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Patrick Waterson [a]

[a] Loughborough University Design School, Loughborough University, Loughborough, LE11 3TU, UK

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World War II and other historical influences on the formation of the Ergonomics Research Society

Patrick Waterson*

Loughborough University Design School, Loughborough University, Loughborough LE11 3TU, UK

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Little has been written about wartime ergonomics and the role this played in prompting the need for a society dedicated to ergonomics within the UK, namely the formation of the Ergonomics Research Society (ERS) in early 1950. This article aims to fill this gap in our understanding of the history of ergonomics in the UK and provide further details of the types of research undertaken by wartime research groups and committees such as the Institute of Aviation Medicine, Medical Research Council Applied Psychology Unit and the Flying Personnel Research Committee. In addition, the role of societal developments such as wartime links with the USA, the post-war drive to increase productivity and collaboration with industry and the recommendations of government committees in stimulating the work of the ERS are described in detail. This article also offers some reflection on present-day ergonomics in the UK and how this contrasts with the past.

Statement of Relevance: This article will provide practitioners with a historical perspective on the development of ergonomics from its roots in the Second World War. These developments shed light on current trends and challenges within the discipline as a whole.

Keywords: history of human factors and ergonomics; Ergonomics Research Society; Second World War human factors and ergonomics

'Nothing comparable has been achieved in civilian life to match the personnel research committees which carried out ergonomic research for the armed services during the 1940s'

(Broadbent 1979)

1. Introduction

The comment made by Donald Broadbent in his 1979 Ergonomics Society annual lecture underlines the importance of understanding the emergence of modern-day ergonomics in the UK in terms of its roots in research carried out in World War II. Within the UK, the Ergonomics Research Society [ERS – the present day's Institute of Ergonomics and Human Factors (IEHF)] came about partly as a result of research carried out by groups drawn from the various branches of the armed forces in the Second World War. In the last few years, a number of publications have appeared describing the history of ergonomics in the UK. These have covered topics such as the history of the Ergonomics Society (Waterson and Sell 2006), developments during the 1960s (Waterson and Eason 2009), as well as the role of key individuals within ergonomics such as Sir Frederic Bartlett (Stanton and Stammers 2008) and Kenneth Craik. With the exception of the work of Professor Rob Stammers (2006, 2007) on the work of one of the founding fathers of ergonomics in the UK, Hywel Murrell, one of the main gaps in coverage of the history of ergonomics in the UK relates to the activities during the Second World War. Part of the reason is that much of the material dating before the formation of the ERS in 1949 is often inaccessible or difficult to obtain. In addition, many of the people associated with the earliest days of the ERS are no longer alive. Some material, however, is available from the previous historical accounts, but only in a very brief form (e.g. Edholm and Murrell 1973, Singleton 1982).

1.1. *Aims and organisation of this article*

The aim of the present article is to provide an overview, as compared to a detailed survey, of the types of research and wartime activity that led up to the formation of the ERS. A definitive account of wartime ergonomics is likely to require the services of a professional historian and to involve extensive research in the various archives that hold relevant

*Email: p.waterson@lboro.ac.uk

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material (e.g. the National Archives in Kew, London; Wellcome Library, London). A second aim of this article is to examine in more detail the work of wartime committees and research groups and their role in stimulating the need for the ERS. The final section of this article examines the present-day ergonomics in the UK in the light of wartime work and lays out further avenues of research which could be pursued in order to provide a more extensive treatment of this aspect of the history of ergonomics in the UK. This article covers the period from before the Second World War up until the conference held by the Department of Scientific and Industrial Research (DSIR) in 1960 (DSIR 1961).

1.2. Sources of information used during preparation of this article

In general, a strategy of working backwards from some of the names of the first members and organisational groups associated with the earliest days of the ERS was adopted. In order to do this, a number of sources of information were consulted including reports and minutes of the various wartime committees and groups stored at the National Archives, Kew. Visits were also made in order to examine materials held at the Medical Research Council (MRC) Cognition and Brain Sciences Unit in Cambridge and the Wellcome Library in London. In addition, previous histories covering subjects related to ergonomics (e.g. aviation medicine – Gibson and Harrison 1984) and accounts of the wartime work of specific groups and institutions (e.g. the work of the Department of Anatomy at Oxford University and the MRC Applied Psychology Unit (APU) in Cambridge) were examined in detail. Finally, the papers written by key individuals (e.g. Sir Frederic Bartlett) were also used in order to construct an outline of ergonomic-related activity during wartime. A full list of the material consulted during the preparation of this article, including the details of specific reports held in archives, is obtainable from the author.

2. Prehistory

2.1. Fifteenth century – World War I

One of the aims of this article is to demonstrate the key role played by World War II in helping to shape and establish the discipline of Ergonomics and the formation of the ERS in 1949. World War II, however, represents only part of the story and a huge amount of earlier scientific work in Europe and the USA, as well as a number of societal developments, provided a larger context in which post-war activities involving ergonomics 'crystallised'. Monod (2000), for example, describes the influence of scientific work relevant to ergonomics which was carried out in the fifteenth to nineteenth centuries. This work includes Leonardo da Vinci's drawing and other studies of human anatomy and movement, Le Vauban's investigations of working hours during military campaigns (1682) and Bernadino Ramazzini's (1701) work on disease which paved the way for the modern study of occupational medicine (Cockayne 2007). The historian Anson Rabinbach's (1992) describes in more detail in his book 'The Human Motor – Energy, Fatigue and the Origins of Modernity' how the work of individuals in the eighteenth and nineteenth century provided a context for the emergence of a scientific approach to the study of work during the early part of the twentieth century. Some of the key individuals and scientists mentioned in Monod (2000) and Rabinbach (1992) are shown in Figure 1.

The work of Étienne-Jules Marey (1830–1904), for example, was influential in a number of fields including cardiology, photography and cinematography. Marey's laboratory experiments with animals and birds on muscle fatigue and movement ultimately led him to develop a theory of the 'economy of human work' and laws of time and motion. Some of these ideas were taken up by F.W. Taylor in his work on scientific management (Rabinbach 1992, p. 117). The publication in 1914 of Jules Amar's 'Le moteur humain' ('The Human Motor') represents an important part of the drive towards a more scientific and experimental approach to the study of work. Amar invented a number of devices including the 'ergometer', which combined a bicycle with a respirator and a means of recording physical exercise in the form of a graph. Together, Marey and Amar's work represents some of the precursors of the later studies of fatigue within ergonomics (e.g. Floyd and Welford 1953).

Aside from groundbreaking work in anatomy and physiology, the nineteenth century resulted in some of the most important examples of early work within experimental psychology (Hearnshaw 1987, The Psychologist 2010). The work of the German psychologists Gustav Fechner (1801–1887) and Wilhelm Wundt (1832–1920), for example, was instrumental in establishing the fields of psychophysics and vision science (Fechner), as well as the methods of experimentation and the discipline of psycholinguistics (Wundt). The later work of J.B. Watson (1878–1958) on 'Behaviourism' similarly contributed to experimental studies of work and influenced such later influential figures within ergonomics such as Donald Broadbent (e.g. his work on the foundations of empirical and behavioural psychology – Broadbent 1961, 1973). Finally, Hugo Münsterberg's (1863–1916) research helped to move psychology out of the laboratory and towards the

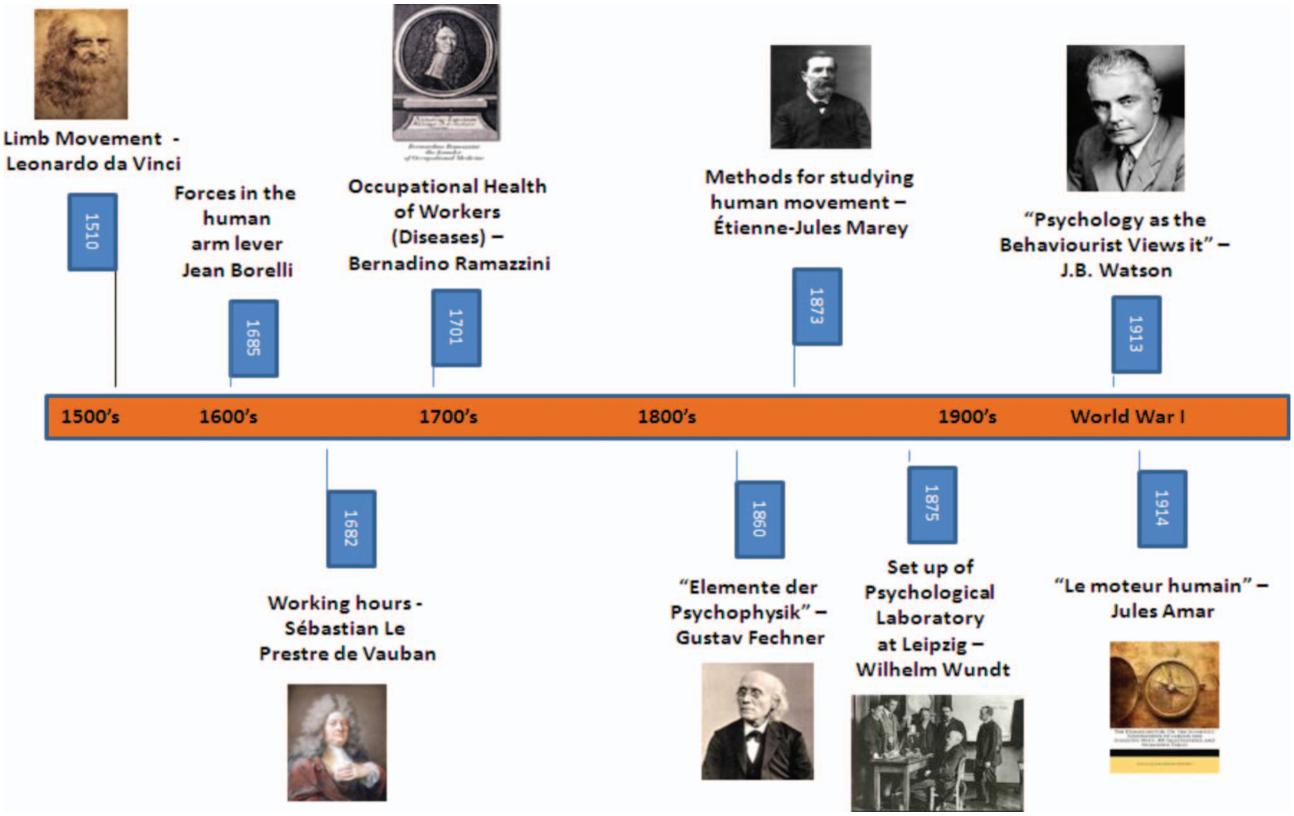

Figure 1. Timeline fifteenth century – World War I.

study of applied problems within industrial settings. The emphasis on applied psychological studies within working environments grew in importance in the immediate period preceding the First World War, one of the key influences being the work carried out by F.W. Taylor (1856–1915) and Henry Ford (1863–1947) on scientific management, time and motion study and the standardisation of planning, tools and working methods (The Science Museum 2004).

2.2. *Developments post-1918*

The outbreak of World War I prompted the need to expand the armed services and led to a large number of civilian conscriptions (e.g. pilots, drivers and telegraph operators). In order to judge the suitability of these conscripts, a number of selection and intelligence tests were devised. Between 1917 and 1918, for example, approximately two million recruits in the USA were tested in batches of up to 500 a time using intelligence tests. The increase of women working in munitions factories meant that because of the absence of modern training methods they had to learn skilled trades very quickly. Workloads increased due to the pressure of arms production during wartime; in some cases, overtime exceeded 100 h a week. One consequence of long hours and poor working conditions was an unexpected decline in the health and morale of workers and strikes, high levels of absenteeism and injury proving to be common. In 1917, the DSIR and the MRC were asked to investigate the condition of industrial workers, and, as a result, the Committee on the Health of Munitions Workers (later to become the Industrial Fatigue Board in 1918) was appointed to investigate the causes of fatigue. Under the direction of this committee, research workers from the biological sciences were called in for the first time to investigate the behaviour of workers in industrial settings. Figure 2 illustrates some of the most significant developments and key individuals in the period between the First and Second World Wars.

In the USA, the work of Lillian (1878–1972) and Frank Gilbreth (1868–1924) during the 1920s carried out a number of studies of time and motion, alongside work on fatigue. One of the most significant of their contributions was their attempts to 'humanise' elements of the scientific management approach popularised by F.W. Taylor and colleagues. Their work proved to be influential not only in areas such as postural analysis and work design, but also in applying an engineering perspective to industrial working settings and forming the basis of the discipline of

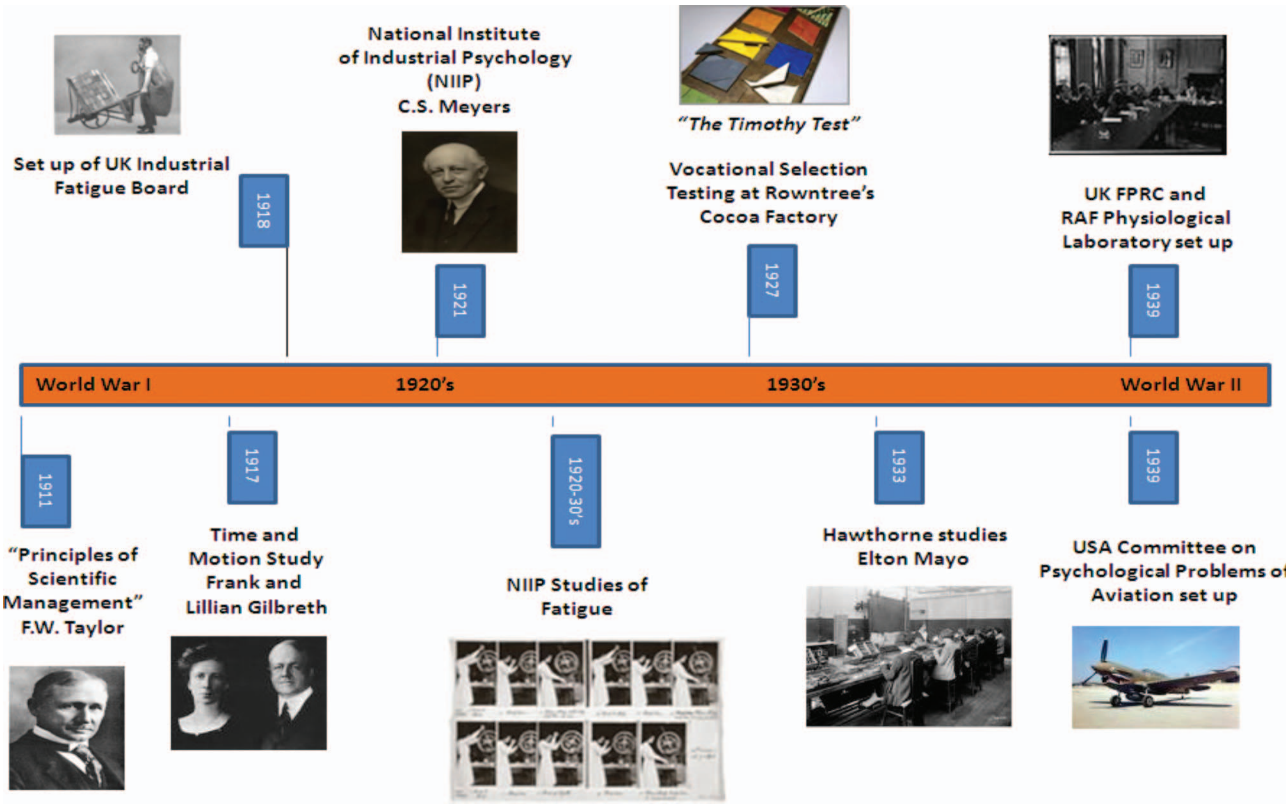

Figure 2. Timeline World War I–World War II.

industrial engineering in the USA. The work of Elton Mayo (1880–1949) at the Hawthorne Works in Chicago continued this line of research and was instrumental in demonstrating the role of group influences on worker productivity. Mayo's studies demonstrated that worker satisfaction was linked to group identity and belonging. This work later influenced the 'Human Relations' movement in the period following the Second World War and can be viewed as an important milestone in the history of research on job design and team working.

In 1921, the Cambridge Psychological Laboratory was set up as a non-profit organisation partly in order to continue the collaboration of researchers and practitioners that had begun during the First World War. One of the main contributions the laboratory made was to make available the results of physiological and psychological research to industry. During the same year, the National Institute of Industrial Psychology (NIIP) was set up by Charles Myers. The aim of the NIIP was to 'promote by systematic scientific methods a more effective application of human energy in occupational life and a correspondingly higher standard of comfort and welfare for the workers' (Welch and Myers 1932, quoted in Bunn 2001). The combined work of the Cambridge Psychological Laboratory and the NIIP before the war can in many ways been seen as important precursors of later research within ergonomics.

2.3. *The earliest days of the UK ERS (1949–1952)*

As is well known from other sources (e.g. Edholm and Murrell 1973), the term ergonomics was first coined by K.F.H. Murrell in 1949. A number of authors including Singleton (1982) and Murrell (1965) describe how the ERS came about as a result of wartime and immediate post-war work conducted in the UK and USA. As Singleton (1982, p. 1) puts it:

> 'The intention was to facilitate the exchange of ideas and expertise between the many disciplines which had made a contribution to the increased effectiveness of human performance during the Second World War'.

Right from the beginning, the ERS was supported by two honorary members, who also played a major role in wartime research, namely Sir Wilfred Le Gros Clark (1885–1971, Lees Professor of Anatomy at Oxford) and Sir Frederic Bartlett (1886–1969, Professor of Experimental Psychology at Cambridge). The presence of these very prominent individuals and their various fields of expertise reflects the balance between anatomy and physiology on the one hand and psychology on the other, which existed within the ERS in its earliest days.

Murrell (1980) in a article looking back on his career describes that as a result of informal discussions with fellow members of the members of the Operational Efficiency Subcommittee of the Naval Motion Study Unit (NMSU), it was clear that there was a desire to meet with the members from other disciplines and to have the opportunities to discuss common problems of human work. In July 1949, a dozen people drawn from all three services and from various disciplines met at the Admiralty, Queen Anne Mansions in London (the location of the NMSU) in order to discuss possibilities. The results of their discussion led to the formation of the Human Research Group with Group Captain Bill Stewart as Chairman (Institute of Naval Medicine) and Lieutenant Peter Randle as Secretary. Six months later in early 1950 the groups changed its name to the ERS.

Edholm and Murrell (1973) list in the appendices to their history of the ERS the attendees of three meetings held at various locations in London in July–September 1949. The 37 people who attended these meetings span a range of scientific disciplines and organisational groupings. A selection of these people is shown according to these groupings in Figure 3(a) and 3(b).

3. World War II research

3.1. The context of World War II research activity

The outbreak of war in 1939 Second World War brought about a huge need to allocate workers and their skills to the most appropriate jobs and tasks needed for the war effort. This need sparked an immediate revival in interest in personnel selection methods and training methods. By 1942, there was an acute shortage of aircraft, and, to counter this, the Production Efficiency Board of the Air Ministry was set up in order to decide upon the most optimal way of utilising labour in the aircraft industry. Time and motion techniques and personnel training schemes were implemented by the Board throughout industry. Within the fields of environmental psychology and physiology, the Industrial Health Board, formed in 1929 from the old Industrial Fatigue Research Board, was charged with studies relating to working hours, rest pauses and environmental conditions in factories. A number of personnel research committees, one for each of the armed forces, was set up by MRC in 1939 in order to investigate and provide solutions to the problem of selecting and training personnel. At the same time, collaboration with the USA began to take place on a firmer basis from 1940 (Hartcup 2000), and research groups in the UK and USA regularly kept in contact and exchanged scientific findings as they came about (Fitts 1946).

The types of environments in which war took place were more extreme than those to be found in the First World War (e.g. desert conditions, tropical jungles and arctic convoys). Similarly, technology and equipment were more complex and advanced (e.g. radar and sonar), and pilots, soldiers and sailors were faced with much more sophisticated weaponry as compared to 1914–1918. Together, these developments placed great demands and stresses on operators.

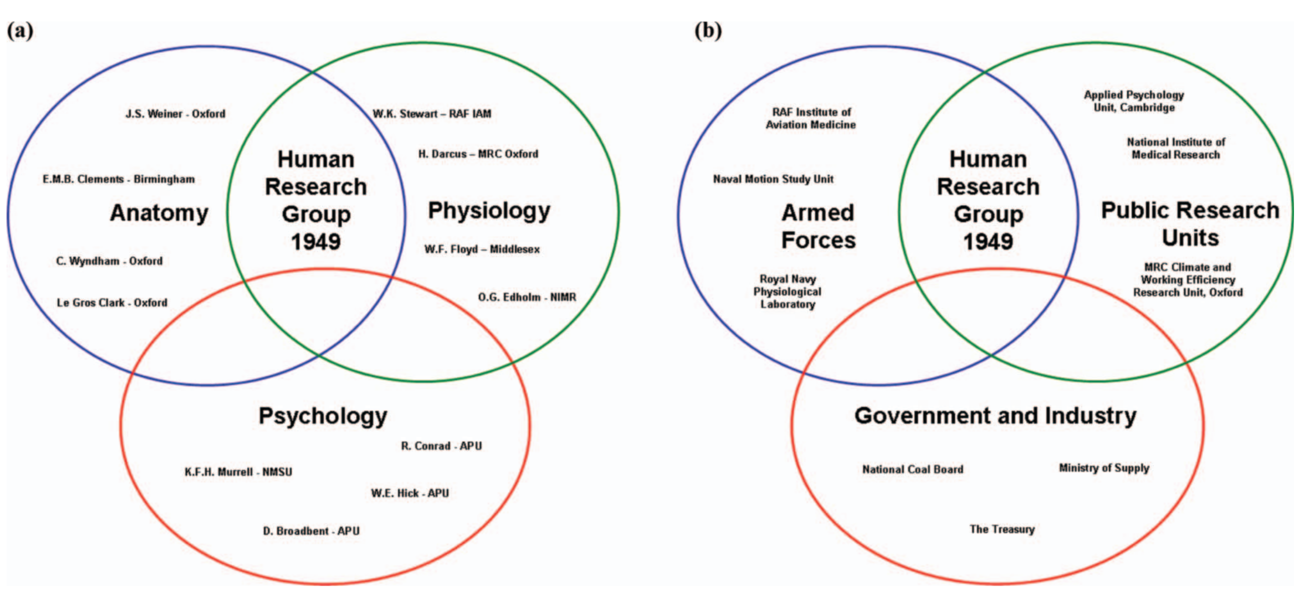

Figure 3. (a) Disciplinary groups at the 1949 meetings and (b) organisational groups at the 1949 meetings.

In 1939, the MRC responded to these challenges by setting up a number of research establishments including the Climactic and Working Efficiency Research Unit in Oxford, APU in Cambridge (from 1944) and the Division of Human Physiology in Hampstead.

The work of pilots provides one example of how precarious and dangerous the lives of servicemen could be during the war. Reid (1976), for example, reports that at one time during the war bomber crews had a 1-in–10 chance of surviving a full tour of 30 sorties. Many of these fatalities came about as a result of flying accidents and could be attributed to human error of some form or another. Aside from pilot fatigue and error, the major physiological stresses due to flying were lack of sufficient oxygen intake by pilots in the cockpit and associated spells of blacking-out during flight. These problems were brought about as a result of decreases in atmospheric pressure with an increase in altitude and the changes that occur with sudden alterations of velocity. Over the course of the war, improvements in equipment for oxygen intake as well as training for pilots in dealing with decompression (e.g. posture training) were gradually introduced. These and other developments are described in terms of the work of specific wartime organisational groups in more detail in the next sections of this article.

3.2. Examples of the work of wartime organisational groups

Murrell (1965) describes the main disciplines that were involved in early ergonomic research as being: anatomy, physiology, psychology, industrial medicine, industrial hygiene, design engineering, architecture and illumination engineering. This section of this article focuses on five research groups or organisations which span a selection of these disciplines. The role of one group (the Army Personnel Research Establishment – APRE) and the impact it later had upon the development of ergonomics within the UK is not covered in the present article (due to difficulties in tracking down historical information); however, the role of APRE and its wartime personnel in shaping the discipline should be acknowledged.

3.2.1. *The Flying Personnel Research Committee (FPRC), 1939–1950*

The decision to set up the FPRC came about as a result of a reorganisation of Royal Air Force (RAF) medical research in May 1939 (Green and Covell 1953). Gibson and Harrison (2005) report that an additional motivation for the set-up of the FPRC had been the visit in May 1937 of Wing Commander Philip Livingston to German aviation medicine establishments. Livingston was at that time alarmed by the scale of well-staffed facilities in Germany and lobbied for improvements in the UK. As a result in 1939, the Secretary for Air announced the setting up of a committee to investigate 'medical aspects of all matters concerning personnel which might affect safety and efficiency in flying' (Gibson and Harrison 2005, p. 690). The initial priorities for the committee at the beginning of the war were oxygen equipment, protection against excessive gravitational forces; work on noise, vision, fatigue and the causes of accidents (FPRC 1950). During the duration of the war, research within the committee was broadly split between work on physiology and psychology alongside research investigating aspects of psychiatry and acoustics.

In January 1940, the RAF Physiological Laboratory was formally opened at the Royal Aircraft Establishment in Farnborough under the direction of Dr B.H.C. Matthews from Cambridge University. In October 1939, psychological research was assigned to the Psychological Laboratory at Cambridge University under the direction of Sir Frederic Bartlett. A final strand of research was conducted on animal physiology and aspects of altitude problems (e.g. the causation of bends and effects of drugs and alcohol on altitude tolerance amongst pilots) at Edinburgh University under the direction of Professor I. de Burgh Daly. All of these groups reported back to the FPRC through the various members of the committee including both Bartlett and Matthews, who were also the members of the ERS in its early days.

The account given by Green and Covell (1953) alongside an FPRC report from June 1950, which lists some 600 other reports commissioned by the Air Ministry, provides some idea of the range of topics within physiology and psychology which were the subject of research during the war. Examples of these topics and a timeline of events during the war are shown in Table 1.

Whilst it is clear that the various groups associated with physiology and psychology worked on separate problems during the war, it also clear that, through the committee, they established very clear lines of communication and, in some specific instances, collaboration. Matthews (1944, 1945), for example, describes how problems such as the stresses caused by high altitude and high velocity flying such as anoxia and resultant pilot blackouts were solved by new equipment such as pressure suits and changes to the posture of pilots during flight. These types of solutions often had knock-on effects such as the need for workspace redesign within the cockpit. Changes to the

Table 1. Examples of research activities of the FPRC (Source: FPRC 1950).

FPRC report no.	Title	Authors	Date and wartime events
11	Loudspeakers for intercommunication	Royal Aircraft Establishment	February 1939
17	Medical examination of flying personnel	Bartlett, Carmichael, Whittingham and Witts	March 1939
19	Oxygen range of aircraft	Matthews	March 1939
			War begins – September 1939
89	Administration of oxygen with the RAF respirator	Ruffell-Smith	January 1940
115	Prevention of effects of cold in aircraft	Carmichael	March 1940
126	Experiments on Flying Fatigue	Bartlett	March 1940
			German invasion of Holland – May 1940
			Early RAF Sorties 1940–1941
146	Psychological studies of problems of flying training	Grindley	May 1940
			Battle of Britain – July–October 1940
			Bomber Offensive – 1940–1945
177	Final observations on the crouch as a preventive of blacking-out	Stewart	August 1940
188	Effect of anoxia on manual performance (machine gun tests)	Craik	September 1940
222	Preadaptation spectacles and use of a mydriatic (Eumydrin) and effect on the nigh visual capacity of bomber operational crews	Livingston	November 1940
			Battle of the Atlantic – July 1940–May 1943
247	Ability to discriminate dimly illuminated silhouettes	Vernon	January 1941
263(a)	Physiological effects of reducing the symptoms produced by rapid change in speed and direction of airplanes	Poppen	March 1941
269	Blacking out in the defiant aircraft	Stewart	March 1941
342	Instrument lighting for night use	Craik	July 1941
406	Investigation on effects of aeroplane noise on flying personnel under training	Dickson and Gilchrist	January 1942
426	Perception of movement in relation to landing an aircraft	Grindley	March 1942
413	Second report on aviation medicine in Canada and USA	Macdonald	December 1942
415	Legibility of different coloured instrument markings and illuminated signs at low illuminations	Craik	January 1943
519	Clinical observations on selection tests in the decompression chamber	Davis and Russell	February 1943
514	Method for studying work of teleprinter switchboard	Browne	April 1943
528	Means of measuring instantaneous rates of respiration	Roxburgh	June 1943
529(l)	Assessment of temperament by psychological methods of 1000 bomber pilots at No. 7 Personnel Receiving Centre, Harrogate	Chambers	February 1944
549	Suggested method for measuring attenuation of sounds by flying helmets	Dickson, Fry, Swindell and Brown	August 1944
573	Notes on some physiological effects of centrifugal force encountered in flight	Stewart and Davidson	March 1944
586	Faulty perception caused by blank spells without signals during experiments on prolonged visual search	Mackworth	April 1945
			Victory in Europe – May 1945

cockpit and the layout of instrumentation led in turn to the involvement of psychologists and researchers in anthropometry in carrying out evaluation exercises and suggestions for new designs. The combination of expert knowledge in physiology, applied psychology, anthropometry and aircraft design was later coordinated in 1945 by the Ministry of Supply's Cockpit Layout Committee.

A final aspect of the work of the FPRC which is worth mentioning is the extent to which it facilitated collaboration and exchange of research findings with other groups in Commonwealth countries and the USA (e.g. the National Research Council of Canada, the Royal Australian Air Force Flying Personal Research Committee and the USA Committee on Medical Research of the Office of Scientific Research and Development).

3.2.2. *RAF Physiological Laboratory (Institute of Aviation Medicine), Farnborough*

The RAF Physiological Laboratory was established in August 1939 at Farnborough initially with a staff of four research workers and a shared decompression chamber and some equipment borrowed from Cambridge University. The first compression chamber run was on 29 August 1939 (5 days before the war was declared). The laboratory was run by Dr B.H.C. Matthews throughout the war with the close support of the secretary of the FPRC, Air Commodore Harold Whittingham. The Physiological Laboratory later became the RAF Institute of Aviation Medicine (IAM) in 1945. Initially having separate sections for acceleration, altitude, biochemistry, biophysics, personal equipment and teaching, the mandate of IAM was to conduct both pure and applied research in support of flying personnel. IAM was headed in 1945 by Dr Brian Matthews and later by one of the founder members of the ERS, Group Captain Bill Stewart in 1946. IAM obtained a decompression chamber (moved from the Physiological Laboratory) in 1945, and this was supplemented by a climatic chamber in 1952 and human centrifuge in 1955. The latter facility is still in operation today and was designated a Grade 2 Listed Building in August 2007. The work of the RAF Physiological Laboratory and its successor IAM during the war and immediately following it can perhaps be best described by focusing on two examples: work on hypoxia and the provision of equipment for oxygen supply; and research conducted on survival clothing (Gibson and Harrison 1984, 2005)

During the First World War, most RAF pilots fought without the use of oxygen; the Second World War and the need for higher altitude flying highlighted the dangers of lack of oxygen (hypoxia) within the cockpit. At the beginning of the war, the RAF mainly used continuous flow oxygen systems in its aircraft. These systems proved to be wasteful and unreliable. Lung-actuated oxygen supply could not be used because of deficiencies in the oxygen masks. As a

Figure 4. Photograph of Second World War economiser.

result of these problems, Dr Brian Matthews came up with the idea of the economiser (Figure 4).

The economiser works by facilitating the flow of oxygen from the regulator into a rubberised fabric bag maintained under pressure by a spring-loaded plate. Matthews calculated that the systems would save a Wellington bomber from carrying over 500 lb (227 kg) of oxygen bottles. By September 1940, the first trials began with Spitfire aircraft, and, by August 1941, 50,000 economisers had entered service. Although the economiser did not completely fix the hypoxia problem, the device remained in service until the 1980s. Matthews led a team that did research on a variety of other issues, these included bale-out oxygen tanks, new oxygen masks and studies of the mechanisms of induced loss of consciousness caused by increased gravitational forces.

The second example of work conducted during the war at Farnborough is the research carried out by Edgar Pask and colleagues on flying clothing (Harrison and Gibson 1982). Pask is chiefly remembered for his work on survival clothing, in particular the design of life preservers for use during bail out by pilots over sea. One of the problems of carrying out simulations of the use of these types of life preservers is that it proved difficult to recreate the conditions of an unconscious man floating in water. In order to recreate these conditions, Pask allowed himself to be anaesthetised and immersed in water in a swimming pool (Figure 5). As a result of carrying out the simulations, life jackets and other types of flying clothing were redesigned and helped to save the lives of many airmen during the war. Pask also carried out work on a variety of issues related to survival at sea including methods of resuscitating unconscious airmen rescued from the sea (Pain 2002).

Figure 5. Photograph of simulations of life preserver (Edgar Pask as subject).

3.2.3. Cambridge Psychological Laboratory and MRC APU

Early work conducted at the Cambridge Psychological Laboratory focused on problems such as how to make improvements to cockpit radio communication systems. Aircraft in the early days of the war used what were known as 'Gosport tubes' – a voice tube which facilitated communication within the cockpit to give instructions and directions. These had been shown to be the cause of a number of accidents, and, as a result, Bartlett and colleagues were asked to provide advice on radio communication (Bartlett 1940).

According to Fitts (1946), the Cambridge Psychological Laboratory reported studies on other aspects of the psychological requirements in aviation equipment design as early as 1940. Bartlett (1942) attributed about 70% of all accidents to human error. One of the main explanations at the time was pilot fatigue. Experiments using simulations showed that fatigue, although a contributory factor, was not the only explanation, poor design of controls and instrumentation, amongst other factors were also to blame (Davis 1948, 1949). Donald Broadbent, himself a pilot during the war, later commented: 'the technology was fine, but it seemed to be badly matched to human beings' (Broadbent 1980, p. 44). The AT6 aircraft he was flying at the time had two identical levers under the seat, one for pulling the flaps and another which was used at the end of the landing run. Confusing between the two levers was relatively easy leading to errors and, in some cases, fatalities.

Kenneth Craik's work on pilot error using the Cambridge cockpit represents one of the most well-known pieces of research carried out at the laboratory (and later from 1944 under the directorship of Craik, the APU). Craik (1940) describes how the cockpit was actually a spitfire cockpit donated by RAF Farnborough which was fitted with intact controls and an instrument panel similar to that used in operational sorties. All of the instruments could be mechanically operated by the experimenter. Pilots were 'sent out' on a simulated flight and their movements could be recorded and analysed afterwards (Figure 6).

Research using the Cambridge cockpit was some of the first to demonstrate that skilled behaviour is dependent to a large extent on the arrangement and interpretation of displays and controls. The work helped to emphasise the importance of designing controls and instrumentation design that fitted the capabilities and limitations of the operator. Craik (1944) describes how later work focused on a variety of topics centred around the issues of control and display including research on the design of instruments, machinery and the layout and illumination of maps and panels. Mackworth (1944) and Hick (1946) also report findings relating to the aiming of bombs at targets and rifle aiming which had been carried out in collaboration with the Ministry of Aircraft Production and the Army Operational Research Group. A good deal of other work was conducted on naval tasks such as vigilance during operational watches (Carpenter 1946, Mackworth 1950). In addition, a number of other research studies were conducted during the 1940s on non-military industrial tasks such as scale and dial reading (Vernon 1946) and the use of muscle forces in manual control design (Hick 1945).

Following the war, research at the APU focused more on problems within the civilian domain including the design of road safety posters (Belbin 1950) and the impact of cinema clubs on children's attitudes and behaviour (Fellows and Mitchell 1949). Some important work was held over for publication until the end of the war; this includes the work of Bartlett and Mackworth (1950) on the design of operational control rooms. After the war, the ergonomics of cockpit design and many other problems in applied military psychology transferred to the RAF IAM. The tradition of research carried out at the APU and directly influenced by the work Kenneth Craik and other APU researchers was carried on by Wing Commander Ruffell-Smith and colleagues at RAF IAM.

The role played by the Cambridge Laboratory and the APU in stimulating the growth of research in ergonomics cannot be understated. Neville Moray speaking at a conference held in 2005 to celebrate the legacy of the APU summed up the contribution in terms of the distinction between pure and applied psychology:

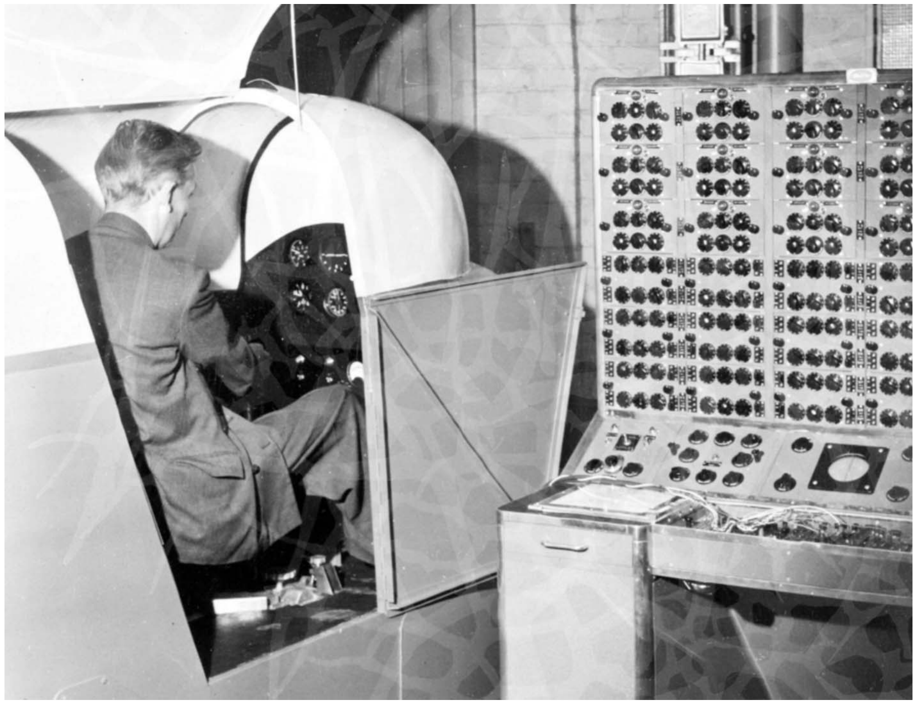

Figure 6. Photograph of Cambridge cockpit (Source: MRC Cognition and Brain Sciences Research Unit (CBRSU)).

> 'Applied people, whether engineers or psychologists are concerned primarily with prediction: it does not matter if they know their theories to be incorrect providing they predict what will happen. "Pure" researchers (academic psychologists) are concerned with explanation, not prediction. The APU could just as well have been called the Institute for Ergonomics or the Institute for Human Factors'
>
> *(Moray 2005)*

3.2.4. School of Anatomy, Oxford University

The study of anatomy has a long history at Oxford University stretching back to the sixteenth century. A formal Department of Human Anatomy was established at Oxford in 1893. The name of Sir Wilfred Le Gros Clark (Dr. Lee's Professor of Anatomy at Oxford, 1934–1962) regularly crops up in early meetings of the ERS, and it is clear that he was an early and valued supporter of ergonomics within the UK. The work of Le Gros Clark and his colleagues during the war focused on a range of ergonomic issues including carrying out an extensive anthropometric survey of service personnel in order to get adequate measurements of body size and their range of variation (Le Gros Clark 1946). The survey was carried out in collaboration with Dr G.M. Morant from the War Office and involved a number of unexpected problems alongside the design of special measuring apparatus. For example, one problem proved to be that little information at the time was available on the amplitude of movement of joints of the body whilst operating different types of equipment. Similarly, anatomical textbooks contained information on the movement of individual joints, but little on the movement of joints in combination. These problems called for new research as many operational tasks such as tracking aircraft movements using binoculars required a detailed understanding of not only eye movements, but also the movements of neck muscles. These problems and many others promoted the need for close interactions between researchers in anatomy and the designers of equipment and were often carried out across disciplinary boundaries (e.g. anatomy, engineering and physiology).

A significant amount of research was conducted at Oxford on the design of seating for use with wartime equipment, particularly for naval warfare (Darcus and Weddell 1947, Weddell and Darcus 1947 – Figure 7). This seat was later adopted as a standard by the British Iron and Steel Research Association for use in its steelworks.

Seating proved to be of considerable importance for a variety of wartime personnel (e.g. tank drivers and ship lookouts) where the tasks facing the operator involved maintaining a steady body posture and locating a target, often whilst under extreme conditions such as violent movements associated with defence and attack. As a result, the seats needed to be designed in order to meet a number of requirements including

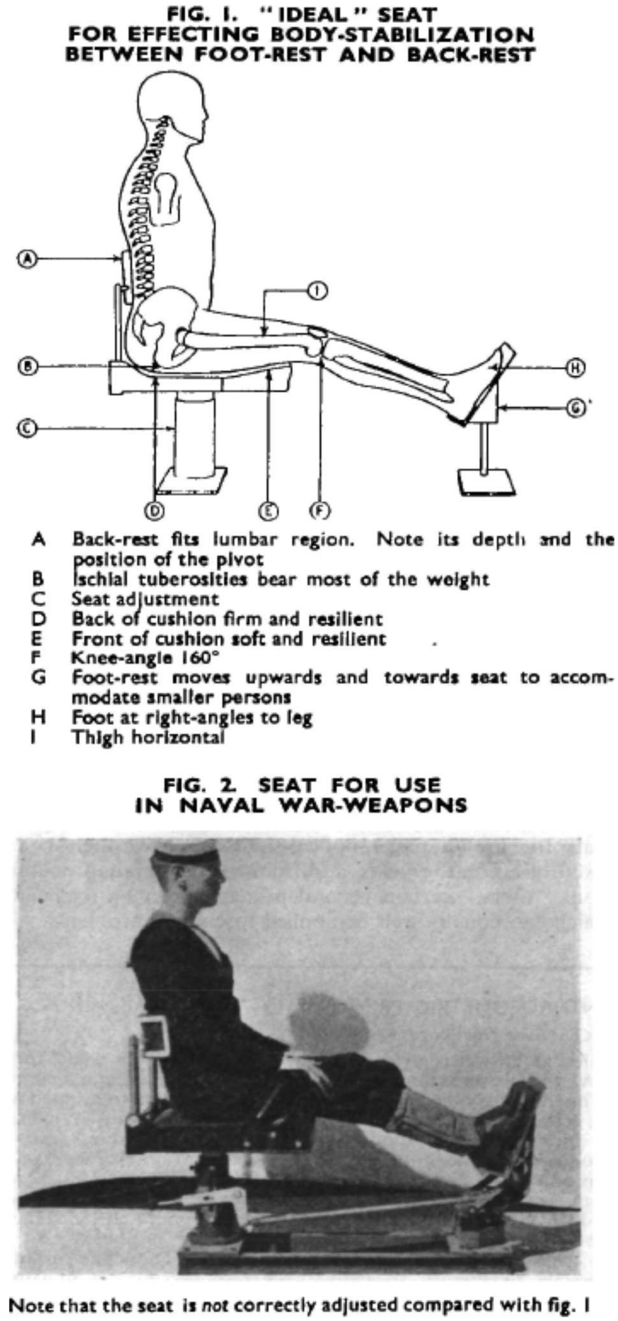

Figure 7. Excerpt from Darcus and Weddell (1947).

minimising discomfort and fatigue over long periods of use, permitting maximum stabilisation of the body whilst keeping the arms free to manipulate controls and being strong enough to cope with severe usage. These requirements proved very difficult to satisfy and only after extensive experimentation and testing were optimal seats designed for specific wartime equipment and service personnel.

A number of other lines of anatomical research which overlapped with ergonomics were pursued at Oxford; these included studies of the impact of air raids on different types of houses and shelters. This type of work helped rescuers to identify the locations within houses following an air raid where survivors were most likely to be found. Other work conducted by Joseph Weiner (1915–1982) in 1940, another founder member of the ERS, examined how to most effectively ventilate air raid shelters during their occupancy and increase the flow of air throughout these types of temporary buildings.

3.2.5. Admiralty NMSU

In a series of papers covering the work of Hywel Murrell, Stammers (2006, 2007) sets out the main areas of work of the NMSU during the 1940s and early 1950s. Amongst the topics that were research at the NMSU were the application of motion study techniques for analysing ammunition handling and gun drill tasks. The aim of this type of work was to reduce time taken to do tasks and manning levels. Later on during the late 1940s and early 1950s, research, similar to that described by Bartlett and Mackworth (1950), was carried out on the physical layout of control rooms and the lines of sight used by control room personnel, as well as barriers to effective physical communication. Other parallels can be drawn between the work of the NMSU and Cambridge APU, for example, research at NMSU was conducted on the aspects of continuous performance in watch-keeping tasks and the optimal shape and orientation for the design of dial displays.

Murrell (1980) recounts in his autobiographical account of his career that the Naval Motion Unit was set up in the summer of 1948 and that the name of the unit was a misnomer as most of the work was concerned with he termed ‘human engineering’. In the late 1940s, ‘human engineering’ was sometimes used in connection with human factors research in the USA, and, during this time, it was clear that Murrell built up a close relationship with the American Office of Naval Research – Paul Fitts, Cliff Morgan and Alphonse Chapanis, all of whom were regular visitors to the UK during the 1940s and 1950s. Likewise, research at the NMSU was influenced by similar research conducted within the USA; for example, British Standard 3693 (Murrell 1973) concerning the readability of dial faces, was informed by the work of Alphonse Chapanis and C.J. Berger (Murrell 1954).

4. The immediate post-war context

4.1. Maintaining multidisciplinary relationships and groups

Following the war, there was clearly a good deal of enthusiasm for continuing, and building upon, the good working relationships which had existed within wartime multidisciplinary groups. In an article entitled 'Psychology after the War', Bartlett (1944, p. 5) points to the need to build upon the outcomes of wartime research:

> 'The guiding principle is to determine how the most widely distributed capacities in the way of mental and bodily behaviour can be efficiently exercised. In a number of war directions this has been done, but exceedingly little has been effected with regard to common industrial functions or any of the arts of peace'.

Much of the work of organisational groups and units during the war had been short term and highly problem focused with the emphasis being on the delivery of quick results. Craik (1945) uses a distinction which appears to have gained some currency during the war; he describes research concerned with 'fitting the job to the man', giving the example of the design of machinery from industrial design which is safe and does not cause accidents, and 'fitting the man to the job' work, for example, studies of the efficacy of training and methods for personnel selection. He likewise stressed the need to capitalise on the work conducted during the war and seek to go beyond short-term concerns (p. 26):

> 'The essential thing is that the scientific abilities of the members for basic research which ought, sooner or later, to have its effect on particular problems, should not be swamped by work of transitory and local value'.

A final quote from Mackworth made at a meeting of the British Association held in Newcastle in 1949 ('Human Problems in the Design of Machinery and Working Methods') demonstrates that one outcome from wartime research was a perception that there was a need to continue on with ergonomic research and to produce a more systematic body of findings that could be generalised to a wide range of work contexts:

> '... many instances were quoted ... in which ordinary common sense has been lacking in the planning of the physical, psychological and social environments in which people work'
> *(Mackworth 1950, p. 982)*

> 'These rapidly changing requirements stress once again the need for investigation directed towards discovering the principles of the subject, rather than for studies which are only ad hoc investigations'
> *(Mackworth 1950, p. 984)*

The first major organised event in the history of the ERS is the symposium 'Human Factors in Equipment Design' (Floyd and Welford 1954) which was held in Birmingham in 1951, followed by the 1952 Cranfield symposium on 'Fatigue' (Floyd and Welford 1953). Many of the participants at these symposia were from either Oxford or Cambridge, alongside researchers from London, Durham and Leeds Universities. It is clear that even at this early stage that the ERS attracted a great deal of interest from overseas scholars, as is borne out by the number of participants attending the two symposia from countries such as Sweden, Denmark and the USA. The two symposia also helped to sharpen the focus of early research on ergonomics particularly as it related to gaps in knowledge. Le Gros Clark (1954) describes how little was known about the mechanical capacity of the human body in working environments; a lot of studies, for example, had inferred the working of muscles from the study of cadavers.

The late 1940s and early 1950s represent something of a melting pot of ideas and work centred around productivity. One possible driver for the emergence of ergonomics within the UK was the desire to establish the subject alongside other disciplines which occupied similar territory (e.g. industrial and occupational psychology – Bartlett 1948). A similar inference is that there was a need to distinguish ergonomics from these disciplines and to capitalise on it unique features (e.g. the combination of psychology and anatomy and physiology).

4.2. *Wider societal developments*

Following the war, there a number of other societal developments that clearly shaped the emergence of ergonomics as a discipline within the UK. The wartime need to utilise national resources, both physical and human, eventually led to a 'flowering of statistical and factual studies that helped to lay the foundations of the welfare state' (Shimmin and Wallis 1994, p. 48). Cherns and Perry (1976) similarly point to the unique conditions which the war created and the consequences this had for post-war research within the universities. These included the need for selection and testing for a range of jobs which demanded skills rarely found in civilian life; studies of human skill which proved to be invaluable in dealing with the new tasks required of aircrew and vigilance task of operations room and radar watches; the discovery that weapons and their users formed one system: many of the difficulties in training men to use them in operating and in maintaining them were attributable to the fact that they were not designed with operators or maintenance personnel in mind. These types of conditions encouraged studies which crossed the boundaries between the engineering, biological and behavioural sciences.

The availability of funding for research from government during the late 1940s and early 1950s also did much to get ergonomics as a discipline off the ground. In 1947, the Labour Government set up a Committee on Industrial Productivity with a panel on Human Factors chaired by Sir George Shuster – Shimmin and Wallis 1994, pp. 48–49). One outcome from the panel was the recognition that scientific knowledge was patchy and non-existent in some areas, and, as a result in 1950, it was decided that work start on two DSIR/MRC joint committees – one on Human Relations in Industry and the other on Industrial Efficiency in Industry. Later, in 1952, a Conference on Human Relations on Industry took place and one of the recommendations from the conference was the need for academic research on 'Human engineering studies (fitting the job to the man)' (Ministry of Labour and National Service 1952).

Within ergonomics and the ERS emerged the proposal in 1959 that the European Productivity Agency should draw up a large-scale project on ergonomics (later to become the 1959 Zurich conference, preceded by conferences in Cambridge in 1955 and Leiden in 1957) – management and labour representatives from 13 countries. ERS contacted DSIR in order to organise a similar conference in the UK (1961 DSIR conference). At the same time, the Trades Union Congress (TUC) requested DSIR to bring along the results of recent research to the notice of industry. Requests were supported by the Human Sciences Committee, and, so, plans were held for the 1961 conference (Jephcott 1961). As a result of these and other developments, the DSIR conference on ergonomics in industry (DSIR 1961) took place in 1960. By 1958, financial support for the various committees that helped to get ergonomics off the ground (partly stemming from US Conditional Aid funds) and industry's interest in the human sciences had increased and 'a sound nucleus of fundamental research activity had been established' (Singleton 1982, p. 72).

4.3. Anglo-American relationships

During the 1950s' collaborations with American and allied forces, scientists continued and extended in scope. The ERS membership list for 1951, for example, lists a number of prominent USA scientists including Paul Fitts, Leonard Meade and Clifford Morgan as members. Singleton (1982) highlights the USA as a providing a role model for the development of ergonomics within the UK and Europe, whilst acknowledging that American 'Human Factors' was oriented towards psychology and engineering from the beginning, as compared to Europe where anatomy, physiology and psychology were more prevalent. A survey by Kraft (1958) demonstrated in the mid–1950s a rapid expansion of human factors within USA companies partly stimulated by USA Department of Defence edicts regarding the design of military equipment and the expansion of the space programme during the late 1950s. In many respects, this proved to be a spur for European ergonomics to 'catch-up' with American developments and emulate the success of industrial take-up of human factors and ergonomics.

The early days of the Human Factors and Ergonomics Society (HFES; founded in 1957 as the Human Factors Society) share many similarities with the immediate post-war history of the ERS. The HFES 50th Anniversary booklet (Stuster 2006), for example, contains many recollections by early HFES members of the character of meetings and topics for discussion during the 1950s. Harold Van Cott (cited in Stuster 2006, p. 7) describes how the HFES evolved out of the meetings sponsored by the organisations such as the Office of Naval Research, the Army Research Office and Air Force Office of Scientific Research. These meetings were mainly small, informal gatherings which gradually grew in size until there was a need for a more formal organisational structure. Alphonse Chapanis' account of his scientific career (Chapanis 1999) along with Meister's history of human factors and ergonomics (1999) also describes the emergence of HFES from wartime research groups. Many of these groups were working on similar problems to those described earlier on in Section 3 such as pilot error, equipment design and anthropometry. The need and desire to share, communicate and extend the results from these types of studies helped to provide a basis for the formation of societies and bodies within human factors and ergonomics on both sides of the Atlantic. Further discussion of the role of international developments is taken up later on in Section 5.3.

5. Discussion

This section summarises the main outcomes and other factors which shaped the emergence of ergonomics in the UK and the formation of the ERS in 1950. These factors include developments before World War II; outcomes from Second World War activities; developments in other countries and later 'catalysts' occurring in the late 1940s and early 1950s within the UK. Figure 8 summarises these factors and their influence on the ERS up until the 1960s.

5.1. Developments before World War II

The scientific developments described within Section 2 alongside the influence of World War I and wider

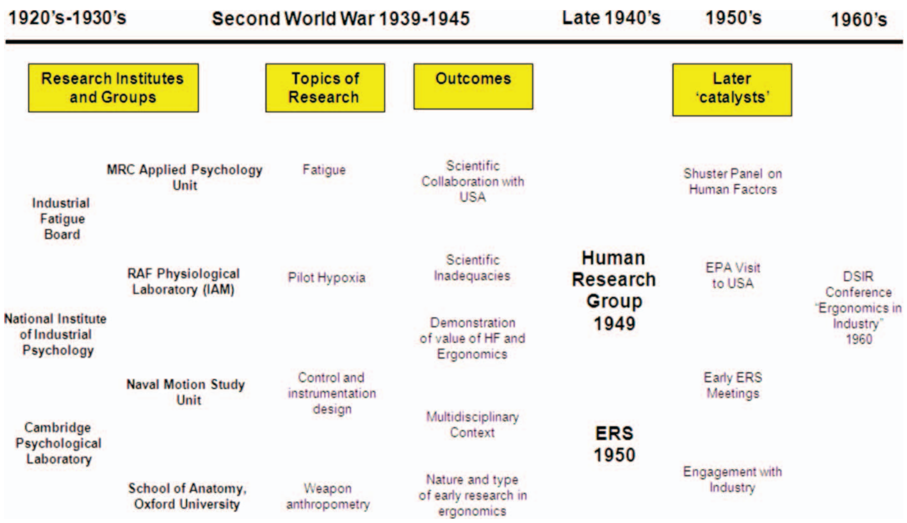

Figure 8. Second World War outcomes and other factors shaping the development of ergonomics in the UK.

changes within society, clearly set a context for both the content of activity within ergonomics (e.g. anatomy and psychology), as well as the need to transfer findings from basic science into practical interventions within work-based settings (e.g. factories and offices). The influence of nineteenth century scientific developments in particular (e.g. experimental studies of fatigue), shaped the course of later research which can be described as falling within the remit of ergonomics. It should be noted that these advances and societal changes shaped the development of most of the sciences in the period before World War II. Many of these, such as engineering, played a much bigger role within ergonomics later on in the history of the discipline (e.g. systems engineering – Waterson and Eason 2009).

5.2. *Outcomes from the Second World War*

The close working relationships and collaborative partnerships formed during the Second World War to a very large extent brought about and fostered the development of ergonomics as a discipline in its own right following the war. The need to solve practical military problems under time pressure and limited resources partly meant in many cases that ergonomics came about in order to provide solutions to practical problems and gaps in scientific knowledge. The close interrelationship between physiological and psychological factors and the role these played in helping to suggest improvements to the design of equipment, for example, also suggested new areas of scientific investigation (e.g. physiological phenomena often had psychological consequences – e.g. stress and mental fatigue). Likewise, anatomical studies of equipment use sometimes resulted in the need for workspace design and the involvement of other specialisms (e.g. psychology). Similar relationships between disciplines (e.g. engineering and psychology) were struck up during the war and continued to this day.

The need to coordinate and communicate results from early research in ergonomics during the war also prompted the need for the ERS. It is clear that there was a high degree of overlap between many of the research topics investigated by the various organisational groups described earlier on in this article (e.g. work on the design of controls and instrumentation). In some instances, there may have been the danger of research being out of date or repeated and these concerns necessitated some kind of forum for the exchange and dissemination of research findings across the multidisciplinary boundaries that make up the subject matter of ergonomics. These types of concerns may have been especially relevant given the degree to which successful, mutually beneficial relationships had been struck up between research in the tradition of human factors in the USA and ergonomics in the UK.

Another outcome from the war may have been the realisation that there was a need for the sort of holistic, integrative perspective provided by ergonomics. Such a perspective cut across disciplinary boundaries with the aim of improving work environments:

> '... individual machines and their operators should be integrated so as to produce a single entity working at maximum efficiency'
>
> *(Le Gros Clark 1946, p. 41)*

Likewise, the growing sophistication of technology raised meant that the safety of operators might be compromised. These types of issues raised the need for some of the fundamental areas of early research in ergonomics such as allocation of function (Fitts 1951):

> 'the human element must be linked up with the mechanical otherwise the machine will outpace the men'
>
> *(Senior Wartime RAF Medical Officer quoted in Hartcup 2000, p. 132)*

Finally, the nature of much of wartime research in ergonomics often based upon an 'objective and experimental stance' and its ability to convince 'hard-nosed' individuals of the value of this type of work helped the discipline to be taken seriously (Stammers 2006). These types of attributes of ergonomics, alongside the unique combination of combining anatomical and physiological aspects of work environments, may have attracted the attention of employers and industrialists to the value of ergonomics.

5.3. *Developments in other countries*

As noted in Section 4.3, the formation of the HFES in 1957 and descriptions of the origins of that society bear many similarities with the early days of the ERS. The notion that the discipline of ergonomics came about primarily as a result of the ERS is misleading. Rather, the work of multidisciplinary wartime groups created a set of conditions within other countries, primarily the USA, which promoted the need for the new discipline of ergonomics. The likelihood is that scientific collaboration between the USA and UK during the war speeded up this process. The founding of the new discipline of ergonomics has much to do with the ERS, but this is only part of the story. The role of HFES and other societies [e.g. the German 'Gesellschaft für Arbeitswissenschaft' ('Society for Work Science') – founded in 1953] should be seen as playing an equally important role.

5.4. *Later post-war 'catalysts'*

As attested by other accounts of the early days of the ERS (e.g. Edholm and Murrell 1973), there was a huge amount of enthusiasm for bringing together researchers with a common interest in ergonomics following the war. During the 1950s, the subject could be said to have begun in earnest, and the decade leading up to the 1960 DSIR conference saw what began as a small-scale gathering of like-minded individuals grows into a fully fledged body of researchers and practitioners within the ERS. In many respects, the tone of some of Murrell's writing on the subject reflects an element of surprise at the success with which ergonomics took off. Three factors, aside from initial enthusiasm, could be said to have shaped developments during the 1950s. Firstly, the availability of government funding following on from the Shuster panel and other committees. Secondly, the outcomes from the EPS mission to the USA, where many of the participants came back from the USA (e.g. Singleton) with the desire to emulate the success of American human factors engineering and establish ergonomics within the UK. A final catalyst could be said to be the interest shown by industry in ergonomics right from the earliest beginnings of the ERS in 1949 as evidenced by the attendance of industrialists at early meetings of the society.

6. Linking the present to the past

6.1. *Changes within the ERS (IEHF)*

The changes that have taken place within the ERS and its transition into today's IEHF have been described in detail in other articles which record the history of the society up until 1999 and developments in the 1960s (Waterson and Sell 2006, Waterson and Eason 2009). One of the key developments has been the move from the IEHF as a purely scientific group to a body representing ergonomics as a professional practice. Murrell (1970) sums up this transition:

> 'One thing I am sure none of us had envisaged was the development of a professional ergonomist. We were, if you like, society oriented rather than individual oriented; in other words, we felt that ergonomics would provide a forum for the exchange of information between scientists rather than a body of knowledge which would require experts for its application'.

To a large extent, this split between the academic and the practitioner groupings within the modern-day IEHF continues to be an issue of continued debate and is reflected in attempts to gain formal recognition and status in the form of current drives to achieve Chartership within the UK (an issue which dates back to the 1960s).

Another important change is the worldwide growth of ergonomics (Caple 2010) and the establishment of bodies such as the International Ergonomics Association (IEA). The context and scope in which the IEHF operates is a global one and much larger as compared to the early days of the ERS. One consequence is the volume of information generated by the activities of the various groups and societies which make up the IEA. Scientific and professional exchange on the scale associated with the post-war ERS is in some respects more difficult to achieve.
In short, the identity of the IEHF has shifted from what might be term 'backroom wartime personnel'

(Waterson and Sell 2006, p. 791) to a much larger organisational entity serving the needs of academics and practitioners. One of the main challenges for the future will be attempting to reconcile some of the differences and problems caused by simultaneously trying to be a 'learned society' and a professional practitioner organisation.

6.2. *Changes to the 'scientific DNA'[1] of human factors and ergonomics*

The last 60 years have seen many changes to the core scientific sub-disciplines which make up ergonomics. The post-war period could be characterised as a three-way split between those who worked in anatomy, physiology and psychology (Figure 3a). One consequence of this early multidisciplinarity was that ergonomists approached working environments from a 'holistic' point of view (Singleton 1982). Changes to the design of an aircraft cockpit, for example, were most likely to have been informed by a set of evaluations covering not only anthropometrics, but also physiological (e.g. oxygen supply) and cognitive factors (e.g. pilot error). As the discipline developed during the 1960s, other specialisms and disciplines began to be involved within ergonomics. To take the example of the cockpit again, we might have expected ergonomists during the 1960s to draw on research from job design and ask questions about management attitudes to safety within the airline or military organisation. Today, a whole range of disciplines spanning systems engineering, risk management and organisational behaviour are likely to be interested in issues associated with the design of cockpits and aviation safety.

During the 1960s, the 'systems approach' within ergonomics took on a precedence which has lasted until the present day, and a lot of research was informed from cybernetics and general systems theory. In many respects, a concern in applying a systemic

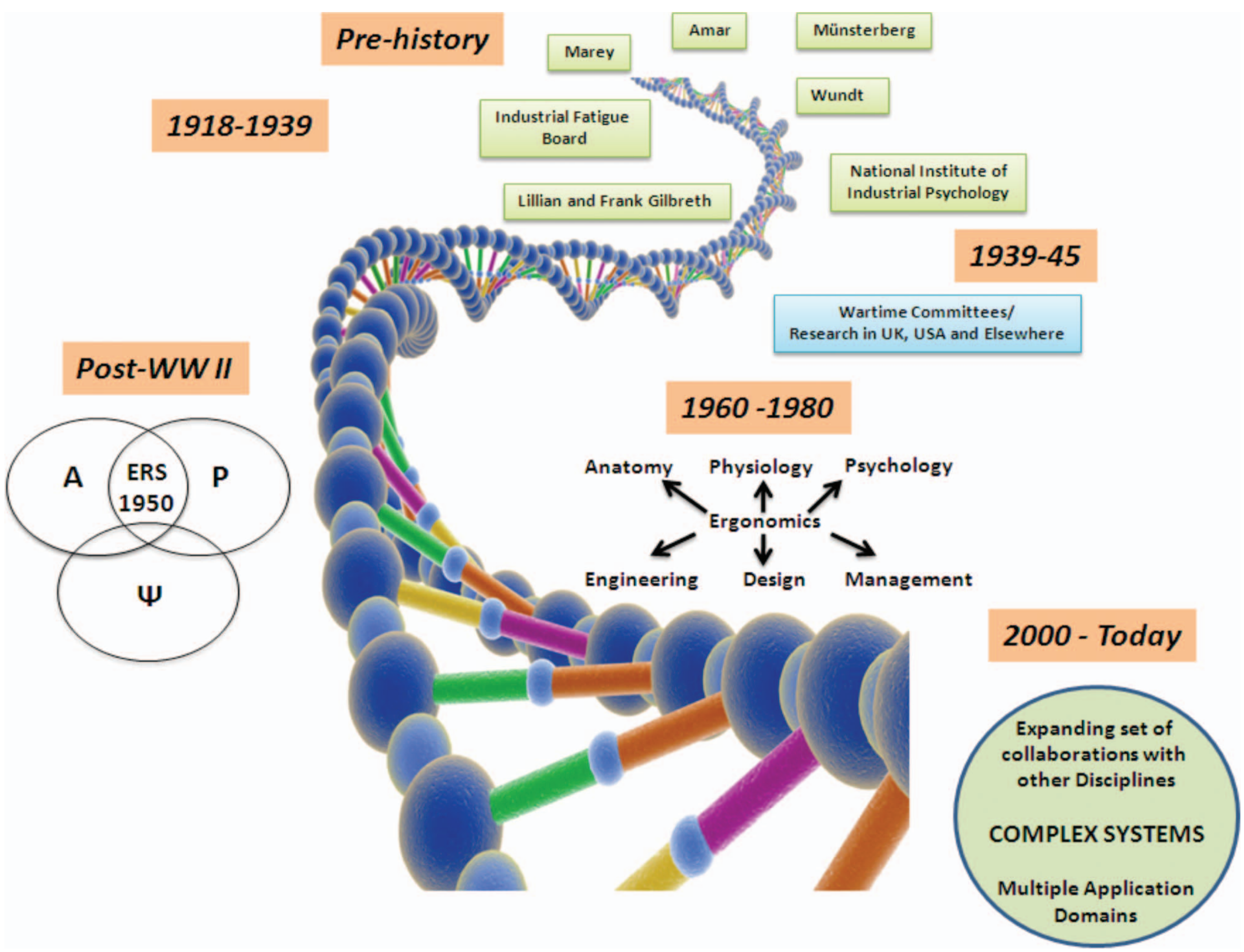

Figure 9. The 'scientific DNA' of ergonomics over time.

approach to ergonomic issues could be said to be one of the factors which 'glues' together all of the elements and sub-disciplines within ergonomics. In order to cope with the number of disciplines which 'interface' with ergonomics, Pheasant (1986) described the discipline as an 'information channel' comprising not only anatomy, physiology and psychology, but also three other disciplines (engineering, design and management). Figure 9 is an attempt to show some of the developments within the 'scientific DNA' of ergonomics stretching back to the prehistory of ergonomics.

Speculations about the future shape and form of ergonomics are difficult and likely to prove misleading in the longer term. Recent analysis of publication trends point to a waning interest in physiological aspects of ergonomics (e.g. Waterson et al., in preparation); however, these require further work and there is a need for more detailed research on this topic. Present-day ergonomics appears to draws on an even larger set of related subjects and disciplines as compared to the past. Much of this work draws on systems approaches within ergonomics and elsewhere (e.g. risk management and safety science). As ergonomics grows, there is also a danger that some of the original 'territory' of the discipline is lost to other specialisms. This is particularly the case where core components of ergonomics (e.g. adopting a systemic perspective in order to analyse complex systems) are misunderstood or misapplied within work environments (e.g. health care – Waterson 2009, Catchpole 2011).

7. Conclusions and future work

In many ways, the prehistory of ergonomics helps to shed light on the current state of the discipline. In this article, material relating to scientific research relevant to ergonomics pre-1939 has only been touched upon; much more material could be mentioned and there is scope for much more research to be undertaken. It remains an open question as to whether the success of wartime committee work quoted by Donald Broadbent above can ever be replicated in the future. The work conducted during the war is testament to what can be achieved under very difficult circumstances and when boundaries between disciplines are temporarily discarded in order to achieve a common aim. Many people, for example, would suggest that ergonomics has become too specialised and that working relationships between experts from psychology and biology are much rarer today as compared to the past. Similarly, a look back at the history of early ergonomics might cause us to ponder the nature of the discipline as a whole – is it a discipline in its own right or a loose coupling between specialisms? It is fair to say that these types of questions have dominated discussions within ergonomics and the IEHF for a long time and are likely to do so for the foreseeable future.

The account of wartime and immediate post-war ergonomics given in this article is best interpreted as only a relatively modest survey of the territory which needs to be explored in much further depth. The present article only really touches the surface. For example, the work of other types of research establishments (e.g. the various wartime MRC establishments and units aside from the APU and IAM) could be pursued in further detail. Likewise, much more has been written about wartime aviation ergonomics, as compared to the work of army and navy groups. As a result, it is possible that the present account overemphasises or overlooks some aspects of the history of UK ergonomics before 1949. During the writing of this article, it became clear that there is a large amount of material available in various archives. Much of this is hard to locate given the problems involving in cataloguing wartime research papers and government communications. Future work should aim as much as possible to investigate this in more detail (particularly material held in the National Archive in Kew). Finally, there is a need for to extend the account given in this article to include wartime research carried out in other countries (e.g. the USA) and Europe.

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Note

1. I am grateful to one of the reviewers of this article for suggesting this term.

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