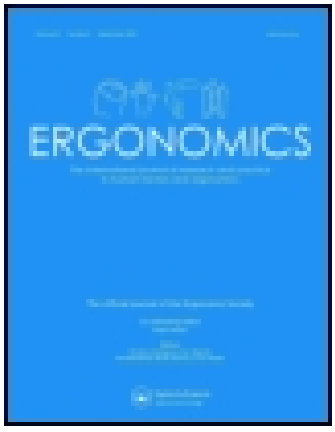

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'1966 and all that': Trends and developments in UK ergonomics during the 1960s

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'1966 and all that': Trends and developments in UK ergonomics during the 1960s

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The 1960s represents a key decade in the expansion of ergonomics within the UK. This paper reviews trends and developments that emerged out of the 1960s and compares these with ergonomics research and practice today. The focus in particular is on the expansion of ergonomics as a discipline within industry, as well as more specific topics, such as the emergence of areas of interest, for example, computers and technology, automation and systems ergonomics and consumer ergonomics. The account is illustrated with a detailed timeline of developments, a set of industrial case studies and the contents of important publications during the decade. A key aim of the paper is to provide the opportunity to reflect on the past and the implications this may have for future directions for ergonomics within the UK.

The paper provides practitioners with an insight into the development of ergonomics in the UK during one of the most important decades of its history. This is especially relevant given the fact that in 2009 the Ergonomics Society celebrates its 60th anniversary.

Keywords: general ergonomics; industrial ergonomics; human–machine systems; consumer ergonomics

> Machines are ahead of human beings; things control minds; society is limping and stumbling as it tries to keep up with technological change.
>
> (Calvino 1962 cited in Forgas 2008)

1. Introduction

The quote from the Italian writer Italo Calvino was made during a debate held on 'industry and literature' at the beginning of the 1960s. Calvino sums up what were to become dominant themes in later accounts of the period, namely, the growth of automation and the increasing role played by technology within society. Both of these themes are important within ergonomics and continue today as sources of debate in research and practical applications of the subject. Similarly, many issues have declined in interest or relevance as compared to 40 years ago. Much has been written about the origins of ergonomics (e.g. Waterson and Sell 2006, Stammers 2007, Stanton and Moray 2008, Stanton and Stammers 2008a,), alongside other discussions centred around pioneers within ergonomics and the future of the discipline (e.g. Frederic Bartlett). By comparison, little detailed information is available covering specific periods within the development of ergonomics. This paper focuses on the 1960s within UK ergonomics for a number of reasons. First, the 1960s can be seen as a mid-point between the immediate post-war roots and birth of ergonomics and its subsequent development into a fully fledged discipline. Second, during the 1960s, ergonomics became firmly established within industry and made firm steps towards closer engagement with civil, government and industrial users and practitioners (Chapman and Stone 1964). The late Brian Shackel (1927–2007), in a paper written to celebrate the 50th anniversary of ergonomics within EMI (Shackel 1991) (Table 1), viewed the period as a bridge between earlier work on military ergonomics and a later focus on consumer ergonomics in the 1970s.

In 2009 the UK Ergonomics Society celebrates its 60th anniversary. It seems timely and appropriate to stand back and review trends and developments over the period and compare these with present day ergonomics.

1.1. Historical sources and materials

This paper draws on a number of different sources of information relating to the 1960s. These include general histories covering the immediate post-war period and subsequent decades (e.g. Thomson 1965,

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Table 1. Characteristics of focus of ergonomics over the years (Shackel 1991).

1950s	Military ergonomics
1960s	Industrial ergonomics
1970s	Consumer ergonomics
1980s	Computer ergonomics
1990s	Information ergonomics
2000+	Leisure ergonomics
	Space ergonomics

Sandbrook 2005, 2006), as well as publications relating to ergonomics available in books and journals written in the 1960s and more recently. Historians sometimes refer to the interval between 1956–1974 as the 'long 1960s' (Sandbrook 2006) and accordingly these dates have been used as starting and end points in the paper. Reference is also made to materials that were used to prepare a history of the Ergonomics Society (Waterson and Sell 2006 – e.g. the outcomes from interviews held with ergonomists and other prominent individuals). Finally, some of the materials used in the paper are based on an archive of material from the late Brian Shackel (e.g. photographs).

2. Significant events and milestones

The years leading up to the 1960s proved to be eventful ones for ergonomics in the UK. In 1959 the Ergonomics Research Society (ERS) held its annual conference and celebrated at the same time the first 10 years of the Society. One account of the conference at the time (Rodger 1959) raised the issue of the identity of ergonomics and what members of the Ergonomics Society had in common – was it simply made up of individuals drawn from 'certain technological wings of certain human sciences and their agents and users in industry?'. Whilst this question has relevance today (e.g. current changes to the name of the Ergonomics Society), it is clear that by the end of the 1960s the debate had moved on and other matters were taking precedence (e.g. the involvement of practitioners).

During the 1950s and to some extent the early part of the 1960s, there was a concern that within the UK ergonomics was very much aligned with work study and the activities of work study engineers (e.g. evaluation of workplace lighting, time and motion studies). By the end of the decade ergonomics had become established, not only within the universities, but also within industry. These developments accordingly brought about changes to the nature of the discipline, as well as the role of the ergonomist. Table 2 sets out a timeline covering significant developments within ergonomics in the UK alongside wider historical events and societal changes.

2.1. Events leading up to the 1960s

2.1.1. Activities centred around the European Productivity Agency

The activities of the European Productivity Agency (EPA) and the close relationship it had with the ERS during the 1950s helped to establish and raise the profile of ergonomics within industry. The EPA was a body that worked under the auspices of the Organisation for European Economic Co-operation and in 1954 a working party was set up to consider the possibility of an international conference to promote ergonomics in industry (Edholm and Murrell 1973, p. 24). The plans for a conference were subsequently postponed; however, in the meantime the EPA proposed that a sponsored visit to the USA by a European party should be organised. The visit to the USA subsequently took place in 1956 with Tom Singleton as the representative from the UK and K.F.H. Murrell as the organising secretary. The outcomes from the visit were later presented at a seminar in Leiden in March–April 1957. The title of the Leiden seminar was 'Fitting the job to the worker' and involved seven ERS members, including Singleton, Murrell, R. Sell, W.F. Floyd and R. Stansfield (Edholm and Murrell 1973, p. 26). In 1959 the plans for a EPA sponsored conference were revived and the conference was held in March in Zurich. The conference brought together scientists, employers and trade unionists with the aim 'to change attitudes to work in the field of ergonomics rather than immediately to convey a great deal of factual material' (Edholm and Murrell 1973, p. 27). The Zurich conference led on to a subsequent conference in 1960 sponsored by the Department of Science and Industry.

2.1.2. Department of Science and Industrial Research Conference 1960

At the start of the decade a conference on 'Ergonomics and Industry' took place in London (27–29 September 1960). The title of the Department of Science and Industrial Research (DSIR) conference reflected the degree to which ergonomics had taken off as a subject for application within industrial settings and had evolved from its wartime, military roots. Some indication of the importance of the conference can be gathered from the fact that the opening address was given by the then Minister for Science, Viscount Hailsham. Similarly, the fact the conference was sponsored by the government at the time provides further evidence that ergonomics was taken seriously by politicians and policy makers.

In total over 200 companies were represented at the conference and papers were presented covering a

Table 2. Timeline of events.

Date	Developments within UK Ergonomics	Developments within UK and elsewhere
1949	Ergonomics Research Society formed (July)	Balance of payments crisis for Attlee's government leads to sterling's devaluation against dollar
1950		Attlee Government elected (February)
1951	Symposium held in Birmingham on 'Human Factors in Equipment Design' (Floyd and Welford 1954)	Festival of Britain (May) Churchill Government elected (October)
1952	Symposium held in Cranfield on 'Fatigue' (Floyd and Welford 1953)	Queen Elizabeth II crowned
1953	European Productivity Agency (EPA) meeting held in Zurich	Watson and Crick discover structure of DNA in Cambridge (April)
1954	EMI Laboratory set up by Brian Shackel	Roger Bannister runs the first 4-min mile
1955	Joint MRC/DSIR Conference on 'Individual Efficiency in Industry' held in Cambridge, 31 March–1 April. (Conference was hosted by Sir Frederick Bartlett and attended by a number of industrial representatives).	Eden Government elected (May) Commercial TV starts in the UK (September)
1956	EPA sponsored mission to USA (later published as Murrell 1958)	Clean Air Act passed in Parliament (July) First Nuclear Power station opens (Calder Hall) (October) Suez Crisis (November)
1957	*Ergonomics* journal first issue	Eden resigns as prime minister (Macmillan replaces him) (January) UK tests first hydrogen bomb (May) Windscale nuclear reactor disaster
1958	British Productivity Council produces a film 'Fitting the Job to the Worker'	Motorway system opens (M6 Preston Bypass)
1959	Ergonomics Research Society Conference – 10 years of Ergonomics Establishment of first professorial Chair in Ergonomics at Loughborough (W.F. Floyd) European Productivity Agency Conference, Zurich.	Macmillan Government elected
1960	DSIR Conference on Ergonomics in Industry Publication of Murrell's 'Fitting the Job to the Worker'	Penguin Books found not guilty of obscenity in the 'Lady Chatterley's Lover' case
1961	First IEA Congress (Stockholm) Postgraduate course in Ergonomics set up at Loughborough by W.F. Floyd (Stone 2009) One year course in ergonomics set at Cranfield (designed for military and civil service personnel) Masters course in Ergonomics (MSc) set up at Loughborough University	Russian astronaut Gagarin orbits the earth

(*continued*)

Table 2. (*Continued*).

Date	Developments within UK Ergonomics	Developments within UK and elsewhere
1962	DSIR issues 'Ergonomics in Industry' handbooks (later published as Applied Ergonomics Handbook - 1st Edition, edited by Brian Shackel (1974)	Cuban missile crisis (October)
1963	MSc course in 'Work Design and Ergonomics' set up at Birmingham University	France vetoes UK's entry into Common Market (January) Robbins Report of Education (new universities are established) (October) Macmillan resigns as prime minister (Hume replaces him) (October)
1964	Sir Harry Melville addresses the Ergonomics Society Conference – lecture mentions the increasing importance of systems approaches within ergonomics First undergraduate courses in ergonomics offered at Loughborough University (Stone, 2009). First graduates from the course in 1968.	Abolition of Resale Price Maintenance (opens up the possibilities for transformation of the retail sector) Wilson Government elected (October) Industrial Training Act
1965	Social Science Research Council set up (December)	Nationalisation of the Steel Industry (May) Nuclear Installations Act 1965 Comprehensive School system introduced (July) Death Penalty abolished (November)
1966	'Human Operator in Complex Systems' meeting at University of Aston	England win the football world cup (July)
1967	IEA Congress held in Birmingham (held under the patronage of HRH Prince Philip)	Abortion and homosexuality legalised First Heart Transplant Operation (December)
1969	ERS celebrates 20 years of Ergonomics *Applied Ergonomics* first issue	Concorde aircraft makes its maiden flight Landing on the Moon
1970	Set up of Institute of Consumer Ergonomics (ICE), and HUSAT at Loughborough	Heath Government elected
1971	High involvement of ERS members with standards and attendance at BSI committees	First British soldier killed during the 'troubles' in Northern Ireland (February) Decimalisation introduced North Sea Oil concessions are auctioned (August)
1972	Tom Singleton gives annual Society lecture on Human Error	'Bloody Sunday', Northern Ireland (August) Expelled Ugandan Asians settle in UK
1973	18 UK Universities and Institutes in total offer courses of one form or another in Ergonomics	UK joins European Economic Community Oil price soars as OPEC cuts supply to US and Western Europe. UK enters recession
1974	Increasing evidence of research on consumer ergonomics (e.g. Whitfield 1972)	Wilson elected after 'hung parliament' Health and Safety at Work Act 1974

MRC = Medical Research Council; DSIR = Department of Scientific and Industrial Research; ERS = Ergonomics Research Society; HUSAT = Human Sciences and Advanced Technology.

diverse range of industries and services (e.g. London Transport, British Steel, Smiths Instruments). The proceedings from the conference (Department of Scientific and Industrial Research 1961) record that eight symposia tool place, ranging in theme from 'The place of ergonomics in industry', 'Ergonomics and products' to 'The future of ergonomics'. The latter symposium provides some clues as to what ergonomists were concerned with at the time, as well as their predictions for the future. W.F. Floyd, for example, speaking of the problems of defining what was meant by ergonomics commented that:

> I think this puts us in the position of being able to say that there is no such a thing as an ergonomist – yet. I believe that might be when this process reaches maturity, but I do not foresee this happening for a number of years.
>
> (Department of Scientific and Industrial Research 1961, p. 161)

In the same symposium, Donald Broadbent commented that predictions of the future were likely to de doomed to failure, whilst also suggesting that ergonomics would expand from a consideration of manual labour to a consideration of management issues:

> What will those people [ergonomists] be doing? In part, the same things that they are doing today; but only in part. I suspect in the year to come there will be wider applications, with the disconcerting result that the board of directors as well as the man on the shop floor will be the subject of ergonomic study.
>
> (Department of Scientific and Industrial Research 1961, pp. 159–160)

The theme of the role of ergonomists in industry and changes to the nature of work will be addressed later in the paper in section 4. The next section examines in more detail the topics of interest that preoccupied researchers and practitioners during the 1960s.

2.2. *Topics of interest in academia and practice*

One way of gaining insight into the topics that preoccupied the minds of ergonomists and related professions (e.g. applied psychologists) is to look at the types of textbooks and training courses that were published and available for study over the decade. Table 3 sets out the contents pages of four books that were published from 1965–1974. In addition, the syllabus for a short course in ergonomics from 1961 is presented in Table 4.

Looking through the contents of both the textbooks and courses from the 1960s and today, the first impression is how little seems to have changed. The comments made by Broadbent (Department of Scientific and Industrial Research 1961) seem to have partly come true. Many of the topics that one would expect to find today in postgraduate courses in ergonomics, for example, were being taught, albeit with a different content and emphasis, 40 years ago. This is perhaps unsurprising given the nature of ergonomics. However, what has changed the most would seem to be the expansion of the basic core elements of ergonomics (e.g. anthropometry, control and display design) into more specialised areas of investigation (e.g. posture and comfort, human–computer interaction (HCI)). These changes had implications for the role of the practising ergonomist, moving from someone capable of having an overview of all of the topics in ergonomics, spanning anatomy, physiology and psychology, to a more specialist role (section 4.2). In addition, by the end of the 1960s techniques for evaluation and design within ergonomics (e.g. task analysis) begin to make an appearance. The trend toward the development of methods and techniques designed for specific application domains within ergonomics continues up until the present day. The next section focuses in more detail on a selection of topics that reflect both continuity and change over the course of the 1960s to the present day.

2.3. *Focus on selected topics*

2.3.1. *Computers and technology*

Throughout the 1960s, with the advent of interactive computing, computer applications were spreading quickly in business and industry. Computer processing was undertaken by large, mainframe machines that had hitherto been the province of computer specialists. Now 'time sharing' systems enabled a mainframe to service many remote terminals at the same time and people who were not computer specialists could experience an interactive dialogue with the computer. At first this was undertaken using teletype machines but these were soon superseded by visual display units or terminals (VDTs). The widespread use of interactive computing raised many human issues and ergonomists quickly became involved in research, evaluation and design roles. In all three of the case studies reported in section 3, for example, the ergonomic teams were engaged in the development of various forms of HCI. At first, the dominant concerns were familiar hardware and environmental subjects: the 'knobs and dials' of the keyboard and the display, the workstation and the lighting. Cakir *et al.* (1980) produced an early 'VDT manual' to provide design guidance on these subjects.

However, it soon became evident that interactive computing also created some new challenges for human performance. One was response times. Early forms of time sharing could produce delays in responses from the computer that could last minutes at

Table 3. Topics of research – representative book publications.

Publication	Contents
Ergonomics – Man in His Working Environment (Murrell 1965)	Introduction: the nature of ergonomics Part 1: the elements of ergonomic practice The physical basis of man's perception of his environment The human body: Bones, joints and muscles; metabolism and heat regulation; body size, limits of movement and functioning of limbs; the nervous system. Man as a system component Part 2: practical ergonomics Design factors: layout of equipment; design of seating; design of instrumental displays; compatibility; design characteristics of controls. Environmental factors: environmental temperature and humidity; noise; the visual environment; vibration. Organizational factors: methods of investigating work; the organization of work; inspection; shift work; age.
Psychology of Work (1st edition, edited by Peter Warr 1971)	Theory and application in psychology (Broadbent) Shiftwork (Wilkinson) Skill performance and stress (Poulton) Learning (Annett) Man–machine systems (Singleton) Accidents (Kay) Ageing (Griew) Selection (Drenth) Occupational guidance (Lancashire) Judgements of people at work (Warr) Decision-making (Sime) Managers – Effectiveness and training (Fineman) Motivation (Blackler and Williams) Employee participation (Hespe and Little) Intergroup relations and bargaining (Stephenson) Organisations as psychological environments (Payne)
Introduction to Ergonomics (Singleton 1972)	The provision of energy The application of forces Problems of body size and posture The effects of climate Limitations of the sense organs The design of controls The design of displays Man/machine information exchange Temporal, social and economic conditions of work Age, fatigue, vigilance and accidents Acquisition of evidence about individual behaviour Acquisition of evidence about system behaviour The design of work Assessment, presentation, and interpretation of evidence Retrospect and prospect
Applied Ergonomics Handbook (1st edition, edited by Brian Shackel 1974 – first published as series of booklets issued by DSIR)	Industrial use of ergonomics (Singleton) Instruments and people (Shackel and Whitfield) Design of work for the disabled (Griew) Inspection and human efficiency (Belbin) Ergonomics versus accidents (Sell) Noise in industry (Broadbent) Men, machines and control (Provins) Thermal comfort in industry (Fox) Lighting of workplaces (Longmore) Seating in industry (Branton) Layout of workspaces (Jones) Current trends towards systems design (Singleton)

DSIR = Department of Scientific and Industrial Research.

any point in the dialogue and this proved very disruptive to task-oriented thought processes. Today, this problem is only apparent when one wants to download large files and the response speeds have largely disappeared from the research agenda. However, the issue of software ergonomics that

Table 4. Syllabus for a 2-week appreciation course on the 'Design of equipment for human use' (Wade 1961).

The body as a heat engine and the problem of physical fatigue
The human being as a receiver and processor of information
The need to experiment, and the problems of experimenting on human performance
Body structure and the limits of limb movement
The use of statistics
Anthropometry, seating and manual weight lifting
The contribution of motion study to equipment design
Photographic techniques of motion study
Planning experiments
Display of information
Vigilance and inspection
Control design
The layout of equipment
The working environment: lighting, colour radiant heat and noise
Load, speed and stress
The effect of ageing on performance
The application of ergonomics; physiology, anthropometry and physiology
Ergonomics and automation
The human factors in equipment design
Relations of the designer with management and work people

became recognised in this period has become progressively more significant. Early forms of dialogue with computers were based on the programming languages used by computer professionals, but these were not a good basis for HCI when the humans were accountants, clerks, engineers, managers and so on; people who were naïve users with regard to computers. So the search began for forms of software interaction that would be natural and easy for the ever-widening population of computer users. By the mid-seventies this had distilled into the search for usability (Shackel 1984) and, as personal computers came into being, 'point and click' graphical interfaces exploiting the capabilities of the mouse were fast becoming the de facto standards for HCI. Ergonomists played leading roles in this process. The Human Sciences and Advanced Technology (HUSAT) Research Institute at Loughborough University was established in 1970 and specialised in the study of human aspects of computing technology, and many information technology companies such as IBM, Phillips and British Telecom began to establish human factors groups and usability laboratories in which to test their new products.

Although there was a number of attempts to undertake theory-driven research in this field (e.g. Card *et al*. 1983), the main emphasis was applied to create standards and style guides for interaction design, to establish usability evaluation methods and to institutionalise usability design as an integral part of the way new products and systems were developed. By the 1980s HCI and usability engineering was developing into a major international sub-discipline occupying a territory somewhere between computer science and ergonomics. The first international conference in the INTERACT series was held in London in 1976 and the journal *Behaviour and Information Technology* was launched in 1981.

Today, HCI is a feature not just of commercial systems but of a wide variety of consumer products and it is a testament to workers in this field that a large proportion of the population can now make regular use of these sophisticated products without any specialist training. There is now a large army of usability engineers in companies around the world dedicated to ensuring that new products meet human factors standards. It is sobering, however, to note that these professionals are more likely to have computer science qualifications than degrees in ergonomics. Ownership of this inherently multi-disciplinary subject was always an issue exemplified by the use of the term 'human–computer interaction' by ergonomists and the term 'computer–human interaction' (CHI) by computer professionals. It was the CHI professionals who actually designed usable forms of interaction such as the graphics interface. Ergonomists who work professionally in this field are increasingly also gaining qualifications in information technology so that they can play a full role in the development of new products and systems.

2.3.2. *Automation and systems ergonomics*

One of the many developments that came about as a result of the increasing automation of tasks was the formation of what later became established as systems ergonomics. Singleton's (1958) work within the shoe industry, for example, had underlined the importance of understanding the combined influence of management, technology and human–machine components on work and productivity. Likewise, Welford's (1960) booklet in the DSIR series on 'Ergonomics and automation' linked ideas from systems theory to human and machine performance issues. Sir Harry Melville's (1963) address to the Ergonomics Society gives some idea of the positive light in which the systems approach was viewed:

> The machine and its operator inevitably form a single system in which the characteristics of both contribute significantly to the performance of the whole. The human characteristics concerned include not only the basic capacities of the human body and brain, but also the effects of individual and social experience, the aims, ambitions, hope and fear that a man brings to any task he performs.

The symposium held in 1967 on the 'Human operator in complex systems' at Aston University

brought together a number of researchers and practitioners from academia and industry with interests and enthusiasm for systems ergonomics. Singleton (1967) described reading the concepts and ideas that had come from systems theory as a 'eureka experience', whilst at the same time noting that there were many who were sceptical of the systems approach. This had in itself led to a new schism with ergonomics. In the 1950s there had been tensions between psychologists and physiologists, by the later 1960s attention was more focused on those who came from the 'knobs and dials' tradition and those who were perceived as 'systems men'. Singleton cites research on management decision-making (e.g. the work of Lisl Klein and colleagues), vigilance and workload, as well as the views of the general public toward automation as important topics worthy of future investigation. The symposium also contains contributions covering issues such as allocation of function (Whitfield 1967), automation in meat handling (Shackel *et al.* 1967) and the role of the operator in specific contexts (e.g. the National Grid; Sell and Pulsford 1967). It is worthwhile noting in passing that the systems approach in recent years has gained in popularity in a number of domains (e.g. safety and health care ergonomics) and many of the issues mentioned in the symposium (e.g. shortage of hospital beds, motorway crashes; Jones 1967) are as topical today as compared to over 40 years ago.

2.3.3. *Job and work design*

The 1960s was a decade when motivation to work, job satisfaction and job design were important topics on the research agenda. One reason was that many of the industrial jobs in manufacturing at the time involved repetitive tasks and machine pacing and many studies had shown that operators in these jobs had low levels of job satisfaction. They tended to be alienated from both the companies they worked for and the work systems they were part of. The poor industrial relations climate in the UK in particular during this time meant that both industrialists and government were interested in improving the lot of people at work. Many of the researchers in this field came from industrial sociology and occupational psychology, but ergonomists also recognised the applied importance of these issues. Welford, for example, in the Ergonomics Society lecture in 1966 emphasised the need to understand motivation and job satisfaction if one was to fully understand the factors that affected performance at work (Welford 1966).

Many theories emerged from research in this period. The most popular were the relatively simple and easy to grasp theories of Maslow and Herzberg, which could be used to explain the relative roles played in job satisfaction of extrinsic factors, such as pay and recognition, compared with intrinsic factors, such as the challenge of the task itself. Later, more sophisticated theories emerged (Parker and Wall 1998), which demonstrated the role of a wide array of factors in the experience of job satisfaction. These theories had a range of applied consequences from the design of payment systems to management training. However, the recognition of the importance of intrinsic factors fed directly into methods of job design (i.e. the assignment of tasks to work roles in the work system). Several authors (e.g. Davis and Canter 1956, Trist *et al.* 1963) created lists of job design criteria that emphasised the need for a variety of tasks in a job and discretion and autonomy with regard to how tasks were undertaken. These concepts also became part of broader movements that gained momentum in the 1960s; the development of forms of industrial democracy, the study of the quality of working life and the development of socio-technical systems theory as a systems approach that sought both effective work system performance and worthwhile and satisfying work for people to undertake. Recognition of the importance of implementing these ideas in industrial practice came in the UK through the creation of the Work Research Unit in the Department of Employment and in the European Union through the formation in 1975 in Dublin of the European Foundation for Living and Working Conditions.

There appeared to be rich promise in this era that the application of these theories and methods would produce more satisfying work and that this would help create more effective and adaptable work systems. Today, although this field of study is still being developed, it is not such a prominent research discipline and is receiving less attention from industrialists and government. A possible reason is that most of the low-skilled manufacturing jobs that were the focus of concern have moved from the developed world to the developing world as mass production has moved to the Far East. There is now less concern in the developed world for the design of jobs to increase job satisfaction and more concern about job stress. The design solutions currently in vogue are less about job design and more about flexible work schemes that enable workers to achieve a better quality of work/life balance.

2.3.4. *Consumer ergonomics and standards*

Over the last 50 years UK household income has doubled in real terms according to the latest government statistics (Office for National Statistics 2008). The beginnings of this trend can be traced back

to the 1960s, when consumer spending on household products and services began to take off. Some indication of the involvement of ergonomists in the design of consumer products can be judged from the fact that between 1965 and 1973 some 174 references to ergonomics were made in *Design*, a popular magazine read by professional designers. Over the decade, the magazine published a range of articles written by ergonomists covering a wide range of products and design-related issues, including accidents and design, agricultural machinery, bathroom ergonomics and product evaluation. Later, the importance of ergonomics was recognised by the fact that two people associated with design ergonomics were involved with the magazine's 1973 consumer good awards (Stuart Kirk at Loughborough and Bruce Archer at the Royal College of Art).

During the late 1950s a good deal of research was conducted on the anthropometric properties of chairs and tables (e.g. Akerblom 1954, Floyd and Roberts 1958). Work on chairs and seating requirements continues to the present day (e.g. Corlett 2005) and is one of the main (and sometimes only) interpretations of the term 'ergonomic' amongst the general public. Later, the field of consumer ergonomics expanded considerably and took in a range of different types of product, some highlights include the following:

- Studies of drivers and driving behaviour conducted at the Applied Psychology Unit (APU) in Cambridge by Ivan Brown and colleagues (e.g. the use of car radios and other concurrent tasks on driving – Brown *et al.* 1969, see also section 3.2).
- Work on household appliances and kitchen design conducted by W.F. Floyd and colleagues at Loughborough University and the Institute of Consumer Ergonomics in Loughborough (e.g. the usability and anthropometric properties of household jugs – Floyd *et al.* 1965, the ergonomic design of kitchens and tasks related to housework – Ward 1970).
- The design of coins and the problems associated with the move to decimalisation of UK currency conducted at the APU in Cambridge by Patricia Wright and colleagues (e.g. Wright 1968, Wright *et al.* 1969).
- Development of a hospital bed, which later became a British Standard, for the National Health Service by Bruce Archer and colleagues at the Royal College of Art (The Times Newspaper 2005).

By the early 1970s, the issue of standards had taken on more importance than it had in the past within ergonomics. Members of the Ergonomics Society had taken part in standards committees (e.g. furniture design) since the early 1960s and representation on other committees increased through the decade. However, a survey by Whitfield (1972) found that of 400 standards relevant to ergonomics, none had any actual mention of ergonomics within them. The problem at the time was seen as poor communication of what ergonomics consisted of, as well as few attempts to integrate ergonomics into standards. Over the course of time, this appears to have improved (Stewart 2000) and ergonomists are today widely involved in the design of standards, particularly as they relate to information technology.

2.3.5. *Ageing and population change*

The topic of an ageing population and the impact this had upon the industrial workforce provided many debates during the late 1950s and early 60s. This is reflected in the number of papers on ageing in the Ergonomics Society conference proceedings and the journal *Ergonomics* over the period. In addition, a number of research groups and centres, some funded by organisations such as DSIR and the Nuffield Foundation, were active across the country (e.g. Liverpool, Bristol, University College London).

In 1951, people between the ages of 50 and 59 years represented 43% of the population compared to 39% in 2003, whereas the proportion of those aged over 85 years increased from 1.6% in 1951 to 5.5% in 2003 (UK Statistics Authority 2008). One of the main issues that attracted the attention of ergonomists at the time was how to retrain older workers. A typical example is Simon and Wolf's (1963) study, which looked at the reaction times, speed and efficiency of older people when carrying out tasks involving inspection and visual acuity. Similarly, other papers drawn from industry concentrated on older workers carrying out inspection tasks, such as repairing telephone exchanges (e.g. Jameeson 1966). The work of Eunice Belbin at UCL is notable since it later became influential in the design of training programmes for older workers (Belbin and Downs 1964). What is striking about most of the work on ageing at the time is that it tended to be conducted within the laboratory and involved experiments measuring reaction times using simulated work-based tasks (e.g. postal sorting). It was only much later in the 1970s that issues such as the job satisfaction of older workers or the difficulties they might have had in adjusting to new jobs were addressed.

3. Case studies of ergonomics in industry and research

As mentioned earlier, the 1960s saw the expansion of ergonomics into industry. In particular, ergonomists actively collaborated with a number of trade associations and were employed in a variety of industries (e.g. Boot and Shoe Research Association, Furniture Development Council). Described here are three examples of case studies of ergonomics within companies.

3.1. The Ergonomics Laboratory at EMI Electronics Ltd

In 1954 Brian Shackel, then working at APU in Cambridge, was invited to establish a team at what was at the time EMI Engineering Development Ltd (later EMI Electronics Ltd) in Feltham, Middlesex. Initially, the team was called the 'Psychological Research Laboratory' because the name 'ergonomics' was not considered to be sufficiently well established. It became the EMIE Ergonomics Laboratory in 1965.

In addition to being in the music industry, EMI employed large teams of engineers, many of whom worked on large military system developments. However, EMI was also very active in developing commercial systems and products and, during the 1960s, was at the forefront of UK efforts to develop the first transistorised computers. Brian Shackel saw the role of the Ergonomics Laboratory as to apply ergonomic knowledge and principles to the work of the engineering teams in the company.

> As a service ... the major function of the ... laboratory is to aid project engineers and draughtsman in the design of equipment to ensure compatibility of operation between the machine and the man.
>
> (Shackel 1967, p. 4)

3.1.1. Military ergonomics

Initially, the majority of the work undertaken was in relation to military projects. Anderson and Beevis (1970) record that this included work on the interfaces for radar and infrared displays. The group quickly recognised that whilst much of their work was on standalone products, the military work took them into large systems design projects. They became involved, for example, in the design of ship's operations rooms, vehicle environments and fleet information systems. This led to an abiding concern for systems ergonomics and the role that ergonomics could and should play at all stages of the development of large systems.

3.1.2. Consumer and product ergonomics

Outside of the military work of EMIE, the laboratory worked with many other engineering teams. At the time, Morphy Richards was part of EMI and this gave the laboratory the opportunity to evaluate and contribute to the design of many domestic products whilst they were in development. This included electric drills, electric carving knives, record players and hairdryers (Figure 1).

3.1.3. Computers and information technology

One of the major developments in EMI was what was at the time the largest all-transistor computer in Europe, the EMIDEC 2400. The team was involved in prototype development of the control console for the computer in 1959 and was able to trial and evaluate several different interfaces (Shackel 1962). This led to a strand of work about human issues in the emerging computer industry, which included not only the hardware interface but also the software interface for interactive computing. Several members of staff later became prominent contributors to human–computer interaction, a subject that became a major international discipline as the information age developed (Figure 2a,b).

3.1.4. Large-scale systems

Shackel was concerned that the laboratory should not restrict itself to work on EMI products and systems and secured management agreement to offer the

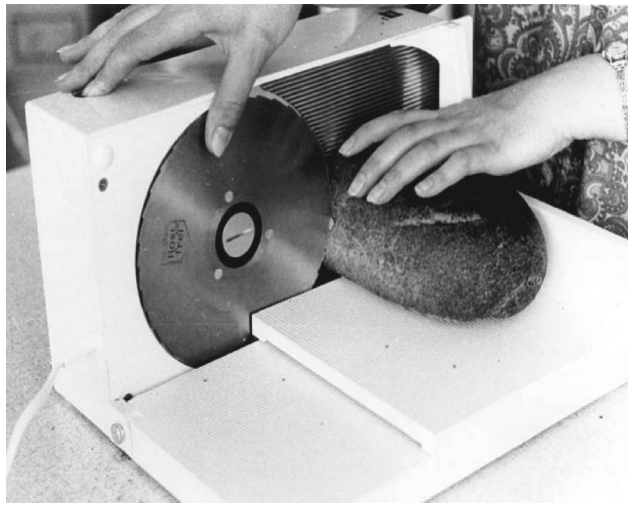
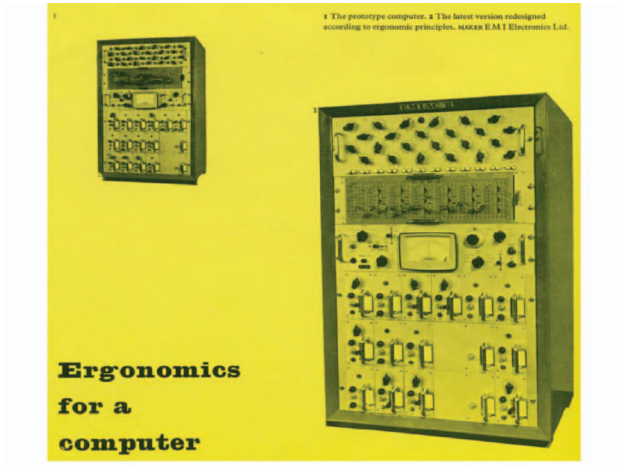


Figure 1. Faulty position of on–off switch on electric bread cutter. The position of the on–off switch leads to serious risk of slicing the right thumb.



(a)

(b)

Figure 2. (a) Installation of EMIac analogue computers – prototype (source: Shackel 1959a,b); (b) installation of EMIac analogue computers – ergonomically redesigned production machine.

services of the laboratory to other companies. As a result, the laboratory was able to work on product and systems development with design teams in a wide variety of environments. As a result of collaborations with Lisl Klein, then social science advisor in ESSO UK (Klein 1976), the laboratory created a mock-up of the bridge of an oil tanker in order to test bridge layout and equipment design for a new fleet of oil tankers. It also ran trials of alternative layouts for a new control room for the ESSO refuelling depot at Heathrow Airport (Shackel and Klein 1976). As Anderson and Beevis (1970) report, the group steadily developed the analytic and design skills to make systematic contributions across a broad range of human issues in complex system design including workload assessment, selection and training, task analysis and design, work group design, man–machine allocation of tasks and the design of equipment, environment and workspaces. This range of techniques was applied in system developments, such as the development of an airline reservation system employing 200 reservation clerks and the design of an automated meat handling system for the Port of London (Shackel *et al*. 1967).

From small beginnings the group grew to over 10 full-time professional staff in 1970. Although it had research interests, its major contribution was to develop the methods and techniques for working with designers and engineers to translate ergonomics knowledge into forms that could influence the development of products and systems. Anderson and Beevis (1970) conclude that:

> The presence of a specialised group like this laboratory in industry not only fulfils a need to that industry but by straddling the gap between university research and private consultants, points the way for the proper development of the subject.
>
> (p. 232)

In 1970 Brian Shackel joined Loughborough University to create the HUSAT Group of researchers (later to become the HUSAT Research Institute) and continue his work on HCI. The laboratory continues until this day and as a result of various changes of ownership is now part of Quintec Associates. In 2004 it celebrated 50 years of the work of the laboratory. Today, the laboratory sustains the focus on making integrated human factors contributions throughout the development life cycle of complex, usually military, systems.

3.2. Medical Research Council Applied Psychology Unit

The Medical Research Council APU in Cambridge played an important and fundamental role in the development and application of UK ergonomics. During the preparation of the material in Waterson and Sell (2006), for example, the APU was consistently mentioned by those interviewed in terms of the quality of research it produced in applied ergonomics and experimental psychology. In addition, the APU was cited as one of the best examples of successful collaborations between researchers in ergonomics based at the unit and their industrial counterparts. Figure 3a,b shows some of the work conducted by the APU during the war on the redesign of operations rooms (Bartlett and Mackworth 1950).

Part of its success can be attributed to the influence of Donald Broadbent (1926–1993) throughout the period 1958–1974 and his role as director of the APU. In his work at the APU, as well as elsewhere, Broadbent emphasised the need to relate theory to applied problems. As he stated in one of his books:

FIG. 25. Improved design for Operations rooms

(a)

FIG. 1. A sector operations room

(b)

Figure 3. (a) Wartime control room showing problems of distance and limited viewing angle of controllers from the plotting table; (b) improved structure with controllers nearer to and above the plotting table. (Source: Bartlett and Mackworth 1950.) Although not published until after the Second World War, this study was carried out 1943–1945.

'... the test of intellectual excellence of a psychological theory, as well as its moral justification, lies in its application to concrete practical situations' (Broadbent 1973, p. 7).

This ethos seems to have dominated the work of researchers in ergonomics (human factors) in the APU during the period of Broadbent's directorship:

> I think this broad range of human factors research was obviously drawing on, but also hopefully contributing to, theory development within the unit. The other point which I think is equally important is the collaborative way in which we set up research with outside organizations such as British Telecom, British Rail, the Post Office, the Coal Board, and so on. I think these groups not only benefited from the theoretical concepts that were being researched and developed within the unit; they also benefited from the methodology that unit staff were developing.
>
> (Ivan Brown quoted in Reynolds and Tansey 2003, p. 37)

The early work of the APU had been concerned with military problems arising from work carried out during the Second World War, such as pilot fatigue, the effects of environmental stress and the vigilance of radar operations (for more information on the wartime and immediate post-war history of the APU, see Hayward 2001, Medical Research Council CBU, 2005). Between 1956 and 1970 the number of scientific staff employed at the APU remained relatively constant (approximately 20 scientists) with increases over time in the numbers of research assistants and other technical staff working on a variety of projects. Ivan Brown and colleagues (Brown *et al.* 1970) provided an overview of these projects in a paper published in *Applied Ergonomics* and elaborated upon these during the discussion at the Witness Seminar held at the Wellcome Trust Centre in June 2001 (Reynolds and Tansey 2003). Amongst the research topics were the following.

3.2.1. *Application of psychological theories*

- Research on signal probability and response time and the relationship this had at the time to information theory (Broadbent 1958), its application to industrial inspection tasks and sonar detection (Colquhoun 1967).
- The relationship between sleep loss and level of awareness over periods of time (Wilkinson 1961).
- The application of theory to practical problems such as the relationship between the perception of written material and the style of printing used (Poulton 1960).
- Studies of searching strategies and fault-finding in electronic equipment (Dale 1959).

3.2.2. *Post office studies*

From 1960 the APU carried out a large number of studies under a consultancy agreement led by R. Conrad with the Post Office (later the Royal Mail). Conrad was appointed Human Factors Consultant with the Post Office during the early 1960s and led studies that aimed to design communication systems that were capable of being more efficiently used by the general public. These studies would today fall under the rubric of research in the area of improving the

usability of everyday technologies such as telephones and visual displays. Conrad and his colleagues carried out studies on a variety of topics including the relationship between letter-sequence redundancy in short-term memory and the effective recall of the letters and digits that make up postal codes (Conrad 1967) and the advantages of presenting telephone numbers as groups of digits rather than individually expressed in terms of theories of encoding in memory (Conrad 1960) (Figure 4).

3.2.3. *Studies of car driving*

Ivan Brown and his colleagues produced a number of important studies with practical implications concerning the influence of fatigue during prolonged driving on the impairment of skill. Brown's work is also possibly the earliest to address the current topical issue of the impact that using a mobile phone has upon attention whilst driving (Brown *et al.* 1969).

3.2.4. *Physiological rhythms and shift work*

A number of studies were carried out on the topic of the relationship between circadian rhythms and physiological changes, such as body temperature, particularly as they related to shift work patterns. These studies had many practical implications for the design of rotating shift systems, including the selection of individuals best suited to work efficiently according to this type of shift pattern (Colquhoun 1967).

3.2.5. *Designing for everyday life*

Brown *et al.* (1971) point to the closer links with Europe, which were forming at the end of the 1960s, as one reason why research on designing systems that affected the general public became more frequent within the APU and elsewhere. For example, the conversion to decimal currency in 1971 promoted studies of the visual and tactile properties of alternative design for decimal coinage (Wright *et al.* 1969).

Figure 4. Medical Research Council Applied Psychology Unit research in the Post Office. In the early 1960s mechanisation of letter-sorting envisaged a keyboard operator copying postcodes to enable mail to be sorted electronically, as illustrated (source: Reynolds and Tansey 2003).

3.3. *British Iron and Steel Research Association*

Sell (1971) and Crawley (1972) provide small-scale histories of ergonomics-related research and application within the British Iron and Steel Research Association (BISRA). BISRA came into existence following the Second World War and received its income initially from a levy on all steel companies within the British Iron and Steel Federation. Funding was also provided from the USA by The Marshall Plan I, the form of conditional aid funds (provided also to the Tavistock Institute in London). This was matched at the time by a grant from the Department of Scientific and Industrial Research (later renamed the Ministry of Technology). In 1954 the total income of the BISRA was around £500,000; by 1971 this had risen to approximately £2.2 million.

The origins of ergonomic work at BISRA can be traced back to war time, when the director between 1946 and 1969 (Sir Charles Goodeve) had been involved with operational research with the Admiralty. Similar links existed through the involvement of other individuals working at BISRA with the Ergonomics Society (Miss I.M. Slade) and previous experience using ergonomics within the aviation industry (Dr L.N. Bramley). Some of the research topics carried out at BISRA included the following.

3.3.1. *Crane cab design*

At the request of the DSIR the ergonomics group at BISRA became involved in the redesign of crane control cabs. One of the problems with the existing design of these types of machinery was that little thought had been given to the field of vision required by the driver. As a result of building a workshop model, the crane cab was redesigned and enabled sight lines to be determined for the cab driver, thereby increasing the safety of the cab as a whole (Sell *et al.* 1961a).

3.3.2. *Physical conditions of work*

Because of the nature of working in the iron and steel industry, BISRA partly concentrated on research aimed at protecting workers against exposure to heat. Some of this work originated out of research projects in collaboration with the Medical Research Council's

Environmental Physiology Research Unit. Part of this involved carrying out studies on the effects of radiant heat stress upon performance (Ketterington 1969) (Figure 5a,b).

3.3.3. *Accidents and safety*

In collaboration with the Tavistock Institute, BISRA carried out investigations of the accident patterns of recently employed workers at a large Sheffield steelworks. Hill and Trist (1955), for example, found that over time workers learned how to avoid accidents and that their absence patterns also eventually come into line with other workers in the rest of the factory. BISRA also carried out research on safety posters and demonstrated their effectiveness, particularly within high-risk work contexts (Laner and Sell 1964).

3.3.4. *Process operation*

DSIR also financed a study of the skills involved in process operation with BISRA working with E.R.F.W. Crossman at Oxford University and R.J. Beishon at Bristol University. This work involved taking measurements of the outputs from a steel mill and comparing these with recordings of the operator's behaviour. The outputs from these studies formed the basis of a set of new design recommendations for hot strip mills (Sell *et al.* 1961b).

3.3.5. *Man–computer interaction*

A variety of different types of studies, in what was then known as man–computer interaction, were conducted at BISRA in the mid- to late-1960s. These included investigations of the legibility of different types of digital displays (Simpson 1971), allocation of function and automation, as well as larger-scale simulations of the decision-making of operators when interacting with large-scale computer-generated data (Ketterington 1970).

4. Changing perspectives in ergonomics

Over the course of the last 40 years, a huge amount of change has occurred within industry and society. For example, the three research institutes, laboratories and units described in section 3 no longer exist. Many other changes have been brought about to the nature of research and practice within ergonomics (Stanton and Stammers 2008b). Table 5 sets out some of these.

4.1. *The nature of work*

Perhaps the single biggest change that has occurred since the establishment of ergonomics after the Second World War has been the changes that have occurred to the nature of work. In the immediate post-war period, ergonomists were preoccupied with subjects such as

(a)

(b)

Figure 5. (a) Helmet designed within British Steel; (b) diagram of inside the helmet and its workings. This breathing protection helmet was developed by ergonomists at the British Steel Corporation, led by David R. Davies; it received a Design Council Award for innovative design and a Queen's Award to Industry for the manufacturer.

Table 5. Changing perspectives in ergonomics.

	1940s/1950s	1960s	1970s	Present day
Characteristics of work and society	Manual, repetitive tasks	Increasing automation in the workplace	Health and safety concerns, unemployment	Decline in manufacturing sector and rise of service industries, global working
Characteristics	Dominance of military Ergonomics	Rise of industrial ergonomics	Consumer ergonomics takes off	Health and safety ergonomics increases in importance
Developments	Fatigue, controls and displays	Systems ergonomics	Safety-critical ergonomics (e.g. nuclear)	Focus on bespoke methods, tools and techniques within ergonomics
Changes to academic ergonomics	No courses in universities, subjects too new	University courses started, short courses for industry	Further expansion of courses and broader coverage of topics	Many courses, although some threats to existence
Changes to practice	Move from a wartime 'back room' operation to industry	Many practitioners in industry	Smaller-scale consultancies begin	Large range of consultancies with a range of sizes, many consultancies specialised in certain areas
The role of the ergonomist	No real role as such, specialisms (e.g. psychology, physiology)	Generalist – experience of most areas of ergonomics	Increasing specialisation, generalist role dying out	Specialist, expert
Domains	Military, engineering, transport, iron and steel	Computer ergonomics, transport	Nuclear, consumer ergonomics	Diverse range of domains, new areas such as healthcare

fatigue brought on by jobs or tasks, which often stretched workers to their physical and physical limits. McFarland (1971) describes how some of the work conducted using the 'Cambridge Cockpit' at the APU, for example, demonstrated that pilots routinely suffered from psychological stress, as well as fatigue brought on by long working periods of flying, which significantly decreased their levels of skill and timing. During the 1950s and 1960s the focus of research within ergonomics changed to attempts to understand the combined effects of physical and mental workload, alongside aspects of environmental context and the tools/machines used by workers (Burger and DeJong 1962). The increase of automation in factories in the mid- to late-1960s meant that workers were often in the position of 'machine minders'; as a result, topics such as monotony and boredom began to be studied under the heading of job design (Broadbent 1961, Edholm 1970). The impact of UK legislation on Health and Safety during the early 1970s, alongside prominent disasters such as the one that occurred at Flixborough in 1974, changed the nature of research in ergonomics once again. During the 1970s ergonomists increasingly began to examine safety and the causes of accidents and disasters in more depth as compared to earlier studies (Turner 1978). The field of job design also began to address the issue of workplace stress and the impact this had upon worker performance and absenteeism (Cox 1978).

Within UK ergonomics more widely there has been a great deal of continuity in terms of the types of domains that have been investigated and areas where practising ergonomists work. Military ergonomics, for example, continues to be a focus of investigation, as well as forming one of the largest areas of employment for ergonomists. More recently, other areas have risen to prominence (e.g. health care ergonomics) alongside more traditional domains such as transport (e.g. railway and aviation ergonomics). What is perhaps more evident is that the predictions made by many in the 1960s that employees would spend less time at work and more time in leisure activities have not come true.

4.2. The role of the ergonomist

One of the most frequent comments that came about during the interviews with ergonomists active in the Ergonomics Society (Waterson and Sell 2006) was that it was possible in the 1960s for one person to have an overview of all of the various aspects and components of ergonomics. Many people stressed that the introduction of courses at the beginning of the 1960s had resulted in ergonomists who were capable of adopting a 'holistic' or 'whole systems' perspective in tackling applied problems. By the beginning of the 1970s it was becoming clearer that ergonomists were becoming more specialised. One of the main reasons for this was the growth of the discipline and the spread of ergonomics into domains that required detailed knowledge and specific skills.

In the very early days following the Second World War it appears that those involved in ergonomics were trying to establish an identity for themselves. Chapanis (1999) notes that human factors researchers and ergonomists were in close competition with established professions such as engineering, mathematics and physics. During the 1960s the growth of ergonomics in industry was more successful in the UK, as compared to the USA (Drury 2008a). In subsequent decades the subject matter of ergonomics within the UK became more diversified. One negative outcome from the expansion of ergonomics was that some of its 'territory' was lost to other disciplines. During the 1960s, for example, the subject matter of design was made up of various interdisciplinary groups (Murrell 1985) and it was normal for ergonomists to work alongside designers, engineers and other related professions in pursuit of a common task (e.g. product design). Over the course of time, two developments seem to have taken place. First, ergonomists became 'decoupled' from design and marginalised, their activities sometimes seen as relevant, but not essential as compared to other concerns (e.g. design aesthetics). Sudjic (2008) notes that this development is true of design as a whole and not just ergonomics. During the 1960s a paramount consideration was practicality and meeting the needs of consumers, whereas in the 1980s and 90s the emphasis shifted to manufacturers' perceptions of consumers' needs. A second development was that other disciplines started to use ergonomics themselves without actually involving ergonomists. For example, in the 1980s and 90s HCI came about as a subject in universities and industry and much of HCI borrowed concepts and ideas from ergonomics. In many respects the success of ergonomics in industry in the 1960s also proved to be something of a disadvantage in subsequent decades.

4.3. Growth of theory and methodology

One of the biggest changes to have occurred over the last 40 years is the growth of theory and methodology within ergonomics. At the beginning of the 1960s it was not clear what separated ergonomists from other groupings (e.g. work study engineers – time and motion; Hailsham 1961). By the end of the 1960s it was clear that there was a need for specific methods and techniques that could be used within specialised domains or to address generic problems in ergonomics

(e.g. task analysis). What is perhaps most interesting about the period is how many of the studies that are described, irrespective of whether they were industrial or university-based, involved the use of experiments or laboratory-based investigations. Most studies involved some sort of tightly controlled experimental procedure, where the types of outcome measures involved reaction times or other quantifiable dependent measures. In the 1970s studies became more eclectic and techniques such as error analysis and reliability assessment started to appear. Only in the 1980s did the first qualitative studies start to appear within ergonomics. The first mention of the need to assess the costs and benefits of ergonomic interventions can be traced back to the Society lecture given by Bonjer (1971).

4.4. Other changes

In the course of reading through material from the 1960s, it is clear that there was a huge amount of enthusiasm for ergonomics, not only amongst ergonomists themselves, but also amongst industrialists and researchers from other disciplines. The era was characterised by a 'can do' type of attitude, where applying the results of research to practical problems was common and to a large extent taken for granted. Amongst ergonomists there was also a great deal of faith in the ability of technology to deliver clear benefits to society at large (Drury 2008b). This situation has changed over the subsequent decades and the drive to establish ergonomics as an academic discipline has taken on more and more importance. Similarly, during the 1960s it appears that many people thought they were on the edge of a breakthrough and that ergonomics would establish itself as a discipline with a clear identity and existence in its own right. Whether this has been achieved today is a source of continual debate; however, it seems that there is still a long way to go before these objectives are met. Much can be learnt from the work carried out by British ergonomists in the 1960s and it remains to be seen how many issues, then current, re-emerge as topics of interest in the future.

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