Handbook of HUMAN PERFORMANCE

Edited by

A. P. SMITH & D. M. JONES

Volume 1

THE PHYSICAL ENVIRONMENT

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General Preface

In this three volume series, the effects of different states and environments on performance are examined. That contemporary research in this area could not be encompassed in one volume marks not just the diversity of effects which now come under this rubric but also its maturity as a subject area. Twenty years ago, this would have been a slim volume indeed!

What are the factors which caused the growth of interest which led to the book? No single factor can be identified, rather the interplay of several factors seems to be responsible. Initially, interest centred on the use of task-performance as measures of central nervous system efficiency and as indices which by-passed the difficulty of obtaining objective measures of the person's state. Models of human performance became more refined in the decades after the Second World War, because the judicious selection of tasks meant that a more analytic approach could be used. This approach yielded more than a simple index of performance to represent overall efficiency. Rather, using a battery of tasks or by careful analysis of the microstructure of individual tasks (often focusing on the interplay of several measures), qualitative judgements could be made about the action of the agent. The term 'efficiency' in this context is somewhat misleading because it seems to imply that the main interest is in loss of efficiency and in obtaining some single quantitative index of the person's state. Although this might be part of the motivation, particularly for the early studies, latterly much more interest has centred upon discerning different classes of response. This helps to further our understanding of the physiological basis for each of the effects and the likely interplay of factors.

The increasing portability and cheapness of microprocessors has also played a role in the increasing scope of work. By using microprocessors, field observations may now be made with the accuracy that was hitherto only possible in laboratories. We can now judge the effect of a particular factor at the place of work and moreover for extended periods of time. In each of the contributions, authors have provided an up-to-date account of the empirical

work in the area. Where possible, findings are presented from both laboratory and field settings and in each case discussion of methodological issues will also be found. Some work is still in the very early stages and hence highly developed and integrated theories are not always the rule. The volumes provide, in their breadth and depth, a cross-section of interesting work in the area of human performance.

The three volumes reflect the division of work in the area into three distinct but often interacting domains. Volume 1 has its roots in occupational health and work psychology. It contains some of the longest established areas of interest: noise, heat, distraction and vibration. New industrial processes and machines have introduced new concerns such as the increasing use of solvents in the chemical industry, the concern about hyperbaric environments in the search for oil and the behavioural effects of electrical fields and ionization in the distribution of electricity. The contents of Volume 1 also reflect the fact that much more work is now undertaken in offices than in factories (at least in the Western world). Visual display units, once a rarity, now seem ubiquitous. Although the settings in which they are used are by and large more hospitable in some respects than the traditional shop-floor, the pace, content and organization of work will still have consequences on efficiency.

Volume 2 contains research which is very much less traditional and which has been marked by enormous growth in the last decade. Here the emphasis is on the relationship between health and behaviour. Three complementary approaches can be discerned. First, there is growing evidence and concern about the effect of behaviours such as smoking and alcohol consumption on performance and well-being. Second, the behavioural consequences of illness (acute and chronic, mental and physical) in terms of the effects on performance are examined. Third, and perhaps the longest recognized is the interest in psychological side-effects of treatment both on mental and physical health.

Volume 3 continues to regard the state of the person, but its scope is in terms of chronic, long term, slowly-changing effects of state. This volume also takes up the theme of chronic and acute change in state by setting aside a section to the study of individual differences in state and trait. The periodicity of the day–night cycle has implications for efficiency because alertness varies with the time of day, the nature and, more particularly, the length of work. Even when undisturbed, these factors produce a change in efficiency. When disturbed, by shiftwork or emergencies, the consequences are normally much more dramatic. There is obvious practical interest in knowing what effects new patterns of work will have on the person both in the short term for efficiency and in the long term, for health.

Preface to Volume 1

The emphasis in this volume is on the effects of the setting in which the person undertakes work. Five main types of environment are distinguished: settings involving sound and vibration, thermal environments, gaseous environments, electromagnetic environments and visual environments. This list is not exhaustive, as the reader will readily appreciate. The scope of the sections and chapters reflects those areas which are relatively well-established and whose literature is sufficiently coherent to be of consequence in theoretical and applied terms.

As with the other volumes in the series the authors try to outline methodological difficulties as well as conceptual advances. The first section, focusing on sound and vibration, begins with an account of the effects of noise where the main variable of interest is the intensity of the noise. This is a topic of long-standing interest, as is the chapter on the effect of vibration. A new theme, that of the disruptive effect of meaningful noise is taken up in Chapter 2. This is an area in which the results are only just beginning to cohere and for which the practical implications in the 'age of information' are particularly important. In the section on thermal environments both ends of the temperature continuum are addressed. The effects of high temperatures, which are costly and difficult to control but which are an almost inevitable side-effect of working with machines, are discussed in Chapter 4. Although the effects of low temperature (discussed in Chapter 5) are more unusual, the special circumstances of deep-sea diving and Arctic environments have added special relevance to results in this area.

The contemporary relevance of the volume is particularly highlighted in the section on gaseous environments. In Chapter 6 the effects of a broad range of air pollutants is discussed. Recent interest in industrial processes involving solvents is the theme of Chapter 7. The special circumstances that apply to diving and the gases required to reach depth demanded by oil exploration among other things, are discussed in Chapter 8. This theme of examining agents which are a side effect of recently developed technology

is sustained in the penultimate section. Here the effects of electrical fields (Chapter 9) and ionization (Chapter 11) are discussed.

The final section deals with the visual environment. Chapter 11 gives a general introduction to the topic and deals with methods of measurement and the main findings. Special emphasis is given in Chapter 12 to the growing problem of visual display units. Here, an essentially integrated approach is adopted in which the visual problems are seen as part of the whole.

The chapters testify to the broad scope of environmental effects, to the diversity of mental function which may be impaired and to the complexity of unraveling the links in the causal chain between a single causal agent and the behavioural effects. Although much has been accomplished, much more needs to be researched. The future prospect is both busy and interesting.

Dylan Jones and Andrew Smith

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Noise and Performance

A.P. SMITH & D.M. JONES

This chapter consists of two main sections. The first is concerned with the effects of noise on performance efficiency in the workplace, and the second section deals with laboratory studies of noise and performance. Many of the older studies used noise levels which would now be discouraged because of the risk to hearing. These results are nevertheless still relevant to present problems and have been extremely useful in the development of theory. As well as the intensity of the noise, other parameters such as the duration and meaning of the noise will also be discussed. Individual differences in response to noise are reviewed, as are other factors which modify the effect of the noise.

The first question that needs to be addressed is 'What is meant by the term noise?' The term has at least three meanings: (1) a sound which one does not want to hear; (2) a sound varying randomly and aperiodically in intensity and frequency, and (3) a sound which interferes with the reception of another (i.e. masks it). Any particular sound may be classified as noise by one or more of the above criteria, and the same sound may be classified as noise in one situation but not in another. The first meaning allows for the possibility that a sound will be regarded as noise by one person but not by another.

The unit of measurement of the *intensity* of the noise is the *decibel.* A logarithm scale of magnitude is used because the dynamic range of power to which we are sensitive (between the absolute threshold – the level we can barely detect – and the terminal threshold – the level we can barely tolerate) is immense. The decibel scale gives logarithms of ratios where:

$$\mathrm{dB} = 10 \log \frac{E}{E_0}$$

where E = the energy being measured and E_0 = a reference standard.

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Often, reference levels are given in terms of pressure, and the levels expressed in this way are referred to as sound pressure levels (SPL):

$$\text{Number of decibels (SPL)} = 20 \log \frac{P}{p_0}$$

where P = the pressure produced by a source and p_0 = a standard reference value which corresponds roughly to the minimum pressure detectable by the human ear.

The reader is referred to Kohler (1984) for a detailed account of the measurement of noise intensity. However, it is important to be aware of the following facts:

1. Subjective loudness increases less rapidly than energy or pressure. An increase in the region of 10 dB is necessary to double the loudness as judged by the listener.
2. Doubling sound pressure increases SPL by 6 dB and multiplication of sound pressure by a factor of 10 increases SPL by 20 dB.
3. Doubling sound energy, on the other hand, leads to an increase of only 3 dB.
4. Sound level meters allow differential attenuation of the frequency range. This is important because the ear is not equally sensitive to all frequencies and three weighting networks can be used to simulate the action of the ear. The A-weighted network was chosen to simulate the sensitivity of the ear at low intensities, the B-weighted network was intended for medium intensities, and the C-weighted network for higher intensities. The A- and C-weighted networks are more likely used, with the C-weighted network giving equal weight to all frequencies, and the A-weighting giving greater weight to the frequencies which contribute more to the effects on people.
5. Sound intensities usually vary over time and the L_{eq} value for such a signal is the dB(A) level of a constant sound which, if continued over the same period, would represent the same total energy as the variable sound.

The *frequency* of the noise has been shown to be important and this is measured in terms of hertz (Hz) which correspond to the number of peaks of pressure per second. Human ears are sensitive to sound between approximately 20 and 20,000 Hz. The *duration* of the noise is also important. Noises of very short duration are termed *impulse noises* whereas longer ones with a thud-like quality are called *impact noises.* Noises which are switched on and off are referred to as *intermittent noise.* This switching may be regular (periodic) or irregular (aperiodic). Both intermittency and regularity have been shown to be very important in determining the effects of noise.

Our knowledge of the auditory effects of noise has advanced to the stage where dose–response relationships are clearly defined. Any performance task involving auditory information is likely to be impaired by the presence of