as for the whole sample, except that it was significantly lower than overall for Unit 2: Analyses and interprets findings of ergonomics investigations  $z = -3.78$ ,  $p < 0.005$ ,  $r = 0.29$  (small); and higher than overall for Unit 7: Implements recommendations to improve human performance,  $z = -4.15$ ,  $p < 0.005$ ,  $r = 0.25$  (small).

### **Other groups**

Median confidence did vary for the ergonomist academics across the nine Units (Friedman's ANOVA:  $\chi^2(8) = 60.87$ ,  $p < 0.01$ ); other professionals (Friedman's ANOVA:  $\chi^2(8) = 98.44$ ,  $p < 0.01$ ); and students (Friedman's ANOVA:  $\chi^2(8) = 30.192$ ,  $p < 0.01$ ), however it varied in line with the overall sample.

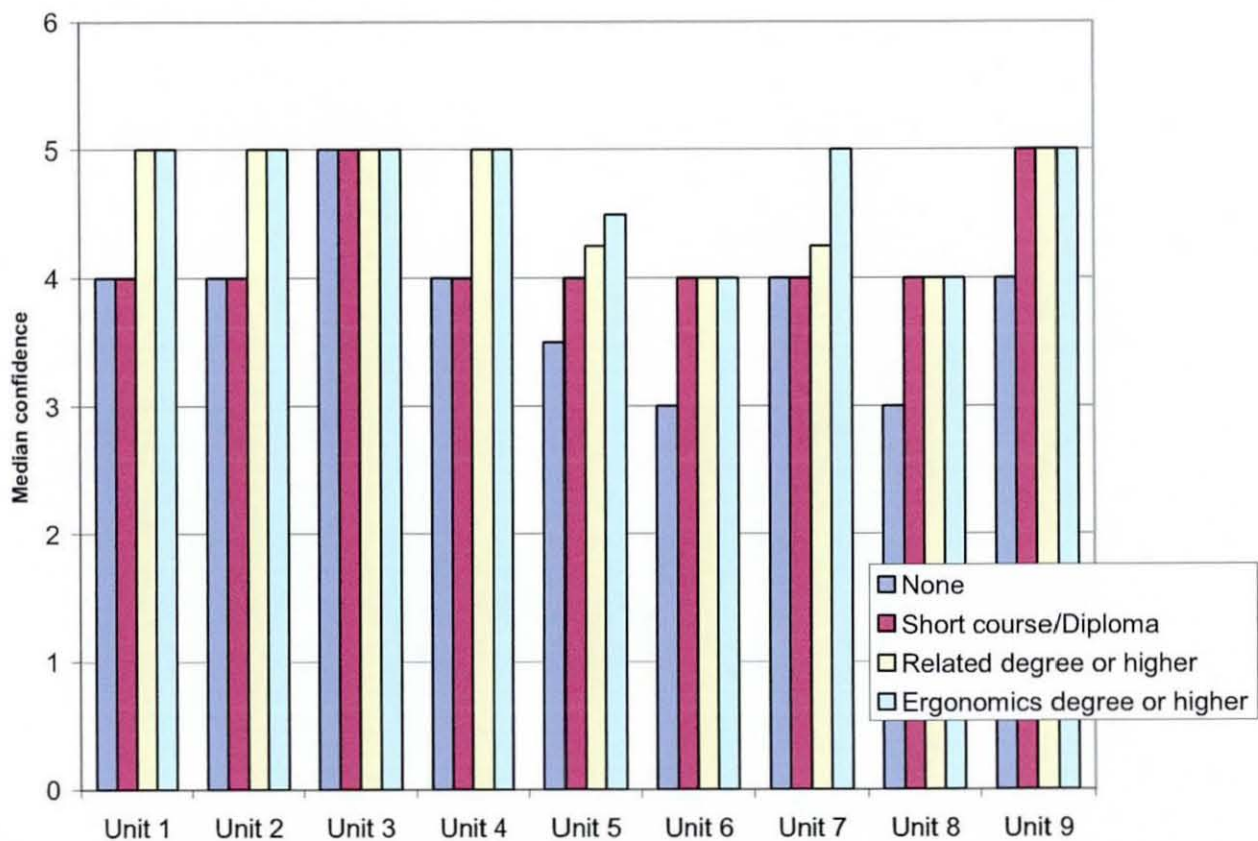
**Summary**

Each of the four professional groups had confidence which varied in line with the whole sample, except for the ergonomist practitioners, whose median confidence was lower than that of the whole sample for Unit 2 (Analyses and interprets findings of ergonomics investigations), and higher for Unit 7 (Implements recommendations to improve human performance).

**2. Effect of Qualification level.....**

**a. .... on overall confidence**

Closely linked with profession is qualification level. The Kruskal Wallis reported above for qualification level showed it has a significant effect on confidence ( $H(4) = 29.37, p < 0.01$ ). The median confidence in each unit for each of the qualification level groups is shown in Figure 4.8 below.



**Figure 4.8: Median confidence for each unit for each qualification level group**

As table 4.5 shows, confidence increases with level of qualification.



**Table 4.5: Mean ranks for median confidence across qualification groups**

<b>Ergonomics Qualification Level</b>	<b>Overall Median Confidence</b>	<b>Mean Rank Median Confidence</b>
None	4	63.53
Short course/Diploma	4	81.42
Related Degree	5	99.81
Ergonomics Degree	5	101.02

In order to test for significant differences, Mann Whitney tests were carried out as follows:

Test 1: No qualification with short course/diploma

Test 2: Short course/diploma with related degree

Test 3: Related degree with Ergonomics degree

Test 4: No qualification with Ergonomics Degree

A Bonferroni correction was applied giving a critical level of significance for the post-hoc tests of  $0.05/4 = 0.0125$ . There was no significant difference in overall median confidence between the 'none' and the 'short-course/diploma group nor the 'short course/diploma' and 'related degree' groups, nor the related degree and the ergonomics degree groups. However there was a significant difference between the 'none' and the 'ergonomics degree groups', ( $U = 454$ ,  $p < 0.01$ ,  $r = 0.30$ ). The short course/diploma group was approaching significance when compared with the Ergonomics degree group ( $p = 0.02$ ).

### **Summary**

In summary, having an ergonomics or related degree was associated with significantly higher confidence than having no ergonomics qualification.

### **b.....on confidence in specific units**

A Friedman ANOVA was carried out for each qualification level group, on their median response to each Unit. Where this was significant, post-hoc tests were carried out comparing the Unit median with the overall median confidence for that professional group.

### ***Ergonomics Degree or Higher***

Median confidence did vary for the 'ergonomics degree or higher' participants across the nine units when a Friedman's ANOVA was carried out ( $\chi^2(8) = 162.67$ ,  $p < 0.01$ ). For this group, median confidence differed as for the whole sample, except that it was significantly lower than overall for Unit 2,  $z = -3.00$ ,  $p < 0.01$ ,  $r = 0.21$ .

### ***Other groups***

Median confidence did vary across the nine units for the 'related degree or higher' participants ( $\chi^2(8) = 39.13$ ,  $p < 0.01$ ), 'short-course/diploma' participants ( $\chi^2(8) = 54.33$ ,  $p < 0.01$ ), and 'none' participants ( $\chi^2(8) = 30.96$ ,  $p < 0.01$ ), however it varied in line with the overall sample.

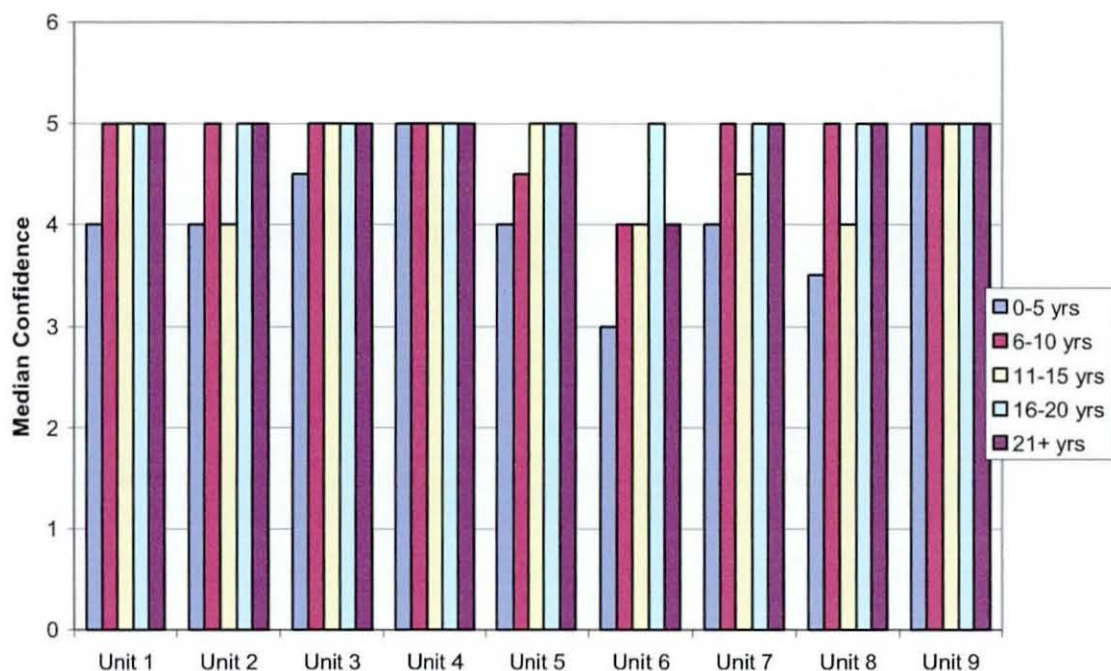
### ***Summary***

Each of the four qualification level groups had confidence which varied in line with the whole sample, except for the ergonomics degree holders, whose median confidence was lower than that of the whole sample for Unit 2 (Analyses and interprets findings of ergonomics investigations).

## **3. Effect of Years of experience.....**

### **a. ....on overall confidence**

The Kruskal Wallis reported above for Years of Experience showed that it has a significant effect on confidence ( $H(4) = 29.37$ ,  $p = 0.0001$ ). The median confidence in each unit for each of the years of experience groups is shown in Figure 4.9 below.



**Figure 4.9: Median confidence for each Unit for each ‘years of experience’ group (professional sample)**

As table 4.6 shows, confidence increases with years of experience.

**Table 4.6: Mean ranks for median confidence across years of experience groups**

Years of experience	Overall Median Confidence	Mean rank median confidence
0-5	4	53.26
6-10	5	85.60
11-15	5	89.33
16-20	5	98.44
21+	5	105.05

Because the 0-5 years group had the lowest median confidence in each unit (Table 4.6) this was chosen as the initial comparison group, followed by the 6-10 group.

Mann Whitney tests were carried out as follows:

Test 1: 0-5 with 6-10

Test 2: 6-10 with 21+

A Bonferroni correction was applied giving a critical level of significance for the post-hoc tests of  $0.05/2 = 0.025$ . There was a significant difference in overall median confidence between the 0-5 and the 6-10, ( $U = 535$ ,  $p < 0.02$ ,  $r = 0.41$  - medium) and therefore it is assumed with all the other groups. There was no significant difference between the 6-10 and 21+ groups, and therefore it is assumed with none of the others.

### **Summary**

In summary, having six or more years of experience was associated with significantly higher confidence than having fewer than 6 years of experience.

#### **b. ....on confidence in specific units**

A Friedman ANOVA was carried out for each experience group, on their median response to each unit. All groups varied in line with the overall sample; 0-5 yrs ( $\chi^2 (8) = 107.57$ ,  $p < 0.01$ ); 6-10 yrs ( $\chi^2 (8) = 47.25$ ,  $p < 0.01$ ); 11-15 yrs ( $\chi^2 (8) = 64.47$ ,  $p < 0.01$ ); 16-20 yrs ( $\chi^2 (8) = 64.47$ ,  $p < 0.05$ ) and 21+ yrs ( $\chi^2 (8) = 30.98$ ,  $p < 0.01$ ).

### **Summary**

All years of experience groups' confidence varied in line with the whole sample.

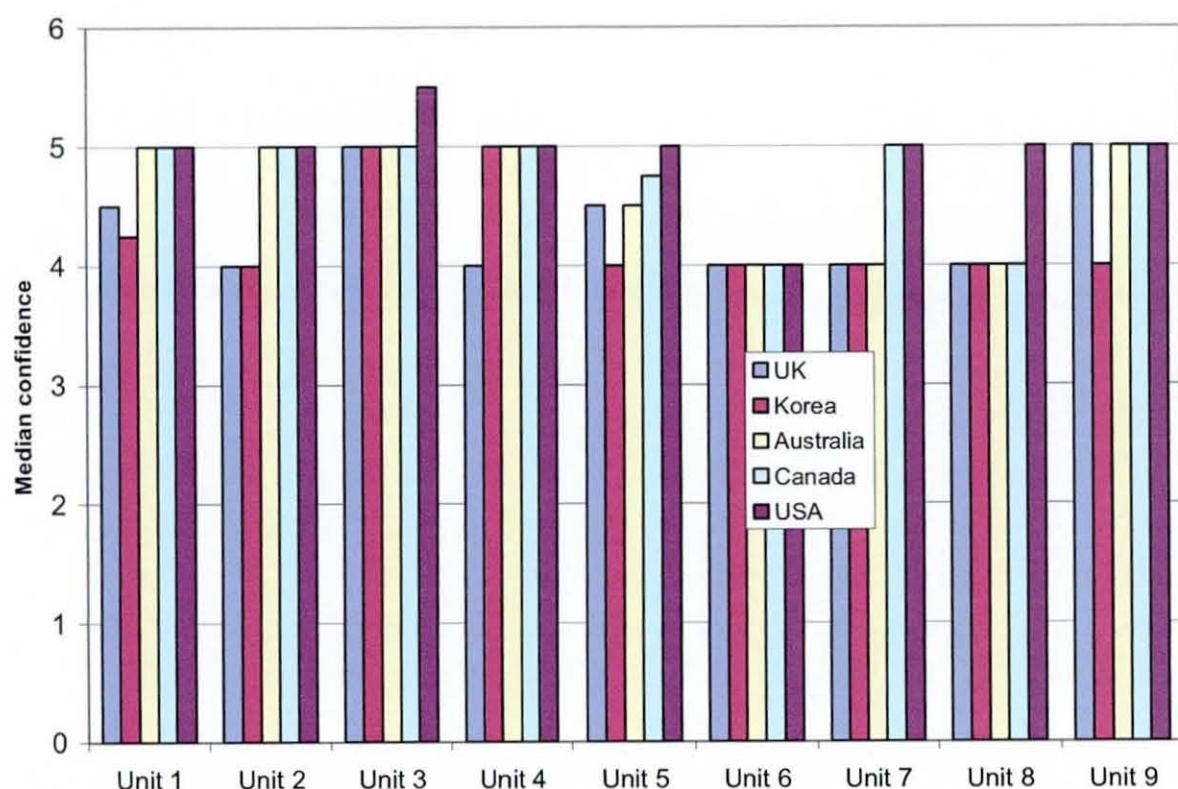
## **4. Effect of Country.....**

### **a. ....on overall confidence**

5 countries had sufficient data to allow comparison. The Kruskal Wallis carried out showed nationality has a significant effect on confidence ( $H(4) = 9.78$ ,  $p < .05$ ).

Each nation's median confidence in each unit is represented below (Figure 4.10).





**Figure 4.10: Median confidence for each unit for each country**

Overall median confidence by country was as follows (table 4.7):

**Table 4.7: Mean ranks for median confidence across national groups**

Country	Overall Median Confidence	Mean Rank Median Confidence
USA	5	103.44
Canada	5	96.56
Australia	4.5	81.32
Korea	4	79.73
UK	4	74.91

Because the USA had the highest median confidence in each Unit, this population was chosen as the initial comparison group, followed by Canada. Mann Whitney tests were carried out as follows:

Test 1: USA with UK

Test 2: USA with Korea

Test 3: UK with Canada



A Bonferroni correction was applied giving a critical level of significance for the post-hoc tests of  $0.05/3 = 0.016$ . There was a significant difference in overall median confidence between the USA and the UK, ( $U = 496.5$ ,  $p < 0.01$ ,  $r = 0.30$  - medium) but with none of the other groups.

### **Summary**

Overall the USA had the highest and the UK the lowest median confidence. Being from the USA was associated with significantly higher confidence than being from the UK. There were no other statistically significant national differences.

### **b. ....on confidence in specific units**

A Friedman ANOVA was carried out for each country's median response to each unit. Where this was significant, post-hoc tests were carried out comparing the unit median with the overall median confidence for that national group.

### **USA**

Median confidence did vary for the USA participants across the nine units when a Friedman's ANOVA was carried out ( $\chi^2 (8) = 65.26$ ,  $p < 0.01$ ). For this group median confidence differed unit by unit as for the whole sample, except that it was significantly lower than overall for Unit 2,  $z = -3.32$ ,  $p < 0.01$ ,  $r = 0.42$  (medium).

### **Other Nations**

Median confidence did vary for the Canadian participants ( $\chi^2 (8) = 41.04$ ,  $p < 0.01$ ); the Australian participants ( $\chi^2 (8) = 43.94$ ,  $p < 0.01$ ); the Korean participants ( $\chi^2 (8) = 32.26$ ,  $p < 0.01$ ) and the UK participants ( $\chi^2 (8) = 122.04$ ,  $p < 0.01$ ) however it varied in line with the overall sample.

### **Summary**

Each of the five national groups had confidence which varied in line with the whole sample, except for the USA group, whose median confidence was lower than that of the whole sample for Unit 2 (Analyses and interprets findings of ergonomics investigations).

4.3.5 Relationship between the factors affecting confidence

In order to elucidate whether each of the four factors (profession, qualification level, years of experience and nationality) affected confidence independently, contingency tables were produced. The independent variables were collapsed in line with the significant findings in section 4.3.4 above. The sample was split into two groups for each variable, based on median confidence (one group with median confidence of 5 or more, the other with less than 5). This produced the following two categories for each variable;

- Ergonomists (median confidence > 5) and other professionals (median confidence < 5)
- ergonomics/related degrees (median confidence > 5) and other qualifications (median confidence < 5)
- 6 or more years experience (median confidence > 5) and 0-5 years' experience (median confidence < 5)
- North Americans (median confidence > 5) and other nations (median confidence < 5)

Pearson's Chi square tests were then used to test for independence. The results are presented in Table 4.8.

Table 4.8: Independence of factors affecting confidence.

	Profession	Qualification level	Years of Experience	Nationality
Profession	-	Related p = 0.001 Ergonomists had higher ergonomics qualification level than other professionals	Related p= 0.001 Ergonomists had more experience than other professionals	Related p= 0.01 A higher proportion of North Americans are Ergonomists than 'other' national group.
Qualification level		-	Independent	Related p= 0.01 A higher proportion of North Americans have degrees than the 'other' national group.
Years of experience			-	Related p= 0.01 A higher proportion of North Americans have 0-5 years experience than the 'other' national group.
Nationality				-

### **Independence of Years of experience from other factors**

Years of experience varies independently of training level ( $\chi^2 (1) = 2.1$ ). However, Years of experience is associated with profession with only 19% of the Ergonomists having 0-5 years of experience, compared with 43% of the other professionals ( $\chi^2 (1) = 10.25$ ,  $p < 0.001$ , Cramer's  $V = 0.25$ ,  $p < 0.001$ ). Years of experience is also associated with nationality ( $\chi^2 (1) = 5.11$ ,  $p < 0.05$ , Cramer's  $V = 0.176$ ,  $p < 0.05$ ) with 35% of the North Americans having 0-5 years experience compared with only 20% of the 'other' national group.

### **Independence of Profession from other factors**

As described above, profession is associated with years of experience (ergonomists have more experience than the other professionals) and also with Nationality ( $\chi^2 (1) = 9.26$ ,  $p < 0.01$ , Cramer's  $V = 0.23$ ,  $p < 0.01$ ) with 80% North Americans being ergonomists compared with 58% of the rest of the nations. It is also associated with level of qualification ( $\chi^2 (1) = 51.4$ ,  $p = 0.001$ , Cramer's  $V = 0.55$ ,  $p = 0.001$ ) with 94% ergonomists having a related/ergonomics degrees compared with 45% of the other professionals.

### **Independence of Qualification level from other factors**

Qualification level is independent of years of experience for the whole sample ( $\chi^2 (1) = 2.6$ ) but is associated with profession (described above) and with nationality ( $\chi^2 (1) = 10.57$ ,  $p < 0.001$ , Cramer's  $V = 0.25$ ,  $p < 0.001$ ) with 91% North American have degrees compared with 70 % of the rest.

### **Independence of Nationality from other factors**

#### **USA vs UK**

Closer examination revealed that both the ergonomists and degree holders in the UK and USA had significantly greater confidence than the other professionals and holders of other qualifications, in line with the whole sample findings. (USA degree holders vs others;  $U = 52.5$ ,  $p < 0.05$ ,  $r = -0.44$  (medium); USA ergonomists vs other professionals;  $U = 64$ ,  $p < 0.05$ ,  $r = -0.42$  (medium); UK degree holders vs others;  $U = 39.5$ ,  $p < 0.01$ ,  $r = -0.42$  (medium); UK ergonomist vs other professionals;  $U = 80.5$ ,  $p < 0.05$ ,  $r = -0.29$  (small)).

It would be expected, therefore, that the USA should have more of the ergonomist degree group than the UK. Indeed the distribution of ergonomists compared to other

professionals across the two nations is not independent ( $\chi^2 (1) = 9.35, p < 0.01$ , Cramer's  $V = -0.34, p < 0.01$ .) Nor is the distribution of degree holders compared to other qualification holders independent ( $\chi^2 (1) = 6.33, p = 0.01$ , Cramer's  $V = -0.285, p < 0.05$  . However it is the lower confidence nation (the UK) which has the higher proportion of ergonomists and degree holders.

There was no significant difference in the distribution of US and UK participants across the 0-5yrs and 6+ groups.

## **4.4 Discussions**

### **4.4.1 High and Low confidence**

The discussions in this section cover the first of the study aims; namely to determine the confidence levels of a group of ergonomists and other professionals in each of the IEA's competency units.

#### **Unit specific high and low confidence**

Overall, the sample of respondents had confidence which varied significantly across the different units. When analysed at the Unit level, the respondents had lower confidence in three units in particular; units, 6, 7 and 8. These units cover the making, implementing and evaluation of recommendations. It is notable that the consultants' confidence in Unit 7 – implementing recommendations - was higher than their confidence in evaluating recommendations. This might reflect their lack of opportunity to evaluate the impact of their work.

By contrast, the overall sample had higher confidence in units 2, 3, 4 and 9. These units cover the analysis, interpretation and documentation of ergonomics findings, along with the demonstration of professional behaviour. Interestingly, the ergonomist consultants had lower confidence than the overall sample in Unit 2 (analysis), which in combination with their higher confidence in Unit 7 (implementation of recommendations) suggests the consultants were more solution focused and less analysis focused than their academic colleagues.

Overall, however, it would seem that these participants feel more confident of their abilities to analyse problems, than their abilities to propose and evaluate solutions to them. According to Wilson (2000) different aspects of ergonomics practice can be assigned to different 'traditions'; for example, explanation and prediction are part of

the science tradition; design is part of the engineering tradition and implementation and evaluation emanate from the craft tradition (Wilson, 2000). From our findings, it would seem ergonomics advisors are generally more comfortable in the 'science' domain as outlined above, than they are in the 'craft' domain.

This idea is taken further by Jackson and McKergow in their development of the 'Solutions Focus' model (2006). They argue that problem-focus, rather than solution-focus is the norm for many arenas of modern thinking, and that this is not necessarily the most useful approach for affecting change. Whilst much of modern medicine and many technological disciplines have been successful due to their problem focus, they argue 'it is less useful when the issue involves interactions between people'.

Overall this suggests that the higher confidence competencies (analysis and interpretation) might reflect the problem-focus approach traditionally taken in ergonomics training. Whilst understanding the problem is a necessary part of ergonomics consulting (Shorrock & Murphy, 2005) an equivalent focus on interpersonal and solution-focus skills in their training might serve ergonomics advisors well.

#### **4.4.2 What affects confidence?**

The second study aim was to ascertain which characteristics of the participant sample are linked with high and low confidence. Confidence was significantly correlated with profession, years of experience, qualification level and nationality.

##### **Effect of Professional Group and Qualification level on overall confidence**

Overall, the sample's median confidence varied with profession and qualification level. These variables were strongly associated with each other. The ergonomists demonstrated higher confidence overall than the other professionals who in turn demonstrated higher confidence than the students. Those with ergonomics/related degrees had higher confidence than those with lower qualifications. These findings are commensurate with much of the literature on expertise; that higher qualification level is one indicator of expertise (Shanteau et al, 2002)

##### **Effect of Years of experience**

As the number of years of experience increased, so did the sample's median confidence. Whilst this is an intuitive finding, previous work has shown that the increased confidence which comes with greater experience is not necessarily

indicative of increased ability (Shanteau et al., 2002). Furthermore, because 'years of experience' was associated with profession (and qualification level) it is impossible to attribute the increase in confidence to it.

### **Effect of Nationality**

All of the other factors which affected confidence could be predicted to do so in a particular way (for example, confidence increased with years of experience, or qualification level). By contrast, nationality was a nominal categorisation, and its effect could not be predicted in the same way. As the results demonstrate, however, there were differences in overall median confidence between the different countries, with the UK and Korea scoring lowest, and the North Americans (Canada and the USA) highest.

Clearly, the most obvious explanation for the disparity in self-report ergonomics confidence between the different groups is that there is a genuine disparity in confidence, and by proxy in this study, competence. However, other studies have reported potentially confounding behaviours linked with cultural differences in self-reporting (e.g. Heine et al., 2001 & 2002; Triandis, 1980-1981).

The first area of note, is the impact of the reference group for individuals responding to self-report likert scales. The 'reference group effect' refers to the fact that an individual responding to a scale will tend to use those around them against whom to judge themselves (Heine et al., 2002; Peng et al, 1997). For example, where a characteristic like height is being measured, whether one belongs to a nation whose average height is 6ft or one whose average height is 5ft 5, will impact on where a 5ft 8 respondent marks a Likert scale for 'I am tall'.

If the reference group effect were impacting on the results in our study (in other words if the low confidence was relative to a highly confident population), those recording lower confidence (Korea and the UK) should come from nations known to be high in confidence. Likewise, those recording the higher confidence scores (USA, Canada) should emanate from a population known to lack in confidence in general. However, previous authors working in an educational setting (Lundeberg et al, 2000) have demonstrated that Asian participants (from Taiwan) had a lower mean confidence than those from the United States. Rather than our results emanating from the 'reference group effect' this study suggests that the north American and Korean confidence may be the result of a cultural tendency for higher or lower

confidence. No such research was found discussing the cultural confidence tendency of those from the UK.

Another potential confounder, is the response style on Likert scales which different nations demonstrate. Comparisons of 'Western' and 'Asian' populations have demonstrated an Asian tendency to mark the midpoint of scales, compared with a Western tendency to mark the extremes. Dolnicar and GrÅdn (2007) compared Australians with 'Asians' ( a group comprising Chinese, Indonesian, Indian, Malaysian, Thai, Lebanese, Singaporean and Sri Lankan participants) and found the Australians had a more extreme response style.

Lee et al. (2002) found Japanese and Chinese participants were more likely to choose the midpoint response than American participants, but found this only for items expressing positive feelings. Chen et al. (1995) compared participants from the US, Canada, Taiwan and Japan, finding the US participants more likely than the other three to use extreme values, and that Taiwanese and Japanese were more likely to use the midpoint. These studies suggest, therefore, that the greater confidence demonstrated by the Australians and Americans and lower confidence demonstrated by the Koreans in this study may be the result of a cultural response style, rather than a reflection of their confidence. Whilst there is a notable lack of studies which include participants from the UK, most of those represented above would include the UK in the 'Western' group. It is an interesting finding, therefore, that the UK participants demonstrated such low confidence, particularly in light of the discussion points in the section below (specific findings from the UK/USA sample).

Nationality did not vary independently of the other factors, being associated with both profession and qualification level. However, as the next section will discuss, some of the variation in confidence with nationality and profession/qualification level, was not in the direction which would be predicted.

### **Specific findings from the UK/USA sample**

Because these two nations varied significantly, closer analysis was undertaken. It would seem that there is an important cultural issue here. In the UK, despite the fact that the sample has more Ergonomists/individuals with degree level training, the confidence is lower than in the USA sample. There are a number of possible explanations.

The first may be that this competency framework favours those trained and practicing in the USA, because their education and assessment programmes are based more closely on it than those in the UK. The Board of Certification in Professional Ergonomics(BCPE) (used by both US and Canadian ergonomists) and The Ergonomics Society of Australia both have competency listings with clear similarities to the IEA's.

The Australian list has many of the same elements as the IEA's and is organised in the same format (Carmichael, 1997). That of the BCPE is like the IEA listing in that it specifies particular tasks and activities and covers all of the same areas (BCPE, 2004).

By contrast, in the UK there is no such description of activity in a competence listing. Instead, as described in section 2.8 of this thesis, ergonomists wanting to gain registered status must demonstrate a breadth of education or experience in a number of academic areas (mentioned only in passing as the 'theoretical bases' in the IEA listing), and must then self-generate a log book of activities (the Ergonomics Society, 2008c). The IEA listing may therefore be much more familiar in style and content to the North American and Australian respondents, whose training and certification may have been based around its headings. This might automatically lead to higher confidence if respondents immediately recognise the descriptors, organised in a familiar format.

The second possible explanation is that, culturally, the participants from the USA will tend towards recording higher confidence, either because that is how they really feel, or because that is how they think they should feel. It is noteworthy, however, that outward confidence is a characteristic of experts (Shanteau, 1988).

#### **4.4.3 Limitations**

The sampling strategy in this study was both pragmatic and opportunistic, taking the chance afforded by conferences to garner opinion from those involved with ergonomics. The advantage of this strategy was that it included those working in the field who were not necessarily members of a cognate society, and would therefore be difficult to sample in any other way. Given the third overarching aim of this thesis (to examine the differences between non-ergonomists who apply ergonomics principles and the work of professional ergonomists) gaining access to the non-ergonomist population was important.



The disadvantage of this strategy was that it restricted those given the opportunity to respond, to those attending a conference. This is likely to represent only a small proportion of the population of those applying ergonomics principles in the workplace. Given only a subset of those attending conferences completed the questionnaires, the sample is potentially even less representative. This means the findings should be generalised with caution.

Finally, the use of self-report data is likely to be confounded by the fact that this list was described as the 'core competencies for ergonomists' (as opposed to advanced or specialist competencies or competencies for anyone giving ergonomics advice). The ergonomist respondents might therefore have felt obliged to inflate their confidence so as to appear competent as professionals, in a way that the other non-ergonomists might not.

#### **4.4.4 Usefulness of the core competencies and further work**

The third aim for this study was to ascertain the applicability of the IEA's competencies to the assessment of the expertise of ergonomics advisors. Overall, the list of core competencies did discriminate between professionals in a manner that would have been predicted. Respondents with more experience, higher qualification levels and more years of experience had higher confidence and the questionnaire did discriminate between qualified ergonomists and other professionals.

A potential confounder, however, is that nationality also has a significant impact on confidence, and is related to all of the factors above. The sample presented here is too small to control for nationality and further work should be carried out to examine its impact. In addition, the reported importance of each of the competencies is a significant aspect of their usefulness, and a more successful way of measuring this than via the questionnaire used in this study would be worthwhile.

The relationship of confidence and competence is unlikely to be exact, and in an ideal world the question would have asked about competence not confidence. Given the inflammatory nature of asking about competence, however, it has been a useful proxy.

Ideally, the possession of each competency should be demonstrable in a way not reliant on self-report data. If that is achievable then further work could be conducted to examine whether possession of each of these competencies does in fact impact

on the effectiveness of an ergonomics advisor's work. Which competencies are the best predictors of effectiveness could then be established (Boyatzis, 2002).

#### **4.5 Summary and conclusions**

The aims of this study were to

- Determine the confidence levels of a group of ergonomists and other professionals in each of the IEA's competency units.
- Identify which characteristics of the participant sample are linked with high and low confidence.
- Determine the applicability of the IEA's competencies to the assessment of the expertise of ergonomics advisors.

The IEA core competencies list successfully differentiated between ergonomists, other professionals who carry out some ergonomics and students. Overall, ergonomists were significantly more confident of their abilities as described by the IEA's competencies than non-ergonomists and students, as were participants with more experience and higher ergonomics training level.

The North American participants appeared more confident than other nations, in particular, than those from the UK. The higher confidence demonstrated by participants from the USA over those from the UK, was in spite of the fact that the UK had more qualified Ergonomists in this study. This could be a result of; the Americans being more familiar with the competency style of describing the work of ergonomists; a cultural confidence tendency; or possibly because those from the USA are simply more competent.

In general all of the participants were less confident of their abilities to make, implement and evaluate recommendations than they were of analysing, interpreting and documenting problems. This suggests that a 'problem' rather than a 'solution' focus characterises these participants' approach, though this was least marked for the consultants, whose confidence was higher than the other groups in implementing solutions and lower for analysis of the problem.

This study has demonstrated quantitative, self-report differences in core competencies, between ergonomists and a range of other professionals who engage in ergonomics. It has also demonstrated a confidence difference between ergonomists from different countries. Both this and the study reported in Chapter 3

garnered opinion from Ergonomists from any specialism. The next two studies will build on the findings from these first two, but will sample participants from one country, and one specialism (physical (musculoskeletal) ergonomics) in order to reduce the number of variables.

The next chapter study (Chapter 5) will investigate further the differences between ergonomists and other professionals engaged in ergonomics (demonstrated in this study), using focus groups to look for some of the KSAOs identified in Chapter 3 by examining participants' ergonomics knowledge, aims, approaches and activities.

### **Chapter 1 – Introduction**

- Problem statement
- Research aims
- Research Paradigm
- Thesis Structure

### **Chapter 2 - Literature review**

- Establishing the nature of expertise and how it is identified and measured
- Establishing the nature, extent and findings of previous work examining expertise amongst ergonomics and allied professionals

### **Chapter 3 – What characterises good and expert Ergonomics Advisors?**

- 3 Focus groups (n = 26) with Ergonomists
- Model building of features of good and expert ergonomics practice

### **Chapter 4 – The self reported competencies of Ergonomics Advisors**

- 217 competency questionnaires from 6 national ergonomics conferences
- Establishment of areas of high and low confidence across the breadth of IEA ergonomics competencies.
- Relationship of competence and expertise

### **Chapter 5 – The Knowledge and Activities Ergonomics Advisors**

- 8 Focus groups (n = 55) with Ergonomists and other professional groups engaged in ergonomics advising
- Template analysis and model building of ergonomics expertise from knowledge and activities differences

### **Chapter 6 – The decision making expertise of Ergonomics Advisors - part 1**

- ULD risk assessment task undertaken by 58 PREs and EOPs and a control group of 148 students
- Establishment of comparative expert performance using the CWS index of expertise

### **Chapter 7 – The decision making expertise of Ergonomics Advisors - part 2**

- Investigation of the content of risk assessment decisions
- Relationship of decision content and expertise

### **Chapter 8 – Discussions, Implications and Conclusion**

- Discussions and implications of findings from all studies
- Limitations
- Recommendations for further research
- Conclusion

## **Part 2**

### **Chapter 5 – An in-depth investigation of the knowledge, aims, approach and activities of ergonomics advisors dealing with MSDS**

#### **5.1 Introduction**

##### **5.1.1 Research presented in this Chapter**

The fourth research objective in this thesis was to ascertain the breadth of ergonomics knowledge and activities which characterise PRE and EOP, physical, ergonomics advisors. This chapter describes the findings from a focus group study designed to begin answering this question for those UK based professionals working in the physical ergonomics arena. Focus groups were selected as a method for accessing a wide range of different professionals who engage in ergonomics, and acquiring information about their ergonomics knowledge, aims approach and activities. Template analysis was undertaken of the resultant discussion, with the use of a template generated *a priori* and added to during the course of the study.

Discussions covered topics such as ‘what do you understand ergonomics to be?’, ‘what is your aim in doing ergonomics?’ and ‘what activities do you undertake which involve ergonomics?’. Differences are apparent in the depth and breadth of the different professionals’ ergonomics knowledge, the goals for which they used ergonomics and the type of ergonomics activities in which they engage. The resulting self report, qualitative data suggest that there are differences between ergonomists and others who apply ergonomics principles. The possible implications of these differences are discussed.

##### **5.1.2 Differentiating between experts and others in a domain**

As outlined in the literature review (Chapter 2) experts are characterised by a number of attributes, one of which is a sufficient knowledge of their domain (Shanteau, 1992). In chapter 3, several features of the knowledge of a high performing ergonomics advisor were defined. These included that the knowledge should be practical (not just theoretical), that it should cover the broad range of

human sciences, be scientific, be integrated, be beyond common knowledge and be factually correct. If these are features which ergonomists say define the knowledge of a high performer in their domain, it is reasonable to look for these features when endeavouring to compare ergonomists and other professionals who engage in ergonomics.

In addition to these *attributes* of ergonomics knowledge which emerged from the study in Chapter 3, further aspects of the knowledge *content* which should be held by those with 'a sufficient knowledge of their domain' can be found by examining the ergonomics definitions. The following section provides a résumé of these aspects.

### **Ergonomics Knowledge in the literature**

In their paper entitled 'Defining Ergonomics/Human Factors' for the Encyclopaedia of Ergonomics and Human Factors (2001), Wogalter et al. present a table of example ergonomics definitions from a sample of 190, taken from 134 different sources. These are represented in Table 5.1 below (these authors considered human factors and ergonomics as synonymous).

These definitions provide a useful set of themes to look for when examining the knowledge of different professionals engaged with ergonomics. From these definitions, the headings might be:

Ergonomics involves

- Understanding humans/people/users
- Understanding jobs/tasks/systems
- Optimising the fit between the person and their environment
- Using this knowledge for design
- Using this knowledge in work and non-work contexts

**Table 5.1: Example definitions of Ergonomics.**

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Brown, O., and Hendrick, H.W. (1986)	... the relations between man and his occupation, equipment, and the environment in the widest sense, including work, play, leisure, home, and travel situations.
Chapanis, A. (1995)	... is a body of knowledge about human abilities, human limitations and other human characteristics that are relevant to design
Hancock, P. A. (1997)	... is that branch of science which seeks to turn human machine antagonism into human-machine synergy.
Mark, L.S. and Warm, J.S. (1987)	... attempts to optimize the fit between people and their environment.
Howell, W. and Dipboye, R. (1986)	Person-machine system design.
Meister, D. (1989)	... the application of behavioural principles to the design, development, testing and operation of equipment and systems.
Clark, T.S. and Corlett, E.N. (1984)	... study of human abilities and characteristics which affect the design of equipment, systems, and jobs and its aims are to improve efficiency, safety, and well being.
Sanders, M.S. and McCormick, E.G. (1993)	... designing for human use.
Wickens, C.D. (1992)	... is to apply knowledge in designing systems that work, accommodating the limits of human performance and exploiting the advantages of the human operator in the process.

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Wogalter et al., 2001

In addition to building an understanding of ergonomics from its definitions, further understanding about the 'ergonomics approach' can be drawn from consideration of what ergonomics professionals do. The UK Ergonomics Society website explains the approach of ergonomics professionals in the following way:

"Underlying all ergonomics work is careful analysis of human activity.....<via> 'job and task analysis'.....The second key ingredient is to understand the users. This commitment to 'human-centred design' is an essential 'humanizing' influence on contemporary rapid

developments in technology, in contexts ranging from the domestic to all types of industry.” (The Ergonomics Society, 2004)

This makes explicit the ‘user centred’ nature of ergonomics.

The International Ergonomics Association (IEA) supplements this aspect with the additions that ergonomics is a

“scientific discipline ..... and the profession that applies theory, principles, data and methods to design... Ergonomists contribute to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people.” (IEA, 2004)

In so doing, the emphasis on scientific method is made manifest. The IEA continues by describing the holistic nature of the ergonomics approach:

“Practicing ergonomists must have a broad understanding of the full scope of the discipline. That is, ergonomics promotes a holistic approach in which considerations of physical, cognitive, social, organizational, environmental and other relevant factors are taken into account.” (IEA, 2004)

From this description the holistic approach should include consideration of the physical, cognitive, social, organisational, environmental and other factors of the people and systems. So in addition to the themes laid out above, anyone taking an ergonomics approach should describe being:

- User centred
- Scientific
- Holistic (in taking into account physical, cognitive, social, organizational, environmental and other relevant factors)

### **Goals for using Ergonomics**

In a paper addressing issues facing ergonomists at the start of the new millennium, Wilson (2000) includes the ISO Working draft definition of ergonomics (ISO, 1999).



“Ergonomics produces and integrates knowledge from the human sciences to match jobs, systems, products and environments to the physical and mental abilities and limitations of people. In doing so it seeks to safeguard safety, health and well-being whilst optimising efficiency and performance.”

Key aims of practicing ergonomics are described in this definition; namely to optimise

- health
- safety
- well-being
- efficiency

Wilson adds his own definition, highlighting the importance of the interactions between people and the systems in which they perform, and the overall aim of designing these interactions:

“Ergonomics is the theoretical and fundamental understanding of human behaviour and performance in purposeful interacting socio-technical systems, and the application of that understanding to design of interactions in the context of real settings.” (Wilson, 2000)

### **Summary of the aspects of Ergonomics Knowledge and the aims for its use**

From this discussion about the nature of ergonomics the following list summarises the features of ergonomics proscribed by the definitions of the discipline and the approach of its practitioners (with exemplar sources indicated in brackets):

Ergonomics involves

- Understanding users/people/humans (e.g. Chapanis, 1995)
- Understanding jobs/tasks/systems(e.g. Ergonomics Society, 2004)
- Understanding the interactions between users and jobs (e.g. Wilson, 2000)
- Using this knowledge for design (e.g. Sanders & McCormick, 1993)
- Using this knowledge in work and non-work contexts (e.g. Brown & Hendrick, 1986)

The characteristics of the approach are

- User centred (e.g. Ergonomics Society, 2004)
- Scientific (e.g. Hancock, 1997)
- Holistic (in taking into account physical, cognitive, social, organizational, environmental and other relevant factors (e.g. IEA, 2004)

The aims for using ergonomics are to enhance

- health (e.g. ISO, 1999)
- safety (e.g. Clark & Corlett, 1984)
- well-being (e.g. Clark & Corlett, 1984)
- efficiency (e.g. ISO, 1999)

### **Activities undertaken**

In addition to examining the knowledge, approach and goals or aims of different practitioners in the ergonomics arena, MacDonald (2006) has proposed that there are likely differences in the activities undertaken by non-ergonomists 'doing ergonomics' and "the work of professional ergonomists". It is also reasonable, therefore, to examine the ergonomics activities that each of these groups undertakes in order to compare the breadth of activity amongst them.

Therefore, these broad areas of knowledge, approach, aims and activities were selected for further investigating the third of the research questions of this thesis; namely, what are the differences between non-ergonomists who apply ergonomics principles and the work of professional ergonomists?

### **5.1.3 Study Aims and objectives**

The aims of this study presented in this chapter were threefold:

- to examine any differences between ergonomists' and other professionals' knowledge about ergonomics.
- to identify the aims and approach of the professional groups when carrying out their ergonomics work.
- to establish what ergonomics activities are carried out by the different professional groups.

## **5. 2 Methods**

### **5.2.1 Study Design, Sampling and Participants**

The advantages and disadvantages of various qualitative methods were presented in Table 3.1 (Chapter 3). Focus groups were selected as the appropriate methodology for this study because, as Kitzinger argues, they can be used to examine what and how people think, why they think in particular ways and their understandings and priorities in a given area (Kitzinger, 1996). These attributes of the focus group methodology reflected the aims of this study almost exactly.

All three aims of this study involved identifying differences between ergonomists and other professionals who carry out ergonomics, therefore the theoretical sample population is made up from Ergonomists and these other professionals. Homogeneity was sought for each group, with each focus group containing participants from only one profession so that there would be no inter-profession challenges during the sessions.

Recruitment was therefore carried out in a stratified, purposive way, with groups of participants recruited from local professional groups and training course delegates. To be included, participants had to attest to using ergonomics to deal with musculoskeletal health issues in the workplace. The professional groups targeted were: Occupational Health Advisors (OHAs); Health and Safety Advisors (HSAs); Specialist Furniture/Equipment Suppliers (FSs) and Ergonomists, as all these groups are known to undertake ergonomics in the workplace.

Initially one focus group with each of these 4 professions was carried out, however, in line with the advice outlined by Lincoln & Guba (1995), a second focus group with each profession was then conducted to enhance the reliability of the findings.

### **5.2.2 Procedure**

Eight focus groups were undertaken (2 with each type of professional), consisting of 55 participants from different professions who are known to be engaged in musculoskeletal health ergonomics.

The groups lasted between 1 and 1 ½ hours and involved between 5 and 11 participants. Each group started with an activity to put the participants at their ease and encourage discussion. This involved giving each participant two photographs

of an individual at a workstation (Appendix C) and asking them to look for any ergonomics issues they could see. They were also asked about any additional information they would like, beyond what they could glean from the photograph. Discussions were then facilitated using a set of structured questions. These questions included 'What do you consider ergonomics to be?'; 'What's your aim when using ergonomics?' and 'What activities do you do that you consider to be ergonomics?'

The first focus group with each profession was fully transcribed and the second partially transcribed (see below for further explanation). The analysis of the transcripts is described in the next section.

### **5.2.3 Analysis**

The first group with each of the professions was recorded and transcribed in order to examine their knowledge and understanding about ergonomics; their approach and aims in using ergonomics; and their activities which they viewed as including ergonomics. The analyses of these different aspects are described below.

#### **Template Analysis of knowledge about, approach and aims for using ergonomics**

Template analysis of the groups' knowledge of, approach to and aims for using ergonomics was undertaken. This was the chosen method because "template analysis works particularly well when the aim is to compare the perspectives of different groups of staff within a specific context" (King, 2004).

Template analysis involves the production of a list of codes *a priori*, which are used to label sections of transcript relating to a particular theme. The codes can be added to as the analysis progresses if themes which were not predicted become apparent (King, 2004). This method therefore fits in a position between content analysis (Weber, 1995) and Grounded Theory (Glaser & Strauss, 1967). In the former, the codes are all pre-determined and are not added to. Furthermore, their occurrence and distribution are analysed statistically; an approach slightly at odds with a purely qualitative approach.

In the latter, no *a priori* codes are determined but instead all emanate from the data via a prescriptive set of data gathering and analysis procedures (King, 2004). Template analysis therefore provides a flexible approach where *a priori* knowledge

can be used (both attributes being impossible with Grounded Theory) but where this a priori knowledge can also be supplemented by new knowledge as a study progresses (not possible with content analysis).

Codes in template analysis tend to be arranged hierarchically, with groups of similar codes being organised under a common thematic heading (King, 1998). The initial headings of ergonomics 'themes' were generated from the definers outlined in section 5.1.2 above. The initial template used is shown in Figure 5.1.

Having fully transcribed the first focus group with each of the professions, the second was also recorded, partially transcribed and analysed using the same template. This allowed for re-enforcement of themes which had already been raised by that profession, and the addition of any not yet covered. Any discussion which covered these themes was used, irrespective of whether it was part of the initial photographic exercise, or if it was in answer to any of the subsequent questions.

### **Activities undertaken which included ergonomics**

As explained above, each group was also asked to describe the activities they undertake in which they use their ergonomics knowledge, in order to compare across the groups. No further data reduction was required and the activities raised by each profession were simply listed and compared.

### **5.2.4 External validation**

An external validator was present in each focus group to take notes of the key themes discussed. He then used these notes, along with the transcripts when gauging the trustworthiness of the findings represented here.

#### **1. Ergonomics Knowledge Attributes**

- practical (not just theoretical) knowledge
- scientific
- integrated

#### **4.Ergonomics knowledge aims**

- optimise the fit between user and task/job/environment – in order to
  - a. Enhance health
  - b. Improve safety

- beyond common knowledge
- factually correct

- c. Enhance well being
- d. Improve efficiency

## **2. Ergonomics knowledge content**

- cover the broad range of human sciences
- understanding users/people/humans
- understanding jobs/tasks/systems
- understanding the interactions between users and jobs

## **3. Ergonomics knowledge application**

- for design
- in work contexts
- in non-work contexts

## **5. Ergonomics approach**

The characteristics of the approach are

- a. User centred
- b. Holistic (in taking into of physical, cognitive, social, organisational, environmental and other relevant factors)

**Figure 5.1: Initial Template**

5.3 Findings

5.3.1 Participants

The participant details are represented in Table 5.2 below:

Table 5.2: Participant details

Group	Mean Age (Years)	Gender	Mean experience in Occupational Health and Safety (Years)	Ergonomics training level
Ergonomists (n = 13)	34.7 ± 10.2	8 male 5 female	9.9 ± 9.8	7 - BSc Ergonomics 6 - MSc Ergonomics
HSA's (n = 17)	38.2 ± 8.2	14 male 3 female	6.2 ± 4.1	14 - OH and S vocational training 3 - As above + ergo short course
OHA's (n = 11)	40.1 ± 6.1	0 male 11 female	11.0 ± 5.1	7 - OH vocational training 4- As above + ergo short course
FS (n = 14)	34 ± 10.3	13 male 1 female	3.8 ± 4.6	12 - ergo short course 2 – degrees + ergo short course

KEY: HSA = Health and Safety Advisor; OHA = Occupational Health Advisor; FS = Furniture Supplier

5.3.2 Additions to the template

The template generated before the focus groups (Fig 5.1) was used to analyse the discussions. Additional themes were added as they emerged during the discussions (*in red italics below*) Figure 5.2.

Overall three additional main themes were added to the template (analyse problems, propose solutions, ergonomics is an approach/philosophy as well as a set of knowledge/methods). 16 sub themes and 2 ‘sub-sub’ themes also emerged.

### 1. Ergonomics Knowledge Attributes

- practical (not just theoretical) knowledge
- scientific
- integrated
- beyond common knowledge
- factually correct

### 2. Ergonomics knowledge content :

- cover the broad range of human sciences
- understanding users/people/human
  - a. *knowledge*
  - b. *behaviour*
  - c. *out of work influences*
- understanding jobs/tasks/systems
  - a. *job design*
  - b. *scheduling*
- understanding the interactions between users and jobs
  - a. *context of use*

### 3. Ergonomics knowledge application

- for design
  - a. *tools*
  - b. *systems*
  - c. *products*

- in work contexts
- in non-work contexts

### 4. Ergonomics knowledge aims

- optimise the fit between user and task/job/environment to
  - a. Enhance (not damage) health
  - b. Improve safety/reduce injuries
  - c. Enhance well being (*make users happy*)
  - d. Improve efficiency (reduce costs)
  - e. *Improve Comfort/ reduce discomfort*
  - f. *Increase Productivity (increase output)*
    - o *Increase profitability*
  - g. *Feel like I'm helping*
  - h. *Build a sales relationship*
  - i. *educate*
- *Analyse problems*
- *Propose solutions*

Continued.....

Figure 5.2: Template with emergent themes



## 5. Ergonomics approach

- *Ergonomics is an approach/philosophy as well as a set of knowledge/methods.*

The characteristics of the approach are

- a. User centred
- b. *Participatory*
- c. Holistic in taking account of
  - i. physical
  - ii. psychological
    - *cognitive*
  - iii. *(psycho) social*
  - iv. organizational
  - v. environmental
  - vi. other relevant factors
- d. *As for c, but holistic in terms of acceptability of the advice/solution generated by the approach*

Fig 5.2 Template with emergent themes *continued*

### 5.3.3 Analysis using the template

In the results section below the group responses are categorised by the 5 thematic headings from the template. These are

1. Ergonomics Knowledge Attributes
2. Ergonomics Knowledge Content
3. Ergonomics Knowledge Application
4. Ergonomics Knowledge Aims
5. Ergonomics Approach

A summary of the groups' responses is then provided under the template headings (Table 5.3).

Where verbatim quotes are included, the participant is identified by the group in which they took part (e.g. *Ergo Gp 1*, or *OHA Gp 2*) and by a participant number (e.g. *P26*). So for example, a participant in the first focus group of Furniture Suppliers could be identified as follows: *FS Gp 1 – P8*.

#### 1. Ergonomics Knowledge Attributes

The attributes of ergonomics knowledge generated by the focus groups in Chapter 3 were that the knowledge should be practical, scientific, integrated, beyond common knowledge and factually correct. For the most part, it was only the ergonomists in this study who mentioned these attributes; covering all of them in both groups.

Each of the 8 groups discussed the need for practical knowledge, with each group discussing their practical, workplace activities and one ergonomist noting

*Ergo Gp 1 - P22 – ....'Ergonomists tend to be quite practical people...'*

The scientific nature of ergonomics went largely unmentioned, being discussed in one of the OHA groups and otherwise only noted by both groups of ergonomists, who talked about their work as 'analysis' and explained;

*Ergo Gp 2 – 'it's the application of science....of knowledge about people'*

The need for integration of the different aspects of ergonomics knowledge was also covered by both ergonomist groups and one of the OHA groups. In the example below, one OHA demonstrates the integration of her physical and psychological knowledge regarding pain and depression, as well as the wider workplace knowledge regarding the impact of an individual off work on the rest of the team:

**OHA Gp 1- P 17-** 'And if they go off then it doesn't do that person any good because they're going to start to get depressed and pain sets in. It doesn't help the people who are left at work so that doesn't help the manager.'

In terms of the knowledge being 'beyond common knowledge' and 'factually correct', once again both groups of ergonomists made mention of these attributes, directly or indirectly, with one OHA group also noting that 'lots of people don't know what it involves'. Specifically, one ergonomist group noted the importance of the core values of ergonomics being necessary to avoid ergonomics becoming just 'catchphrase' (Ergo Gp 1 - P24), whilst another ergonomist remarked upon having to follow someone else into a company who had not had their facts correct:

**Ergo Gp 1 - P21-** 'So there area a lot of new standards coming in, or likely to be coming in, guidance on whole body vibration, and again, I've been called in by a large company to do a survey of a big plant they had because somebody else had gone in with a vibration meter and made a complete mess of something and they were panicking.'

## **2. Ergonomics Knowledge Content**

Only one of the focus groups explicitly described the fact that ergonomics knowledge covers the range of human sciences, listing them as follows:

**Ergo Gp 1 - P22 –** Because you're going to accept that, or you may accept that ergonomics has got bits of psychology, bits of engineering, bits of biomechanics, bits of anatomy or whatever.....'

However, many participants did demonstrate knowledge of the human sciences areas, discussing psychology and the human body in particular.

All eight of the groups discussed the importance of understanding both users/people/humans and their jobs/tasks/systems.

**OHA Gp 1 - P20** – 'I think if you have somebody come to you with an ache and a pain .....as well as some education and taking a medical history and referring onto the appropriate practitioner, is to go and look at the person's task at work. ...'

With some groups covering more detailed aspects of the users, such as their knowledge, behaviours and out of work influences;

**FS Gp 1- P3** – 'we will obviously assess that procedure , but we will also assess lifestyle as well.... if somebody has a mousing problem that they developed or an upper limb disorder and then they're actually going home and spending 12 hours on the computer on the internet, it's not covered but we need to know.'

More detailed aspects of understanding the job, such as job design and scheduling were also discussed. All of the groups also explicitly described the interaction between the individual and the job:

**Ergo Gp 2 - P1** – 'I'd say it's the science of the human and their environment interactions....'

Most of the groups noted that considering the context of use was an important factor when applying ergonomics:

**Ergo GP 1 - P21-** 'It can't be ergonomic in isolation. It can only be ergonomic in the context of its usage.'

### **3. Ergonomics Knowledge Application**

#### ***Design***

All of the groups acknowledged that 'design' was the ultimate activity resulting from the application of ergonomics principles.

**HSA Gp 1 - P9** – 'It's also considering the design so any design of any situation from Day 1 – it's part of the design process.'

The groups also demonstrated that a number of different outputs could result from this design, including tools, products and systems:

**OHA Gp 1 - P19** – 'It's not just the physical environment, it is the task in the broadest sense. Not just the furniture or whatever, it's the actual design of the work and that side. The sort of softer issues as well.'

**Ergo Gp 2 – P8** – 'And I said, well it puts people at the centre of designing a job, or writing software, or designing a piece of equipment.'

### **Work**

All the groups discussed the application of ergonomics in the work environment:

**FS Gp 1 - P2** – 'You could say it helps to improve their working experience. It makes their working experience more enjoyable in a direct way.'

### **Non-work**

The non-work application of ergonomics was less well covered, with just over half the groups making mention of it.

**OHA Gp 1 - P15** – 'I think the only other thing is that it's not just at work because I think sometimes.... you know if you can help people and tell them where they're going wrong, that helps them outside work. And I think people often assume that problems are work related when often they're not just work related and I think you know if you can help them, or help them to help another member of their family then you know that's part of the education and I think that's what we do as well.'

There was a dispute over whether non-work environments were the remit for ergonomics in one of the ergonomist groups.

**P23** – ‘I just, I go back, the basics why we started in ergonomics is work..... factories and things, and when you start drifting off, I feel as though you know we shouldn’t be helping people with leisure things.’

#### **4. Ergonomics Knowledge Aims**

##### ***Optimise the fit between the user/people/humans and task/job/environment***

As described above, the knowledge discussion was started with open questions such as ‘What do you consider ergonomics to be?’ or ‘What is ergonomics?’. All of the groups responded with a quick ‘sound-bite’ definition of ergonomics such as:

**HSA Gp 1 - P14** – ‘Fitting the job to the worker isn’t it?’

##### ***Enhance (not damage) Health***

The improvement in health was raised as an outcome of ergonomics application by a number of groups. Some references were made to ensuring health was not detrimentally affected:

**FS Gp 1 - P8** – ‘When they sell products ..... you’re selling one that is being ergonomically suited to enable that user to be more efficient and use it for longer periods without causing damage to their health in any way.’

And at other times the idea was to use ergonomics to keep individuals at work, whose health had already been affected, in order to ensure the health benefits of being at work could be realised:

**OHA Gp 1 - P17** – ‘....but the aim is to keep them at work, and so by adjustment, you know if they do have some slight problem, by adjustment of what they’re doing...’

##### ***Improve Safety/reduce injuries***

Seven of the eight groups discussed the role of ergonomics in enhancing safety.

**HSA Gp 1 - P11**- ‘So in designing the plant right and making sure the kit’s in the right place and you can operate it. And then you can control it by having your control room set up in the appropriate way with the

right amount of information.... You're on-line, and if you're on-line in general, that's the safest condition you can be.'

### ***Enhance well-being (make users happy)***

Six of the eight groups cited making users happy or enhancing their well-being as one of their goals;

**FS Gp 1 - P1** – 'If someone has a pain in their shoulder, their neck or whatever, if you can give them a solution which will help relieve that situation..... if they're happy at the end of it we're happy then.'

Two groups felt that the process of engaging with the users was helpful in enhancing their well-being and 'improving morale':

**Ergo Gp 1 - P22** – 'I would like to feel that I've just left someone better off than I found them, you know. Even if nothing's going to change, sometimes speaking to somebody for an hour, and listening to them properly, and taking them seriously does that.'

### ***Improve Efficiency (reduce costs)***

The link of ergonomics with improving efficiency (viewed also as reducing costs) was mentioned by four of the groups:

**FS Gp 1 - P8** – 'When they sell products I mean they're selling mice, but your not just selling a mice, you're selling one that is being ergonomically suited to enable that user to be more efficient ....'

**OHA Gp 1 - P19** – 'So that they can carry on doing the job for years and years because it's much cheaper than employing anyone else.'

**HSA Gp 1 - P9** - 'Efficiency. It's a business way, it's about better business.'

Though the discussion in one ergonomist group underlined that efficiency gains should not be at the cost of the user's well-being:

**Ergo Gp 1 - P22** – '....time and motion was focussed on trying to get the most efficient use out of the person..... it [ergonomics] might be

making the person more efficient, but I'm interested in they're going home at the end of the day, the same way they arrived in the morning.'

### ***Improve comfort/reduce discomfort***

All eight groups cited improving comfort as being one outcome of applying ergonomics:

**OHA Gp 1 - P16** – 'Enabling the body to be in the best position where it's comfortable and natural.'

### ***Increase Productivity (increase output)***

Only one of the eight groups mentioned improving productivity explicitly:

**HSA Gp 1 - P9** – 'To improve productivity for example.....I'll give you an example... there's one rig out there where the motions are such that because of the motions people are sick all the time, they can't concentrate properly and there's a lot of down time as a result. As soon as they improved the motion characteristics, production got better.'

One further group mentioned increasing profitability, which is linked with both productivity and efficiency:

**FS Gp 1 - P8** – 'It's what xxxxxx has said before, if you sell someone the right chair, it makes the individual not only better in their own health themselves, but also makes them more profitable..'

### ***Feel like I'm helping***

Three groups cited the desire to help, as being a goal of their ergonomics:

**Ergo Gp 1 - P24**– I'd have to concur with P22, one side of it is helping people, helping people to be happy where they work,

### ***Build a sales relationship***

All four of the furniture supplier and ergonomist groups were made up from participants working commercially. These four groups made reference to the sales aim in their work:



**FS Gp 1 - P1** – ‘And of course that’s building up our reputation – the more assessments that we do and the more satisfied customers we have – it’s all to help long term business isn’t it?’

### **Educate**

Many of the groups had a ‘higher’ level aim than the immediate individual or work environment to which they were applying ergonomics principles. This aim involved educating people about ergonomics and its benefits:

**FS Gp 1 - P3** – ‘I would say that my personal ambition is to get people to think of health and safety, and I would include ergonomics in there, as a help not hindrance.’

**Ergo Gp 1 - P21**- ‘My aim is that by carrying on with litigation, you promulgate the idea that getting the ergonomics right is important.’

**Ergo Gp 1 - P22**-‘Not just the word, but do you know what I mean, selling it a little bit more, making people a bit more aware, leaving a few people with a bit more knowledge.’

### **Analysing problems and Proposing solutions**

The ergonomists and furniture suppliers talked explicitly about analysing problems and, along with one group of health and safety advisors, generating solutions.

**Ergo Gp 1- P21**- .... I tend to regard most of what I do as analysis.

**HSA Gp 1- P12** – ‘And we’re doing a lot of work trying to design out, trying to come up with solutions for designing out the risks. .... it’s trying to come up with solutions on safe systems of work, basically, to prevent injury.

In one of the ergonomist groups, the emphasis on the analysis stage, rather than solution stage during formal ergonomics training was noted:

**Ergo Gp 1- P22** – ‘I think it’s quite interesting that I would say, and I don’t know whether other people feel this, that the training you receive.. is largely to do with finding out what the problem is.....and it doesn’t actually get you very far in solving the problem. And yet from a client

perspective, ok they want to know exactly what the problem is, but they really want to know what to do about it.'

## **5. Ergonomics Approach**

*Ergonomics is an approach/philosophy as well as a set of knowledge/methods.*

The ergonomists were alone in discussing ergonomics as encompassing an approach or philosophy, as well as a set of methods:

**Ergo Gp 2- P6** – 'I think it's a way of thinking actually. I think what ergonomics does, certainly the way it's taught at University, when I see graduates I think they don't have particularly useful skills but they've got a really good way of thinking about stuff.'

### ***User centred***

All 8 groups alluded to the user-centred approach which defines ergonomics;

**Ergo Gp 1 - P22** – 'I think what P24 was saying about the focus on people, is the thing that holds ergonomics together.'

**Ergo Gp 2** – 'User centred anything'

### ***Participatory***

Four of the groups discussed the participatory nature of what they do:

**HSA Gp 1- P13** – 'So I always think it's important to have a .....an operational person on there – they come up with the best ideas to be honest. They know the job, and no-one else does.'

### ***Holistic/ whole systems based***

The holistic/systems approach was mentioned widely, with every group making reference to this facet of ergonomics. Sometimes it was mentioned explicitly;

**Ergo Gp 1 - P25** – 'So looking at the whole systems, not just the individual at a work station.'

More often it was implicit in the conversation. For example, in the discussion following the photograph exercise in one of the furniture supplier groups, a number

of issues which could not be gleaned from the photo were brought to the fore, demonstrating an holistic approach:

**FS Gp 1 - P3** – ‘..... I would have liked to have known how she’s moving her laptop about.....And if she’s working at other locations.....If she’s working from home.....What she’s doing beyond her desk or if that’s not her desk, beyond that area there. And if I was speaking to her, if she had issues, what they were...’

### ***Physical Aspects***

Physical aspects were covered by each of the groups

**HSA Gp 1 - P12** – ‘It’s functionality of the body, isn’t it? It’s making sure that the body’s not put under any unnecessary sort of stresses or strains whilst carrying out an activity over a prolonged period of time.’

### ***Psychological and Psychosocial aspects***

The psychological aspects were further defined by the term ‘cognitive’, and linked with the social aspects by the term ‘psychosocial’. Both these areas were discussed by most groups with the notable exception of the furniture suppliers.

**Ergo Gp 1 - P22** – ‘You know, I typically give them an example of like fighter aircraft, or something like that so that people are also thinking about controls and displays and information processing as well as just the physical stuff.’

**HS Gp 1 - P14**- ‘Psychosocial factors.....Things like stress, um workload, too much work on your plate...’

**OHA Gp 1 - P19** – ‘Things like work pace and the decisions you’re expecting people to make, and the information they’re getting in and the information that’s going out.’

### ***Organisational and Environmental Aspects***

Both of these areas were generally well covered by the groups. For example in one of the OHA groups, the impact of organisational staffing decisions were discussed:

***OHA Gp1 - P17*** – ‘I find with staffing levels that quite often....they have a real problem because somebody's gone off sick, and they're picking up their workload... And so they're doing extra hours, they're working at a faster pace, they're doing more work.’

In response to the scenario photograph, one OHA noted a number of environmental issues:

***OHA Gp 1 - P17*** – ‘You have no idea either from there about the lighting or whether she's holding her head back that way because she's in a draft, whether she sits correctly.’

### ***Holistic in terms of the acceptability of the advice/solution generated***

The ergonomists were unique in discussing the extension of their holistic/systems approach beyond the analysis of an issue and into the generation and proposal of their recommendations.

***Ergo Gp 2 - P5***- ‘I think as well, it's understanding....the agenda behind why you've actually been called in in the first place. Because it's not always as obvious as it might seem. So kind of it's satisfying a number of parties whether it's the person who's got a problem themselves but also the organisation as well. ....’

***Ergo Gp 1 – P22*** – ‘...I get the feeling with some sort of health and safety approaches... they say ‘you must have a guard’ and that's just the answer.....and they say ‘well we can't’.....and I don't want to leave somewhere, knowing that they won't do that.....I do want to try and work with them.... And that's why I sort of end up giving them some training...’

### ***Summary from Template Analysis***

Each of the groups' responses are summarised under the template headings in Table 5.3 below.

**Table 5.3: Summary of focus group discussions**

Theme	Ergo	OHA	HSA	FS
<b>1. Ergonomics Knowledge Attributes</b>				
• practical (not just theoretical) knowledge	••	••	••	••
• scientific	••	•		
• integrated (pain and depression)	••	•		
• beyond common knowledge	••	•		
• factually correct	••			
<b>2. Ergonomics knowledge content</b>				
• cover the broad range of human sciences	•			
• understanding users/people/humans	••	••	••	••
a. <i>knowledge</i>	••			
b. <i>behaviour</i>	••	••	•	•
c. <i>out of work influences</i>	•	•		••
• understanding jobs/tasks/systems	••	••	••	••
a. <i>job design</i>	•	••	•	•
b. <i>scheduling</i>	••	••		
• understanding the interactions between users and jobs	••	••	••	••
a. <i>context of use</i>	••	••	••	••
<b>3. Ergonomics knowledge application</b>				
• for design	••	••	••	•
a. <i>tools (work products)</i>	••	••	••	••
b. <i>systems</i>	••		•	
c. <i>products (non-work)</i>	•	••	•	
• in work contexts	••	••	••	••
• in non-work contexts	••	•		••

Key • = mentioned in one group •• = mentioned in both groups

HSA = Health and Safety Advisor; OHA = Occupational Health Advisor; FS = Furniture Supplier

Table 5.3 *continued*

Theme	Ergo	OHA	HSA	FS
<b>4.Ergonomics knowledge aims</b>				
• optimise the fit between user and task/job/environment – in order to	••	••	••	••
a. Enhance/ not damage health	•	••	••	•
b. Improve Safety/reduce injuries	••	••	••	•
c. Enhance well being ( <i>Make users happy</i> )	••		••	••
d. Improve Efficiency (reduce costs)	•	••	•	
e. Improve Comfort/ reduce discomfort	••	••	••	••
f. Increase Productivity (increase output)			•	
i. Increase profitability			•	•
h. <i>Feel like I'm helping</i>	••			•
i. <i>Build a sales relationship</i>	•			•
j. <i>Educate</i>	••			•
k. <i>Get someone back to work</i>	•	•		
• Analyse problems	••			•
• Propose solutions	••		•	••
<b>5.Ergonomics approach</b>				
• <i>Ergonomics is an approach/philosophy as well as a set of knowledge/methods.</i>	••			
The characteristics of the approach are				
a. User centred	••	••	••	••
b. Participatory	•	•	••	
c. Holistic in taking account of	••	••	••	••
i. Physical	••	••	••	••
ii. Psychological				
• cognitive	••	•	•	
iii. (Psycho) social	••	••	••	
iv. Organizational	••	••	•	••
v. Environmental	•	••	••	••
vi. Other relevant factors				
d. <i>As for c, but holistic in terms of ensuring the acceptability of the advice/solution generated by the approach</i>	••			

Key • = mentioned in one group •• = mentioned in both groups

HSA = Health and Safety Advisor; OHA = Occupational Health Advisor; FS = Furniture Supplier

### **5.3.4 Activities**

The ergonomists cited the broadest range of ergonomics activities, being alone in undertaking expert witness work, ergonomics educational material development and macro ergonomics work. The specialist furniture suppliers cited the fewest ergonomics activities, with the emphasis being on 1-to-1 workstation assessment and giving equipment advice.

All four of the professions cited a number of activities in common, including Display Screen Equipment (DSE) compliance assessments, industrial workstation assessments and giving tool/equipment advice. The responses are summarised in Table 5.4.

## **5.4 Discussion**

### **5.4.1 Initial aims**

The aims of this study were threefold:

- to examine any differences in the different professionals' knowledge about ergonomics.
- to identify the aims and approach of the professional groups when carrying out their ergonomics work.
- to establish what ergonomics activities are carried out by the different professional groups.

The discussions will be structured in the following manner. First, the additions to the template will be covered. This will be followed by the overall breadth of coverage of the template, as well as the breadth of activities undertaken, in order to establish the extent to which knowledge, aims, approach and activities were covered by the different groups.

Next, the specific differences between the groups in these areas (knowledge, aims, approach, activities) will be discussed, followed by possible reasons and potential implications of the differences. Finally the limitations of this work and overall conclusions will be discussed.

**Table 5.4: 'What activities do you do which you consider involve ergonomics?'**

	Ergonomists	HSAs	OHAs	FSs
DSE Compliance Assessments	•	•	•	•
Specialist Office Workstation assessment	•	•	•	•
Industrial Workstation Assessment	•	•	•	•
General Ergonomics Assessment	•	•	•	•
Vehicle Assessment	•		•	
Manual Handling Assessments	•	•	•	
Physical Environment Assessment	•		•	
Access to work Assessment	•			
DSE Assessor Training	•		•	
Manual Handling Training	•			
Ergonomics Training	•			
Health and Safety Induction Training			•	
Design	•	•		•
Accident Investigation/Post event analysis	•	•		
Product Sales	•			•
Tools/equipment advice	•	•	•	•
Management processes/Policy work	•		•	•
Expert witness work	•			
ISO committee work	•			
Educational material development	•			
Macro ergonomics	•			

KEY: HSA = Health and Safety Advisor; OHA = Occupational Health Advisor; FS = Furniture Supplier



### 5.4.2 Additions to the template

18 sub themes were added to the template which provided additional detail to the main themes gleaned from the literature. However, three additional *main* themes (analyse problems, propose solutions, ergonomics is an approach/philosophy as well as a set of knowledge/methods) emerged during the discussions. The first of these ('analyse problems') could, in fact, have been gleaned from the UK Ergonomics Society definition used to provide the *a priori* template:

"Underlying all ergonomics work is careful analysis of human activity.....<via> 'job and task analysis'.....The second key ingredient is to understand the users. This commitment to 'human-centred design' is an essential 'humanizing' influence on contemporary rapid developments in technology, in contexts ranging from the domestic to all types of industry."  
(The Ergonomics Society, 2004)

The second additional main theme (propose solutions) is *implicit* in the definitions used to generate the template (for example solutions would be required in order to be 'turning antagonism into synergy'....'optimising fit'.....applying 'principles to the designing, testing and operation of equipment and systems'). However, the lack of explicit reference to solutions in the literature may be a reflection of the focus on analysis rather than solution during training as described by one of the Ergonomists; the 'training you receive.. is largely to do with finding out what the problem is.....and it doesn't actually get you very far in solving the problem'.

It could also be argued that the third additional theme (describing ergonomics as a philosophy or approach as well as a set of knowledge and methods) was also implicit in the definitions originally used to generate the template. For example, that ergonomics is a set of knowledge or methods is clear from definitions such as Chapanis (1995); ergonomics . . . 'is a body of knowledge about human abilities, human limitations and other human characteristics that are relevant to design'; or Hancock (1997); ....ergonomics . . . 'is that branch of science which seeks to turn human machine antagonism into human-machine synergy.'

That it is a philosophy or approach is implied by definitions such as Meister (1989); ... ergonomics is. . 'the application of behavioural principles to the design, development, testing and operation of equipment and systems'; or Wickens (1992); ..ergonomics ....'is to apply knowledge in designing systems that work,

accommodating the limits of human performance and exploiting the advantages of the human operator in the process.'

#### **5.4.3 Breadth of coverage (knowledge, aims, approach and activities)**

Each profession showed a relatively broad coverage of the knowledge, aims and approach of ergonomics, making reference to the majority of the themes on the template. The ergonomists had the most comprehensive discussions. They covered 43/46 themes in at least one group, with the other professions covering around two thirds of the themes (between 28 and 31).

In terms of activities, the furniture suppliers cited the fewest (8) whilst the ergonomists mentioned the most (20). The OHA's and HSAs cited 10 and 9 activities respectively. The specific differences between the groups will be discussed in the next section.

#### **5.4.4 Comparison of knowledge attributes, content and application and the implication of differences.**

##### ***Attributes***

Whilst all of the groups highlighted the need for practical ergonomics knowledge, the ergonomists were unique in covering the other knowledge attributes in both groups (scientific, integrated, beyond common knowledge and factually correct). These attributes were put forward during previous focus groups with ergonomists (Chapter 3) and they are, perhaps, attributes that only members of the profession would be concerned with.

For example, the fact that the ergonomists were almost alone in bringing the application of science forward as key to their practice is perhaps a mark of the difference between what has been described as 'non-ergonomists 'doing ergonomics' ..... and the work of professional ergonomists' (MacDonald, 2006). Wilson (2000) cites a personal publication from Meister (1995) who posits that ergonomics is the only discipline that relates humans to technology, *scientifically*. If this is indeed its unique contribution, it is an important omission by the non-ergonomist groups in this study.

## ***Content***

This part of the template was generally well covered by all of the groups, with the exception of an explicit statement about ergonomics covering the broad range of human sciences. Whilst all of the groups made mention of various human sciences during their discussions, the ergonomists alone made this foundation explicit. As this was originally an attribute defined by the previous study (Chapter 3) the same may be true of this attribute as the others (namely that only members of the profession would be concerned with them).

## ***Application***

The furniture suppliers saw the design output from ergonomics being largely work products (rather than systems or leisure products), which represents the narrower product based focus they demonstrated during their discussions.

The HSAs were alone in not mentioning non-work applications for ergonomics in either of their groups. This may be one aspect of what MacDonald (2006) describes as a 'lack of understanding of the larger picture' by those professionals who do some ergonomics. However, the reality is that the health and safety advisors would have their ergonomics work confined to the workplace, as they were all occupationally based.

### **5.4.5 Comparison of Aims and Approaches and the implications of differences**

#### ***Aims***

As described above, the ergonomists covered almost all of the 'aims for using ergonomics' themes, though neither they nor the OHAs mentioned 'productivity' or the related 'profitability'. This omission is a concern in terms of selling the benefits and raising the profile of ergonomics (Hendrick, 2003; Oxenburgh and Marlow, 2005; Koningsveld et al., 2005).

It was a notable difference between the ergonomists and furniture suppliers, for whom the sales benefits of enhanced workforce productivity were clearly stated; 'if you sell someone the right chair, it makes the individual not only better in their own health themselves, but also makes them more profitable..'. It would seem that the furniture suppliers were more focussed on marketing their products than the ergonomists were on marketing ergonomics.

Whilst omitting to mention the productivity impact may be a lost marketing opportunity for ergonomics, it is also evidence of an area of knowledge (and therefore expertise) that may be insufficiently developed amongst many of the participants in this study.

Where there was similarity between the ergonomists and furniture suppliers was in their additional aims for using ergonomics. Both professions cited 'helping', 'building a sales relationship' and 'education' as amongst their goals.

In Chapter 3, one proposition was that furniture suppliers' recommendations would be driven by product sales whereas the ergonomists' would be driven by wanting what is best for the individual. In this study, the furniture suppliers did report increasing sales as motivating them in their ergonomics work, but so did the ergonomists. Equally, both ergonomists and furniture suppliers discussed 'wanting to help' as being a driver for them.

The desire to educate about ergonomics ('spreading the word') was mentioned by both groups of ergonomists. This might stem from the fact that, as members of a profession, ergonomists feel they have exclusive ownership of their area of expertise (Evetts et al., 2006) and they consequently want to enhance the benefit they bring to society by publicising it.

It is possible, therefore, that similar answers would have been forthcoming from, for example the OHAs, had they been asked about their aims when undertaking Occupational Health activities, rather than ergonomics activities (which form only part of their role); similarly from the other professional groups if asked specifically about their own professional domain.

The final differences in aims between the groups arose from whether or not they discussed 'analysing problems' and 'proposing solutions' as goals of their work. The ergonomists and furniture suppliers were most closely aligned in this, mentioning both aspects, with the HSAs discussing solutions in one of their groups, and the OHAs discussing neither aspect in either group. This omission by the OHAs may be a terminology issue, in that they use their ergonomics primarily in their dealings with individuals whom they are supporting back to work, or whilst at work. They would perhaps not see these individuals as 'problems' which they must 'analyse' in order to find 'solutions'.

The HSAs are likely to deal with individuals, but are much more likely to deal with 'workplace problems' in which individuals are involved and to which they need to find a solution. In addition, the 'solution' aspect is a sales feature for the furniture suppliers.

### ***Approach***

The ergonomists were alone in discussing ergonomics as an approach or philosophy, as well as a set of knowledge and methods. Previous work examining the role for qualitative methodology in ergonomics specifically targeted individuals who had 'written on the subject of ergonomics philosophy' (Hignett & Wilson, 2004). This suggests that the existences of an 'ergonomics philosophy' may be a generally held idea by those in the profession. However, whilst it is an interesting opinion to hold, it is not obvious how it would impact on the day to day use of ergonomics in the workplace.

The ergonomists were also unique in carrying their holistic/systems approach into describing how to ensure their advice/solutions were accepted. In other words, not only did they endeavour to consider all aspects of the system in generating their solutions, they continued to do so when discussing the delivery of the solutions. Previous research has shown that considering the 'stage of change' of the recipients of ergonomics advice leads to better uptake of solutions when compared to others who do not take this approach (Whysall et al., 2005).

In terms of the characteristics of the approach, all 8 of the groups covered the domains outlined by the IEA (physical, cognitive, social, organizational, environmental and other relevant factors) with the notable exception of the furniture suppliers, who omitted to mention the psychological aspects in either of their groups. Instead, their focus was on the physical. Though covering all the domains, at least superficially, is key to the 'holistic' nature of the ergonomics approach, it would seem that it is not just non-ergonomists who might view the 'psychological' as separate to 'ergonomics':

'Over the past few years I have noticed an increase in the number of people who recognize the word 'ergonomics' and believe they know what it means; however, a high proportion of these people believe that 'ergonomics' refers to quite a small set of purely physical issues.

Depressingly, this narrow interpretation of ergonomics is common even among ergonomists, particularly in the USA. For example, a recent item on the Ergoweb list specifically excluded cognitive aspects of interface usability from the 'ergonomic' ones:

*The Ergonomics Report™* asked researcher-designer Susan Tuttle of Motorola ... whether ergonomics is an afterthought for the cell phone industry. She rejected the suggestion emphatically. "We ... at Motorola are constantly working to improve usability of our products, both from an ergonomic perspective, as well as from a cognitive perspective on the usability of the user interface ..." (MacDonald, 2006)

Wilson (2000) argues that whilst it is understandable to partition ergonomics into specialisms such as the IEA's domains, 'it is its very systems perspective and holistic nature that provides the strength of ergonomics.' The omission of the psychological is therefore likely to be a significant omission.

#### **5.4.6 Comparison of Activities and implications of differences**

In this study, the furniture suppliers cited the fewest activities (8) whilst the ergonomists mentioned the most (20). The OHA's and HSAs cited 10 and 9 activities respectively, with the overlap for all four professions being in Display Screen Equipment (DSE) compliance assessments, industrial workstation assessments and giving tool/equipment advice.

There was, therefore, an obvious difference between the ergonomists and the other professionals in the number of ergonomics activities they reported, with ergonomics training, macro level ergonomics interventions, expert witness work and ISO committee work being the domain of ergonomists alone. Hignett (2000) discusses the fact that ergonomists are skilled to deal with issues pertaining to working groups, organisations and general populations (macro-ergonomics), rather than just at the more individual level. This unique macro-level capability was borne out in this study as being the domain of the Ergonomists.

It would seem that whilst a range of professionals are willing to undertake workplace assessments which ergonomists would count as falling into their remit (e.g. DSE compliance and industrial workstation) there is evidence of self-limitation amongst non-ergonomist professionals when it comes to higher-level ergonomics interventions.

#### **5.4.7 Possible reasons for the differences**

##### ***Training***

The ergonomists were unique in having degree level or higher ergonomics training. The furniture suppliers had short course ergonomics training, and the OHAs and HSAs had ergonomics training as part of their vocational training (with some having additional short course training). It would seem that the higher level training of the ergonomists is reflected in the greater breadth of ergonomics knowledge and wider range of ergonomics activities. However, it is also clear that even short course ergonomics training led to an awareness of the majority of the themes on the template and the reporting of a number of activities which ergonomists would undertake.

##### ***Experience***

The furniture suppliers had the least experience in the occupational health and safety domain, and this may have contributed to their omissions from the template themes. The OHAs had the most experience which may account for their covering more themes than the other two non-ergonomist groups. However, years of experience is confounded by the fact that someone with 5 years experience may have spent all 5 years dealing only with ergonomics issues whilst someone with many more years experience may not have focused exclusively on ergonomics.

##### ***Profession vs. part of job role***

Many of the themes covered by the ergonomists alone were aspects which could be viewed as emanating from critical contemplation of the profession to which they belong. The omission by the other professionals to discuss ergonomics as a philosophy, the attributes of ergonomics knowledge (rather than simply its content) and the systems approach to having solutions accepted, may simply be the result of a less introspective approach to a discipline which forms only part of their job, when compared to the ergonomists.

#### **5.4.8 Limitations**

The issues raised in this study offer an insight into the differences between ergonomists and other non-ergonomist professionals who undertake ergonomics in the musculoskeletal health arena. However, it is acknowledged that the participants in this study may not be typical and having only 2 groups of each may not be

representative. It is possible that further groups of each of the professions would allow for 'saturation'.

It is acknowledged that the way the template was used meant that even a cursory mention of a particular aspect counted as demonstrating knowledge in that area. Further work could examine the depth of understanding of the concepts on the template, in order to see if there were further differences between the professional groups.

The extent to which the views put forward here reflect actual practice is unknown, and the 'text-book' (fitting the task to the person) nature of the answers at the outset suggests a desire to conform to expected norms. However, by incorporating the implied and direct responses from the whole discussion with the initial response to the questions asked, efforts have been made to overcome this potential limitation.

The groups were deliberately made up from single professions, often with individuals who were already colleagues or knew one another. This encouraged free-flowing conversation, and avoided the power-struggles which could have been evident had the groups been mixed with, say, ergonomist and non-ergonomist professionals. One disadvantage of the homogeneity of the groups, however, is there was generally consensus, with only one example of dissent in any of the 8 groups. Consequently, the 'thrashing out' of issues which comes from challenging voices was not in evidence, and the potential for 'groupthink' was enhanced (Janis, 1972). On balance, the advantages of single profession groups were deemed to outweigh the disadvantages.

## **5.5 Summary and Conclusions**

This study has identified that ergonomists have a broader knowledge of ergonomics than the other professional groups participating, but that all of the groups covered the majority of pre-determined ergonomics themes during their discussions. The additional sub-themes which emerged during discussions added breadth to the template, and all three additional main themes (ergonomics as a philosophy, and analysing problems) could arguably have been gleaned *a priori* from the sources used. However, the lack of explicit reference to the third main theme which emerged (proposing solutions) resonates with the issue raised by one ergonomist that 'training you receive.. is largely to do with finding out what the problem is.....and it doesn't



actually get you very far in solving the problem'. This has implications for the training provided to ergonomists and others who employ ergonomics principles.

In the study reported here, the lack of emphasis on the scientific nature of ergonomics as well as the lack of reference amongst some groups to the cognitive aspects, stand out as potentially important omissions (Meister, 1995; McDonald, 2006). The absence of any reference to productivity by the ergonomists is also an important omission with respect to 'selling the benefits' of the discipline.

The question as to whether any theme can be omitted whilst allowing ergonomics to be adequately employed remains unanswered. As described in Chapter 2 (section 2.3.1) the concept of experts having 'complete' knowledge compared to the partial knowledge of novices has been proposed (Chi, 2006b). In the study described there, expert physicians picked up both 'key' and 'small' events on a trace, whereas the novices noticed only the 'key' events. The experts also detected and ignored artefacts, unlike their novice colleagues. Chi (2006b) argues that these differences demonstrate the more complete knowledge of the experts; a concept related to greater knowledge but not equivalent to it. It is possible that the less complete knowledge of the non-ergonomist professionals could have a similar impact as that described by Chi (2006b). In other words, the main ergonomics aspects of a situation are likely to be picked up, but smaller aspects may be missed and unimportant aspects may be attended to.

In addition to differences in knowledge, the number of ergonomics activities in which the different groups engage showed the ergonomists to be the most prolific group. This would be expected based solely on time available, as the non-ergonomist professionals undertook ergonomics as only part of their larger job role. However, in addition to the quantitative difference in the number of activities undertaken, the ergonomists were alone in naming and describing macro-level interventions amongst their activities. This macro level ability has been described as a key output of the training ergonomists receive (Hignett, 2000).

When discussing their aims in undertaking ergonomics, the furniture suppliers did propose product sales as being one driver, though this sat amongst a raft of others and increasing sales was also an aim of the ergonomist groups. This may, in part, refute the allegation made by one Ergonomists in the study reported in chapter 3; that the sales motivator was both paramount and unique to furniture suppliers.

Overall then, in each of the areas examined in this study (knowledge, approach, aims and activities) the ergonomists were more comprehensive than the other groups. One definer of an expert is having 'adequate domain knowledge' (Shanteau, 1992) and though the ergonomists had more, this study alone does not answer for their knowledge adequacy, nor does it determine inadequacy amongst the other professions (who covered fewer but none-the-less the majority of the themes).

If the number of activities undertaken can be seen as a proxy for the number of skills attained, then the Ergonomists also behaved more like experts by that measure. However, their performance ability in any of the activities was not tested.

Having demonstrated some subjectively reported expertise, an objective measure of performance is required to test the findings. The results from this study therefore informed the development of the next, which undertakes objectively to measure the performance of some of these different professional groups in one specific ergonomics activity. The fact that all of the groups attested to carrying out industrial assessments sanctioned the development of industrially based scenarios about which judgements could be made. This study will be the subject of Chapter 6.

### **Chapter 1 – Introduction**

- Problem statement
- Research aims
- Research Paradigm
- Thesis Structure

### **Chapter 2 - Literature review**

- Establishing the nature of expertise and how it is identified and measured
- Establishing the nature, extent and findings of previous work examining expertise amongst ergonomics and allied professionals

### **Chapter 3 – What characterises good and expert Ergonomics Advisors?**

- 3 Focus groups (n = 26) with Ergonomists
- Model building of features of good and expert ergonomics practice

### **Chapter 4 – The self reported competencies of Ergonomics Advisors**

- 217 competency questionnaires from 6 national ergonomics conferences
- Establishment of areas of high and low confidence across the breadth of IEA ergonomics competencies.
- Relationship of competence and expertise

### **Chapter 5 – The Knowledge and Activities Ergonomics Advisors**

- 8 Focus groups (n = 55) with Ergonomists and other professional groups engaged in ergonomics advising
- Template analysis and model building of ergonomics expertise from knowledge and activities differences

### **Chapter 6 – The decision making expertise of Ergonomics Advisors - part 1**

- ULD risk assessment task undertaken by 58 PREs and EOPs and a control group of 148 students
- Establishment of comparative expert performance using the CWS index of expertise

### **Chapter 7 – The decision making expertise of Ergonomics Advisors - part 2**

- Investigation of the content of risk assessment decisions
- Relationship of decision content and expertise

### **Chapter 8 – Discussions, Implications and Conclusion**

- Discussions and implications of findings from all studies
- Limitations
- Recommendations for further research
- Conclusion

## **Chapter 6 – The Cochran-Weiss-Shanteau Performance Index as an indicator of Ergonomics Expertise**

### **6.1 Introduction**

#### **6.1.1 Outline of research presented in this chapter**

Having established differences in the self-reported ergonomics capability of different groups of professionals undertaking general ergonomics work (Chapter 4) and specifically in the knowledge, aims, approach and activities of those involved with physical ergonomics work (Chapter 5), the aim of the next study was to assess expertise more objectively. This study aimed to address the fifth of the research objectives of this thesis, namely; to identify any differences in judgement expertise between PRE and EOP physical, ergonomics advisors, on one specific task<sup>1</sup>.

#### **6.1.2 Background**

In this chapter, non-ergonomist professionals working in the field of musculoskeletal health, who apply ergonomics principles, are termed 'ergonomics advisors'. As outlined in Chapter 5, in the UK, ergonomics advisors might include Health and Safety Advisors (HSAs), Occupational Health Advisors (OHAs) and Physicians, Physiotherapists, Occupational Therapists, and Specialist Furniture Suppliers. The purpose of this study was to examine the expertise of some of these professional groups in one aspect of musculoskeletal disorder (MSD) management; namely Upper Limb Disorder (ULD) risk assessment.

#### **6.1.3 Expertise and ergonomics**

As reported in Chapter 2 (section 2.7), expertise in others, particularly in decision making, is a subject of interest to Ergonomists as part of their practice (Farrington-Darby & Wilson, 2006; Piegorsch et al., 2006). However, expertise in ergonomists themselves is also of importance for the profession, in spite of the paucity of studies in this area (Piegorsch et al., 2006). Some of the few studies which have examined expertise amongst ergonomics practitioners have looked at expert-novice differences when undertaking different types of ergonomics work (Haslam et al., 1992; Jones et al., 1999; Stanton & Young, 2003; Winnemuller et al., 2004)

<sup>1</sup> Aspects of this chapter have been presented in Williams, C., Haslam, R. & Weiss, D. (2008) The Cochran-Weiss-Shanteau Performance Index as an indicator of Upper Limb Disorder Risk Assessment Expertise, *Ergonomics* (in press)

These studies demonstrated that there is a performance enhancement effect at typical ergonomics tasks which comes from even short course training. This enhancement continues with the more involved training typically required of fully qualified ergonomists, and may also be linked with more extensive experience.

Other studies have compared experts (Keyserling & Wittig, 1988; Piegorsch et al., 2006), demonstrating consensus between experts in both their mental models and decisions made. The first of these studies also found that there was tentative consensus between ergonomics experts and an objective ergonomics tool.

In the majority of these expert-novice and expert-expert ergonomics studies, 'experts' were selected based on their qualifications rather than any empirical measure. With this previous work in mind, the ergonomics activity of interest for this study will be discussed.

#### **6.1.4 Risk assessment**

ULD risk assessment forms part of the tasks ergonomists and ergonomics advisors will commonly undertake. Identifying jobs with risk factors linked with the development of ULDs as well as other MSDs is relatively common-place (Dempsey et al., 2005; Keyserling & Wittig, 1988; Keyserling et al., 1993; Piegorsch et al., 2006). As Chapter 5 outlined, all the professional groups taking part in that focus group study attested to undertaking industrial ergonomics assessments which, amongst other aspects, are likely to involve ULD risk assessment.

In brief, the process involves having knowledge of the potential risk factors; observing work tasks and workplaces for evidence of these risk factors; quantifying them; and finally making a judgement on the likely outcome. This process is known as risk assessment and is aided by a relatively strong evidence base for the risk factors associated with ULDs, as well as by a number of ULD risk assessment tools.

The literature has established associations between the development of ULDs and the presence of certain risk factors, via reporting schemes (e.g. Cherry et al., 2001), epidemiological reviews (Bernard et al., 1997) and population surveys (Bureau of Labour Statistics, 2006; European Foundation for the Improvement of Living and Working Conditions, 2007; Jones, 1998; HSE, 2005). These known risks have then been incorporated into risk assessment tools such as Rapid Upper Limb Assessment tool (RULA) (McAtamney & Corlett, 1993), Occupational Repetitive Actions Index

(OCRA) (Colombini, 1998; Colombini et al., 2002; Occhipinti & Colombini, 2007), and the Quick Exposure Checklist (QEC) (Li et al., 1999) as well as into governmental guidance such as the 'Washington State Ergonomics Rule' (WAC) (Washington State Department of Labor and Industries, 2000) and 'Upper Limb Disorders in the workplace (HSG60)' (HSE, 2002) .

This last set of risk assessment guidance, HSG60 (as described in Graves et al., 2004), incorporates the evidence from many of the other sources, as a statement of best practice in ULD risk management for non-specialists. These sources include; WAC (Washington State Department of Labor and Industries, 2000) the QEC (Li et al., 1999), the 'Upper Extremity Checklist' (Keyserling et al., 1993), RULA (McAtamney & Corlett, 1993) OCRA (Colombini, 1998) and the 'TUC Guide to Assessing WRULDs Risks' (Buckle & Hoffman, 1994).

Seven risk areas are outlined in HSG60 as being evidentially linked with the development of ULDs. These are; repetition, force, duration of exposure, awkward posture, psychosocial factors, individual differences (issues such as age, experience etc) and working environment (issues such as temperature, lighting and vibration). These areas form the basis of what any ergonomics advisor or ergonomist would investigate when assessing a workplace for ULD risk and has the advantage for this study of being targeted at non-specialists.

#### **6.1.5 The Cochran-Weiss-Shanteau (CWS) performance index**

In the extensive literature on expertise outside of the ergonomics discipline, the ability to evaluate domain-specific situations correctly has been held to be an important indicator of expertise. Customarily, empirical measures of this ability compare responses made by those being assessed with those of established experts. In essence, this approach presumes that the judgements of the established experts are correct. In turn, the established experts were certified because their judgements matched those of a previous generation of experts.

Weiss and Shanteau (2003) proposed a way to break through the circularity in this reasoning by measuring two necessary, observable properties of expert judgement. Just as these properties are necessary in a mechanical measuring instrument, they ought to be exhibited within the judgements of a candidate expert. An expert should respond differently to different stimuli, and should respond similarly to similar stimuli.

Weiss and Shanteau (2003) labelled these properties discrimination and consistency respectively.

Furthermore, they proposed a performance index that combines the properties into a ratio called CWS. The consistency property is “reverse-scored” (i.e. as inconsistency) because it serves as the denominator of the ratio. The motivation for combining the properties is that someone without true ability can adopt simple strategies for maximizing one at the expense of the other (e. g. vary responses widely or hardly at all), but only someone who is an expert within the domain can achieve both simultaneously. A key feature of the CWS index is that the analyst can assess the degree of exhibited judgemental expertise without presuming to know the true values of the objects being judged.

In practice, the variance among responses to different stimuli is used as the estimate of discrimination and the variance among responses to the same stimulus is used as the measure of inconsistency. All that is needed to fuel these computations is an individual's data set containing repeated responses to a variety of stimuli. The true values of the stimuli do not matter. Variances, with their heavy weighting of large discrepancies, have traditionally been used by statisticians to capture precision of measurement (Grubbs, 1973), with a ratio format the usual arrangement for comparison.

$$\text{CWS} = \frac{\text{Discrimination}}{\text{Inconsistency}}$$

Where discrimination is high and inconsistency is low (prerequisites for expertise though not sufficient for it), the CWS index will be high. Conversely, where discrimination is low or inconsistency is high, the CWS will be low. Whilst high CWS is not sufficient to guarantee expertise, it is necessary. No one whose CWS is low can said to be judging expertly. The caveat is that because validity is not presumed, there is no certain way to insure that the judge is attending to the correct aspects of the stimuli. Of course, no assessment approach that is unwilling to make the strong assumption that a gold standard of truth is available can do any better. A major advantage of this index is that it is objective, in the sense that it can be calculated from the judgements themselves without requiring an expression of opinion. Thus, CWS obviates the need to use the decisions of an ‘expert’ as an unproven gold

standard against which to compare the decisions of the other study participants (for example as used in the studies outlined in sections 2.7 and 6.13 above.)

As discussed above, one of the more common tasks which ergonomics advisors undertake is risk assessment. To do so, advisors examine the workplace for evidence of specific hazards (diagnosis) and make a judgement based on that evidence about the likely outcome (prognosis). In this way they undertake similar activities to clinicians, auditors and other judges. Indeed, the CWS index has been successfully used in a number of different situations including; to discern between expert and novice financial auditors and personnel selectors (Shanteau et al., 2002); to demonstrate the improvement in performance with training in occupational therapists (Weiss et al., 2006); and to highlight the differences in diagnostic competency amongst medical doctors faced with patients reporting possible symptoms of heart failure (Weiss & Shanteau, 2003) and occupational therapists making clinical judgements for children with cerebral palsy (Rassafiani et al., 2008). It was proposed, therefore, that the CWS index might be an appropriate, objective method with which to assess ergonomics judgements.

Some of the other attributes linked with expertise in addition to high levels of discrimination and consistency are; lengthier experience (James, 2007); higher certification (Shanteau et al., 2002); superior knowledge (James, 2007; Shanteau et al., 2002) and certain behavioural characteristics such as greater confidence (Abdolmohammadi & Shanteau, 1992; Shanteau 1988; Shanteau et al., 2002).

The study reported in this chapter examines how discriminating and consistent different ergonomics advisors are in their '*diagnoses*' and '*prognoses*', when it comes to ULDs, without looking at the content of the judgements. In addition, the training level and duration of experience of the participants were also recorded, so as to look at these potential predictors of expertise alongside the CWS method. Behavioural characteristics were not examined in this study.

#### **6.1.6 Aims**

At the outset there were three specific aims for this work. To :

- identify which individuals/groups giving ergonomics advice are the most 'expert' judges in terms of their consistency and discrimination.



- identify which characteristics of the participants are associated with better judgement performance.
- elucidate whether CWS is a useful method for evaluating judgement expertise in the context of ergonomics.

## **6.2. Methods**

### **6.2.1 Judgement scenarios**

In order to employ the CWS index, repeated, measurable judgements needed to be gathered from participants in an area of ergonomics with which they were familiar. Evaluating different work environments and making judgements about the likelihood of staff complaining of ULDs was the chosen judgement task and a method of presenting situations about which judgements could be made was required. Other studies examining clinical reasoning by physical therapists concluded that work carried out 'live' in the clinical environment (i.e. 'on the shop floor' in this context) was too variable to allow for cross subject comparison (James, 2001; James, 2007). A more controlled method of presenting judgement situations was therefore required.

The situations needed to be presented in a manner which would have face validity to the participants and could be administered conveniently, without recourse to complicated technology. They also needed to be sufficiently difficult to allow the participants to demonstrate their 'expertise', whilst being within the understanding of all of the participants. In other words, both 'floor' and 'ceiling' effects should be avoided (Farrington-Darby & Wilson, 2006).

With all these issues in mind, short, written scenarios were produced about which judgements could be made, describing real environments encountered during the professional experience of one of the authors. This approach of providing controlled scenarios, rather than following individuals as they worked 'live', had been endorsed previously by the creators of the CWS index; as "reproducible success in controlled settings predicts success in real-world applications" (Weiss & Shanteau, 2003). Written scenarios were chosen over 'video' clips because of their relative ease in both generation and administration.

### **6.2.2 Risk Areas**

The scenarios needed to have different 'risk' stimuli embedded in them, which were evidence-based. To this end, the HSE's HSG60 document (HSE, 2002) was used as a starting point for defining the stimuli, as it outlines both the risk factors and, where

known, the particular levels of the risk factors which should be cause for concern. It is also useful in that it includes psychosocial risk factors, which are implicated in the reporting of ULDs (Graves, 2004).

For the purpose of this study, the number of risk factors included in the scenarios was intentionally limited, in order to restrict the number of scenarios generated. The reason for this was that all of the risk factors used were to be incorporated into scenarios in all of the different combination options of 'present' or 'absent'. Therefore, if there were  $n$  risk factors, there would need to be  $2^n$  scenarios, as there were two 'states' for each risk factor ('present' or 'absent'). As a consequence, it was decided to limit the number of risk factors to five, as thirty-two scenarios ( $2^5$ ) would be a practicable number to generate, where sixty-four ( $2^6$ ) or more was not.

To this end, five of the seven risk areas were selected from those outlined in HSG60. Those selected were repetition, force, duration of exposure, awkward posture and psychosocial factors. Effectively, this only omitted 'individual differences' (issues such as age, experience etc) and 'working environment' (issues such as temperature, lighting and vibration).

### **6.2.3 Incorporating the risk factors into scenarios**

The risk areas (or 'cues') chosen had to be represented in the scenarios at a level which was generally accepted as 'present' or 'absent'. Therefore, the guidance outlined in HSG60, as well as the accompanying evidence (Graves et al., 2004) were used to determine these levels wherever possible. The following sections outline each of the risk factors and explain how they were incorporated into scenarios.

#### **'Repetition'**

HSG60 describes repetition with the following definers

- 'the same movements' are 'repeated every few seconds'
- 'A cycle or sequence repeated twice per minute' OR
- 'More than 50% of the task involves performing a repetitive sequence of motions.'

#### **'Force'**

HSG60 descriptors for force are:

- 'For the hand/wrist, high force tasks are those with estimated average individual hand force requirements of 4 kg or above.'

- 'pinching an unsupported object weighing 0.9 kg (2 lbs) or more per hand, or using a similar pinching force (e.g. holding a small binder clip open)'.

### **'Awkward Postures'**

Awkward postures are described in HSG60 for different parts of the Upper Limb. The description of the postures is often in combination with other risk factors such as repetition or long duration. In the scenarios generated for this study, awkward postures were described independently of the duration of exposure or repetition, which were present or absent in their own right. All body parts were considered together such that awkward posture would be described for either the hands/wrists, arm/shoulders or head/neck. The following outlines the awkward postures from HSG60 which have the potential to cause harm:

- For the wrist, deviations from neutral either 'up or down' or 'to either side' are highlighted as problematic where they are **held** or occur **repetitively**, where 'the greater the deviation from a neutral position, the greater the risk.'
- Other postures highlighted as problematic are repetitively turned or twisted hands where the palms face up or downwards; holding the hands with the palms facing downwards; using a wide finger and/or hand span to grip, hold or manipulate
- and postures caused by poorly fitting hand tools in terms of size, shape or handedness.
- Awkward postures were also described for the arms and shoulders; working above the head, or with elbows above the shoulders, as well as with arms repeatedly moving or held out to the side, are cited as risky.
- Static postures of the shoulder or elbow are mentioned along with any other awkward forwards, sideways, backwards or 'across the body' reaching.
- For the 'head and neck' repetitive or held bending or twisting are highlighted as issues, along with awkward postures caused by the visual and/or environmental demands of the work.

### **'Duration of exposure'**

Duration of exposure could be of interest in terms of the length of time an individual does a task or job as a whole, or in terms of the duration of exposure to a particular, known risk factor. For example, a repetitive, forceful task might be concerning after a

shorter duration of exposure than one which is neither of these things. However, even a non-repetitive, 'light' task might be cause for concern if the duration of exposure is extensive. Both represent situations where insufficient recovery time is available for the fatigued musculoskeletal and/or mental system. In the first situation it is simply that fatigue is reached more quickly. HSG60 gives guidance on the duration of exposure in a number of ways but the focus is on risks (postures, repetitions or forces) to which workers are exposed "for more than two hours total per work day".

### **'Psychosocial Factors'**

The following outlines the psychosocial factors flagged in HSG60 as having the potential to cause harm:

- aspects of the work set up such as; paced work; piecework discouraging breaks; frequent, tight deadlines; sudden changes in workload; and unsupervised overtime.
- aspects of the workers such as; whether they find it difficult to keep up; feel they have a lack of support; have insufficient training/information; and have little control.
- a task specific psychosocial issue which is whether the job requires high levels of attention and concentration.

### **Scenarios**

All five risk factors were present and absent in all possible combinations in the thirty-two scenarios which were generated. Some examples of each of the risk factors as used in the scenarios are presented in Table 6.1.

**Table 6.1: Examples of the risk factor cues from scenarios**

<b>Risk Factor</b>	<b>Cue absent</b>	<b>Cue present</b>
<b>Repetition</b>	"Customer demand is such that staff retrieve one every 2 or 3 minutes."	"Operators involved in this task lift single paper clips from a tray and put them in boxes. They count 60, one at a time into each box, and fill a box every minute"
<b>Force</b>	"This task involves placing a thin sheet of plastic weighing about 100 grams onto the top of each jar as it comes down the line."	"Staff in the deli have to retrieve meat joints weighing around 5 kg from the chiller cabinet. They use one hand only for the retrieval."
<b>Duration of exposure</b>	"150 paper cups are dropped one at a time into a stack by operators during the 25 minute period they work here."	"About 60 breadsticks an hour are placed on the line by each operator, and they carry out this task for the majority of their 8 hour shift."
<b>Psychosocial</b>	"They can therefore interact easily and freely, and enjoy good relationships with the management."	"The atmosphere created by the staff and management in the deli is negative. There is low morale, no team spirit and very little interaction between staff as they work."
<b>Awkward postures</b>	"They can keep a neutral posture due to the specially developed 'meat handles' which are attached to each joint before they are put in the chiller."	"Because of the line's orientation, operators must bend their wrists to place the breadsticks on the line."

An example of a scenario is represented below (Figure 6.1), with the risk factors 'key' identifying which factors are present and absent. This key was obviously not included in the scenarios presented to the participants.

**Example**

In order to place the car windscreens into the storage racks, operators have to adopt a posture with arms fully outstretched, to reach the edges of the glass. Each windscreen weighs upwards of 5.5 kg, and is placed into racks at about waist height.

The nature of the task involves lone-working for the 30 minutes that staff work in the racks during their shift. They have to replace 120 windscreens in the session otherwise they receive reduced pay and a reprimand from the supervisor.

How likely do you think it is that staff will complain of an Upper limb disorder (ULD) as a result of this task? Please mark on the scale below.

Very unlikely

Very likely

**Key**

<b>Force risk</b>	Present	'Each windscreen weighs upwards of 5.5 kg'
<b>Repetition risk</b>	Present	'They have to replace 120 windscreens in the session'
<b>Postural risk</b>	Present	'operators have to adopt a posture with arms fully outstretched'
<b>Duration of exposure risk</b>	Absent	'the 30 minutes that staff work in the racks during their shift'
<b>Psychosocial risk</b>	Present	'lone-working' ; 'otherwise they receive reduced pay and a reprimand from the supervisor'

**Figure 6.1: Example of a scenario with risk factors identified**

### 6.2.4 Participants

In order to compare and contrast the judgements of individuals from different groups, participants were recruited from a number of different professions known to give ergonomics advice pertaining to musculoskeletal issues. In order to provide sufficient power to discriminate among groups, we sought a minimum of ten participants from each profession. To recruit this number of individuals, purposive sampling from locally available professional groups was undertaken. To be included, participants had to attest to being involved with using ergonomics to deal with musculoskeletal health issues in the workplace. They were asked to record the number of years'

experience they had in workplace health and safety, and what ergonomics training, if any, they had undertaken.

As a reference group, first year Loughborough University students taking an introductory ergonomics module were also invited to participate. This group was selected because they had some awareness of musculoskeletal disorders and work places from a theoretical standpoint, and would be able to relate to the scenarios. They had not, however, had practical experience of dealing with musculoskeletal disorders and/or their associated factors in the workplace. The final numbers of participants are represented in Table 6.3.

### **6.2.5 Procedure**

As described above, thirty-two scenarios were generated in total, incorporating all of the five risk areas (see section 6.2.2) in all combinations from none up to five. In informal pilot studies, it took too long to make thirty-two judgements twice (two judgements on each scenario being required to test for consistency), and participants lost concentration. Therefore sixteen of the scenarios were randomly selected, and collated in an A5 sized booklet. The risk factors contained in these 16 scenarios are outlined in Table 6.2, though the content of the judgements was not of interest in this study.

All of these scenarios were administered twice to the participants so that they had to repeat their judgements for all of the cases. The order of the scenarios was randomised using a random number generator, and was different in the first and second booklets.

The scenarios were administered with consideration of two conflicting requirements. The first was the need to repeat them relatively quickly after the first administration, in order to be pragmatic about participants' limited time availability. The second issue was the desire to ensure that this was a test of expertise rather than of memory. It was important to avoid participants recalling their judgements from the first time and simply repeating them. This predicated against a rapid repetition in favour of a longer time interval between the two administrations.

In order to accommodate these two factors, the participants were given a brief explanation about the study after which they signed consent forms. They then

worked through the first scenario booklet, marking the scales with a vertical line in the place which best represented their opinion (see example in Fig 6.1). At this point, nothing was said about the fact that participants would repeat the exercise, nor about the fact that this would be an ‘expertise’ measure, so as to avoid them endeavouring to recall their judgements.

**Table 6.2: Risk factors contained in the scenarios**

Scenario Number	Number of Risk Factors	Specifics
1	None	-
2	1	Repetition
3	1	Duration
4	2	Force and Repetition
5	2	Force and Duration
6	2	Repetition and Posture
7	2	Repetition and Psychosocial
8	2	Posture and Psychosocial
9	3	Force, Posture and Repetition
10	3	Duration, Posture and Psychosocial
11	3	Force, Duration and Psychosocial
12	3	Repetition, Duration and Psychosocial
13	3	Repetition, Force and Duration
14	4	Repetition, Force, Duration and Posture
15	4	Repetition, Force, Posture and Psychosocial
16	4	Repetition, Force, Duration and Psychosocial

Having carried out this first round of judgements, participants put their booklets into an envelope, and engaged in another activity for between 60 and 90 minutes. This intervening activity varied from participating in a focus group discussion about ergonomics (Health and Safety Advisors, Occupational Health Advisors,



Ergonomists), to a lecture about design (Students), to a training course on the treatment of shoulders (Physiotherapists); to getting on with their own work (Ergonomists, Physiotherapists). Participants were then given the second booklet and asked to repeat the judgement task, without reference to their initial booklet.

### 6.2.6 Pilot

The whole system (with 16 scenarios repeated twice) was pilot tested with 5 individuals, to ensure that the instructions were clear and that the procedure was manageable. This being the case, these data were discarded and recruitment began for the main study.

### 6.2.7 Analysis

The point at which each participant marked the 100mm line was measured in mm, treated as % likelihood and input into the CWS calculator software available at <http://www.k-state.edu/psych/cws/software.htm>. Ten participants who failed to record a judgement for both repeats of a scenario were excluded from the analysis and are not reported on here.

The software generated a CWS index for each participant. Having generated this index, group means were calculated for each professional and training level group, using the method suggested by Weiss and Edwards (2005). The mean CWS for a group is the square of the sum of the square roots of the individual CWSs. That is,

$$\overline{CWS} = \left( \frac{\sum \sqrt{CWS_i}}{n} \right)^2$$

$\overline{CWS}$  = Group Mean CWS

$\sqrt{CWS_i}$  = Square rooted individual's CWS index

$n$  = number of individuals in the group

84.3 % confidence intervals (CI) were calculated in order to ascertain if the different groups were statistically different in CWS performance. We follow Payton, Greenstone, and Schenker (2003) in employing 84.3% confidence intervals rather than the usual 95% confidence intervals when comparisons are intended. The 84.3% confidence level allows comparisons with a Type I error rate of 0.05. Here the lack of overlap implies that, at the 0.05 level, there is a significant difference between the mean CWSs.

Where

$$CI = \overline{CWS} \pm t \cdot s_x$$

t is used rather than z because group sizes are relatively small and we are therefore using the sample's standard deviation rather than the population's to calculate the confidence intervals. This avoids the assumption of normality.

6.3. Results

6.3.1 Sample Characteristics

In total, 208 individuals took part, with 198 producing complete, usable responses. Descriptive statistics in terms of experience and training level are shown in Table 6.3. In order to rationalise their responses, the participants' ergonomics training level was coded as described in the table footnote.

Table 6.3: Sample size, years of experience, training level and CWS of the different groups

	n	Experience (Mean Years ± SD )	Training level (Median)	Group Mean CWS with 84.3% confidence intervals (CI)
Ergonomists	11	7.9 (± 7.4)	4.0	16.2 (CI 8.3 -26.7)
OHAs	22	12.4 (±7.1)	2.0	7.1 (CI 5.1 - 9.4)
HSAs	11	6.0 (± 3.7)	2.0	5.9 (CI 4.2 -7.9)
Physiotherapists	14	12.2 (± 11.8)	2.0	5.4 (CI 3.4 -7.8)
Students	140	0 (±0)	1.0	5.6 (CI 5.0 - 6.2)

Note: Training levels: 1 = None; 2= Ergonomics training as part of their professional qualification; 3 = Ergonomics Short course, Ergonomics Certificate or Ergonomics Diploma; 4 = Ergonomics BSc, MSc or PhD.

The majority of the participants had no additional ergonomics training beyond their professional qualification, with the students having none at all. By contrast, the

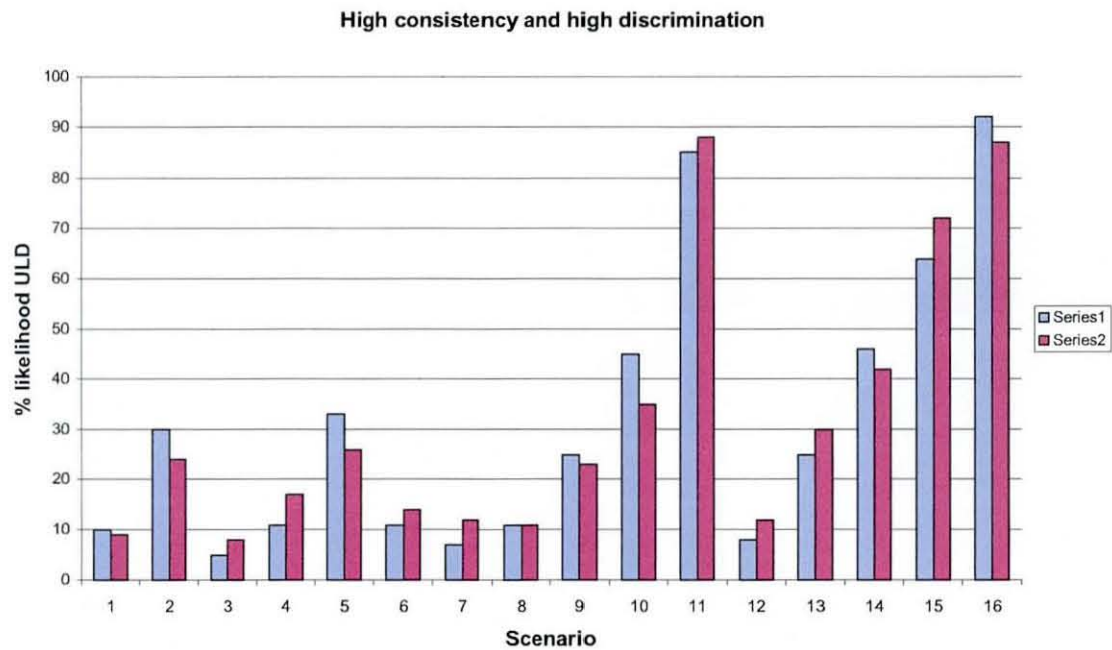
Ergonomists' median was level 4, indicating that a high proportion held a BSc, MSc or PhD in Ergonomics.

The Physiotherapists and OHAs had the most experience practising in the field of Occupational Health, averaging just over 12 years. The HSAs and Ergonomists followed, with 6 and 7 years respectively, followed by the students with 0.

### **6.3.2 Discrimination and Consistency**

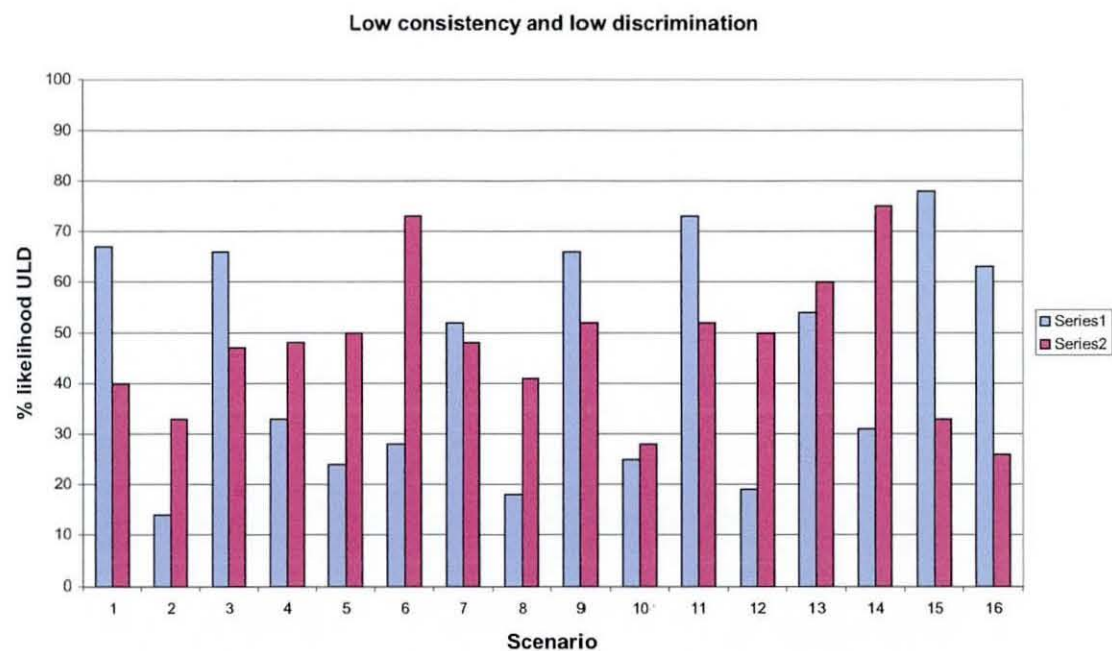
Because the CWS is derived from two parameters, consistency and discrimination, there are 4 different combinations available, if each parameter is considered as low or high. These are; high consistency with high discrimination (the most expert combination); low consistency with low discrimination (the least expert combination); low consistency with high discrimination; and high consistency with low discrimination. Examples from the data set of the most and least expert combinations are represented below, in Figures 6.2 and 6.3.

In Figure 6.2, a highly consistent and discriminating (the most 'expert' combination) participant's judgements are recorded. The ULD likelihoods are plotted for each time this participant made a judgement on each of the sixteen scenarios (series 1 being the first time the judgement was made, and series 2 being the second). This individual exhibits high consistency (as shown by the similarity of the two bars at each data point), as well as high discrimination (as demonstrated by the spread of the bars up the Y axis – from 5% up to over 90%).



**Figure 6.2: Example of a highly consistent & highly discriminating participant**

In Figure 6.3, this participant shows low discrimination, with most responses being placed between 20% and 70%. Furthermore, consistency is also low, as demonstrated by the great variation between the two judgements for the same scenario.



**Figure 6. 3: Example of an inconsistent and undiscriminating participant**

### 6.3.3 Effect of profession, training and years of experience on CWS.

According to the group mean CWS indices (Table 6.3) where a high index indicates more 'expert' judgements, Ergonomists are significantly more 'expert' when making the judgements required of them by these scenarios (mean CWS = 16.2) than their Physiotherapist (mean CWS = 5.4) or their Health and Safety colleagues (mean CWS = 5.9), as well as than the student group (mean CWS = 5.6). These are significant results, indicated by the non-overlapping confidence intervals. Though they also perform better than their OHA colleagues (mean CWS = 7.1), this was not a statistically significant difference.

From Table 6.4 it is clear that as training level increases, so does the mean CWS index. Participants with an ergonomics BSc, MSc, or PhD perform significantly better than those with no ergonomics training at all, or none beyond their initial professional qualification. The difference between those with degrees and those with short courses/certificates or diplomas is not statistically significant.

**Table 6.4: Training level, Group Mean CWS, and Confidence intervals** (higher CWS = better performance)

		84.3%		
		Group Mean	Confidence	
Training level	n	CWS	interval	
None	140	5.64	5.0-6.2	
No training beyond own professional qualification	37	5.71	4.63-6.90	
Short course, certificate or diploma	10	8.66	4.7-13.8	
Ergonomics				
Ergonomics BSc, MSc or PhD	11	16.2	8.3-26.7	

Note: Groups whose confidence intervals do not overlap have mean CWSs significantly different at the .05 level.

Because the whole of the student group had 0 years experience it was removed from the sample to calculate the correlation coefficient of CWS with years of experience. This was not significant (Pearson's  $R = 0.034$ ,  $n = 58$ ).

## **6.4. Discussion**

Three specific aims were outlined for this work. To:

- identify which individuals/groups giving ergonomics advice are the most 'expert' judges in terms of their consistency and discrimination.
- identify which characteristics of the participants are associated with better judgement performance.
- elucidate whether CWS is a useful method for evaluating judgment expertise in the context of ergonomics.

Each of these aims will be discussed in turn.

#### **6.4.1 Who are the most 'expert' judges?**

When using the CWS index of performance as a measure of expertise in this study, ergonomists perform significantly better than their physiotherapist and health and safety colleagues, and significantly better than the students. Although their mean CWS index was higher than their OHA colleagues, this was not a statistically significant difference. However, the Ergonomists were the only group whose confidence intervals did not overlap with the students. So having established that the Ergonomists do perform more 'expertly' when using the CWS index as the metric, what are the available explanations from the data?

#### **6.4.2 Factors linked with better performance**

##### **Level of ergonomics training**

In this study, level of training varied with CWS performance, with the mean CWS increasing as training level increased. All of the ergonomists had 'degree level or higher' qualifications in ergonomics. The majority of the other professionals taking part in this study had only the ergonomics training that formed part of their own professional qualification.

The OHAs were the professional group with the largest number of individuals with some additional ergonomics training; 27% of their number (6 individuals) taking short courses or certificates in ergonomics. They were also the highest scoring 'non-ergonomist' professional group in terms of mean CWS.

Despite the relatively small samples in this study, it is clear that having an ergonomics degree or higher is linked with higher CWS indices compared to having no training at all or to only that which forms part of one's professional qualification. Larger samples would be required to see whether there is a significant difference between the degree level and the short course/certificate/diploma level of training when it comes to judgment performance in these ULD scenarios. What the training findings suggest, however, is that the Ergonomists perform better because they have had higher level training. This result concurs with the findings of Haslam et al. (1992) in that increased training is positively linked with performance, and extends their findings to include a risk assessment task in concurrence with Jones et al. (1999).

## **Years of experience**

Having more years of experience has sometimes been linked with expertise (James, 2007) and sometimes not (Shanteau et al., 2002; Rassafiani et al., 2008). In this study, CWS index did not significantly correlate with years of experience, in line with Shanteau et al.'s proposition that experience is a poor predictor of expertise. This issue may be confounded because MSDs have become such a key issue in the last 5 - 10 years. Consequently, someone with 5 years experience may have spent all 5 years dealing only with MSDs and could perhaps have honed their risk assessment judgement skills by their focus on this. Their performance may be as good as or better than someone with many more years experience who has not focused exclusively on MSDs. This importance of the opportunity to practice a specific skill in a domain in terms of developing expertise has been noted by other authors studying expertise in fields such as weather forecasting and firefighting (Pliske et al., 2004).

### **6.4.3 Usefulness of CWS in the context of ergonomics**

In the study, CWS differentiated between those who might be deemed experts (Ergonomists) in line with the findings of previous studies (Shanteau et al., 2002; Weiss et al., 2006; Weiss & Shanteau, 2003). Clearly, whilst this study has suggested that there are differences in the mental models and levels of expertise amongst our participant groups, there is much which cannot be assumed and would benefit from further investigation. Undertaking a think aloud protocol analysis study or questionnaire study alongside the index (Backlund et al., 2004; James, 2007; Skånér et al., 2005) would help to acquire more detail about how and why the participants make the decisions they make. Investigation of the decision making strategies and schemata in line with other previous work (Piegorisch et al., 2006) for all the groups represented here would also be of interest.

## **Expertise from a decision aid**

HSG60 was devised as a decision aid for the non-expert, to facilitate workplace analysis and risk assessment for Upper Limb Disorders. It would be an interesting further study to take, for example, a sample of the student group, and allow them to use HSG60 as they made their decisions about each scenario. In this manner it would follow the studies of Stanton and Young (2003) more closely and enable conclusions to be drawn about the validity and reliability of a tool like HSG60 in the hands of novices. It would be of interest then to compare them with another student



group who made their decisions without it, as well as seeing how their performance compared to the 'experts' (ergonomists in this study). This would allow for the comparison of high level training (the ergonomists) with live use of a decision aid by those with limited training (the other groups) to ascertain the impact on judgment expertise. This would be helpful in elucidating how expert the higher level performance of the ergonomist actually is. Of further interest might be to see how and if the ergonomists improve by using the decision aid.

### **Extrapolation from controlled environment to the workplace**

A final area of further study would be to see whether superior performance in this judgement study translates into greater success in making judgements in the workplace. Following participants carrying out risk assessments in the field would help to clarify this.

Furthermore, as Cornford and Athanasou (1995) point out 'What separates the expert from merely the competent performer is that the expert can also tell you how to fix those faults and get things working once more'. However, 'getting things working once more' is a multi-faceted activity, based not only on the ability to make sound judgements but on a whole host of other factors such as employee and employer willingness to change (Whysall et al., 2004).

### **6.4.4 Potential limitations of this study**

#### **Language and wording**

Care was taken to base the scenarios on the criteria outlined in HSG60. However, the scenarios were generated by an ergonomist, and potentially described the work situations in a way which favoured the experiential expertise of the ergonomists. That notwithstanding, it is the cues themselves rather than the whole picture which should inform the decisions.

In addition, the intended cue distribution may have been confounded by the fact that there may be strong risk associations with some specific work environments used in the scenarios. For example 'delicatessens' and 'production lines' are environments historically associated with ULDs, and these might be cues in and of themselves when used in a scenario. That said, this effect should remain the same 'within' an

individual's repeated responses, and whilst it might affect discrimination, it should not impact consistency.

### **Sample size**

Practical issues often make it difficult to secure large samples of working professionals. We were perhaps fortunate that a sample size of eleven experts was sufficient for the Ergonomists to separate themselves from the other professionals. Larger samples would generate smaller confidence intervals, which might in turn make it possible to make finer distinctions between the other groups.

### **Judgement Content**

Having examined the nature of the judgements made, as one measure of expertise, further understanding of the expertise of the participants can be gained from examining whether or not their assessment of risk increased in line with the number of risk factors. This is the proposed next step for this research.

## **6.5. Chapter Summary**

This chapter has presented the findings from a study evaluating the judgement expertise of ergonomists and others who give ergonomics advice, using the CWS index of expertise. The combination of judgement consistency and discrimination into one index affords the conclusion that ergonomists are quantifiably different from other ergonomics advisors in their judgement performance in the specific context of ULDs. Whilst not the whole picture, this index is one objective measure of expertise. In this study higher CWS was linked with higher ergonomics training level, but not with longer experience in Occupational Health and Safety. The next study will examine the judgements made with reference to the risk factors contained in the scenarios, to see whether participants increased their judgement of likelihood of staff complaining of a ULD in line with the increase in risk factors.

### **Chapter 1 – Introduction**

- Problem statement
- Research aims
- Research Paradigm
- Thesis Structure

### **Chapter 2 - Literature review**

- Establishing the nature of expertise and how it is identified and measured
- Establishing the nature, extent and findings of previous work examining expertise amongst ergonomics and allied professionals

### **Chapter 3 – What characterises good and expert Ergonomics Advisors?**

- 3 Focus groups (n = 26) with Ergonomists
- Model building of features of good and expert ergonomics practice

### **Chapter 4 – The self reported competencies of Ergonomics Advisors**

- 217 competency questionnaires from 6 national ergonomics conferences
- Establishment of areas of high and low confidence across the breadth of IEA ergonomics competencies
- Relationship of competence and expertise

### **Chapter 5 – The Knowledge and Activities Ergonomics Advisors**

- 8 Focus groups (n = 55) with Ergonomists and other professional groups engaged in ergonomics advising
- Template analysis and model building of ergonomics expertise from knowledge and activities differences

### **Chapter 6 – The decision making expertise of Ergonomics Advisors - part 1**

- ULD risk assessment task undertaken by 58 PREs and EOPs and a control group of 148 students
- Establishment of comparative expert performance using the CWS index of expertise

### **Chapter 7 – The decision making expertise of Ergonomics Advisors - part 2**

- Investigation of the content of risk assessment decisions
- Relationship of decision content and expertise

### **Chapter 8 – Discussions, Implications and Conclusion**

- Discussions and implications of findings from all studies
- Limitations
- Recommendations for further research
- Conclusion

## **Chapter 7 – The content of ULD judgements**

### **7.1 Introduction**

#### **7.1.1 Outline of research presented in this chapter**

Having established that there are objective differences in the consistency and discrimination exhibited by different professionals carrying out ULD judgements (Chapter 6), the content of the judgements is the focus of this chapter. The participants' responses are analysed to determine if there is a correlation between the number of risk factors present in the scenarios and the adjudged % likelihood of staff complaining of ULDs (see Chapter 6). Further analysis is then undertaken to ascertain whether the presence of specific risk factors affects the judges' responses, irrespective of how many risk factors are present. The implications of the findings on ergonomics expertise are discussed.

#### **7.1.2 The content of judgements**

As described in the previous chapter, consistency and discrimination are two important attributes of expert judgements, but they are not sufficient terms alone to describe expertise. It is an acknowledged limitation of the index that judges deemed 'expert' due to their consistency and discrimination, could nonetheless be wrong, and therefore not be experts at all (Weiss & Shanteau, 2003).

One of the advantages of setting up the scenarios with accepted risk factors from the literature is that it is possible to predict, in part, how experts ought to make their judgements. For example, whilst there is still little empirical dose-response data for ULD risk factors, we would nonetheless expect the predicted % likelihood of staff complaining of ULDs to increase, as the number of risk factors increases.

Furthermore, the scenario set-up allows for the investigation of judges' responses to the different types of risk factor, irrespective of how many risks are present.

#### **7.1.3 Aims**

Therefore, the following aims were formulated, to investigate the content of the different groups' judgements:

1. Determine whether the groups' predicted mean % likelihood of staff complaining of a ULD increases as the number of risk factors increases?
2. Establish if participants respond differently to the various risk factors, having controlled for the number of risk factors present.
3. Identify how much of the variance in % likelihood of staff complaining of ULDS can be explained by the number of risk factors and the specific risk factors present.

## **7. 2 Methods**

### **7.2.1 Design, Participants and Procedure**

As described in section 6.2 of the previous chapter, originally 32 scenarios describing workplace situations were generated incorporating all 5 of the selected risk factors (force, repetition, posture, duration and psychosocial factors) in all combinations. However, not all 32 scenarios were administered to each participant so as to reduce the time commitment required to undertake the study.

Instead, 16 of the scenarios were selected at random and administered twice to each participant (ergonomists, health and safety advisors, occupational health advisors, physiotherapists and students). The scenarios had the following set of risk factors incorporated in them (Table 7.1) though they were administered in a random order and assigned numbers randomly so as not to indicate increasing risk levels (see Chapter 6).

### **7.2.2 Analysis**

In order to investigate the study questions, the mean response to each scenario was calculated for each participant by averaging their two responses to each scenario. A group mean for each scenario was then calculated, for the ergonomists (n= 11), OHAs (n = 22), HSAs (n = 11), physiotherapists, (n= 14) and Students (n= 140).

Pearson's R correlation coefficients were then generated for mean % likelihood of staff complaining of a ULD with number of risk factors present (both ratio level data variables).

**Table 7.1: Number and type of risk factors represented by the scenarios**

<b>Scenario Number</b>	<b>Number of Risk Factors</b>	<b>Specifics</b>
1	None	-
2	1	Repetition
3	1	Duration
4	2	Force and Repetition
5	2	Force and Duration
6	2	Repetition and Posture
7	2	Repetition and Psychosocial
8	2	Posture and Psychosocial
9	3	Force, Posture and Repetition
10	3	Duration, Posture and Psychosocial
11	3	Force, Duration and Psychosocial
12	3	Repetition, Duration and Psychosocial
13	3	Repetition, Force and Duration
14	4	Repetition, Force, Duration and Posture
15	4	Repetition, Force, Posture and Psychosocial
16	4	Repetition, Force, Duration and Psychosocial

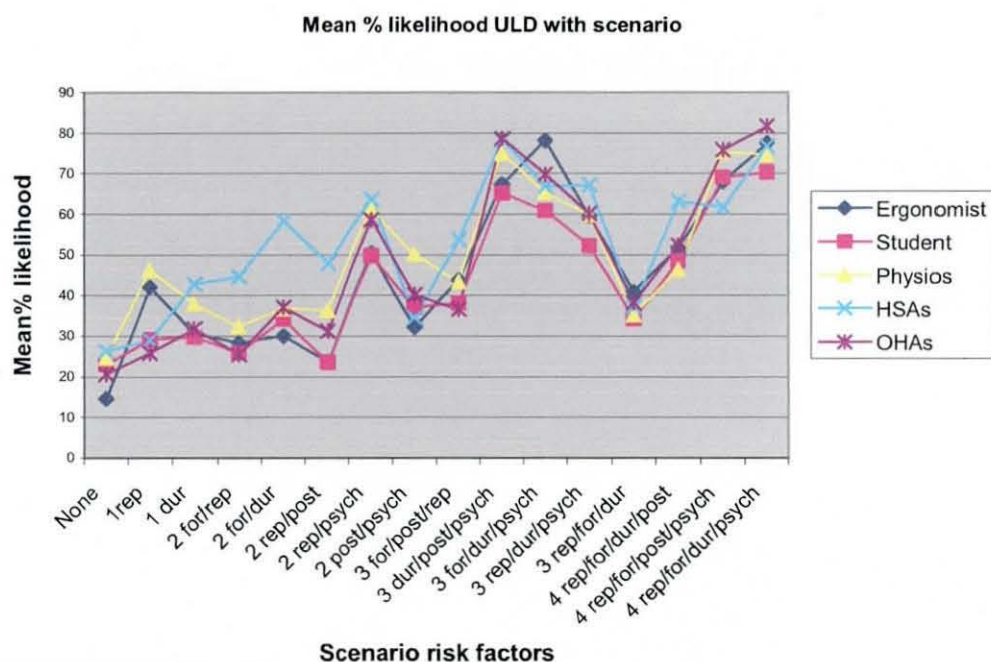
Dummy variables were then created for each of the five risk factors (Field, 2005), to make them dichotomous (scoring each scenario with a 1 where the risk factor was present and a zero where it was not). In this way, five dichotomous variables were created, one for each risk factor. Semi-partial correlations were then produced for each risk factor, as well as the number of risk factors, with mean % likelihood. Semi-partial correlation coefficients describe the unique relationship between one variable and another, whilst controlling for all others.

Finally, the significant semi-partial correlates were used as predictors in a multiple regression, to elucidate how well they predicted the responses of each group.

### **7. 3 Results**

#### **7.3.1 Does the predicted likelihood of ULD increase with the number of risk factors?**

Figure 7.1 represents the mean % likelihood predictions for each scenario, for each of the professional groups. The overall trend is for the mean % likelihood of staff complaining of a ULD to increase as the number of risk factors increases, with marked peaks where the psychosocial risk factor is present.



**KEY:** HSA = Health and Safety Advisor; OHA = Occupational Health Advisor;

**Figure 7.1: Mean % likelihood of staff complaining of ULDs with each scenario**

Table 7.2 presents the means which are plotted in Figure 7.1 along with the standard deviations and 95% confidence intervals. As can be seen from this data, a number of the confidence intervals overlap between groups, they cannot therefore be treated as discreet populations and any inter profession differences must be seen as indicative rather than definitive.

**Table 7. 2: Mean, Standard Deviations and 95% Confidence Intervals for each group's % likelihood ULD ratings**

<b>Scenario (number of risk factors)</b>	<b>Ergonomists Mean St dev (CI 95%)</b>	<b>Students Mean St dev (CI 95%)</b>	<b>Physios Mean St dev (CI 95%)</b>	<b>HSAs Mean St dev (CI 95%)</b>	<b>OHAs Mean St dev (CI 95%)</b>
<b>1</b>	<b>14.64</b>	<b>23.11</b>	<b>24.71</b>	<b>26.36</b>	<b>20.70</b>
<b>(0)</b>	<b>12.57</b>	<b>16.57</b>	<b>11.48</b>	<b>13.18</b>	<b>15.37</b>
	(7.20 - 22.06)	(20.36-25.85)	(18.70 - 30.73)	(18.58 - 34.15)	(14.28 - 27.13)
<b>2</b>	<b>42.14</b>	<b>29.19</b>	<b>46.32</b>	<b>29.09</b>	<b>25.84</b>
<b>(1)</b>	<b>13.79</b>	<b>19.05</b>	<b>14.88</b>	<b>12.02</b>	<b>14.04</b>
	(33.98 – 50.29)	(26.03 – 32.35)	(38.53 - 54.12)	(21.99 - 36.19)	(19.97 - 31.71)
<b>3</b>	<b>30.64</b>	<b>29.81</b>	<b>38.00</b>	<b>42.86</b>	<b>31.75</b>
<b>(1)</b>	<b>19.50</b>	<b>16.31</b>	<b>14.52</b>	<b>19.27</b>	<b>20.87</b>
	(19.11 – 42.16)	(27.11 – 32.51)	(30.39 - 45.61)	(31.48 - 54.25)	(23.03 - 40.47)
<b>4</b>	<b>28.41</b>	<b>25.88</b>	<b>32.39</b>	<b>44.73</b>	<b>25.57</b>
<b>(2)</b>	<b>19.00</b>	<b>16.47</b>	<b>15.07</b>	<b>21.33</b>	<b>9.57</b>
	(17.18 – 39.64)	(23.15- 28.61)	(24.50- 40.29)	(32.12 - 57.33)	(21.57 - 29.57)
<b>5</b>	<b>30.14</b>	<b>34.28</b>	<b>36.86</b>	<b>58.41</b>	<b>37.18</b>
<b>(2)</b>	<b>16.34</b>	<b>21.00</b>	<b>13.20</b>	<b>17.63</b>	<b>16.79</b>
	(20.48 – 39.79)	(30.80- 37.75)	(29.94 - 43.77)	(47.99 - 68.83)	(30.17 - 44.20)
<b>6</b>	<b>23.77</b>	<b>23.58</b>	<b>36.36</b>	<b>48.09</b>	<b>31.30</b>
<b>(2)</b>	<b>8.62</b>	<b>18.00</b>	<b>18.51</b>	<b>26.37</b>	<b>15.93</b>
	(18.68 – 28.86)	(20.60 – 26.57)	(26.66 - 46.05)	(32.51 - 63.68)	(24.64 - 37.95)
<b>7</b>	<b>50.50</b>	<b>49.86</b>	<b>61.25</b>	<b>63.73</b>	<b>58.68</b>
<b>(2)</b>	<b>24.76</b>	<b>22.18</b>	<b>14.48</b>	<b>18.11</b>	<b>15.40</b>
	(35.87- 65.13)	(46.19- 53.54)	(53.67 - 68.83)	(53.02 - 74.43)	(52.25 - 65.12)
<b>8</b>	<b>32.27</b>	<b>37.26</b>	<b>50.29</b>	<b>34.68</b>	<b>40.21</b>
<b>(2)</b>	<b>18.67</b>	<b>20.49</b>	<b>15.26</b>	<b>24.15</b>	<b>15.84</b>
	(21.24 – 43.31)	(33.86 - 40.65)	(42.29 - 58.28)	(20.41 - 48.95)	(33.59 - 46.83)
<b>9</b>	<b>43.82</b>	<b>38.13</b>	<b>43.39</b>	<b>53.82</b>	<b>36.59</b>
<b>(3)</b>	<b>22.01</b>	<b>18.60</b>	<b>9.90</b>	<b>24.98</b>	<b>15.86</b>
	(30.81 – 56.83)	(35.05- 41.21)	(38.21 - 48.58)	(39.05 - 68.58)	(29.97 - 43.22)
<b>10</b>	<b>67.45</b>	<b>65.21</b>	<b>75.00</b>	<b>78.32</b>	<b>78.73</b>
<b>(3)</b>	<b>24.80</b>	<b>21.79</b>	<b>11.70</b>	<b>9.48</b>	<b>13.78</b>
	(52.8 – 82.12)	(61.60- 68.82)	(68.87 - 81.13)	(72.72 - 83.92)	(72.97 - 84.48)
<b>11</b>	<b>78.14</b>	<b>60.91</b>	<b>65.36</b>	<b>66.91</b>	<b>69.82</b>
<b>(3)</b>	<b>11.38</b>	<b>20.45</b>	<b>14.21</b>	<b>19.66</b>	<b>11.98</b>
	(71.41 – 83.04)	(57.52-64.30)	(57.91 - 72.80)	(55.29 - 78.53)	(64.81 - 83.73)



Scenario (number of risk factors)	Ergonomists Mean St dev (CI 95%)	Students Mean St dev (CI 95%)	Physios Mean St dev (CI 95%)	HSAs Mean St dev (CI 95%)	OHAs Mean St dev (CI 95%)
12	59.59	52.28	59.96	67.23	60.20
(3)	22.82 (46.1 – 73.08)	23.56 (48.37- 56.18)	18.21 (50.43 - 69.50)	12.55 (59.81 - 74.65)	17.99 (52.69 - 67.72)
13	40.95	34.21	35.25	37.18	38.23
(3)	19.56 (29.39 – 52.51)	20.07 (30.88- 37.53)	11.67 (29.14 - 41.36)	19.83 (25.46 - 48.90)	17.03 (31.11 - 45.35)
14	51.77	48.55	46.43	63.36	52.34
(4)	19.30 (40.37 – 63.18)	24.45 (44.50- 52.60)	16.10 (38.00 - 54.86)	18.74 (52.29 - 74.44)	20.37 (43.83 - 60.85)
15	68.05	69.07	75.43	61.68	75.86
(4)	22.97 (54.47 – 81.62)	18.07 (66.08 - 72.07)	13.77 (68.21 - 82.64)	25.51 (46.61 - 76.76)	11.92 (70.88 - 80.85)
16	77.64	70.40	74.75	76.77	81.80
(4)	19.31 (66.23 – 89.04)	18.21 (67.38 - 73.42)	13.43 (67.72 - 81.78)	11.63 (69.90 - 83.64)	8.27 (78.34 - 85.25)

KEY: HSA = Health and Safety Advisor; OHA = Occupational Health Advisor;

The correlation coefficients (Pearson's R) and coefficients of determination ( $R^2$ ) for each group are listed in Table 7.3:

**Table 7.3: Pearson's R for mean % likelihood of ULD with number of risk factors**

Group	R	$R^2$
Ergonomists	**0.767	0.59
OHAs	**0.761	0.59
HSAs	**0.741	0.55
Physios	**0.658	0.43
Students	**0.771	0.59

\*\* significant at < 0.01 level

KEY: HSA = Health and Safety Advisor; OHA = Occupational Health Advisor;

**7.3.2 Do participants respond differently to the various risk factors, having controlled for the number of risk factors present?**

The significant, semi-partial correlations ( $p < 0.01$ ) for each risk factor (controlling for number of risk factors) with mean % likelihood are presented in Table 7.3 below.

**Table 7.4: Significant zero order and semi-partial correlations**

Group	Factor	Zero order correlations	Semi partial correlations
		R	R
Ergonomists	Number	0.767	0.493
	Psychosocial	0.732	0.437
OHAs	Psychosocial	0.829	0.548
	Number	0.761	0.438
HSA	Number	0.741	0.741
Physiotherapists	Psychosocial	0.877	0.653
	Number	0.658	0.299
Students	Psychosocial	0.811	0.523
	Number	0.771	0.458

KEY: HSA = Health and Safety Advisor; OHA = Occupational Health Advisor;

**7.3.3 How much of the variance in participants' judgements can be explained by the number of risk factors and the specific risk factors present.**

The individual risk factors and the number of risk factors were potential predictors for regression models. The ultimate regression models with all the significant predictors are represented in Tables 7.4 – 7.8 below.

**Table 7.5: Multiple Regression Model for the Ergonomists**

	<i>B</i>	<i>SE B</i>	<i>β</i>
<b>Step 1</b>			
Constant	14.57	7.79	
Number	12.00	2.91	0.767***
<b>Step 2</b>			
Constant	15.38	5.93	

Number	9.32	2.47	0.550**
Psychosocial	18.59	5.55	0.488**

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Note  $R^2 = 0.767$  for step 1:  $\Delta R^2 = 0.191$  for step 2 ( $ps < 0.01$  ). \*\*\*\* $p < 0.0001$ , \*\*\*  $p < 0.001$ , \*\*  $p < 0.01$ , \*  $p < 0.05$

**Table 7.6: Multiple Regression Model for the Health and Safety Advisors**

	<i>B</i>	<i>SE B</i>	$\beta$
<b>Step 1</b>			
Constant	27.76	6.80	
Number	10.49	2.54	0.741***

Note  $R^2 = 0.55$  for step 1, ( $p < 0.001$ ). \*\*\*\* $p < 0.0001$ , \*\*\*  $p < 0.001$ , \*\*  $p < 0.01$ , \*  $p < 0.05$

**Table 7.7: Multiple Regression Model for the Occupational Health Advisors**

	<i>B</i>	<i>SE B</i>	$\beta$
<b>Step 1</b>			
Constant	33.28	3.95	
Psych	33.19	5.97	0.83****
<b>Step 2</b>			
Constant	15.87	4.58	
Psychosocial	24.49	4.29	0.612****
Number	8.70	1.91	0.489***

Note  $R^2 = 0.688$  for step 1;  $\Delta R^2 = 0.192$  for step 2 ( $p < 0.001$ ). \*\*\*\* $p < 0.0001$ , \*\*\*  $p < 0.001$ , \*\*  $p < 0.01$ , \*  $p < 0.05$

**Table 7.8: Multiple Regression Model for the Students**

	<i>B</i>	<i>SE B</i>	$\beta$
<b>Step 1</b>			
Constant	31.86	3.32	
Psychosocial	25.00	5.02	0.811****
<b>Step 2</b>			
Constant	17.29	3.87	
Psychosocial	18.71	3.62	0.584****
Number	7.28	1.61	0.511***

Note  $R^2 = 0.657$  for step 1;  $\Delta R^2 = 0.210$  for step 2 ( $p < 0.001$ ). \*\*\*\* $p < 0.0001$ , \*\*\*  $p < 0.001$ , \*\*  $p < 0.01$ , \*  $p < 0.05$

**Table 7.9: Multiple Regression Model for the Physiotherapists**

	<i>B</i>	<i>SE B</i>	$\beta$
<b>Step 1</b>			
Constant	37.75	2.73	
Psychosocial	28.26	4.13	0.877****
<b>Step 2</b>			
Constant	28.20	4.00	
Psychosocial	23.48	3.75	0.729****
Number	4.77	1.67	0.334*

Note  $R^2 = 0.770$  for step 1:  $\Delta R^2 = 0.089$  for step 2 ( $ps < 0.05$ ). \*\*\*\* $p < 0.0001$ , \*\*\*  $p < 0.001$ , \*\*  $p < 0.01$ , \*  $p < 0.05$

## 7.4. Discussions

### 7.4.1 Recognising the risks

Analysing the content of the judgements made by the participants in the index study, has revealed that all the groups had a positive correlation between the number of risk factors present and their rating of the likelihood of staff complaining of ULDs. The correlation coefficients were all significant  $p < 0.01$ , with the physiotherapists having the lowest  $R$ .

Therefore it would seem that each group is recognising the risk factors and making predictions in the correct direction accordingly. This suggests that the higher ergonomics qualification of the ergonomist group is not a necessary pre-requisite for risk identification and subsequent outcome prediction in these scenarios, nor indeed is the qualification of the other professionals group over the non-qualified students (see Chapter 6).

However, when the semi-partial correlation coefficients are produced, showing the unique contribution to the variance in ULD likelihood of the different variables, an additional pattern emerges. The correlation coefficients for the number of risk factors present and the outcome are still significant, but they are reduced in all cases except for the HSAs, for whom the number of risk factors is the only significant predictor.

Indeed, the number of risk factors present is the most important predictor of the outcome for only the ergonomists and the HSAs (Table 7.3). The other groups'

predictions are more strongly associated with the presence of the psychosocial risk factor. This will be discussed in the next section.

#### **7.4.2 The Psychosocial risk factor**

Four of the five groups (not the HSAs) responded to the presence of a Psychosocial risk factor by rating the % likelihood of staff complaining of a ULD as higher than when it was not present, having controlled for the number of risk factors present (Table 7.3). None of the other risk factors had significant semi-partial correlation coefficients for any participant group.

In fact, the semi-partial correlation coefficients demonstrate that the presence of the psychosocial risk factor explained more of the variance in the outcome than the number of risk factors present, for the OHAs, Students and Physiotherapists (see Table 7.3).

One reason for this might be because of the wording of the question in the scenarios; participants were asked to rate the likelihood of staff *complaining* of ULDs, and a poor psychosocial environment is perhaps suggestive of staff complaint in and of itself. In other words, participants make an immediate link between the psychosocial risk factors in a scenario (such as 'There is low morale, no team spirit and very little interaction between staff as they work') and staff complaining full stop, whether the complaint is about ULDs or anything else. As they do not make this link between, for example, high force or repetition, and staff complaining, these factors do not generate an inflated outcome score. In other words, it may be due to the interaction between the wording of the scale and the description of that particular risk factor.

Alternatively, it may be because participants feel that psychosocial risk factors are simply more important than the other risk factors, having a greater effect on the occurrence of ULDs in the workplace than the other factors. Indeed in their review of the literature pertaining to the management of Upper Limb disorders, Burton et al.(2008) cite a number of studies which find an association between workplace psychosocial factors and symptom expression, care seeking, sickness absence and disability due to ULDs ( studies cited are NIOSH, 1997; Macfarlane et al., 2000; National Research Council, 2001; Bongers et al., 2002; Woods & Buckle, 2002; Devereux et al., 2004; Burton et al., 2005; Walker-Bone & Cooper, 2005; Woods, 2005; van den Heuvel et al., 2005; Bongers et al., 2006).

The respondents may therefore be responding in a way which is based on their understanding of the importance of the psychosocial risk factor.

The physiotherapists, OHAs and students responded most clearly to the presence of the psychosocial cue. This may be because the psychosocial cue is the most intuitive of all the cues; it is clear even to those with no ergonomics training that 'low morale', 'no team spirit and very little interaction between staff' are risks, whereas recognising the levels of repetition, or forces which are risky takes more training. Alternatively, it may be that the professions who commonly deal with individuals with ULDs at a treatment level (OHAs & physiotherapists) put more store by the impact of a poor psychosocial environment on people at work.

#### **7.4.3 Response patterns of the different groups**

It is interesting that the HSAs were unique in not responding particularly to the psychosocial risk factor. Instead, their rating of the likelihood of staff complaining of a ULD increased as the number of risk factors increased, in line with the design of the study. However, the number of risk factors present explained only 55% of the variation in the HSAs predictions ( $R^2$  from table 7.5) meaning that 45% was either random, or caused by a variable not measured in this study.

The ergonomists, like the HSAs, had most of their outcome variance associated with the number of risk factors present (explaining 77%,  $R^2$  from table 7.4) with an additional 19% being explained by the presence of the psychosocial factor ( $\Delta R^2$  from table 7.4). Therefore overall these 2 factors explained 96% of the total variance in outcome.

The physiotherapists, occupational health advisors and students had more of their outcome variance associated with the psychosocial risk factor than the number of risk factors present. The latter 2 groups were similar in having around 66% of the outcome variance relating to the psychosocial factor, and 20% relating to the number of risk factors present. Both groups, therefore, had around 15% of the variance in outcome unexplained.

The physiotherapists responded most to the presence of the psychosocial risk factor, with this explaining 77% of the variance in the outcome, with only 9% resulting from the number of risk factors present in the scenario. Therefore, they also had around 15% of the variance in outcome unexplained.

Overall then, there were differences in the 'content' of the judgements made by the different groups. The ergonomists' responses were most strongly predicted by the number of risk factors present, followed by the HSAs. Increasing the likelihood judgement as the number of risk factors increases is essentially the 'correct' response, and though all groups did so, these two groups were perhaps the more expert, with the Ergonomists having the largest portion of their variance associated with number of risk factors. In this sense, the Ergonomists demonstrated the most expert behaviour.

#### **7.4.4 Limitations**

The limitations of this study have been described in chapter 6. As explained there, larger samples would allow for greater certainty of the findings as the impact of random variance would be lessened. The overlapping confidence intervals of the group mean responses to a number of scenarios means the inter-professional differences should only be treated as indicative.

#### **7.4.5 Further work**

Using all 32 of the scenarios rather than a sample of 16 would allow for a clearer picture of how the participants respond to the ULD risk factors and whether there were statistically significant differences between the groups.

Carrying out think aloud protocols to understand why participants make the decisions they do would also be of interest, particularly in understanding why the psychosocial factor is of such importance. It might also provide information to help explain the unexplained variance in judgements.

### **7.5. Summary and Conclusions**

Overall, examining the content rather than the nature of the index judgements has demonstrated that all groups respond to an increase in the number of risk factors, by increasing their predicted likelihood of staff complaining of a ULD. This was most apparent in the ergonomists (77% variance explained by number of risk factors) and least apparent in the physiotherapists (9% variance explained by number of risk factors). Therefore, the ergonomists could be said to behave most expertly in terms of their responses to the content of the scenarios.



Interestingly, however, four of the groups also responded particularly to the psychosocial risk factor, having controlled for the effect of the number of risk factors. In three of the groups (OHAs, physiotherapists and students) the presence of the psychosocial risk factor had a greater effect on the judgements than the number of risk factors present.

This might be because the psychosocial risk is more important than the other risk factors and therefore its presence rightly subsumes the effect of the other risk factors. This may be particularly clear to those professionals who deal one-to-one at a treatment level with those complaining of a ULD (OHAs and physiotherapists).

Alternatively, it may be because it is more obvious, even to those with no ergonomics training, because it is a qualitative rather than a quantitative risk; in other words, 'low morale' and 'very little interaction between staff' are clearly risks, whereas knowing what repetition rates or which forces are risky requires more formal knowledge. The overlapping confidence intervals of the group mean responses to a number of scenarios means the inter-professional differences should only be treated as indicative.

### **Chapter 1 – Introduction**

- Problem statement
- Research aims
- Research Paradigm
- Thesis Structure

### **Chapter 2 - Literature review**

- Establishing the nature of expertise and how it is identified and measured
- Establishing the nature, extent and findings of previous work examining expertise amongst ergonomics and allied professionals

### **Chapter 3 – What characterises good and expert Ergonomics Advisors?**

- 3 Focus groups (n = 26) with Ergonomists
- Model building of features of good and expert ergonomics practice

### **Chapter 4 – The self reported competencies of Ergonomics Advisors**

- 217 competency questionnaires from 6 national ergonomics conferences
- Establishment of areas of high and low confidence across the breadth of IEA ergonomics competencies.
- Relationship of competence and expertise

### **Chapter 5 – The Knowledge and Activities Ergonomics Advisors**

- 8 Focus groups (n = 58) with Ergonomists and other professional groups engaged in ergonomics advising
- Template analysis and model building of ergonomics expertise from knowledge and activities differences

### **Chapter 6 – The decision making expertise of Ergonomics Advisors - part 1**

- ULD risk assessment task undertaken by 57 Ergonomists and Ergonomics advisors and a control group of 148 students
- Establishment of comparative expert performance using the CWS index of expertise

### **Chapter 7 – The decision making expertise of Ergonomics Advisors - part 2**

- Investigation of the content of risk assessment decisions
- Relationship of decision content and expertise

### **Chapter 8 – Discussions, Implications and Conclusion**

- Discussions and implications of findings from all studies
- Limitations
- Recommendations for further research
- Conclusions

## **Chapter 8 – Discussions, Implications and Recommendations.**

### **8.1 Introduction**

This thesis has presented the findings from a number of studies examining expertise amongst those who work in the ergonomics domain. Using a multi-methodological approach, this research aimed to explore the two broad questions of what are the features and characteristics of ergonomics expertise, as well as what differences exist between professional ergonomists and others who engage in ergonomics.

These broad competence questions matter because ergonomics advisors in the physical domain deal with issues of health and safety. Their performance matters both ethically (Corlett, 2000) and in business terms (Wilson, 2000; Oxenburgh & Marlow, 2005). This work has relevance to ergonomics education, and to defining, safeguarding and assuring quality of the ergonomics profession.

#### **8.1.1 Structure of this chapter**

This chapter starts with a brief résumé of the findings from each of the studies (8.2.1 – 8.2.5). The characteristics of ergonomics 'experts' are then discussed by comparing and contrasting propositions from the literature with the research findings from this thesis (8.3). The implications of this part of the research are then posited (8.3.5). Subsequent sections (8.4.1- 8.4.4) cover these same topics but with respect to the differences between ergonomically oriented professionals (EOPs) and professionally recognised ergonomists (PREs).

The methodological issues for the whole research programme are then considered in section 8.5, along with recommendations for future work (8.6). Finally a summary of this work's contribution to the body of knowledge is provided (8.7) followed by a final conclusion statement (8.8).

### **8.2 Overview of Research Findings**

A summary of the findings from each of the studies presented in this thesis follows.

### **8.2.1 Ergonomist Focus Groups**

The ergonomist focus groups discussing 'what makes a good ergonomics advisor' provided themes which could usefully be categorised into the 'Knowledge, Skills & Abilities and Other factors' (KSAOs) taxonomy (Kierstead, 1998; Landy & Conte, 2007).

Four characteristics of a good ergonomics advisor were identified across all three of the focus groups. These were; having practical (not just theoretical) knowledge; taking a holistic/systematic approach; being observant/perceptive and having good communication skills. Whilst knowledge for the first two of these characteristics could be acquired from an academic course with work placement opportunities, the second two are less likely to form part of a formal ergonomics training programme.

Eight further characteristics were proposed by two of the three groups. These were that a good ergonomics advisor should have ergonomics knowledge which covers the broad range of human sciences; is scientific, integrated and beyond common knowledge. In addition their skills should include listening, problem solving, solution generation, putting people at their ease and the ability to learn/ be adaptable. Again, the acquisition of these skills is much less likely to form part of a formal ergonomics course than is the ergonomics knowledge content.

The attitudes of the groups demonstrated the term 'expert' was loaded, with some feeling it had negative connotations describing an individual with too narrow a focus to be useful as an ergonomist. Discussions suggested there may be differences in the required characteristics for those in academia compared with those in consultancy, with scientific rigour being more important for the former, and meeting the client needs for the latter.

Differences were raised between the recommendations made by different PREs (seen as acceptable differences) and between the recommendations made by PREs and EOPs (seen as unacceptable differences).

In conclusion, this study has identified some of the features of ergonomics expertise and the characteristics of good/expert ergonomics advisors, in line with the first of the research objectives of this thesis.

### **8.2.2 IEA Competency Questionnaire**

The IEA core competencies list successfully differentiated between PREs, EOPs and students, when used as a self report, confidence questionnaire. Overall, PREs were significantly more confident of their abilities as described by the IEA's competencies than EOPs and students, as were participants with more experience and higher ergonomics training level.

The North American participants were more confident than other nations, particularly, than those from the UK. The higher confidence demonstrated by participants from the USA over those from the UK, was in spite of the fact that the UK had more qualified ergonomists amongst the respondents. This may be a result of; the Americans being more familiar with the competency style of describing the work of ergonomists; a cultural high confidence tendency; or because those from the USA are simply more competent.

In general all of the participants were less confident of their abilities to make, implement and evaluate recommendations than they were of analysing, interpreting and documenting problems. This suggests that a 'problem' rather than a 'solution' focus characterises these participants' approach.

This study has demonstrated quantitative, self-report differences in core competencies, between PREs and a range of EOPs. It has also demonstrated a confidence difference between PREs from different countries.

### **8.2.3 Ergonomics Advisors Focus Groups**

This focus group study investigated further the differences between PREs and EOPs (demonstrated in the IEA questionnaire study) by using some of the KSAOs identified in Chapter 3, as well as other pre-determined themes, during discussions about ergonomics. It identified that ergonomists have a broader knowledge of ergonomics than the other professional groups participating, but that all of the groups covered the majority of pre-determined ergonomics themes during their discussions.

The additional sub-themes which emerged during discussions added breadth to the theme template, and two of the three additional main themes (ergonomics as a philosophy, and analysing problems) could arguably have been gleaned *a priori* from the sources used. However, the lack in the definitions literature of the third

main theme which emerged (proposing solutions) resonates with the point raised by one ergonomist, that 'the training you receive.. is largely to do with finding out what the problem is.....and it doesn't actually get you very far in solving the problem'. This has implications for the training provided to ergonomists and others who employ ergonomics principles.

The lack of emphasis on the scientific nature of ergonomics as well as the lack of reference amongst some EOP groups to the cognitive aspects, stand out as potentially important omissions (Meister, 1995; McDonald, 2006). The absence of any reference to productivity by the ergonomists is also an important omission with respect to 'selling the benefits' of the discipline. The question as to whether any theme can be omitted whilst allowing ergonomics to be adequately employed remains unanswered.

In addition to differences in knowledge, the number of ergonomics activities in which the different groups engage showed the ergonomists to be the most prolific group. However, in addition to the quantitative difference in the number of activities undertaken, the ergonomists were alone in naming and describing macro-level interventions amongst their activities. This macro level ability has been described as a key output of the training ergonomists receive (Hignett, 2000).

When discussing their aims in undertaking ergonomics, the furniture suppliers did propose product sales as being one driver, though this sat amongst a raft of others and increasing sales was also an aim of the ergonomist groups. This may, in part, refute the allegation from the study reported in chapter 3, that furniture sales staff are unique and exclusive in their sales drive.

Therefore, in each of the areas examined in this study (knowledge, approach, aims and activities) the ergonomists were more comprehensive in their coverage than the other groups. One definer of an expert is having 'adequate domain knowledge' (Shanteau, 1992) and though the ergonomists had more, this study alone does not answer for their knowledge adequacy, nor does it determine inadequacy amongst the other professions (who covered fewer but none-the-less the majority of the themes).

If the number of activities undertaken can be seen as a proxy for the number of skills attained, then the ergonomists also behaved more like experts by that measure; though their performance ability in any of the activities was not tested.

#### **8.2.4 CWS Index – nature of ULD decisions**

This study evaluated the judgement expertise of PREs and others who give ergonomics advice, using the CWS index of expertise. The combination of judgement consistency and discrimination into one index affords the conclusion that PREs are quantifiably different from EOPs in their judgement performance in the specific context of ULDs. According to the group mean CWS indices, where a high index indicates more 'expert' judgements, Ergonomists were significantly more 'expert' when making the judgements required of them by the scenarios in this study (mean CWS = 16.2) than their Physiotherapist (mean CWS = 5.4) or their Health and Safety colleagues (mean CWS = 5.9), as well as than the student group (mean CWS = 5.6). Though they also perform better than their OHA colleagues (mean CWS = 7.1), this was not a statistically significant difference.

Whilst not the whole picture, this index is one objective measure of expertise. In this study higher CWS was linked with higher ergonomics training level, but not with longer experience in Occupational Health and Safety. This suggests that experience as an indicator of expertise is not necessarily reliable.

#### **8.2.5 CWS Index – content of ULD decisions**

Examining the content rather than the nature of the index judgements demonstrated that all groups respond to an increase in the number of risk factors, by increasing their predicted likelihood of staff complaining of a ULD. This was most apparent in the ergonomists (77% variance explained by number of risk factors) and least apparent in the physiotherapists (9% variance explained by number of risk factors). Therefore, the ergonomists behaved most expertly in terms of their responses to the content of the scenarios.

Four of the groups (Ergonomists, OHAs, physiotherapists and students) also responded particularly to the psychosocial risk factor, having controlled for the effect of the number of risk factors. In three of the groups (not the ergonomists) the presence of the psychosocial risk factor had a greater effect on the judgements than the number of risk factors present.

This might be because the psychosocial risk is more important than the other risk factors and therefore its presence rightly subsumes the effect of the other risk factors. Professionals who deal one-to-one at a treatment level with those complaining of a ULD (OHAs and physiotherapists) may observe this to be the case, explaining the influence this risk factor had on their judgements.

Alternatively, it may be because it is more obvious, even to those with no ergonomics training (such as the students), because it is a qualitative rather than a quantitative risk; in other words, 'low morale' and 'very little interaction between staff' are clearly risks, whereas knowing what repetition rates or which forces are risky requires more formal knowledge.

### **8.3 Features and characteristics of ergonomics experts**

The following section (8.3.1) provides a brief reminder of the literature, as it pertains to the features and characteristics of experts. This literature is then compared and contrasted with the relevant findings from all of the research studies. The comparison is then made between what the ergonomists proposed as characterising high level performance as an ergonomics advisor (8.3.2) and what they did and did not report or demonstrate having, during the course of the various studies (8.3.3 and 8.3.4). The implications of this comparison for education and practice are then proposed (8.3.5).

#### **8.3.1 Propositions from the literature**

The literature described in chapter 2 outlined a number of features which characterise experts. Shanteau's theory of expert competence (1992) proposed that experts would be identifiable by having:

- a sufficient knowledge of the domain
- the psychological traits associated with experts (Table 2.3 section 2.2.2)
- the cognitive skills necessary to make tough decisions
- the ability to use appropriate decision strategies
- a task with suitable characteristics

In terms of a sufficient knowledge of the domain, the definitions literature provided a full list of aspects of ergonomics from which to examine ergonomists' knowledge (section 5.1.2).



In determining who is an expert, Weiss & Shanteau (2003) specifically proposed consistency and discrimination were two attributes which would be necessary and measurable. The CWS index was developed to measure both these attributes and combine them into one score, with the acknowledgement that they are necessary but not sufficient determinants of expertise. These authors proposed, however, that they were a better measure of expertise than the more traditional expertise definers of qualification level, social acclamation or years of experience (Shanteau et al, 2002).

In the ergonomics arena, the IEA has defined 'core competencies' to examine high level performance in ergonomics. These covered generic professional behaviour as well as all the stages of analysis, intervention and evaluation that might be required of an ergonomist (IEA, 2001). In addition, the BCPE's scope of practice (BCPE, 2004) and the Ergonomics Society's knowledge areas (Ergonomics Society, 2008c) also cover this technical content knowledge and technical skill sets.

Other authors have described less technical skills required to be successful as an ergonomics consultant (Kirwan, 2000; Whysall et al., 2004; Shorrock & Murphy, 2005 & 2007). These included the 'softer' skills required for human-human interactions.

### **8.3.2 Combining propositions from the literature with this research**

The study described in chapter 3 outlined the characteristics (KSAOs) which ergonomists felt were required for high level performance in their profession. As identified in the discussion section of that chapter, the characteristics of the knowledge rather than just the content were described as important by the ergonomists (these were that the knowledge should be practical (not just theory); cover the broad range of human sciences; be scientific; be integrated; be beyond common knowledge; be factually correct).

The Skills and Abilities described were not technical, but were exclusively the 'softer' issues as described by a number of other authors. These skills were; communication; observation/perception; listening; problem solving; solution generation; putting people at their ease; can learn/ be adaptable; facilitation. The other factors listed as important by the ergonomists were being; holistic/systems

driven; caring; realistic/ pragmatic; passionate; consistent and effective; as well as; wanting to help and looking the part.

This list of ergonomist generated characteristics of high performing ergonomics advisors were reported in the summary table in section 3.7 of chapter 3. This table is repeated below, with the relevant units and elements from the IEA listing (Appendix B) alongside each of the KSAOs. Reference is also included to where the KSAOs were assessed during the other studies, along with selected literature references which supports the particular KSAO.

### **Comparison of KSAOs and the IEA's competencies**

As can be seen from Table 8.1, each of the 9 IEA units of competency is represented in the ergonomists' list, with just under half (20/41) of the elements represented. However, some aspects which the ergonomists said were important are not represented in the IEA's core competencies. These include 1 skill raised by all three groups (observation/perception), 3 skills which were raised by two groups (listening, putting people at their ease and being adaptable) as well as one further skill raised by one group (facilitation). In addition, most of the 'other factors' raised by the ergonomists (being caring; realistic/ pragmatic; passionate; consistent and effective; wanting to help and looking the part) are not represented by the IEA's list.

It is possible, due to a relatively small sample size ( $n = 26$ ) that these characteristics are not important for successful ergonomics practice, but are a result of idiosyncratic thinking on the part of these particular participants. This is particularly true where only one group proposed a given characteristic. In addition, KSAOs and competencies exist at different conceptual levels. Competencies are specific behaviours which are described as emanating from the building blocks of knowledge, skills, attributes and other factors (KSAOs) (Kierstead, 1998; Landy & Conte, 2007), so it is perhaps unfair to compare the two lists and expect concurrence. However, even where there is no equivalent IEA competency other authors have raised these KSAOs as important for ergonomics advising (see Table 8.1). It is perhaps legitimate, therefore, to propose their inclusion in both training and competency assessment in the future.

### **8.3.3 What Ergonomists say they need and what they have....**

Further comparison of the findings of chapters 3 and 4 is possible, examining not only where there are similarities and differences between what ergonomists think is

**Table 8.1: KSAOs from chapter 3 and how these relate to the other studies and selected literature references (continued over page)**

	Chapter 3		Chapter 4	Chapter 5	Chapters 6 & 7	Literature
	KSAOs	IEA Units	(IEA Specific Elements)	Themes	Judgements	Selected references in the ergonomics and expertise literature
<b>Knowledge</b>	Practical (not just theory) *	6, 8	(6.1, 6.2, 6.3, 8.4)	All used as focus group themes	tested by index	Shanteau (1992) - a sufficient knowledge of the domain
	Range of Human Sciences†	1, 9	(1.1, 1.5, 9.4)			See definitions section 5.1.2
	Scientific†	1, 2, 9	(1.6, 2.3, 9.3)			See definitions section 5.1.2
	Integrated†	1, 4	(1.5, 4.2)			See definitions section 5.1.2
	Beyond common knowledge†	1, 2, 9	(1.2, 2.4, 9.3)		tested by index	Shanteau (1992) - a sufficient knowledge of the domain
	Factually correct	9	(9.3)		tested by index	Shanteau (1992) - a sufficient knowledge of the domain
<b>Skills and Abilities</b>	Communication*	3, 5, 7	(3.1, 3.2, 5.6, 7.1)			Shorrock & Murphy (2005); Kirwan (2000)
	Observation/Perception*			photo task	tested by index	Shorrock & Murphy (2005); Shanteau (1992) the $\Psi$ traits of experts
	Listening†					Knoff & Hines (1995); Shorrock & Murphy (2005 & 2007)
	Problem solving†	6	(6.1, 6.2, 6.3)	theme emerged		Shorrock & Murphy (2005); Shanteau (1992) the $\Psi$ traits of experts
	Solution Generation†	5, 6	(5.4, 6.1, 6.2, 6.3)	theme emerged		Cornford and Athanasou (1995); Shanteau (1992) the $\Psi$ traits of experts
	Put people at their ease†					Shorrock & Murphy (2005)
	Can learn/ Adaptable†					Shanteau (1992) the $\Psi$ traits of experts
	Facilitation					Knoff & Hines (1995); Devereux & Buckle (1999); Devereux & Manson (2008)

	Chapter 3	Chapter 4		Chapter 5	Chapters 6 & 7	Literature
	KSAOs	IEA Units	(IEA Specific Elements)	Themes	Judgements	Selected references in the ergonomics and expertise literature
Other factors	Holistic/Systems driven *	1,4, 5	(1.3, 4.2, 5.1)	theme emerged		See definitions section 5.1.2
	Caring					Shorrock & Murphy (2007)
	Wanting to help			theme emerged		
	Realistic/ Pragmatic					Stanton (2005)
	Passionate					
	Looking the part					Shanteau (1992) the $\Psi$ traits of experts
	Consistent				tested by index	Weiss & Shanteau (2003)
	Effective					Cornford and Athanasou (1995);
Key	* = concept mentioned by 3 groups		† = concept mentioned by 2 groups			

important, and what the IEA competency list includes, but also whether the ergonomists were more confident in those IEA competencies based on the KSAOs they raised.

As reported in section 4.3.3 of Chapter 4, the professional sample's median confidence was significantly lower than overall for units 6, 7 and 8. Median confidence was higher than overall for units 2, 3, 4 and 9 and there was no significant difference between the overall median confidence and that of units 1 and 5. As table 8.1 shows, the 4 KSAOs which all of the groups from chapter 3 cited as important for good performance (marked with \*) were represented in the IEA competency listing by Units 1, 3, 4, 5, 6, 7 and 8. Of these, Units 3 and 4 were the high confidence units for the whole sample; covering communication and the holistic approach. When the sample was split by profession, the consultants also had Unit 7 as a high confidence unit, covering communication also.

The practical as well as theoretical knowledge units were 8 and 6, which both had low confidence reported. If these are indeed important aspects, it would be reasonable to expect to see high confidence in them and reasonable to assume high confidence is necessary.

The study in chapter 5 (focus groups) incorporated some of the aspects outlined in chapter 3 and also included areas of ergonomics from the definitions literature to examine the understanding of ergonomists and others. The ergonomists discussed the vast majority of themes on the ultimate template, displaying a comprehensive knowledge (suitable in Shanteau's (1992) terms) of ergonomics and its aims and approaches. They also reported a breadth of activities (skills) commensurate with having expertise.

In chapter 6, the ergonomists demonstrated some of the 'cognitive skills necessary to make tough decisions' (Shanteau, 1992) by their superior CWS scores for judgements in the ULD scenario tasks. The basis of this ability on sound content knowledge was demonstrated by the further analysis presented in chapter 7.

### **8.3.4 What Ergonomists are lacking...**

In addition to the low confidence KSAOs noted above, the ergonomists and other professionals recorded low confidence on units 6, 7 and 8, covering the making, implementing and evaluating of ergonomics recommendations (with consultants

being more confident of the implementation than the other ergonomists). This suggests a need for more of a focus on solution generation and evaluation in the ergonomics taught courses. The role of feedback (evaluation) in the development of expertise is known to be pivotal (e.g. Zimmerman, 2006; Ericsson 2003) and therefore it is extremely difficult for an individual to become truly expert without the opportunity for learning afforded by evaluating previous performance.

The ergonomists covered 41/43 of the themes on the template generated in the focus groups study (Chapter 5) notably omitting mention of the productivity/profitability impacts of applying ergonomics principles in the workplace.

### **8.3.5 Summary of the findings regarding the features and characteristics of ergonomics expertise**

The work in this thesis has examined the characteristics of ergonomics expertise and the following list summarises the findings:

1. Focus group discussions with ergonomists have generated a list of KSAOs for high level performance as an ergonomics advisor. This list included a number of 'softer skills' or 'personal attributes'.
2. The list of KSAOs overlapped in part with part of the IEA competency list.
3. Ergonomists recorded low confidence on some of the IEA's competency units, particularly in those regarding the making and evaluating of recommendations.
4. A comprehensive template of themes covering ergonomics knowledge content, attributes, application, approach and aims has been generated.
5. Ergonomists demonstrated their expertise by discussing 41 of the 43 themes on the template, with the notable exception of the productivity/profitability impact of ergonomics.
6. Ergonomists also demonstrated expertise by listing a wide-range of ergonomics activities, and by being both consistent and discerning (as shown by scoring highest on the CWS index of expertise).

### **8.3.6 Implications of the findings regarding the characteristics of ergonomics expertise**

The findings regarding the characteristics of ergonomics expertise imply that:

1. Ergonomics taught courses should endeavour to
  - provide a solution focus rather than predominantly a problem focus

- encourage the practice and development of softer skills such as 'listening' and 'perception'
  - include effectiveness evaluation methods
  - include coverage of the potential productivity impact of ergonomics
2. Ergonomists should endeavour to build evaluation opportunities into their work wherever possible, in order to develop their expertise.
  3. Competency listings such as the IEA's should incorporate more specific mention of behaviours which are based on 'active listening' and 'perception' skills.
  4. National differences in response to the IEA's competency listing should be borne in mind in any future work comparing different nations' ergonomics competence.

## **8.4 Differences between EOPs and PREs**

This following section (8.4.1) provides an overview of the literature, as it pertains to the differences between EOPs and PREs. This literature is then compared and contrasted with the relevant findings from all of the research studies (8.4.2). The implications of this comparison, for education and practice are then proposed (8.4.4).

### **8.4.1 Propositions from the literature**

The literature outlined in this thesis has proposed that there are differences between professionally recognised Ergonomists (PREs) and ergonomically-oriented professionals (EOPs) (Karwowski, 2000; Macdonald, 2006) and some bodies provide certification or membership routes for both (BCPE, 2004; The Ergonomics Society, 2008 c & d). Macdonald (2006), in particular, posited that there are differences between 'the professional practice of ergonomics by ergonomists' and 'the application by non-ergonomists of just some aspects of ergonomics to some kind of problem'. Karwowski (2000) goes further, stating that 'the EOP pretend to have as much to say (at least in occupational settings) as the professionally recognized ergonomists'. His implication is that that the EOPs do not.

As described in Chapter 2, the BCPE provides two main levels of certification, the higher being the Certified Professional Ergonomist (CPE) the lower being the Certified Ergonomics Associate (CEA). These two levels are described in the following way:

**'CPE:** A career problem solver who applies and develops methodologies for analyzing, designing, testing and evaluating systems. A CPE addresses complex problems and advances ergonomics technologies and methods.

**CEA:** An interventionist who applies a general breadth of knowledge to analysis and evaluation. A CEA reacts to performance, safety, health or quality issues in currently operating work systems.'

The handbook provides tables of differences in the scope of practice between these two levels both generally and then more specifically in terms of analysis and assessment, intervention and evaluation. These two groups (CPEs and CEAs) provide a useful benchmark against which to compare the PREs and EOPs taking part in this research.

In the more academic ergonomics literature, Haslam et al. (1992), Jones et al. (1999) and Winnemuller et al. (2004) demonstrated a performance benefit on ergonomics tasks from even brief ergonomics training. They additionally show a benefit of being an ergonomist over having had basic ergonomics training, which could be the result of their additional training and/or more extensive experience in the domain.

Stanton and Young (2003), demonstrated ergonomics novices performed better with ergonomics tools which were more structured. Stanton & Stevenage, (1998) & Baber & Stanton (1996) demonstrated that the novices do better on ergonomics tasks which are less complex, whereas ergonomists can deal with more complexity. So this ergonomics literature also suggested that there would be differences between EOPs and PREs, particularly in their activities (MacDonald, 2006).

Other literature recommended further areas where these differences might lie. For example, the IEA's core competencies list (IEA, 2001) outlines the behaviours considered as key for Ergonomists (see section 4.1.2); this should therefore discern between EOPs and PREs. In addition, the definitions literature provides descriptions of the knowledge content, aims and approach which characterise ergonomics practice (see section 5.1.2), and so differences in the understanding of these areas might also distinguish between the two groups. Alternatively, rather than differences in ergonomics understanding or self-reported competence,



objective performance differences in an exemplar ergonomics activity would afford the opportunity to differentiate between the two groups

The expertise literature provided methods for comparing the two groups in terms of self-report and objective demonstration (e.g. Chi et al, 198; Hoffmann et al, 1995; Hmelo-Silver, 2004; see sections 2.3.5. and 2.3.6).

#### **8.4.2 Emergent differences between EOPs and PREs and links with the literature**

In chapter 4, the IEA competency listing was administered to both EOPs and PREs attending conferences, to establish their confidence levels in the various competency elements. This exercise did differentiate between the two groups, with the EOPs' median confidence score (out of 6) being 4, and that of the PREs being 5. This was a statistically significant difference which demonstrates higher competence (via the confidence proxy) of PREs over EOPs. Furthermore, confidence itself is one of the characteristics of experts (Abdolmohammadi & Shanteau, 1992). Therefore, the higher confidence of the PREs is an indication of expertise in its own right.

What is interesting from that study, however, is that both groups had a similar profile for their low and high confidence units, suggesting that attention needs to be given across the board to training in the low confidence elements.

The study described in Chapter 5 used focus groups with PREs and various groups of EOPs to establish any differences in knowledge about, approach for and aims for using ergonomics, as well as any differences in the ergonomics activities undertaken. This work suggests, in line with Macdonald's (2006) proposition, that there are differences in the activities undertaken, but it did not support Karwowski's view that 'EOPs pretend to have as much to say' as their PRE colleagues, as all of the EOP groups discussed their own limitations and when they would refer a problem on to a PRE (Williams & Haslam, 2006).

In this focus group work, the ergonomists had a broader knowledge, more aims and a wider view of the approach of ergonomics than the EOP groups, though all of the EOP groups covered the majority of the pre-determined themes in their discussions. Interestingly, however, the majority of the PRES described work which would fall under the 'Associate' level of practice as determined by the BCPE, rather

than the 'Ergonomist' level. This suggests that the BCPE description of where to draw the line between the two groups of professionals does not reflect current practice in the UK. Whether the groups' discussions in the focus groups are an accurate representation of what happens 'in the field' remains untested.

However, what was tested in the chapter 6 study, was the consistency and discrimination of PREs and EOPs in a representative but contrived ULD risk assessment task. These features are known to be necessary though not sufficient definers of expertise (Weiss & Shanteau, 2003). This work demonstrated that, as well as the self-reported differences in competence and understanding shown by the studies in chapters 4 and 5, there were objective differences in judgement performance when assessed using the CWS index. In spite of relatively small samples, the PREs were able to demonstrate more 'expert' decisions than the EOPs in that their judgements were more consistent and discriminating.

When the content of these judgements was examined, it became clear that whilst all groups responded to the number of ULD risk factors present in a judgement scenario, increasing their risk judgement in line with the increase in number of risk factors, the PREs were most influenced by the number of risk factor present.

In all of the studies which compared EOPs and PREs, one consistent finding was that having more experience was not significantly related to more 'expert' behaviour. Training level, by contrast, was.

#### **8.4.3 Summary of the findings of the differences between EOPs and PREs**

The work of this thesis demonstrates there are indeed differences between EOPs and PREs, and the following summarises the differences:

1. Short course and 'on-the-job' ergonomics training does provide a relatively broad education across the main ergonomics themes.
2. Training undertaken by PREs (degrees or certification training) affords a broader education than that acquired by the EOPs.
3. PREs are more confident of their ergonomics core competencies than EOPs, though both groups had the same lower and higher confidence areas.
4. PREs undertake a wider range of ergonomics activities than EOPs.

5. In an objective assessment of the judgement expertise of EOPs and PREs, the PREs behaved more expertly in terms of their consistency and discrimination.
6. Each EOP group discussed self-regulation and when they would refer on to a PRE.

#### **8.4.4 Implications of the findings of the differences between EOPs and PREs**

1. The differences between EOPs and PREs advocate for the value of differentiating between the activities which each can perform. This already occurs by self-regulation in the UK; though there is no explicit delineation of activities between registered members and others. It may benefit from a more formal approach, such as that outlined by the BCPE in North America, though the BCPE separation does not currently describe the activities of PREs and EOPs in the UK.
2. The CWS methodology might be a useful way of measuring expertise acquisition as PREs and EOPS progress through training and experiential learning.
3. Short courses should ensure the holistic nature of ergonomics is taught, including the cognitive aspects, even if it is the 'physical' domain in which the trainees will practice.

### **8.5 Methodological considerations**

The limitations of each of the individual studies were outlined as part of the discussions section at the end of each chapter. The following sections chart the strengths and weaknesses of the research as a whole, concluding with a statement regarding the consequential generalisability of the findings.

#### **8.5.1. Mixed methods and critical realism**

A mixed methods approach was taken for this research, to allow for different aspects of the phenomenon of expertise to be examined (Robson, 2002). Whilst this has been criticised in the past for requiring the concurrent adoption of different paradigms (Lincoln & Guba, 1985) the critical realism approach allows for features of positivism and relativism to be integrated (Robson, 2002).

For some aspects of expertise, the mixed method approach allowed for triangulation (Denzin, 1988) of findings. For example, the literature suggested experts need a sufficient knowledge of their domain (Shanteau, 1992); this was

brought up by the ergonomists in chapter 3 (focus groups), demonstrated qualitatively by the ergonomists in Chapter 5 (focus groups) and quantitatively by those in Chapter 6 (CWS index).

In their paper outlining validity and reliability issues for research within the realism paradigm, Healy and Perry (2000) describe six criteria with which to judge the quality of realism research. These can be used to judge the appropriateness of the paradigm for a piece of research as well as for attesting to its quality. They are listed below (Table 8.2) with reference to the work of this research. These features demonstrate some of the strengths of the research carried out in this thesis.

**Table 8.2: Criteria by which to judge Critical Realism Research**

<b>Healy and Perry Criteria</b>	<b>Description</b>	<b>This research</b>
(i) Ontological appropriateness	'The research should deal with complex, social phenomena involving reflective people; the world of ideas, art, science, language, ethics, institutions...'	Expertise is a complex, social phenomenon; PREs and EOPs are reflective people
(ii) Contingent validity	'The research should endeavour to develop a 'family of answers' that cover several contingent contexts and different reflective participants, albeit imperfectly'	Multiple approaches to examining expertise amongst many PREs and EOPs are being undertaken.
(iii) Epistemology – multiple perceptions of participants and peer researchers	The research is neither value-free nor value-laden – but rather value-aware.	Triangulation of data sources and use of peer researcher's interpretations.
(iv) Methodology 1 – Methodological trustworthiness	The research can be audited	Recording, transcriptions, analysis templates, archiving of surveys and index responses, inclusion of quotes in focus group work.
(v) Methodology 2 – Analytic generalisation	Theory building for the most part, rather than theory testing which happens after building and confirmation.	Research issues identified before data collection (e.g. using template for analysis of focus groups)
(vi) Methodology 3 – construct validity	How well are the constructs being measured, in the theory which is being built?	Prior theory from expertise literature is used to generate questions in each study and triangulation of findings.

### **8.5.2 Sampling issues**

The studies were limited in part, by the relatively small sample sizes. Larger samples for the focus group studies (Chapters 3 and 5) would have assured saturation. For the KSAO study, this would allow for a more exhaustive list to be generated, and the key KSAOs to be re-enforced further. However, involving 26 ergonomists has been a sound beginning.

For the template analysis focus groups (Chapter 5), a larger sample might generate a broader template which might discern even more clearly between EOPs and PREs. The 8 groups which were run, however, successfully distinguished between the two groups.

Larger samples for the quantitative studies (Chapters 4, 6 and 7) would afford greater confidence in the findings. That said, even the relatively small samples in chapter 6 allowed for the Ergonomists to demonstrate more expert behaviour, with confidence intervals overlapping with only one group of EOPs.

### **8.5.3 Self report issues**

There are clear limitations in depending on self-report data, such as that of the IEA questionnaire, and the activity reports of the Chapter 5 focus groups. Efforts were made to mitigate this risk, by undertaking an objective measure of competence (Chapter 6) alongside the self-report studies. Clearly, the CWS study only covered one activity (ULD risk assessment) and does not therefore vouch for the authenticity of competence reports of other activities.

### **8.5.4 'Physical' ergonomics focus with UK participants**

The decision to move from participants from any Nationality and any specialism (chapters 3 and 4), to those specifically from the UK and active in the physical (musculoskeletal) domain (chapters 5, 6 and 7) was taken to reduce the number of known variables. Whilst this is defensible in scientific terms, it reduces the scope of the findings. In other words, whilst it is likely that similar differences between EOPs and PREs would be apparent in other specialisms, it is not certain.

### **8.5.5 Profession of the researcher**

It can be argued that the fact that the research reported in this thesis was undertaken by a PRE in the physical (musculoskeletal) domain, provides it with

both strengths and weaknesses. Facilitation of the focus groups reported in Chapters 3 and 5 was aided by the ergonomics knowledge of the researcher. However, this knowledge also presented the potential for bias and for too strong an engagement with the focus group discussions. Every effort was taken to avoid this over-engagement by the use of standardised prompt sheets and the presence of an additional researcher in each of the focus groups. Recourse to an external validator was also undertaken to limit the affects of the personal bias of the researcher during the analysis.

The profession of the researcher was also a benefit in that it gave access to participants, which might otherwise have proven difficult. Contacts built up over 10 years of practice were drawn upon to take part. However, a possible weakness of this sampling strategy is that the participants known to the researcher are potentially like-minded, and may not, therefore, be truly representative. Attempts were made to mitigate this risk by inviting participants who were 'known of' rather than 'known by' the researcher. These participants made up over half of those taking part in the studies in Chapters 3, 5 and 6, and the majority of those in 4.

#### **8.5.6 Using the term 'ergonomics advisor'**

The use of the term 'ergonomics advisor' was motivated by the desire to be inclusive of both PRE and EOPs. It is acknowledged, however, that this means the findings from chapters 3 and 5 where this term was used, will have particular relevance to the consultancy arena, rather than to academic activity.

#### **8.5.7 Generalisability / transferability of the research findings**

As outlined above, this research has a number of strengths and weaknesses. The mixed-methods approach has provided a rigorous basis for the study of ergonomics expertise and the findings should be both reliable and valid for physical (musculoskeletal) EOPs and PREs in the UK. Extrapolation of the findings from this to other ergonomics domains should be done with caution, treating them as indicative rather than conclusive findings. That said, the methods would transfer.

### **8.6 Recommendations for future work**

Although this work has shed new light on a number of different aspects of expertise amongst those who give ergonomics advice, it is by no means exhaustive. A number of areas for further research are apparent from this work.

### **8.6.1 Expansion of/ re-visiting these studies**

AS mentioned in section 8.5.2, each of the studies reported in this thesis would benefit from repetition with bigger samples. The KSAOs outlined in Chapter 3 could also be validated by expert panel review and work could be undertaken to integrate them with an updated IEA competency listing. This would strengthen the current provision for assessment and development of ergonomists. The international confidence differences between ergonomists could also be examined more thoroughly with larger samples.

### **8.6.2 Beginning new work**

Think aloud verbal protocol studies would allow investigation of why EOPs and PREs think what they do when making decisions like those required of them in Chapter 6, and would allow for mapping of their mental models (Piegorsch et al., 2006). The work of this thesis did not specifically test the 'appropriateness of ergonomists' decision strategies' Shanteau (1992) which was the fourth characteristic in Shanteau's theory of expert competence, which could be done using think aloud verbal protocols.

Whilst the BCPE outlines a scope of practice for what have been termed PREs and EOPs in this work, as discussed above, the participants in this work (both PRE and EOP) described activities which the BCPE attributes to the associate level rather than ergonomist level. Work to delineate appropriate tasks for PREs and EOPs in the UK could still, therefore, usefully be done.

Given the importance of gaining feedback to the development of expertise, work to develop applied intervention evaluation methodologies could significantly improve the confidence of EOPs and PREs in the recommendation activities of their work.

## **8.7 Final conclusions**

This research aimed to gain a better understanding of what constitutes ergonomics expertise and what differences exist between ergonomist and non-ergonomist ergonomics advisors. Ergonomics expertise has been proscribed by competency lists and certification 'scopes of practice' but little recent work has investigated their usefulness for this role. Furthermore, whilst a number of studies have demonstrated the superior performance of ergonomists over complete novices on contrived ergonomics tasks, little work has been carried out to compare the knowledge and activities of PREs and EOPs, both of whom are carrying out

ergonomics tasks in the workplace. Even though this comparison has not been made, a number of authors have proposed there would be potentially worrying differences.

This thesis has identified that ergonomics expertise involves soft skills (such as active listening) as well as the harder, more 'technical' skills. In addition, PREs and EOPs alike are less confident of making, implementing and evaluating recommendations, than they are of identifying and recording ergonomics problems. PREs demonstrate broader ergonomics knowledge and activities than their EOPs colleagues, though the EOPs none-the-less showed a breadth of coverage in both of these areas. The advantage of the breadth demonstrated by the PREs, however, was demonstrated by their superior performance in a ULD judgement task, both in the nature and the content of the judgements made.

This work has implications for the training and assessment of both PREs and EOPS, and advocates additional work to delineate more clearly, the roles and activities of the two groups.



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**Appendix A - IEA domains of specialization**

## **Domains of specialization**

Derived from the Greek *ergon* (work) and *nomos* (laws) to denote the science of work, ergonomics is a systems-oriented discipline which now extends across all aspects of human activity. Practicing ergonomists must have a broad understanding of the full scope of the discipline. That is, ergonomics promotes a holistic approach in which considerations of physical, cognitive, social, organizational, environmental and other relevant factors are taken into account. Ergonomists often work in particular economic sectors or application domains. Application domains are not mutually exclusive and they evolve constantly; new ones are created and old ones take on new perspectives.

There exist domains of specialization within the discipline, which represent deeper competencies in specific human attributes or characteristics of human interaction.

Domains of specialization within the discipline of ergonomics are broadly the following;

Physical ergonomics is concerned with human anatomical, anthropometric, physiological and biomechanical characteristics as they relate to physical activity. (Relevant topics include working postures, materials handling, repetitive movements, work related musculoskeletal disorders, workplace layout, safety and health.)

Cognitive ergonomics is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system. (Relevant topics include mental workload, decision-making, skilled performance, human-computer interaction, human reliability, work stress and training as these may relate to human-system design.)

Organizational ergonomics is concerned with the optimization of sociotechnical systems, including their organizational structures, policies, and processes.

(Relevant topics include communication, crew resource management, work design, design of working times, teamwork, participatory design, community ergonomics, cooperative work, new work paradigms, virtual organizations, telework, and quality management.)

**Appendix B – Questionnaire using IEA's Core Competencies**

## International Ergonomics Association Competences

The following questionnaire is being administered as part of my PhD Research entitled 'Ergonomics Advisors – how *expert* are the Experts?', which I am carrying out in the UK. I have already administered it in the UK, Canada, Korea, Australia and Norway, and I am really keen to get more cultural viewpoints.

Your response is incredibly valuable and will make a real difference to our profession in terms of **underlining the value we bring to organisations, and in terms of input to training and CPD**. Please read the instructions carefully, particularly in relation to the scales.

The data will be stored in a secure database, untraceable to the respondents, as all responses will be anonymous. **Please return completed questionnaires to the “IEA Questionnaire” labelled box, in the Registration Area.**

If you have any questions about this questionnaire or about my research, please feel free to contact me using the e-mail address below.  
Thank you in advance for your time.

**Claire Williams**

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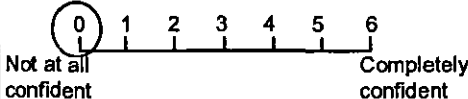
Tel: +44 1509 222 071

**Instructions** - This questionnaire outlines 9 'units of competency', divided into various 'elements' as outlined by the International Ergonomics Association (IEA). Please carry out **2 tasks on each of the elements**.

First, mark the confidence scale next to each element, by circling the point which best represents where you feel **your level of achievement** lies in each of the elements (see example below).

Then **rate the importance of the element** between 1 and 5, in terms of how important you feel it is for ergonomics practice, **respective of how confident you feel about that particular element**. The rating is not relative to the other elements but is a stand alone measure for each element (see example below)

Example:

How confident are you that you....	Personal Confidence scale	Importance Rating 1=Not at all important 5=Critical
1.1 Understand the theoretical bases for ergonomics planning and review.		<b>5</b>

(Respondent feels not at all confident about his/her understanding of the theoretical bases for ergonomics planning and review shown by circling 0 on the scale) **but** feels that this is a critical element for ergonomics practice (shown by rating it with a 5)

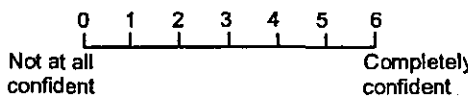
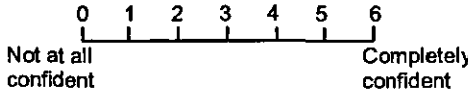
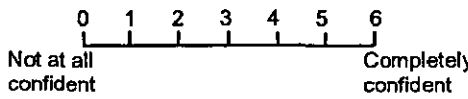
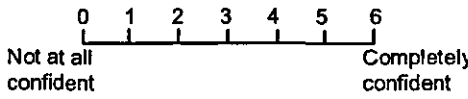
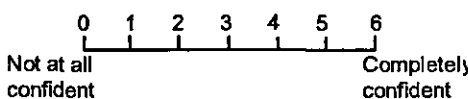
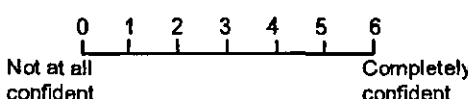
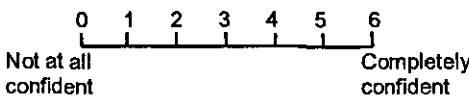
**Respondent Information:** Type of employment (please circle): Academia / In-house Ergonomist / Ergonomics Consultant / H and S advisor / OHA / Physio / Furniture Supplier/ Student / Other - please specify \_\_\_\_\_  
Job title: \_\_\_\_\_

Highest Ergonomics Qualification: \_\_\_\_\_

Years of practice in Ergonomics: \_\_\_\_\_

Nationality: \_\_\_\_\_ Country of Practice: \_\_\_\_\_

**1. Investigates and analyses the demands for ergonomics design to ensure appropriate interaction between work, product and environment, and human needs, capabilities and limitations**

How confident are you that you....	Personal Confidence scale	Importance Rating 1=Not at all important 5=Critical
Understand the theoretical bases for ergonomics planning and review.		
Understand, and build your research and applications on, the high quality state of the art and best practice.		
Apply a systems approach to analysis.		
Understand the requirements for safety, the concepts of risk assessment and risk management.		
Understand and can cope with the diversity of factors influencing human performance and quality of life, and their inter-relationships.		
Demonstrate an understanding of methods of measurement and interpretation relevant to ergonomics analysis and design.		
Recognise the extent and limitations to your own professional competence		

**Unit 2. Analyses and interprets findings of ergonomics investigations**

<b>How confident are you that you....</b>	<b>Personal Confidence scale</b>	<b>Importance Rating</b> 1=Not at all important 5=Critical
2.1 Evaluate products or work situations in relation to expectations for safe, satisfying and effective performance.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
2.2 Appreciate the effect of factors influencing attitudes, health and human performance.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
2.3 Analyse and interpret research data accurately and without bias, consulting appropriately where required.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
2.4 Understand relevant current theory, guidelines, standards and legislation.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
2.5 Make and can justify decisions regarding relevant criteria which would influence a new design or a solution to a specified problem.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	

**Unit 3. Documents ergonomics findings appropriately.**

<b>How confident are you that you....</b>	<b>Personal Confidence scale</b>	<b>Importance Rating</b> 1=Not at all important 5=Critical
3.1 Provide a succinct report in terms understandable by the client and appropriate to the project or problem.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
3.2 Communicate clearly and effectively with clients, other stakeholders (including the relevant work force) if possible, and the general public and scientific community if feasible.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	

**Unit 4. Determines the compatibility of human capabilities with planned or existing demands.**

<b>How confident are you that you....</b>	<b>Personal Confidence scale</b>	<b>Importance Rating</b> 1=Not at all important 5=Critical
4.1 Appreciate the extent of human variability influencing design.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
4.2 Determine the quality of match and the interaction between a person's characteristics, abilities, capacities and motivation, and the organisation, the planned or existing environment, the products used, equipment, work systems, machines and tasks.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
4.3 Identify potential or existing high risk areas and high risk tasks, where risk is to health and safety of the individual completing the task or to any others affected.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
4.4 Determine whether the source of a problem is amenable to ergonomics intervention.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
4.5 Justify decisions on ergonomics interventions or implementations.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	



Unit 5. Develops a plan for ergonomics design or Intervention		
How confident are you that you....	Personal Confidence scale	Importance Rating 1=Not at all important 5=Critical
5.1 Adopt a holistic view of ergonomics.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
5.2 Incorporate approaches which would improve quality of life as well as performance.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
5.3 Develop strategies to introduce a new design.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
5.4 Consider alternatives for improvement of the match between the person and the product, the task or the environment.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
5.5 Develop a balanced plan for risk control, with understanding of prioritisation and costs and benefits involved.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
5.6 Communicate effectively with the client, any stakeholders, the public and professional colleagues.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
Unit 6. Makes appropriate recommendations for ergonomics changes		
How confident are you that you....	Personal Confidence scale	Importance Rating 1=Not at all important 5=Critical
6.1 Make and justify appropriate recommendations for design-based changes	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
6.2 Make and justify appropriate recommendations for organisational planning-based changes	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
6.3 Make and justify appropriate recommendations for personnel selection, education and training	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
Unit 7. Implements recommendations to improve human performance		
How confident are you that you....	Personal Confidence scale	Importance Rating 1=Not at all important 5=Critical
7.1 Relate effectively to clients and all stakeholders, at all levels of personnel.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
7.2 Supervise the application of any ergonomics plan.	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	
7.3 Implement and manage change effectively and sympathetically	<div>0 1 2 3 4 5 6</div> <div>Not at all confident Completely confident</div>	

Unit 8. Evaluates outcome of implementing ergonomics recommendations		
How confident are you that you....	Personal Confidence scale	Importance Rating 1=Not at all important 5=Critical
8.1 Monitor effectively the results of ergonomics change implementation	<div>0123456</div> <div>Not at all confidentCompletely confident</div>	
8.2 Carry out evaluative research relevant to ergonomics	<div>0123456</div> <div>Not at all confidentCompletely confident</div>	
8.3 Make sound judgements on the quality and effectiveness of ergonomics change implementation	<div>0123456</div> <div>Not at all confidentCompletely confident</div>	
8.4 Modify a design or program in accordance with the results of evaluation, where necessary.	<div>0123456</div> <div>Not at all confidentCompletely confident</div>	
8.5 Understand the principles of cost-benefit analysis for any ergonomics change.	<div>0123456</div> <div>Not at all confidentCompletely confident</div>	
Unit 9. Demonstrates professional behaviour		
How confident are you that you....	Personal Confidence scale	Importance Rating 1=Not at all important 5=Critical
9.1 Show a commitment to ethical practice and high standards of performance and act in accordance with legal requirement, in all laboratory research, field research, practical application and any related activities.	<div>0123456</div> <div>Not at all confidentCompletely confident</div>	
9.2 Recognise personal and professional strengths and limitations and acknowledge the abilities of others.	<div>0123456</div> <div>Not at all confidentCompletely confident</div>	
9.3 Maintain up -to- date knowledge of scientific state of the art and national strategies, relevant to ergonomics practice.	<div>0123456</div> <div>Not at all confidentCompletely confident</div>	
9.4 Place your theories, methods, findings and interpretations into the scientific and public forum whenever possible.	<div>0123456</div> <div>Not at all confidentCompletely confident</div>	
9.5 Recognise the impact of ergonomics on people's lives.	<div>0123456</div> <div>Not at all confidentCompletely confident</div>	

Thank you very much for your time. Please return this questionnaire as instructed on the front sheet.

Any comments? \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**Appendix C – Photographic exercise**



## **Appendix 4 – Index of expertise scenarios**

***All 32 scenarios are listed here. For chapters 6 and 7, only 16 of the scenarios were used. They are marked with \* in this appendix.***

**\*Scenario 1**

The task involves moving hand sized empty cardboard boxes from the end of the line for around 20 minutes. The line brings 1 box every 2 minutes and after the 20 minutes, this task is not done again in the shift.

The boxes arrive at around elbow height and are moved to a table next to the line at the same height without the need for any awkward postures.

The operators find the line speed within their capabilities. There is good morale and good mechanisms for feedback and support should any staff member need it.

**Scenario 2**

An operator moves parts weighing 5kg from a line into boxes with one hand because they are too small to use two hands easily. The parts are easily held in one hand with no need to use awkward postures. They transfer them at a rate of around one a minute.

The operators chat whilst carrying out the task, and don't carry out this process for more than half an hour in the shift.

**\*Scenario 3**

The operators in this organisation are well trained and have good structures for support and team work. This task involves placing a thin sheet of plastic weighing about 100 grams onto the top of each jar as it comes down the line. The sheet needs to be approximately placed onto the jar and this can be done in a relaxed manner with no need for awkward postures.

Operators spend around half an hour at this task in a shift and need to cover 1200 jars in this time, using both hands.

**Scenario 4**

In this task the line brings 1 stapler every 2 minutes. The staplers weigh much less than a kilo and fit comfortably into the hand. The operators must place them into boxes which are on shelves above shoulder height.

The task lasts for around 25 minutes, and is not done again in the shift. The operators find the line speed within their capabilities and have good opportunity to chat as they work.

### **\*Scenario 5**

A group of operators carries out this task for the whole of the eight hour shift. There is good interaction and morale amongst staff as they perform this work, which they feel is within their capabilities. The task involves placing plastic mugs into individual boxes as the boxes move along a line. The boxes move along the line so the rim is at elbow height and the operator drops the mugs in without needing to look. The line brings 1 box every 2 minutes to each operator.

### **Scenario 6**

This task involves operators removing empty cardboard boxes from the end of the line. A box arrives every couple of minutes and is dropped into a skip which sits next to the line. The top of the skip is just below the line height so operators can drop the empties into it without the need for awkward postures.

Operators carry out this task for no more than half an hour a day, and they find it monotonous. The supervisor of this task is reported to be a 'bully' and staff do not like working on this line.

### **\*Scenario 7**

Door stops weighing between 4kg and 5kg are unpacked from boxes and placed onto shelves around elbow height, right where they are unpacking. The operators use both hands, with no awkward postures or reaches being required to unpack or shelve the door stops. Staff move around 40 door stops per minute.

There is good team working amongst the operators and supervisors who do this task. They chat freely whilst carrying out this work, and move on after about 25 minutes, not returning for the rest of the shift.

### **Scenario 8**

During this task, operators pick up small but heavy objects between the thumb and fore finger. The objects weigh just over 1 kg and need to be placed into packs as they go past on the line.

This task only lasts about half an hour, and is carried out once in the 8 hour shift. They move about 20 objects into packs over the time they do the task. It is well managed and the staff enjoy working with the supervisor who runs it.

**\*Scenario 9**

Operators are required to move 5kg cans using one hand at a time during the whole of their eight hour shift. The cans are moved from the line to an adjacent table, and the action of moving them doesn't involve any awkward postures. The cans arrive around once every couple of minutes. The staff interact with each other and the supervisor as they work. Morale is high and management listen to any staff feedback that they get.

**Scenario 10**

Staff at this point in the production process don't chat or interact, and feel unsupported and undervalued by the managers of this task. Staff work here for around 25 minutes in a shift. The task carried out involves using high forces to bang the lids onto passing jars using the side of their hands. Their hands are held neutrally as they do so, and generally one big bang is enough to secure the lid. Each operator bangs one lid on every couple of minutes.

**\*Scenario 11**

Operators involved in this task have to use a pinching grip to lift single paper clips from a tray and put them in boxes. They count 60, one at a time into each box, and fill a box every minute. They are highly skilled and no longer need to look at what they are doing. They can therefore interact easily and freely, and enjoy good relationships with the management. This task lasts about half an hour in their whole day.

**Scenario 12**

The whole of the 8 hour shift is spent at this task, with staff packing pillows into boxes. The pillows weigh just less than a kilogram, and are dropped into boxes without any awkward postures being necessary. Staff pack 300 pillows an hour in this way. They chat as they work and implement their own ways of working as they want to.

**\*Scenario 13**

150 paper cups are dropped one at a time into a stack by operators during the 25 minute period they work here. The nature of the task means staff can keep neutral postures whilst doing this job. Staff have no choice over technique or pace, and the management have not been receptive to their ideas for improvement.



**Scenario 14**

Staff working at this part of the factory carry out this task for the whole of their 8 hour shift. They are able to chat as they work and often have friendly competitions with their supervisor.

The task involves scanning the batch of pills as they come down the line, for any which haven't been coated. Because of the line height, staff bend their necks forwards to scan for the pills. Rarely they will see an uncoated pill and have to remove it – the rest of the time they are scanning.

**\*Scenario 15**

As the bread comes to this point in the line, staff have to sprinkle herbs onto the top of it. Staff stand facing up the line and hold their 'sprinkling' arm out to the side across the line each time a loaf comes. They sprinkle the herbs on the loaves, which requires them to have their arm stretched out horizontal to reach the loaf furthest away on the line.

The loaves only come once every couple of minutes, and when the staff have coated 15 they move on to the other jobs. They only do this task once in a shift which they are pleased about because they don't like the supervisor and they work alone at this point in the process.

**Scenario 16**

Operators in this packing area put empty salt and pepper sellers into boxes. They do this task for the whole of their shift, and have to pack 15 boxes an hour with one of each seller.

They have not been trained for their jobs and have poor support from the management who are not interested in any complaints they raise.

**\*Scenario 17**

Staff at this point in the line have to lift metal components out of moulds as they pass by. They chat freely as they do the task, and the supervisor regularly pops in to check if the operators are ok.

The components are lifted out whilst gripping a small knob with a diameter of around 1 cm, between the thumb and first finger.

The components weigh 2.5 kg, and each operator lifts out 600 in their half hour turn at this task. They use both hands.

Once they have completed the 30 minutes, they don't return to this task for the rest of the day.

**Scenario 18**

Marshmallows are moved from the line into bags, using specially designed tongs. The tongs are designed so as not to crush the product, and such that negligible force is required to operate them. They pick up one marshmallow at a time, using their dominant hand only.

The operators bend their wrists to get the marshmallows into the bags and carry out this task for most of their 8 hour shift. They transfer around 60 marshmallows every ten minutes though they can adjust the line speed themselves. There is good team spirit on this process and the operators have made recommendations to management about improvements which have been implemented.

**\*Scenario 19**

The task involves placing 200 gram breadsticks on a line, which are then automatically fed into a slicing and buttering machine. About 60 breadsticks an hour are placed on the line by each operator, and they carry out this task for the majority of their 8 hour shift. Because of the line's orientation, operators must bend their wrists to place the breadsticks on the line.

Work at this part of the line is isolated and monotonous, and there is little operator-supervisor communication.

**Scenario 20**

Staff move 50, four-packs of 1.5 litre fizzy drink bottles from the end of the line into boxes in this location, every hour. The 4 bottles (6 litres) arrive shrink-wrapped, and staff lift them one-handed using the plastic tape handle on the top of the shrink-wrapped package.

The boxes rest on a table at the same height as the end of the line, meaning the top of the box is about 50 cm higher than the line. Staff stand facing the line and lift the bottles over the lip of the box and in (meaning lifting to between elbow and shoulder height). They working out to the side where the table is, though they keep their feet facing the line.

They chat as they work, carrying out this task for most of their 8 hour shift. They are not troubled by the speed of the line, and get on well with their colleagues and managers.

**\*Scenario 21**

Staff in the deli have to retrieve meat joints weighing around 5 kg from the chiller cabinet. They are easily accessible requiring no awkward postures.

Customer demand is such that staff retrieve one every 2 or 3 minutes over the course of their eight hour shift. They use one hand only for the retrieval. They can keep a neutral posture due to the specially developed 'meat handles' which are attached to each joint before they are put in the chiller.

The atmosphere created by the staff and management in the deli is negative. There is low morale, no team spirit and very little interaction between staff as they work.

**Scenario 22**

Staff carrying out this top-shelf replenishing task do not like the isolation of lone-working nor the supervision they receive during the task. The task lasts 30 minutes and is done only once in the shift. It involves reaching to just above shoulder height to replenish light items such as cotton wool and cotton buds. Staff must replenish around 180 items in the 30 minutes

**\*Scenario 23**

The Quality Assurance staff at this bakery have to monitor the cakes as they come out of the oven down the line in front of them. The workstation set-up, enables them to have neutral neck posture whilst surveying the line. The button they need to press every 5 seconds to keep the line running requires little force and is activated by the whole hand.

Staff keep neutral hand postures whilst activating the button, which is located at around elbow height on a surface which supports their arms.

This task is all that these staff do, for the whole of their 8 hour shifts, and they find it monotonous and isolating due to the lone working it involves.

**Scenario 24**

This task involves replenishing the stocks of fizzy drinks in the supermarket's drinks aisle. In particular, these staff load the top shelves with 4 bottle multi-packs weighing 5 kg. They reach above shoulder height to carry out the task.

The replenishing lasts 25 – 30 minutes, once in the 8 hour shift. They are supervised very strictly whilst carrying out the work, with the supervisor aggressively monitoring them as they shelve each of the 25 multi-packs they have to replenish during the session.

**\*Scenario 25**

The whole of the 8 hour shift is spent carrying out this one task. It involves operators piercing a hole through the lids of cans as they come down the line. This involves applying at least 55 Newtons of force to each of the 30 cans they pierce every minute.

The punch tool used for piercing allows staff to have neutral postures as they puncture the lids. The height of the line is such to allow wrist, shoulder and elbow postures to remain relatively neutral during the task.

Staff work in social teams, and along with the supervisor, they generate and implement improvements to the job.

**Scenario 26**

30 minutes of this task are undertaken in an 8 hour shift. Staff have to meet their management defined quota of 40 bags a minute for the 30 minutes, or their pay is reduced.

The task involves moving 4.5 kg bags of flour from the line into crates. The workstation set-up is such that staff can avoid awkward upper limb postures whilst handling. They lift the bags using the handle provided, one bag in each hand.

**\*Scenario 27**

Maintenance staff have a continuous schedule of maintaining the lines in a factory, which runs 24/7. One group is responsible for maintaining the gearing mechanisms by reaching into the machinery above shoulder height, loosening the nuts, removing the bolts, changing the mechanism, replacing the bolts and retightening the nuts again.

The mechanisms weigh 5 or 6 kg and each operator replaces at least one every minute for the eight hour shift. They work well as a team and enjoy what they do. Their supervisor often joins in with the work, knowing the job well and implementing recommendations which come easily to her from the staff.

**Scenario 28**

In order to begin the unpacking process, staff in this area slash the plastic banding holding the boxes together. The knives they use are sharp, and don't require staff to apply much force to cut the bands. The cutting action involves rapid wrist extension, followed by flexion, whilst in ulnar deviation.

They slash about 25 bands every minute, and work at this task for the whole of their 8 hour shift. The task is monotonous and isolated, and the pace is dictated by the line speed which is out of the operators' control.

### **\*Scenario 29**

In order to place the car windscreens into the storage racks, operators have to adopt a posture with arms fully outstretched, to reach the edges of the glass. Each windscreen weighs upwards of 5.5 kg, and is placed into racks at about waist height.

The nature of the task involves lone-working for the 30 minutes that staff work in the racks during their shift. They have to replace 120 windscreens in the session otherwise they receive reduced pay and a reprimand from the supervisor.

### **Scenario 30**

Staff carry out this task alone for the whole of their 8 hour shift. They find it boring, and feel unsupported by the management staff.

The task involves moving large rocks, two-handed from the end of a conveyor into tubs. The shape of the rocks means staff adopt awkward hand and wrist postures to pick them up. The rocks weigh around 10 kg on average, and staff move about 65 per hour.

### **\*Scenario 31**

As large blocks of cheese arrive into the warehouse on waist high conveyors, cutting staff have to half the blocks using specially designed knives. The knives require staff rapidly to apply an initial force of around 50 Newtons, which is reduced slightly as they sustain a push through to the bottom of the cheese block. The design of the knife allows staff to maintain a power grip throughout, along with relatively neutral wrist postures and mid range elbow postures.

They half around 1200 cheeses an hour, for the whole of their 8 hour shift. The conveyor rate is set externally, by the management staff who are driven by the production targets given to them by central office. Staff work in isolation and in the past feel they have been ignored when they have made any suggestions for improvement.

### **Scenario 32**

For this activity, polishing staff have to finish the inside of long, wide bore, metal tubes. This involves using a polishing brush on the end of a 150 cm handle, in order to reach the innermost part of the tube. Because of the length of the handle, staff are effectively dealing with forces of more than 50N through their upper limb joints as they reach into the tubes to perform the polishing action.

The tubes are clamped at just about elbow height at one end, and rest on the floor at the other. In order to carry out the polishing tasks they adopt a number of non-neutral postures including flexing, extending and twisting their wrists, whilst making polishing movements up to 60 times a minute.

This is the task they carry out for the whole of their eight hour shift, and due to the noise of the polishers, there is no interaction between staff in this area. There is a constant supervisory presence, to ensure that staff keep up with the necessary

quotas. The supervisor brings the next tube to the operator as soon as they begin to unclamp the previous one.

