MICROCOMPUTER SUPPORT FOR HEALTH CARE DELIVERY IN THE GAMBIA

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ABSTRACT

Microcomputer support for health care delivery is a relatively new concept in developing countries, despite serious shortages of human expertise. In this light, the concept of microcomputer-based decision support for patient management at the rural health centre level in The Gambia is discussed and developed. Possible methodologies are devised and evaluated, taking into account constraints imposed both by feasibility of hardware for the rural African setting and by appropriate software techniques.

Clinical data were collected for a pilot system, which was implemented using a Bayesian methodology, and assessed, with encouraging results. Further sources of data were then considered in order to generalise the pilot system into a prototype, which was implemented on a portable solar-powered microcomputer.

The evaluation of this prototype system, and the difficulties involved in undertaking rigorous evaluations of this type of decision aid, are described and discussed. Whilst it is not proven that major health benefits would arise from the widespread introduction of such systems, the results of this preliminary study suggest that this type of approach merits further consideration and development.

ACKNOWLEDGEMENTS

The work described in this thesis has been made possible by the cooperation of many people. At the Medical Research Council Laboratories, Fajara, The Gambia, the support of the Director, Dr. Brian Greenwood and of the Senior Clinician, Dr. Tumani Corrah, have been particularly invaluable. Many other colleagues too numerous to mention individually have also been very supportive. Also in The Gambia, the support of various senior members of the Medical and Health Department for the concept of decision support in health care has been helpful.

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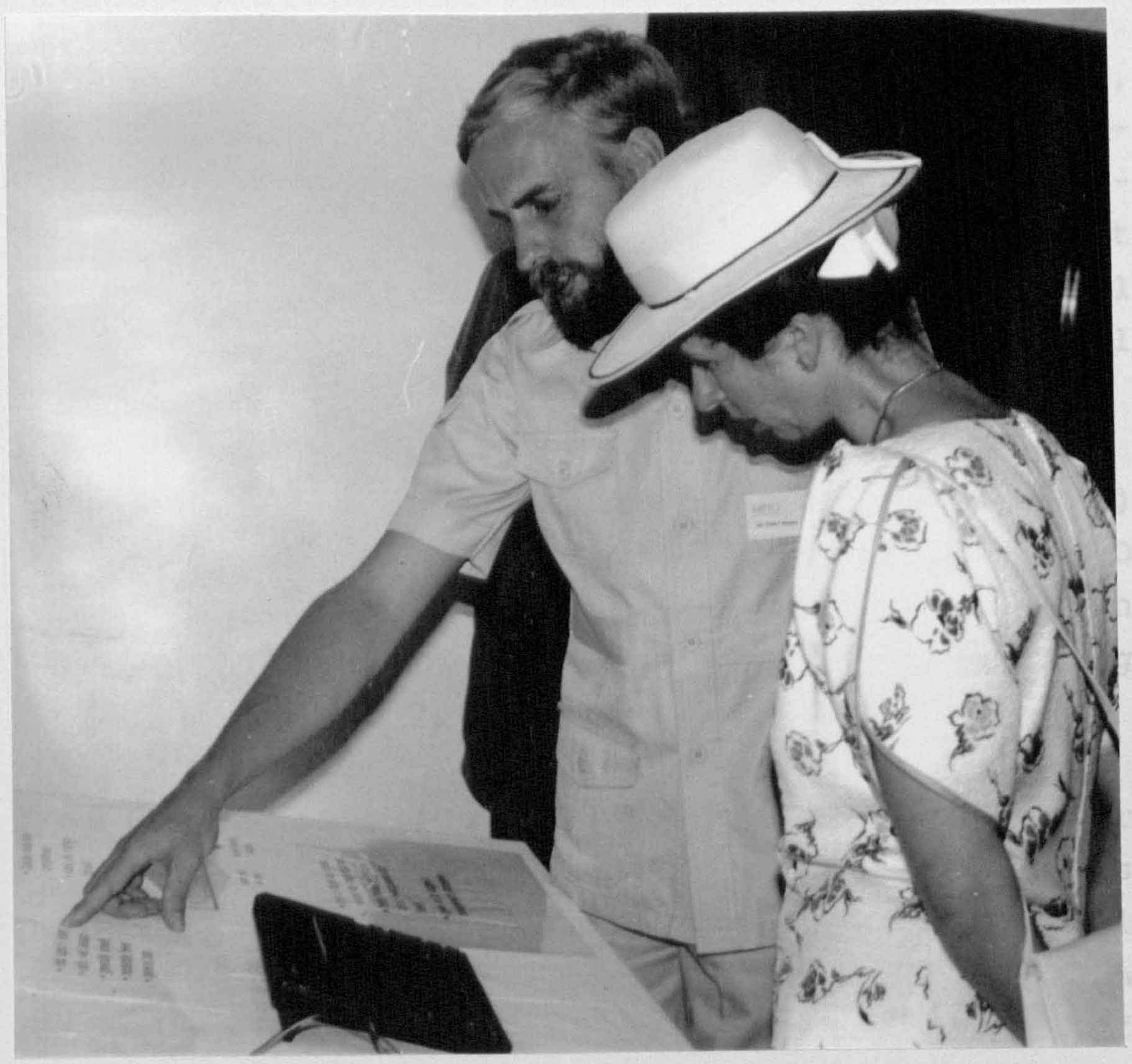
A further source of encouragement came from the International Medical Informatics Association (IMIA) in 1989, in the form of the award of their Gold Medal for the aspects of the study presented at MEDINFO-89 in Singapore, which was particularly appreciated as a recognition of the importance of decision support for developing countries.

Last, but not least, I am grateful to my wife and family for their patience during my periods of preoccupation with this thesis.



Discussing the prototype system with H.R.H. The Princess Royal, during her visit to Fajara in February 1990.

Chapter 1: INTRODUCTION

1.1 Background

1.1.1 Health Care Delivery in Developing Countries

In The Gambia, as in many developing countries, effective health care delivery is fraught with wide-ranging difficulties. These include logistic, infra-structural, financial and manpower problems, amongst others, all of which combine to result in suboptimal levels of health care, particularly in the rural areas.

The much publicised World Health Organisation (WHO) initiative of "Health for All by the year 2000" [WHO 1981], now half way in the time span from inception to completion, therefore still appears to have a long way to go in some parts of the world.

Programmes of action in the search for "Health for All" have been planned and implemented in various guises in different parts of the world. The general concept of strengthening primary health care, in an attempt to move away from the over-resourcing of expensive high level care that has frequently occurred, has been a major feature. The concept of providing medical care at a community level through the use of local personnel with moderate training, rather than advanced university-based education, has underlied most primary health care schemes. The importance of the trained doctor acting in a modified role of supporter for less trained health workers has

been emphasised [Mahler 1983].

One of the most difficult areas in primary health care in developing countries is that of organisation, training and management within the health care system, given a general commitment to devolve health care delivery to the local community level. One important aspect in this is the enhancement of central management, as opposed to health care delivery, facilities [WHO 1988 A]. Infrastructural and other difficulties in developing countries often make the management of an extensive, devolved system very difficult.

A further area of difficulty lies in the planning and subsequent assessment of primary health care programmes. Components that should and should not be included in a national or regional programme are often determined largely by economic constraints in poor countries, where per capita expenditure on health services is typically very low. An objective approach to programme planning is in any case likely to be difficult due to poor or inadequate knowledge of the effectiveness or otherwise of similar previous programmes. The whole area of the assessment of primary health care programmes, particularly in developing countries, is a difficult one [Roemer & Montoya-Aguilar 1988].

1.1.2 Medical Informatics

Medical informatics is a relatively new discipline within medicine, which has seen rapid growth in

recent years, in parallel with technical improvements in and increasing availability of computer technology. Perhaps because of the relatively innovative status of informatics within medicine, routine and established applications are relatively scarce. There does, however, appear to be an increasing recognition of the potential of informatics applications in health care [WHO 1988 B].

1.1.3 Decision Support Systems in Health Care

One aspect of medical informatics is the area of the potential use of information technology in a decision making or advisory role within health care. Much work in this area has concentrated on the theoretical basis of potential systems, and on implementations of large systems, usually on mainframe computers, that typically cover particular medical specialities.

It is clear that one major difference between richer and poorer areas of the world lies in the availability of qualified medical personnel. It is also unfortunately true that most research and development on decision support systems for health care is taking place in, and directed towards, richer countries. At a recent international meeting, the Peter L. Reichertz Memorial Conference on Expert Systems and Decision Support in Medicine [Rienhoff, Piccolo & Schneider 1988] there was a strong correlation between the number of presentations and doctor:patient ratio in different parts of the world (Figure 1.1) [WHO 1988 C]. In fact the work described

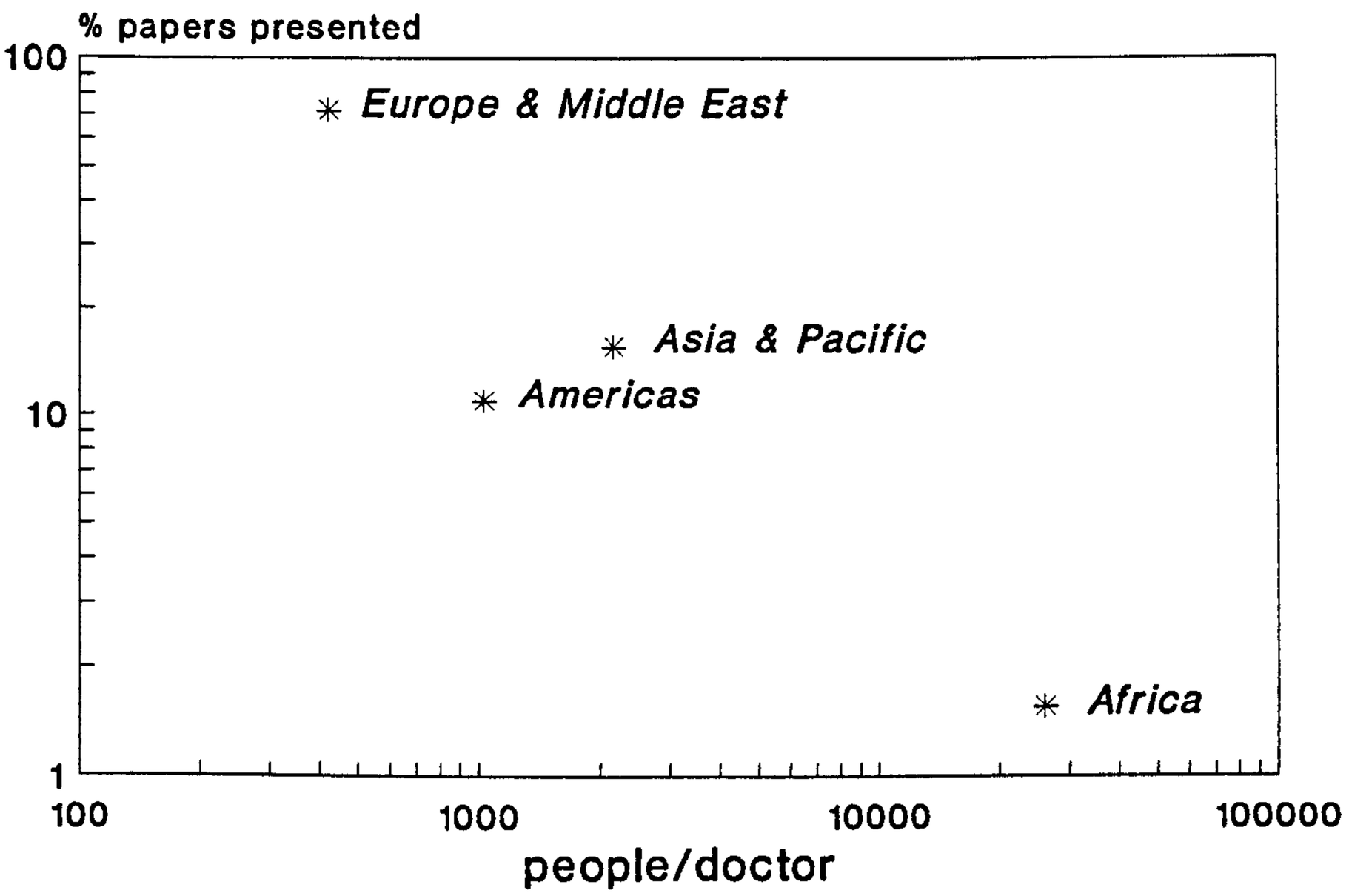


Figure 1.1: Origin of presentations at the Reichertz Memorial Conference, September 1988, in relation to the ratio of people:doctors, in different regions of the world.

in this thesis was the only presentation relating to work in Africa, despite the very low rate of 39 doctors per million people throughout the continent. Thus there appears to exist the paradox whereby the region most lacking medical personnel is also receiving the least attention in terms of the development of decision support for health care.

1.2 Aims

The aims of the studies on which this thesis is based constituted the following:

consideration of the feasibility and potential usefulness of microcomputer-based decision support for health care delivery, at the level of rural health centres in The Gambia

consideration of appropriate methodologies that could realistically be applied to a decision support system in this context

compilation, from a variety of sources, of a set of data/knowledge that would be relevant to such a system

encapsulation of this information into a prototype system

bench evaluations of the methodology and data using the prototype system, followed by a clinical evaluation

1.3 Locality

These studies have taken place in The Gambia during the period 1985 to 1990, based at the United Kingdom Medical Research Council's Laboratories at Fajara (director Dr. B.M. Greenwood). These laboratories have been operated in The Gambia by the MRC since the late 1940s, having previously been used by colonial medical services and as a military medical facility during the second World War.

The MRC Laboratories in The Gambia currently have a main base at Fajara, on the coast near the capital, Banjul, together with three field stations inland. The MRC Dunn Nutrition Unit, Cambridge, (director Dr. R.G. Whitehead) also runs a field station in The Gambia, at Keneba, which is primarily concerned with questions of nutritional physiology.

The research interests of the MRC Laboratories have traditionally been centred on tropical infectious diseases such as malaria and schistosomiasis. More recently this scope has widened to include acute respiratory infections, hepatitis B and AIDS.

Chapter 2: THE GAMBIA

2.1 Introduction

The Gambia is a small country on the coast of West Africa (Figure 2.1). It is 10,690 km^2 in area [Times Books 1987] and the total population recorded at the census of 15th April 1983 was 687,817 [Central Statistics Department 1987]. It has been an independent nation since 1965, and is a member of the Commonwealth. From 1982 until 1989 it was one partner of the Senegambia Confederation.

2.2 History

Islands in the river mouth provided ideal bases for colonising powers. James Island was occupied by the Portuguese as long ago as 1456, and Britain first manned Dog Island in 1661. On the largest island, Britain established a colony, the town of Bathurst (now Banjul) in 1816, and the final shape of The Gambia, as a British colony and protectorate, was defined in 1889. Colonial rule continued until independence was granted on 18th February 1965, with Sir Dawda Jawara as Prime Minister. A referendum in 1970 constituted the country as a republic with H.E. Sir Dawda Jawara as President, a position which he has held ever since. In February 1982 a Confederation was formed with the surrounding state of Senegal, but the strongly British traditions and influences that persist in The Gambia, with contrasting Francophilia in Senegal, resulted in little genuine integration,

Chapter 2: The Gambia

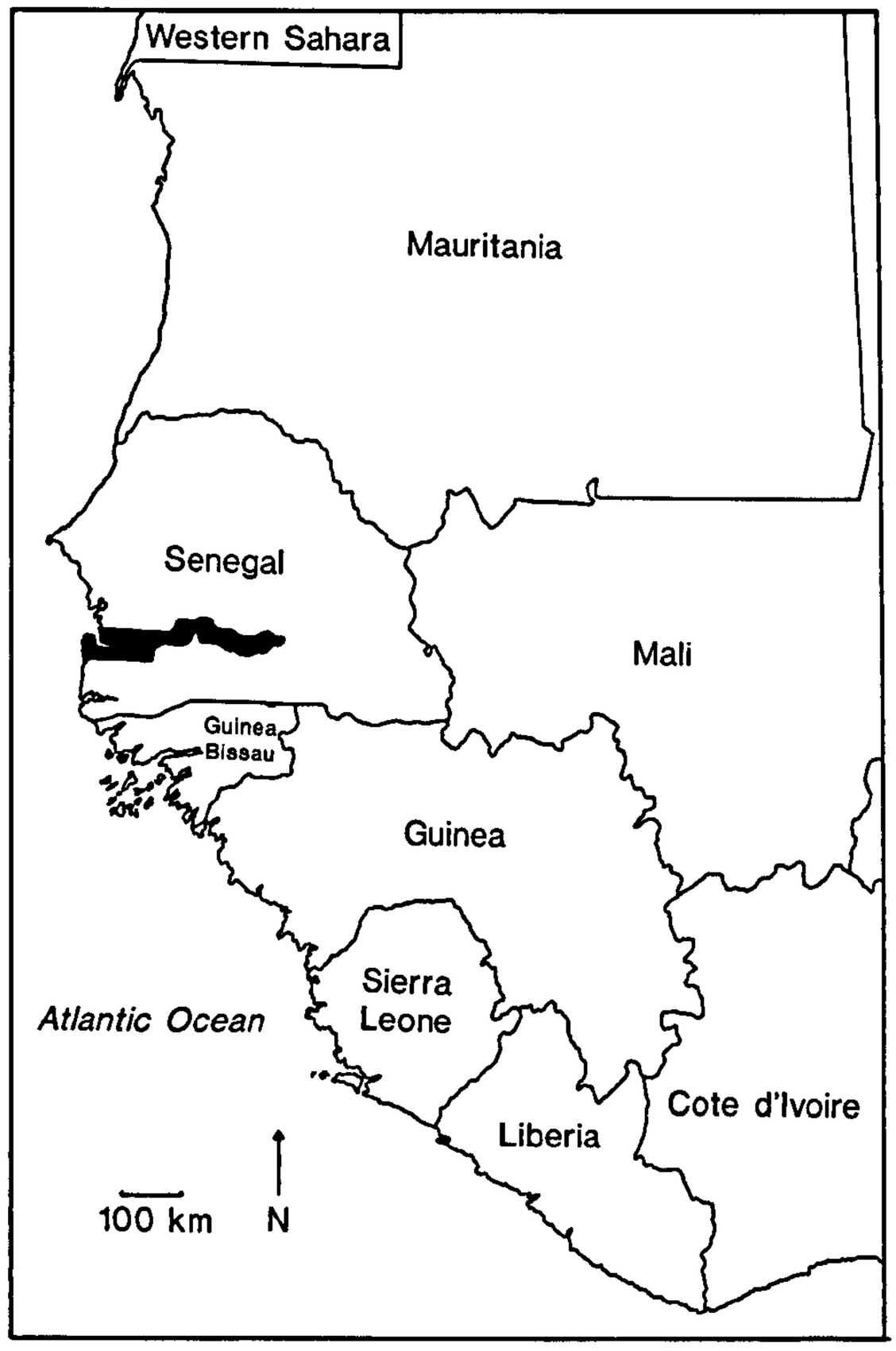


Figure 2.1: Map of West Africa, showing the position of The Gambia.

and the Confederation was disbanded in 1989.

2.3 Geography

The geography of the country is dominated by the river (Figure 2.2), which is saline or brackish as far inland as the stretch between Farafenni and Kuntaur, with some seasonal fluctuation. Tidal variations in the river level extend beyond Basse. Most of the land surface is composed of sandstone laid down during the late Tertiary era [Moffatt, Anderson & Williams 1975]. The predominant pattern of vegetation is Guinea savanna and secondary forest, with very little primary tropical forest remaining. The saline reaches of the river are bordered by dense mangrove swamps.

The Republic of Senegal totally surrounds The Gambia, apart from the Atlantic coastline, with relatively undefined borders. At its widest, The Gambia is 48 km from north to south, narrowing to 24 km inland. The length of the country is 330 km, although actual distances by road or river are considerably longer due to the meandering nature of the river.

2.4 Climate

The Gambia is critically situated on the transition zone between desert to the north and tropical rainforest to the south. Travelling as little as 100 km in either direction results in major climatic

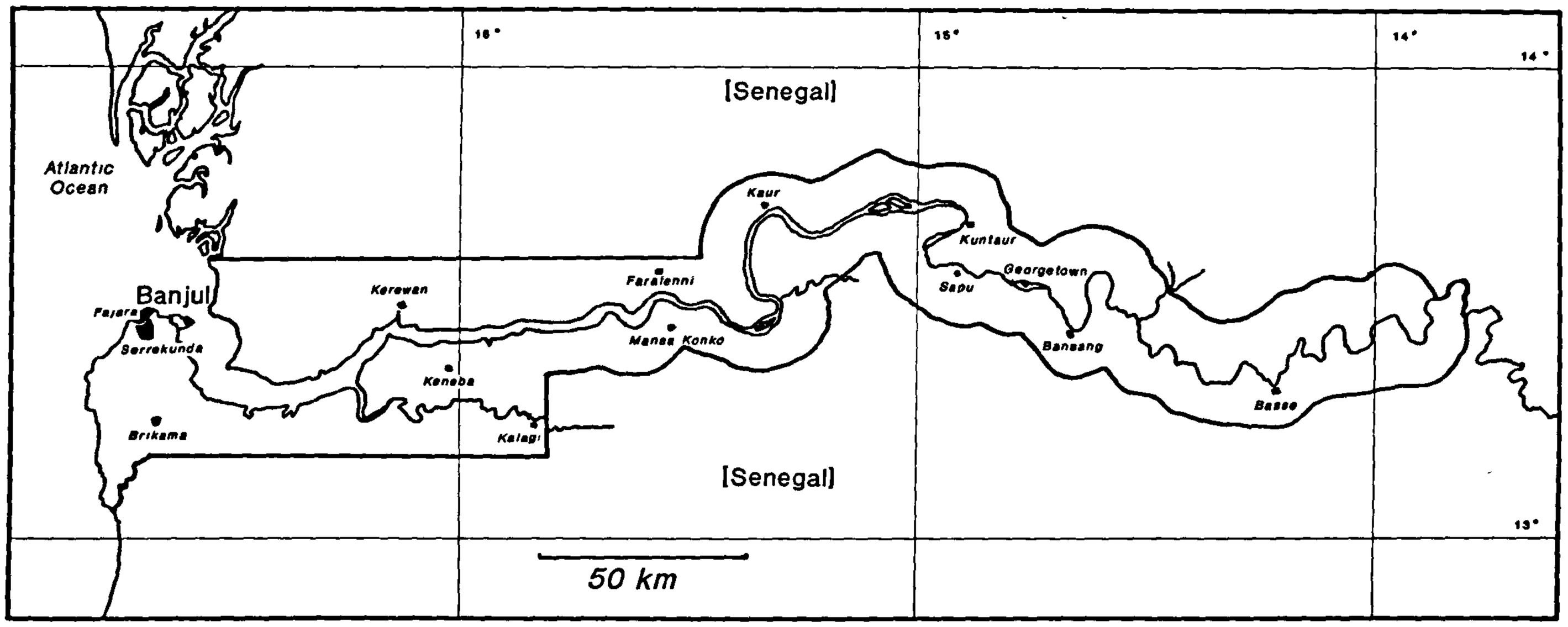


Figure 2.2: Map of The Gambia

variations. Increasing desertification and associated Sahelian droughts have therefore had a major impact on the climate, and consequently on the environment, in recent years.

The annual climatic pattern consists of a single rainy season, normally starting in June or July, peaking in August and ending in October. During the rainy season the relative humidity is high, and remains so for about a month after the last rain. There is then an abrupt transition to relatively cool and dry weather, from which temperatures gradually increase towards the next rainy season. Rainfall, temperature and humidity from March 1987 to June 1988 as recorded at Sapu, near Georgetown, are shown in Figure 2.3.

The single most important long-term meteorological parameter for this type of environment is annual rainfall. Records have been kept at Banjul since 1886 and it is therefore possible to look at long-term trends (Figure 2.4). Despite considerable annual variations, there is a clear trend to lower rainfall, particularly in recent years [Hutchinson 1982].

2.5 Population

In common with many developing countries, accurate registration of births and deaths is not undertaken on a nationwide basis in The Gambia. However, there have been regular censuses every decade since 1901, the latest of which was undertaken on 15th April 1983. This revealed a total population of 687,817,

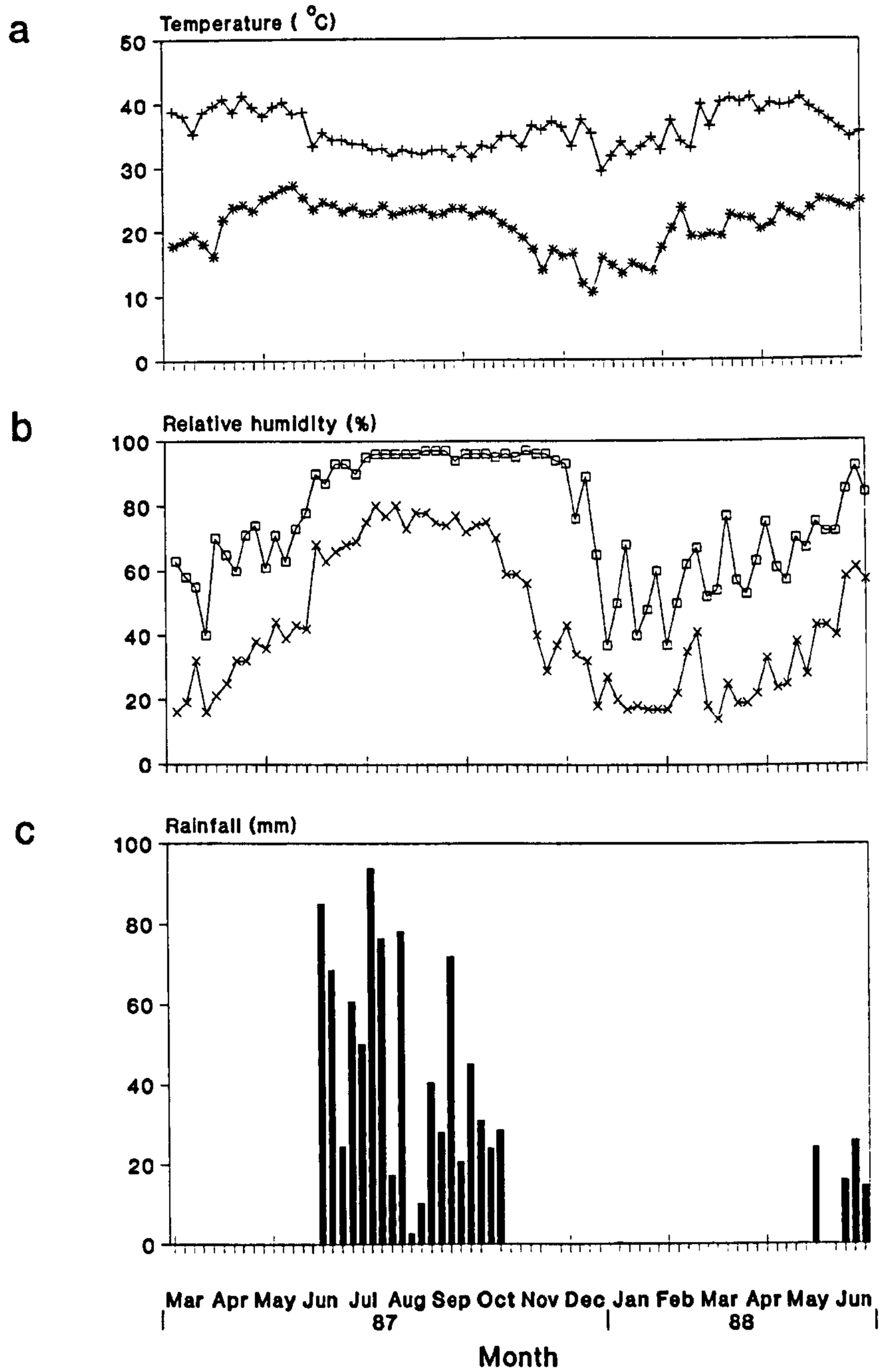


Figure 2.3: Data from the meteorological station at Sapu, near Georgetown, from March 1987 to June 1988, showing (a) maximum and minimum temperature, (b) maximum and minimum relative humidity and (c) rainfall.

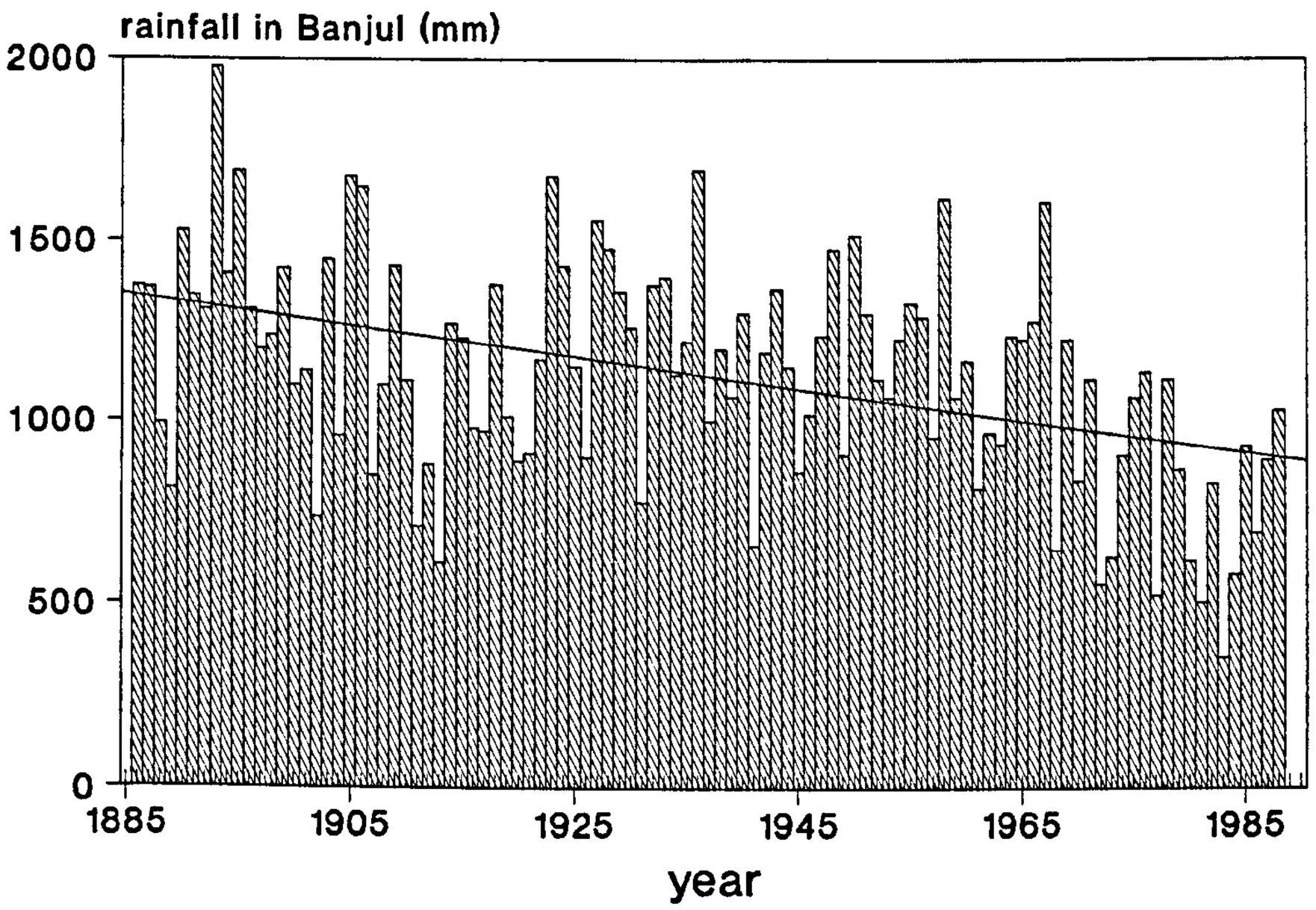


Figure 2.4: Annual rainfall at Banjul 1886-1988.

compared with 90,404 in 1901. This represents a high annual growth rate of 2.5% during this century. In the opinion of the Central Statistics Department, this high rate of growth is probably partly due to in-migration [Central Statistics Department 1987]. The 1983 population density of 64 people/km^2 is very high by African standards.

The population is heavily clustered to the west of the country, in the urban and peri-urban communities associated with Banjul. The population distribution by Local Government area, from the 1983 census, is shown in Figure 2.5.

The age and sex distribution of the population from the 1983 census is shown in Figure 2.6. This shows the large proportion of young people in the population, typical of developing countries. The male life expectancy at birth has been quoted as 41.3 years, female 44.2 years [Central Statistics Department 1987].

A variety of ethnic groups make up the total population, with Mandinka, Fula, Wollof and Jola accounting for 85% of the total population. Serahuli, Serere, Manjago and Bambara account for a further 13%. The remaining 2% of the population includes a small group known as Aku, comprising only 0.8%, who are descended from repatriated slaves following abolition. They are generally Christians, well educated, and were extremely influential in colonial times when they occupied the majority of civil service positions. Their undue influence has since waned, although they are still well represented among

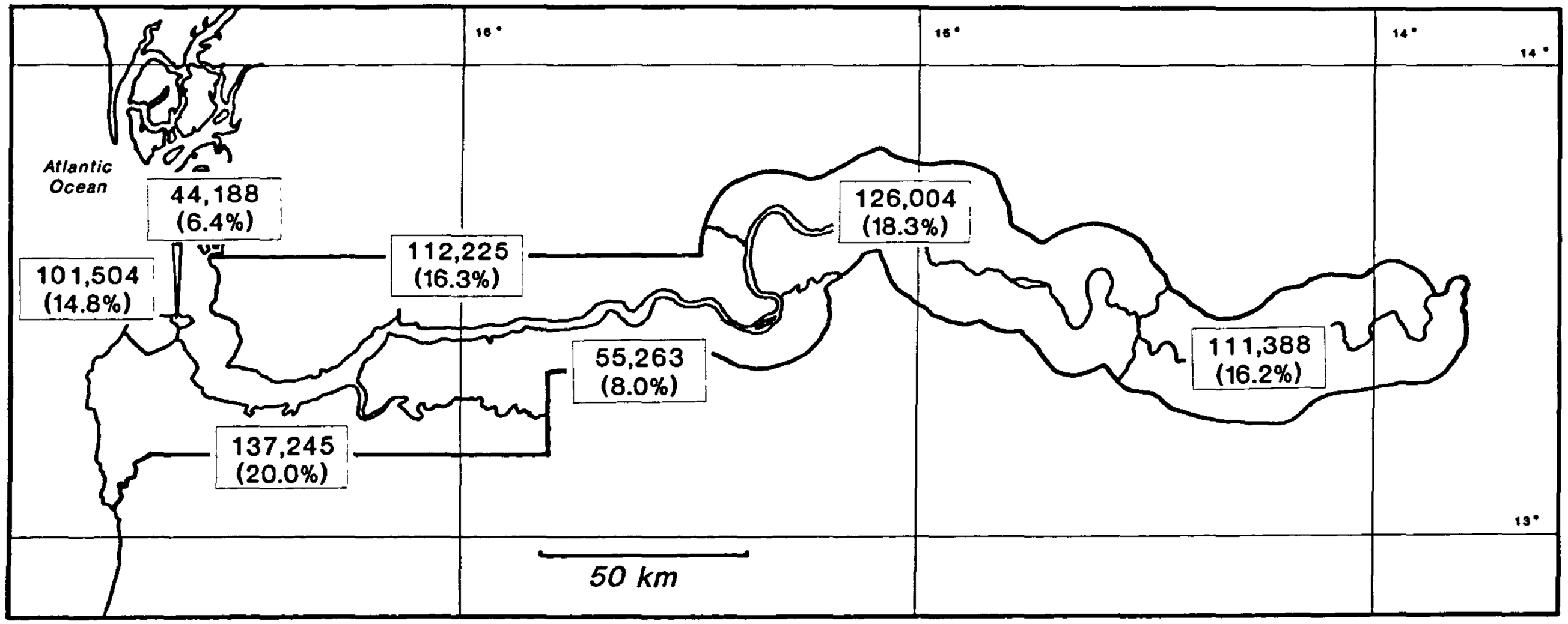


Figure 2.5: Population distribution by Local Government area (1983 census)

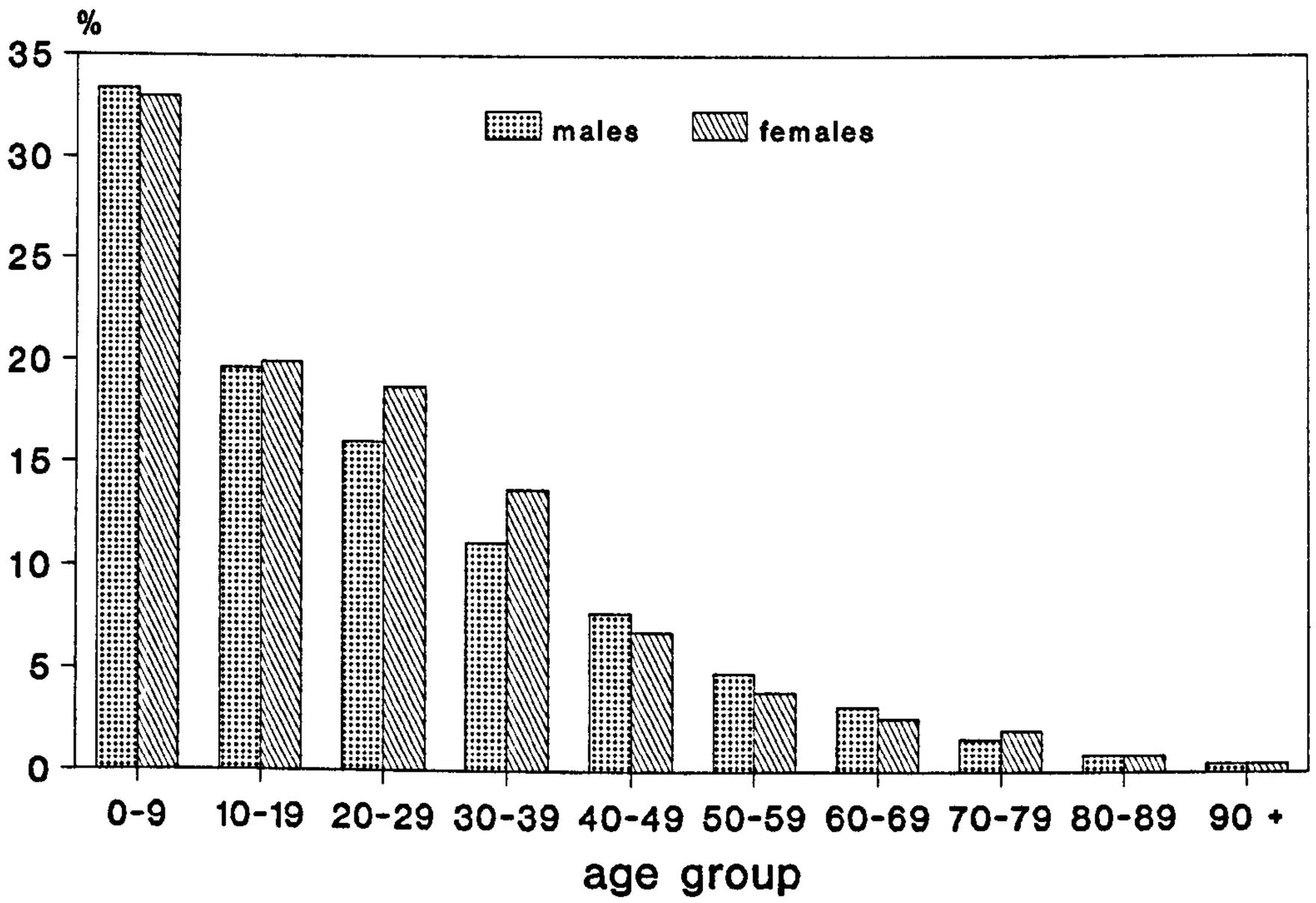


Figure 2.6: Age and sex distribution of the population (1983 census).

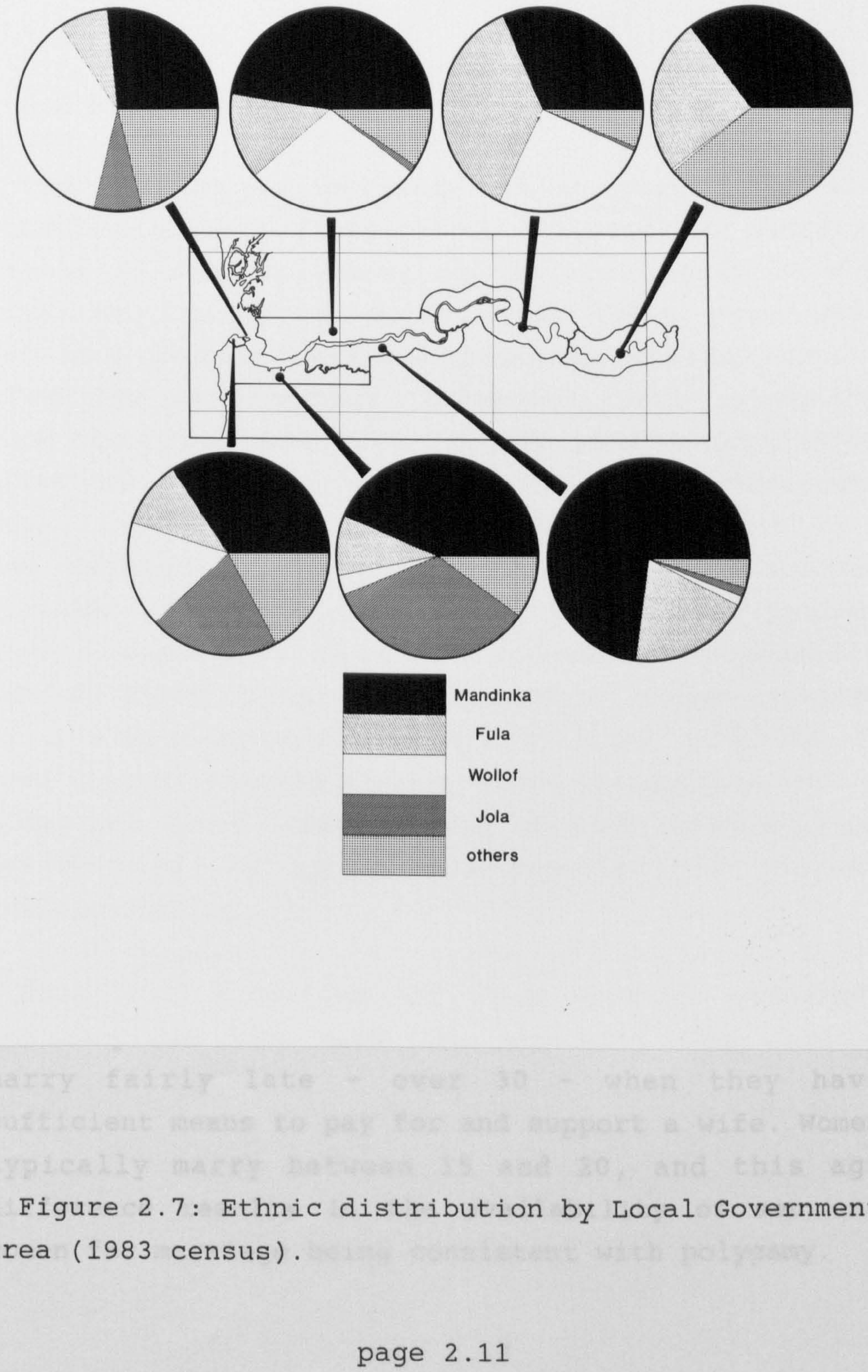


Figure 2.7: Ethnic distribution by Local Government area (1983 census).

the offices of Banjul. Ethnic distributions vary considerably by area, as is shown in Figure 2.7. Religious beliefs were stated as Islamic by 96% of the population [Central Statistics Department 1987].

2.6 Social Organisation

The origins of current social structures are somewhat obscure [Lowe 1975]. Circles of standing stones in many locations on the north bank of the river are thought to be at least 1,000 years old. Settlers probably arrived from the Manding empire after the 12th century. Islam was first introduced from the north-east to a largely animist population after the 15th century but did not become widespread until the 19th century. A traditionally stratified and hierarchical society persists, based on discrete villages of variable size, from 20 to 2,000 people. These consist of discrete compounds, physically fenced, which contain a number of buildings occupied by a single extended family. Villages have one or more central meeting places, known as bantabas, where older men spend large amounts of time. Each village has a chief, or alkalo, who presides over village decision-making.

Both local tradition and Islam sanction polygamy, and many men have more than one wife. Men usually marry fairly late - over 30 - when they have sufficient means to pay for and support a wife. Women typically marry between 15 and 20, and this age difference results in the availability of men and women for marriage being consistent with polygamy.

2.7 Economic Structure

In a country with minimal natural resources like The Gambia, agriculture plays an vital role in the rural economy. The primary cash crop is groundnuts, although successful cropping is crucially dependent on the amount and distribution of rainfall in the season. Various other crops are grown on a mainly subsistence basis.

Tourism has increased during the past decade, but is largely confined to the coastal region. Its economic benefits are limited by extensive involvement of foreign companies, dependence on imported commodities and seasonality.

In collaboration with the World Bank and the International Monetary Fund, the Government decided to float the currency (Dalasi) on the international market in January 1986. Although this rapidly resulted in a devaluation of just over 100%, since then exchange rates have been stable (at approximately D12 to £1). This stability coupled with availability of foreign currency is leading to a gradual increase in trading and manufacturing prosperity, although the economy is still crucially dependent on overseas aid.

Chapter 3: HEALTH IN THE GAMBIA

3.1 Introduction

In the 19th century the West African coast acquired the epithet "the white man's grave" as a result of the high mortality experienced by government officials and missionaries in consequence of exposure to malaria, yellow fever, and other tropical diseases without the benefits of modern drugs and vaccines, and without the acquired immunity of the local population.

This situation is now reversed; it is foreigners and a local elite who have relatively unlimited access to medical care and treatment, while the majority of the indigenous population still suffer from high morbidity and mortality rates.

3.2 Health Services

The Ministry of Health delegates responsibility for delivering health care to the Medical and Health Department, which is headed by the Director of Medical Services. The Department divides the country into three regions, West, Central and East. The regional headquarters (Banjul, Mansa Konko and Bansang) each have a hospital with in-patient facilities, though the Royal Victoria Hospital at Banjul also acts as a national referral centre. Each region then has a network of health centres, which vary in size and in the facilities they offer. A

minority of these are run or supported directly by outside agencies.

Until 1988 health care in the Government system was given free of charge. However problems frequently arose of non-availability of supplies, and various outside agencies including the World Bank set up in 1988 the National Health Development programme. This provided initial funding for supplies on the basis that charges would be levied, and the proceeds used to maintain a revolving fund for future purchases. Fixed charges for consultations, prescriptions, hospital admission, etc. have been defined, and a number of patient groups, notably children, exempted. At this stage the long-term effectiveness of the revolving fund arrangement cannot be assessed. However, the local reaction to the concept of paying for health care seems to be favourable provided that treatment is genuinely more readily available.

In addition to Government health services, there are a number of private practices in operation. In Banjul these are often run by highly qualified medical practitioners for whom available remuneration in Government service would be very unattractive. In provincial towns there are also a number of private clinics and dispensaries operated by generally less well qualified people. Nevertheless they often serve a useful function in providing treatments temporarily unavailable in the Government system.

The Royal Victoria Hospital (RVH) at Banjul dates back to colonial days, and is still the national referral centre. It offers a reasonable range of

surgical facilities, adult and paediatric medical wards, laboratory facilities, etc. A large proportion of the senior staff are non-Gambian, many supported by overseas agencies such as the British Overseas Development Administration (ODA).

In addition to conventional "western" health care there exists a considerable and active group of traditional healers (Fig. 3.1). Many traditional beliefs and practices have become integrated with the Islamic religion, to the extent that charms and jujus often contain Koranic texts. In seeking health care it is not uncommon for people to consult both traditional and "western" practitioners.

3.3 Problems of Health Care Delivery

Apart from general under-resourcing of the health services by international standards (prior to the National Health Development programme the annual Government drug budget was $220,000, approximately $0.30 per capita), there is also a shortage of suitably qualified staff. This is compounded by problems with conditions of Government service, and also a general disinclination among trained staff to reside appreciable distances away from Banjul.

Problems of communication and transport cause further difficulties and make, for example, in-service training very difficult to arrange effectively. Similarly, referral to larger health centres is often difficult and dangerous. A study of maternal mortality around Farafenni showed that

Chapter 3: Health in The Gambia

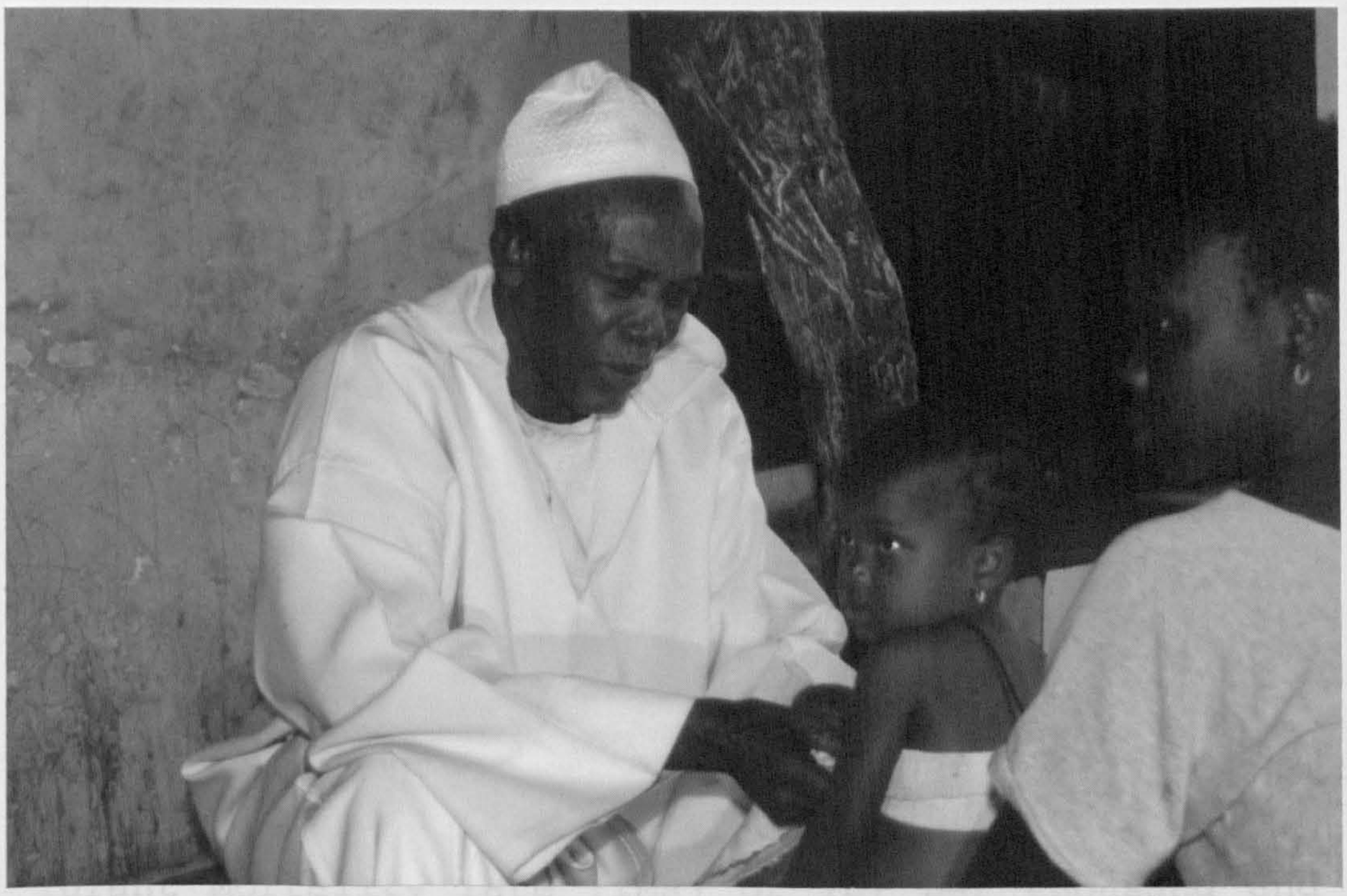


Figure 3.1: A sisebulandilo assesses whether a child has a respiratory infection by comparing the distance from the shoulder across the head to the other shoulder with chest circumference.

deaths generally occurred either at home or on the way to a health centre [Greenwood A.M. et al. 1987].

The appropriateness of health care delivery is difficult to assess objectively. It is the general opinion of clinical personnel at the higher levels of the health system that in many cases patients are inappropriately managed at earlier consultations, either due to lack of suitable drugs or of understanding of the patient's condition. It is hard to substantiate this other than at the anecdotal level however since investigating patterns of patient management at a small health centre would almost certainly alter the normally pertaining situation.

3.4 Mortality

The lack of effective death registration makes accurate assessment of mortality rates on a nationwide basis difficult. Based on the 1983 census, indirect methods of mortality estimation lead to an infant mortality rate (IMR) of 167 per thousand and life expectancy at birth of 42 years [Central Statistics Department 1987]. This is substantially lower than in the 1973 census, though methodological differences preclude an exact comparison. However, it is clear in both censuses that the IMR at the western end of the country is approximately half that at the eastern end. There is a clear long-term trend towards lower infant mortality; in the early 1950s IMR in a group of villages around Keneba was found to be 420 per thousand [Gamble 1952].

More precise estimates of mortality rates and also of cause-specific mortality are available from studies within particular areas. In a rural area around Farafenni (total population 12,500) during a one-year period 1982-3 the infant mortality rate was 142 per thousand live births and child mortality rate (1 to 4 years) 43 per thousand per year [Greenwood B.M. et al. 1987 A]. In this study causes of death were retrospectively assessed by a verbal post-mortem. (The accuracy of this technique was indirectly assessed separately [Alonso et al. 1987]). Of infant deaths, 47% occurred in the neonatal period. In the children who were 1 month to 6 years old at the time of death, 20% of deaths were attributed to acute respiratory disease, 18% to malaria, 12% to meningitis, 11% to malnutrition and/or chronic diarrhoea, and 10% to acute gastroenteritis. Seasonality of deaths was very marked, with 71% occurring between June and November. Only 12% of deaths occurred in a hospital or health centre, and a third of these were in neonates whose mothers had been admitted before delivery due to complications of pregnancy.

In contrast to child mortality in the rural community, cause-specific mortality data for paediatric admissions to RVH during 1988 has malaria accounting for 27% of deaths, malnutrition 17%, acute respiratory infections 11% and meningitis 8% [D. Brewster, personal communication]. Children admitted to the RVH are clearly a selected group; they represent the severe end of the disease spectrum and are not geographically representative, although some will travel long distances to be admitted. However,

it is clear from these data that, unlike national referral centres in other parts of the world, a large proportion of the paediatric mortality at RVH is attributable to a similar group of causes as mortality in the community.

3.5 Morbidity

Major causes of morbidity, particularly among children, are the same group of infectious diseases that constitute major causes of mortality. As with mortality, in adults morbidity is not well quantitated. In children, most assessments that have been made are disease-specific and often confined to a particular part of the country.

3.5.1 Malaria

Malaria is one of the most investigated diseases in The Gambia, starting with work in Keneba as far back as the early 1950s [McGregor & Smith 1952]. At that time, malaria appears to have followed a classic holoendemic pattern, since even at the time of McGregor's survey in April/May 1950, during the dry season, 92% of children aged 1 to 10 years were infected. Infants benefited from maternal immunity, with an infection rate of 63%, while from 11 to 30 years of age 88% were infected, and over 30 years only 20%.

More recently, in the Farafenni area in 1982, a cross-sectional survey of malaria parasitaemia at the end of the rainy season - a period of maximum

prevalence - only found an infection rate of 33% among children under 7 years of age [Greenwood B.M. et al. 1987 B]. In the same area in 1985 cross-sectional parasitaemia was 9% in the dry season and 43% at the end of the rainy season [Snow, Rowan & Greenwood 1987].

In terms of clinical morbidity, however, it is clear that the presence of parasitaemia has little predictive value. There is a general association between high parasite densities and acute clinical malaria, characterised by high fever and generalised illness, but there are many exceptions (Fig. 3.2). Weekly surveillance for episodes of clinical malaria (achieved by weekly measurement of temperature and examination of thick blood films taken from children with a fever of 37.5^{o}C or greater) was undertaken during the rainy season in the same cohort of children found to have a parasite rate of 43% at the end of the rainy season [Snow, Rowan & Greenwood 1987]. This showed a mean rate of 25 clinical episodes per 1,000 observations during the 7 week peak of malaria infection during the rains, and an estimate of 0.25 episodes per child per year. However, other estimates have been made indicating higher levels, around 1 episode per child per year [Greenwood B.M. et al. 1987 B; R.M. Downes, personal communication].

As far as treatment goes, most malaria in The Gambia is sensitive to chloroquine, although there is limited evidence of emerging resistance [Menon et al. 1987].

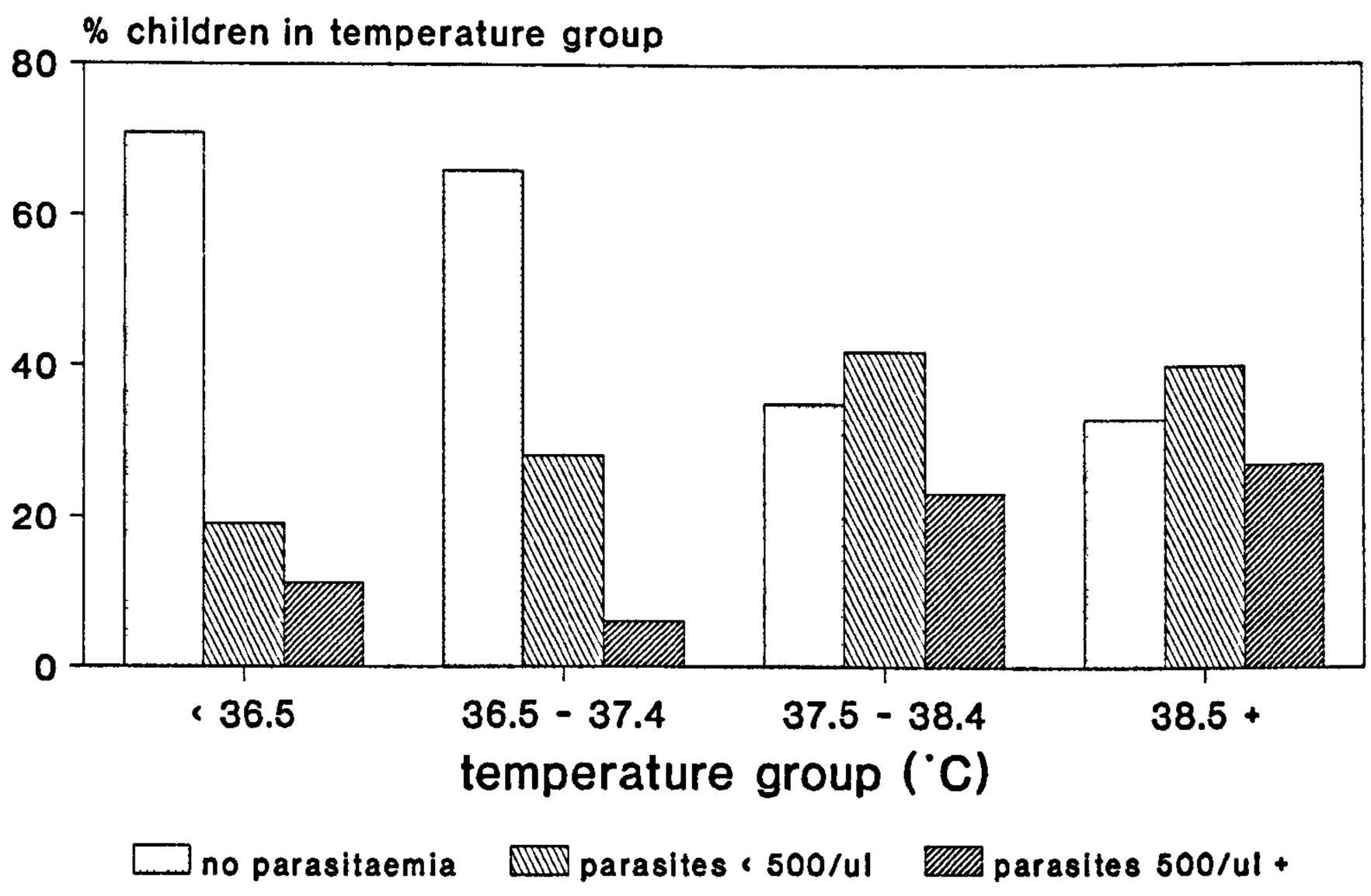


Figure 3.2: Relationship between malaria parasitaemia and axillary temperature in 607 Gambian children studied in a cross-sectional survey in November 1982 (data from Greenwood et al., Trans. Roy. Soc. Trop. Med. Hyg., 81, 478-486.)

3.5.2 Acute Respiratory Infections

A cohort of approximately 500 children aged 0 to 4 years in a rural area around Basse were monitored weekly for a period of one year for respiratory disease. During this surveillance, 222 acute lower respiratory infections, as defined by WHO criteria, were detected [Campbell et al. 1989; World Health Organisation 1985]. Of these cases, 81 showed radiological signs consistent with lower respiratory infections and 25 showed lobar consolidation. Aetiological classification of such disease is not easy at the community level. However it is clear that there are major bacterial and viral causes of respiratory disease. There is also considerable minor morbidity from upper respiratory infections; in the same cohort a further 4,310 episodes of less severe respiratory disease were recorded, amounting to approximately 9 episodes per child per year. It is unclear at present whether particular types of upper respiratory infections tend to lead to acute lower respiratory infections.

3.5.3 Diarrhoeal Disease

Diarrhoeal disease morbidity is difficult to evaluate since, in addition to having multiple aetiologies, diarrhoeal symptoms are frequently recorded in other diseases such as acute respiratory infections and malaria. Reports of diarrhoea have been recorded four times more frequently in children with respiratory disease than in those who were well [Campbell, Byass & Greenwood 1990]. In terms of primary diarrhoeal disease, both viral and bacterial

aetiologies are common. Rotavirus disease, with its characteristically well-defined annual epidemics, has been investigated [Hanlon et al. 1987 A] in the peri-urban community of Bakau. During one of these short intense epidemics, a high proportion of previously unexposed infants may develop the disease.

A general study of aetiology in the same community [Goh-Rowland et al. 1985] found enterotoxigenic E. coli, campylobacter, salmonella and shigella to be the major identifiable bacterial causes of diarrhoea. However, diarrhoeal pathogens were only identified in 28% of diarrhoeal episodes investigated.

3.5.4 Meningitis

Meningitis is a particularly significant disease in rural communities where its rapid onset, particularly when it occurs at night, often means that there is no possibility of travelling to health facilities sufficiently quickly, or indeed, in many cases, before a child dies. Meningococcal meningitis is typically a dry season epidemic disease, not occurring every year. In an epidemic in a rural area around Farafenni in 1982-3, population attack rates were on average 12 per thousand, although in some villages it was up to 8 times higher [Greenwood B.M. et al. 1987 C]. Haemophilus influenzae type B is also an important cause of meningitis, typically affecting infants in the first few months of life, with high case fatality and neurological sequelae rates [Bijlmer et al. 1990].

3.5.6 Pregnancy

Pregnancy is a major cause of morbidity among adult women, given that many women will experience 8 or 10 pregnancies during their reproductive years. The high maternal mortality (22 per thousand) identified around Farafenni [Greenwood A.M. et al. 1987] mainly followed postpartum haemorrages and infections. Susceptibility to malaria infection during first pregnancies is known to be high, and was reported many years ago [McGregor & Smith 1952] although the precise immunological mechanisms underlying this phenomenon are still not clearly understood.

3.5.7 Malnutrition

Malnutrition in young children is a further cause of morbidity, particularly during the "hungry season" of the rains, when previous food stores tend to run out before the growing crops are ready. Weaning, which typically continues into the second year of life, often presents a nutritional crisis. In the first few months of life, however, Gambian mothers' proficiency in breast feeding actually gives higher mean weights than international standards [Rowland et al. 1985]. This advantage is normally lost after 6 months of age, although significant differences between weaned and non-weaned infants through a range of ages has been shown. Malnutrition, occurring independently of other specific diseases, accounted for 14% of admissions to the RVH paediatric ward in 1988 [D. Brewster, personal communication].

Chapter 4: HEALTH INTERVENTIONS

4.1 Introduction

In recent years a number of large scale interventions in health care have been implemented and assessed in The Gambia. Some of these have been aimed at specific health problems, while others have sought to influence the general health of the target population.

4.2 The Keneba Experience

From the early 1950s [McGregor & Smith 1952] the health and demography of Keneba and surrounding villages has been monitored, in one of the longest-standing longitudinal studies of its kind. Original observations were made by establishing a non-residential field station in Keneba village, which was visited from time to time by scientists from the U.K. Medical Research Council laboratories at Fajara, near Banjul. In the early stages of this surveillance there were no significant interventions, and very high rates of mortality and morbidity were observed, as presumably pertained in other parts of The Gambia at that time [Billewicz & McGregor 1981].

In 1974 the field station was taken over by the Dunn Nutrition Unit, Cambridge, U.K., to undertake studies of nutritional physiology amongst the local population. As part of this arrangement, it was

agreed that the field station should provide what is essentially a U.K.-style general practitioner service for Keneba and the two adjacent villages, Manduar and Kanton-Kunda. This includes a daily surgery operated by a U.K. physician, and a U.K. midwife to coordinate maternal health. Both of these posts are a part of the research team, but a substantial proportion of their effort has been devoted to medical services. The effects of this substantial intervention over a ten-year period from 1974 to 1983 have been reported [Lamb et al. 1984]. Infant and child mortality rates for the whole period are shown in Figure 4.1. In comparison with contemporary figures from other parts of The Gambia, the low rates achieved in Keneba in the early 1980s are impressive. An indirect estimate of infant mortality for Lower River Division, in which Keneba is situated, based on the 1983 census, is over 200 per thousand.

This intervention has, however, been the subject of some controversy. The direct costs involved amount merely to the expenditure on drugs, etc. used in the clinic, and in 1983 this amounted to £6,470 for over 19,000 consultations, an average of £0.34 per consultation, or approximately £2 per capita per annum. This however neglects the costs relating to the personnel and facilities at Keneba which have been responsible for the intervention, but are funded as part of the research programme there. These costs would be of the same order, and possibly higher, as those of a single physician general practice in the U.K., based on supporting expatriate staff.

Nevertheless, the dramatic effects of the

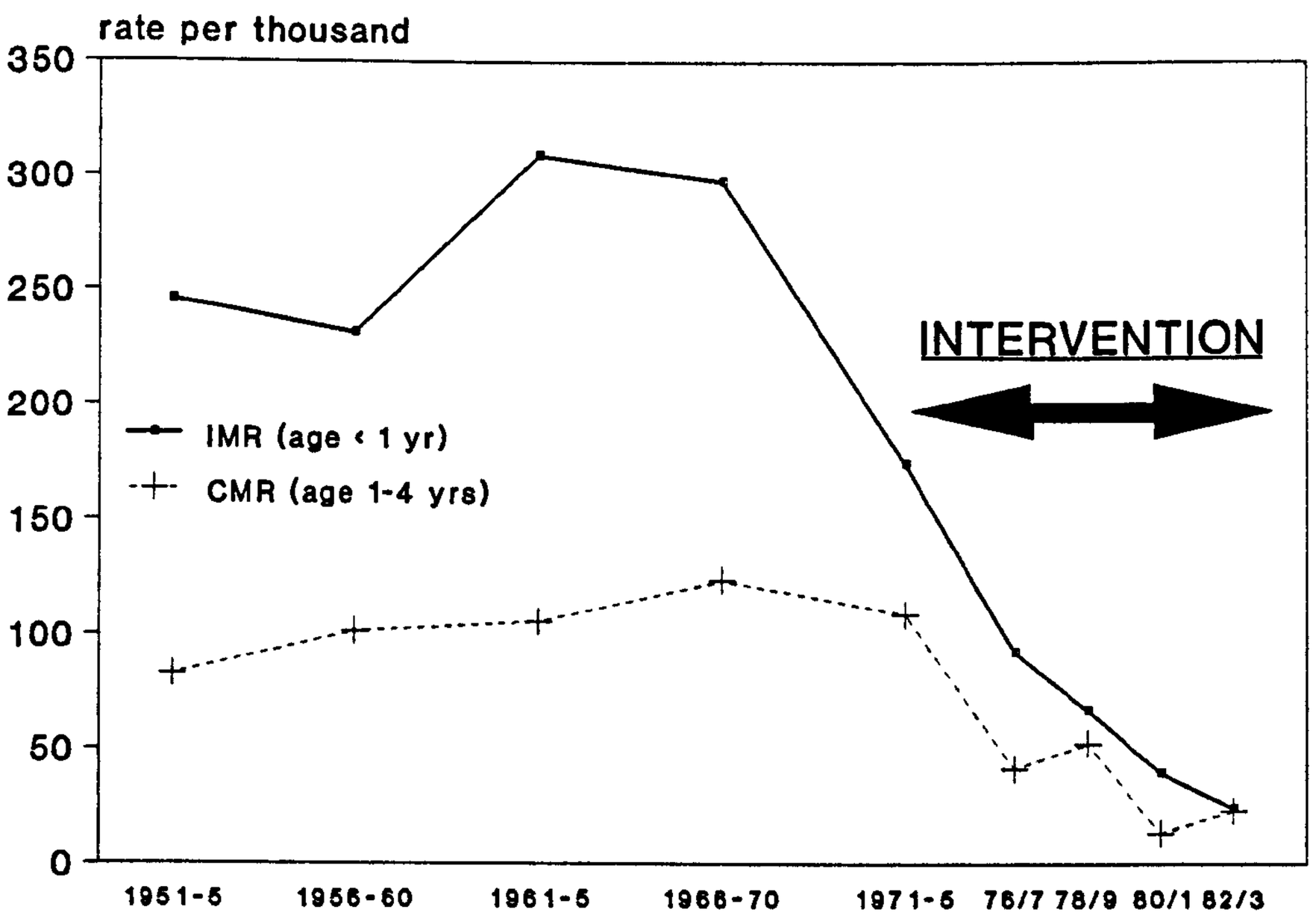


Figure 4.1: Mortality in Keneba 1951-83.

intervention must not be eclipsed by arguments that general implementations on similar lines would be unrealistic in rural Africa. There is some truth in these arguments if one excludes the possibility of economic and political changes on a global basis. However, it has been clearly shown in Keneba that there is the technical potential, given sufficiently intensive medical interventions in Africa, to bring mortality rates closer to the pattern observed in developed countries, and this refutes the propositions that rural African populations are either inherently unhealthy or cannot benefit from European-style medical care.

4.3 Primary Health Care

During the early 1980s a number of schemes were devised and implemented in developing countries world-wide under the general description of "primary health care". The general aim of most of these systems was to bring low-level, but effective, curative and preventative health services to large sectors of the community. Most programmes were designed to rely on personnel with little or no formal training.

In The Gambia, a national plan for primary health care (PHC) was devised, and implemented starting in 1981. The general structure of this plan is shown in Fig. 4.2. The programme involved the selection of an individual from villages of 400 or more people to be designated as the Village Health Worker, who was given basic training and a small supply of simple

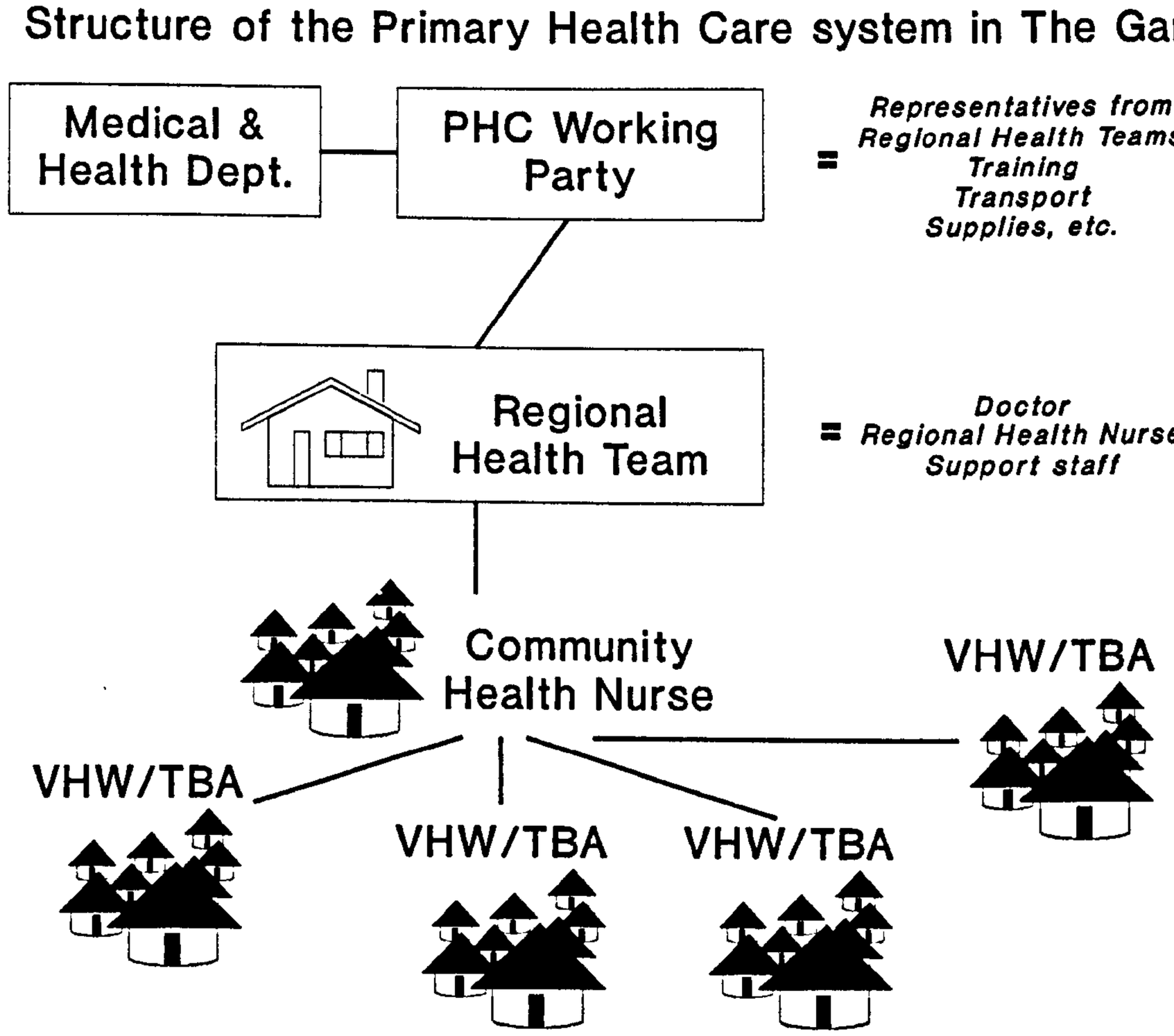


Figure 4.2: Structure of the Primary Health Care system in The Gambia.

drugs. The rest of the village were expected to compensate his efforts for their health care by providing assistance on his farm, and he was authorised to make small charges for drugs to fund stock replenishments. Existing women in the village who had traditional roles as birth attendants (TBA) were also identified and given basic training.

A study of the effects of this intervention in North Bank Division, in villages around the town of Farafenni, was undertaken by the Medical Research Council in 1982, prior to the implementation of PHC in that area. The chronology of this study is shown in Fig. 4.3 [Greenwood B.M. et al. 1989 A].

Infant and child mortality rates in both the PHC (over 400 population) villages and the smaller non-PHC villages were assessed before implementation in 1982/3, and after, in 1984/6. Small but non-significant reductions were found, which probably did not amount to more than the gradual national trend to reduced mortality rates which has been observed over some decades. Both PHC and non-PHC villages showed similar reductions. Cause-specific analysis of mortality also showed no significant differences. Only 30% of the children that died in PHC villages had consulted the VHW during their final illness, suggesting some lack of enthusiasm for the scheme among participating communities, although it was frequently stated that this was due either to the VHW's unavailability or lack of drugs.

Morbidity in infants and children was assessed using monthly interviews. A significantly beneficial

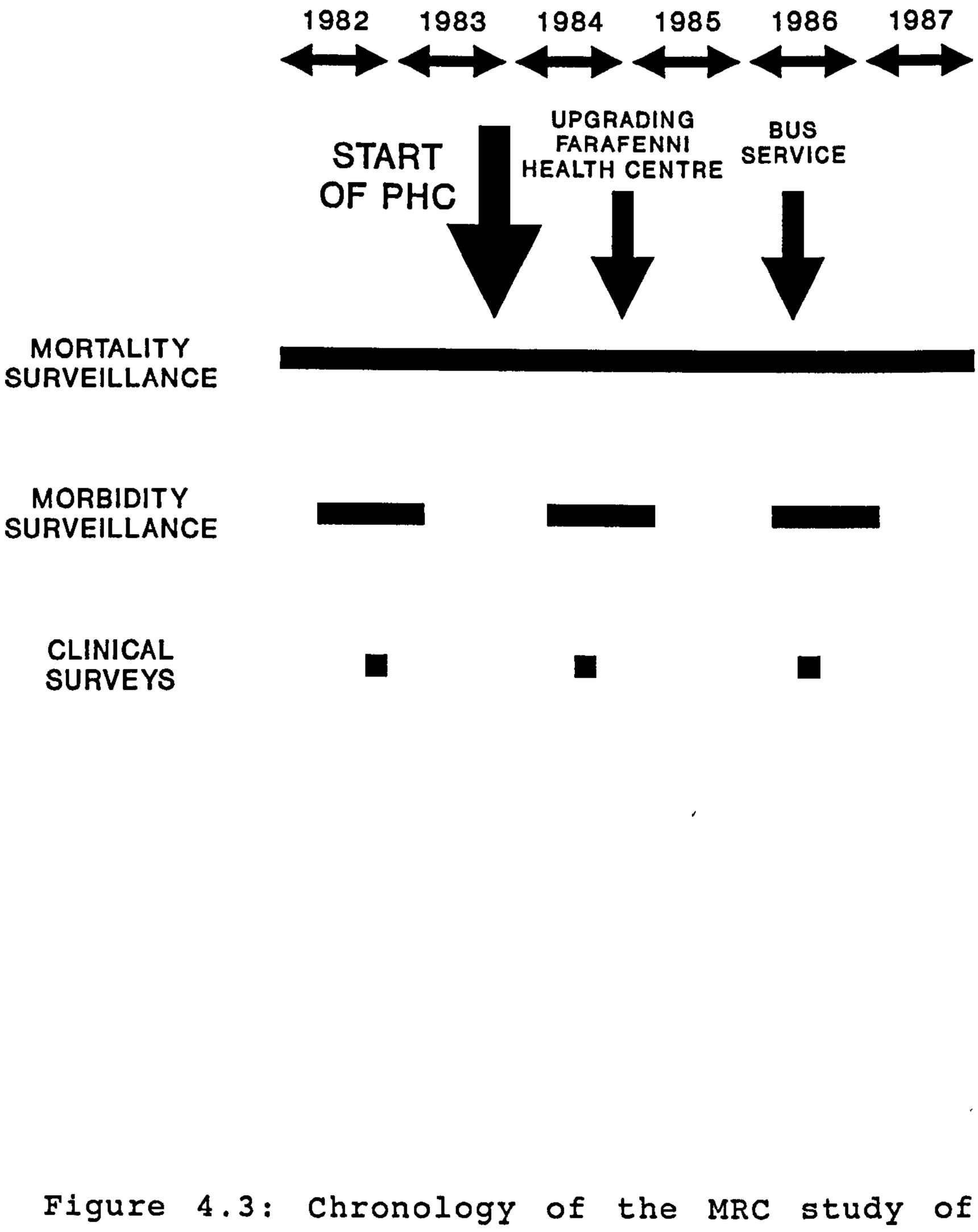


Figure 4.3: Chronology of the MRC study of the Gambian Primary Health Care programme.

effect was found only in the case of severe respiratory disease and diarrhoea/vomiting. No beneficial effects were shown for other disease categories, nor for nutritional status or vaccination.

In parallel to studying the effects of the PHC programme on children, the impact of the trained TBAs on maternal health was assessed [Greenwood A.M. et al. 1989]. This part of the study involved identifying and following all pregnancies in the same group of PHC and non-PHC villages. Ante-natal clinic attendance and tetanus toxoid immunisation rates did not increase significantly with PHC. However, women in PHC villages did make use of the trained TBAs, and more were referred to qualified midwives, health centres and hospitals than from non-PHC villages. Decreases in maternal mortality in PHC villages were not greater than in non-PHC villages however. Whilst some benefits in terms of reduced neonatal deaths after the first week were observed in PHC villages compared with non-PHC villages, stillbirth and perinatal rates did not show a similar effect.

Overall therefore the impact of the Gambian PHC programme on the health of this rural population cannot be regarded as major. Indeed, it is arguable that some of the beneficial changes observed may be due to coincidental interventions such as the provision of a regular bus service to the area, enabling people to seek health care more effectively.

4.4 Malaria Control: Treatment or Prevention?

Although many people look forward to the development and use of effective malaria vaccines, for the time being the available options for handling malaria at a public health level are either treatment, or prevention through vector control or chemoprophylaxis.

4.4.1 Community-based Chemoprophylaxis

As an additional component in the evaluation of PHC (vide 4.3), half of the children and mothers in PHC villages were randomised to receive Maloprim (pyrimethamine and dapsone) or placebo, delivered by VHWs and TBAs fortnightly. A special recording system was devised for these basically illiterate people to record delivery of the drug [Greenwood B.M. et al. 1987 D]. As part of the PHC programme, VHWs had chloroquine available for symptomatic treatment, and so this trial of the use of Maloprim enabled a comparison to be made between treatment alone, and chemoprophylaxis with treatment. Treatment alone had no impact on child morbidity and mortality from malaria, when compared with the smaller non-PHC villages [Greenwood B.M. et al. 1988]. However, a reduction in mortality among the Maloprim group was observed which approached statistical significance, and observed clinical episodes of malaria among the Maloprim group were 2 per thousand monthly observations, compared with 10 per thousand in the placbo group, a highly significant difference. Cross-sectional surveys found lower rates of splenomegaly and parasitaemia, and higher packed cell volume,

among children taking Maloprim. Criticism of chemoprophylaxis as a malaria control strategy has highlighted the possibility of impairment of normal immunological development during the protected period. When the children stopped taking chemoprophylaxis at age 5, they were therefore carefully followed to compare their immunological status and clinical protection with children in the placebo group. No evidence of any detrimental effect has been found [Otoo et al. 1988].

Among pregnant women, Maloprim was given to a 50% randomised sample in PHC villages from the time the pregnancy was detected until delivery. Since it was already known that otherwise immune women become particularly susceptible to malaria during their first pregnancy, it was not surprising to find that the major benefits of Maloprim during pregnancy accrued to primagravidae. Primagravidae taking Maloprim had a higher mean packed cell volume, a lower parasite rate, and a higher mean birth weight [Greenwood B.M. et al. 1989 B]. There were similar trends, but less marked, among multigravidae. The question as to whether a woman protected by Maloprim during a first pregnancy then becomes an immunological "primagravida" during her second pregnancy is currently under investigation at Farafenni.

From these studies it is clear that there are substantial benefits to young children, and women during their first pregnancies, of regular chemoprophylaxis. The effects of taking Maloprim fortnightly were much greater than the entire impact

of the PHC programme, suggesting perhaps that the whole PHC programme as implemented in The Gambia was rather too basic to have major effects.

4.4.2 Vector Control

For a long time attempts have been made to reduce the impact of malaria by controlling the Anopheles family of mosquitoes which are crucial to its continued transmission. Spraying programmes have not been totally efficacious, and may have undesirable environmental consequences. In recent years interest has arisen in the use of bed nets - not a new idea [Lindsay & Gibson 1988], but one which had not previously been seen as a strategy in community health. In many parts of The Gambia nets of some kind are widely used, particularly by Mandinkas. This enabled a retrospective study to assess their impact on malaria morbidity [Bradley et al. 1986]. Although not conclusive, the results suggested that there were benefits associated with the use of nets in terms of less episodes of clinical malaria, lower rates of parasitaemia and splenomegaly, and higher mean packed cell volume. A further retrospective study in another part of the country confirmed these findings [Campbell, Byass & Greenwood 1987], and a major intervention programme was undertaken. In the first phase existing nets in a large Mandinka village were randomised to be treated with permethrin or placebo. This resulted in a reduction of clinical episodes of malaria among children sleeping under treated nets [Snow, Rowan & Greenwood 1987]. A subsequent trial in a group of small Fula hamlets, where nets were not already in use, randomised entire communities to

receive or not receive nets, without insecticidal treatment. This showed only relatively modest benefits of net use [Snow et al. 1988 A]. Lastly, the same group of villages, in the following malaria season, were randomised to permethrin treated nets or placebo treated nets. The process of actually impregnating nets in the field is shown in Figure 4.4 [Snow et al. 1988 B]. This intervention was the most effective [Snow et al. 1988 C], finding a 2.5x greater clinical attack rate for malaria among children in villages with placebo treated nets.

Other traditional methods of reducing the nuisance of insects are practiced in rural communities, based on having certain aromatic woods and resins smouldering in pots within dwellings. However, an evaluation of the effectiveness of this approach failed to detect any changes in malariometric parameters as a result of burning churai [Snow et al. 1987].

In view of the encouraging results for malaria control arising from both the use of chemoprophylaxis and insecticidal bed nets, a trial is being undertaken to investigate the combined effect of a dual intervention.

4.5 Immunisation Programmes

The Expanded Programme for Immunisation started in The Gambia in 1980 [Fitzgerald & Gowers 1983], with a schedule consisting of BCG vaccination at the first clinic visit, oral polio and triple vaccines at 2, 3

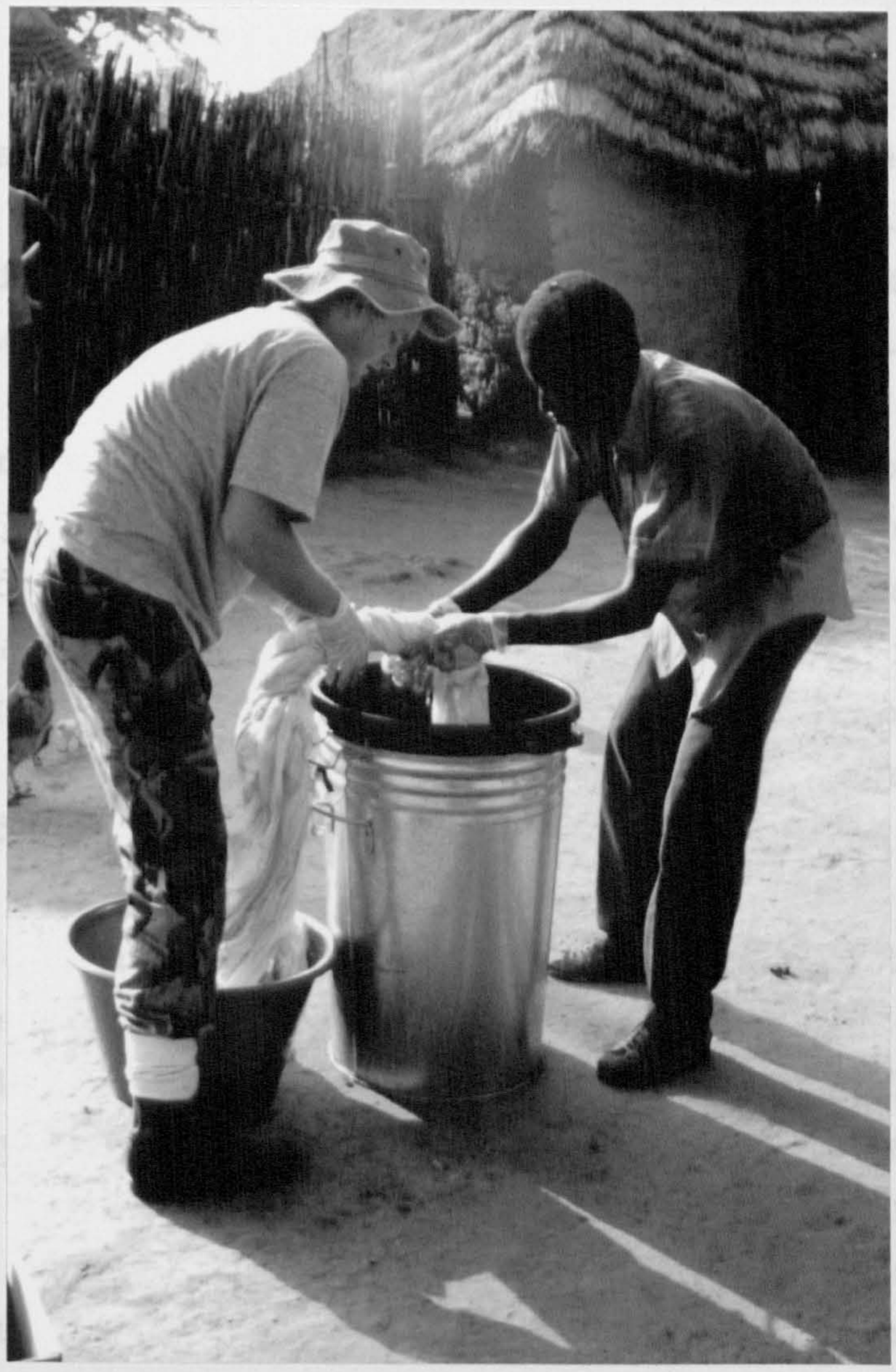


Figure 4.4: Delivering low-technology health care: impregnation of bed nets with insecticide in a Gambian village.

and 4 months, and finally measles and yellow fever vaccination at 9 months. Coverage rates have since been monitored regularly and found to be high [Hall et al. 1989], though coverage tends to be slightly lower in more remote areas of the country.

Despite the good coverage, in 1986 there was an outbreak of paralytic poliomyelitis resulting in a number of cases of long-term paralysis. Some of the cases had received a full course of vaccinations, however, suggesting that seroconversion to all three polio serotypes was less than adequate [Hanlon et al. 1987 B]. A vertical nation-wide vaccination programme was rapidly instituted, which probably played a role in curtailing the epidemic. On reviewing the situation, immunisation policy was changed to include 5 doses of oral polio vaccine (one dose at every scheduled vaccination).

Despite vaccination, outbreaks of measles were still relatively common, until a vertical measles vaccination campaign was undertaken in 1987. Since then very small numbers of measles cases have been reported from any part of the country, in almost all of which there had been contact with the disease in other countries. The current lack of measles in The Gambia is a notable achievement for the immunisation programmes, given the serious manifestations of measles to be found in many developing countries.

Several vaccines that are not part of the normal EPI schedule have been used on a trial basis in The Gambia. One of the problems of measles vaccination is that the normal measles vaccine is highly susceptible

to interference from maternal antibodies, and for this reason cannot be satisfactorily given until 9 months of age, by which time many infants may have been infected. However, trials of the new high-dose Edmonston-Zagreb measles vaccine [Whittle et al. 1988] have shown that comparable protection to the normal regime can be achieved with a single dose at 4 months of age, thereby greatly reducing exposure to infection. It seems likely that this vaccine may be used in immunisation programmes in many parts of the world in the near future.

In 1985 a new bovine rotavirus vaccine (RIT 4237) was tested in the peri-urban community of Bakau. Although rotavirus infection accounts for a relatively small proportion of infant diarrhoea, it is considered to cause more severe disease than other aetiological agents, and for this reason an effective rotavirus vaccine could be of use in developing countries. The vaccine had previously been shown to have a high efficacy against rotavirus disease in Finland [Vesikari et al. 1984]. However, in the trial in Bakau [Hanlon et al. 1987 C], the protective efficacy was only 33%, which would certainly preclude the general use of this particular vaccine. It has been speculatively suggested that the generally high load of gut pathogens in Gambian infants, compared with those in Finalnd, may account for this much lower efficacy. A further component of this trial studied interference between oral rotavirus vaccine uptake and oral polio vaccine uptake by including a group who received killed polio vaccine intramuscularly. The interference effect was not found to be statistically significant, although there

was some evidence of an interaction. This could further prejudice the general adoption of rotavirus vaccine, since from a delivery point of view a successful vaccine would need to be mixed with oral polio vaccine.

A major project to investigate the interaction between hepatitis B infection and subsequent development of hepatocellular carcinoma (HCC) has involved experimental nationwide introduction of hepatitis B vaccine into the general schedules over a 5 year period from 1986. The hypothesis under test is that infantile infection with hepatitis B (infection being almost universal, and asymptomatic, by the age of 5 years) may lead to increased risk of HCC, particularly in individuals who become chronic carriers of hepatitis B. By vaccinating at birth, it is hoped to block transmission in a nationwide cohort of infants, and, by setting up a cancer registry, to assess 30 or 40 years later whether the vaccinated group develop less HCC [Hall et al. 1987]. This is the first community intervention against cancer by vaccination, and is being carried out by the International Agency for Cancer Research (IARC), Lyon, France.

Investigations have also been carried out into attitudes towards vaccination, and factors influencing compliance [Hanlon et al. 1988]. By comparing a group of poorly vaccinated children with a group of fully vaccinated children in the same community, it was possible to show that poorly vaccinated children tended to have less-well educated mothers and poorer fathers. Their mothers were less

inclined to bring children to the health centre for non-curative services, had less understanding of scientific causes of disease, and had more children. This information may prove useful in targeting groups for health education, or for encouragement to bring their children to clinics.

Chapter 5: MEDICAL INFORMATICS

5.1 Introduction

Medical Informatics is a relatively new science on a worldwide basis, bringing together the disciplines of both medicine and information science, as the latter has developed technologically to the point of becoming useful to the former. The International Medical Informatics Association (IMIA) now holds regular triennial congresses known as MEDINFO, which have become major international forums for workers in the field.

5.2 Historical Background

Since the early 1970s the field has been in exponential development mainly because of the increasing availability of less expensive hardware and increasingly powerful software. The last 20 years have seen the advent of microprocessor-based personal computers, development of digital communications and networks and so-called fourth and fifth generation software, geared towards expert systems and artificial intelligence. Within medical informatics, the proportion of effort devoted to expert systems and decision support has increased markedly since the mid-1980s [van Bemmel & Shortliffe 1986].

5.2.1 Medical Expert Systems

Academic interest in the application of computers to clinical medicine has increased steadily since the early 1950s. At that stage, the practical feasibility of using computers was very limited due to their very restricted capabilities, but it was perceived that there was considerable potential in the general possibility of so doing. As long ago as 1959 Ledley and Lusted wrote "Reasoning Foundations of Medical Diagnosis" [Ledley & Lusted 1959], stating that they wished "to analyse the complicated reasoning processes inherent in medical diagnosis" because of "the increasing interest in the use of electronic computers as an aid to medical diagnostic processes". They argued that a more systematic and logical approach to medical decision making might in fact be preferable to clinical "feelings".

Some early attempts at computerising medical decision processes involved the mechanisation of what were essentially elaborate sets of flowcharts, or binary trees [Kleinmuntz 1968]. In the late 1950s interest in Bayesian statistics [Bayes 1763] as a decision making method was raised [Savage 1954]. Later, Savage stated that the "Bayesian viewpoint forms a good framework in which to discuss and develop a language for diagnosis that is sensitive to the complexities of diagnostic decision making" [Savage 1972]. A number of examples of the possible uses of Bayesian statistics in medical decision making emerged [Warner et al. 1961; Pryor & Warner 1972]. The difficulty of estimating probabilities was a problem [Elstein & Bordage 1979]. Clinicians tended

to introduce errors in their estaimations for several reasons. Event frequencies could be wrongly estimated through the event having common features with other events. Overestimation may occur if a particular event, by chance, has occurred frequently in the immediate past and is therefore more available to memory. Clinicians have also been found to be more sure of the accuracy of their estimates than is warranted [Fischhoff, Slovic & Lichtenstein 1977].

For a variety of reasons, medical expert systems did not advance particularly fast during the 1960s and 1970s. There was a feeling that computer expert systems were not a sufficiently reliable medium to be trusted with decisions that would influence patient care [Kleinmuntz 1984]. Nevertheless interest continued among various research groups, most of which worked towards systems using data from large hospital record databases. Various medical record systems were developed with a view towards facilitating access to this kind of data, for example the MUMPS system [Barnett et al. 1981]. Several large systems were developed during the 1970s, the best known of which is perhaps INTERNIST [Miller, Pople & Myers 1982]. This system sought to model American hospital-style internal medicine diagnosis, using artificial intelligence methodology. Evaluation of its clinical "judgement" was reasonable, though judged insufficiently reliable for live clinical applications. It also required major mainframe computer resources to run. Because of the enormous size and complexity of a system designed to cover as wide an area as INTERNIST, to American standards of health care, many other experimental systems have

concentrated in specific specialities. An example is the MYCIN system, specifically geared to the selection of antibiotic therapy, working on a rule-based artificial intelligence approach. Nevertheless, artificial intelligence has not proved to be the ultimate solution that some had envisaged; as recently as 1982 the lack of common sense capabilities in expert systems was specifically commented on [Kolata 1982].

Whilst these (largely American) projects towards artificial intelligence solutions of major complexity had been in progress, other approaches had been developed elsewhere. In Leeds, de Dombal and colleagues, working with what now seems very basic technology, designed a system based on Bayesian statistics to deal specifically with the diagnosis of acute abdominal presentations [Horrocks et al. 1972]. This system proceeded to a clinical trial [de Dombal et al. 1972] with encouraging results. The computer system achieved a level of diagnostic accuracy of 92%, compared with a group of senior clinicians who achieved 80%.

In recent years the increasing power of both software and hardware has led to new systems that come closer to clinical acceptability, although there is still very little widespread utilisation of such systems. Nevertheless, the increasing availability of microcomputers of reasonable power has stimulated interest in clinical decision making systems, since there now seems to be at least a possibility that facilities based in consulting rooms rather than computer centres might be viable. de Dombal in 1984

[de Dombal 1984] made the point that almost every UK school had microcomputer facilities, to say nothing of 11% of households - but that the a priori argument for clinical care being an overwhelmingly human, rather than computerised, activity was still current in relation to medical decision making systems. de Dombal has consistently argued however that a computer system designed to aid medical decison making should be another clinical tool, like X-rays, for example, which can make an important contribution to the whole patient consultation, diagnosis and management setting, but which does not replace in any sense the final judgement of a clinician.

5.2.2 Informatics in Developing Countries

Given the relatively new status of medical informatics worldwide, it is not surprising that devlopments in the field within developing countries have been severely limited. Nevertheless, since one of the major problems facing health services in devloping countries is a shortage of suitably trained and skilled manpower, the possibilities of using informatics to enhance the efficiency of available personnel are exciting.

It has been argued [Ochoa 1983] that importing computer technology does not bridge the developmental gap. On the other hand, [Byass 1987] technology has been found to play a major role in development processes, provided that implementations are locally appropriate. Microcomputers in particular have introduced possibilities not previously considered. Although medical informatics world-wide is expanding

rapidly, the position of developing countries in new developments is frequently ignored [Mill 1986; O'Brien & Channing 1986] and so the gap between utilisation in developing and developed countries may in fact increase rather than decrease.

Futuristic developments such as the use of satellites in computerised health systems [Gillett 1987; Cross et al. 1984] currently seem remote options, but they may constitute a component of future implementations.

Current problems of implementing informatics systems in developing countries have been recognised as including lack of standardisation, lack of skilled manpower, existing organisational problems, reliability problems and infrastructural difficulties of communication [Shires et al. 1983]. The need for systems to be adapted to local requirements, to enhance acceptability and usefulness, have been stressed [Agbalajobi 1983]. Despite the availability of informatics systems, many considerations of health services in developing countries ignore the potential contribution of informatics [Morley 1987; Cumper 1987; Chen 1986]. This continues to happen despite reports of successful implementations at peripheral levels of health services [El Kholy & Mandil 1983] and the finding that computer technology from the developed world can make a positive impact in less sophisticated situations [Gillett 1987]. For example, a nationwide data collection system for previously unavailable health data in Egypt has been documented [Gomaa 1983]. Problems in familiarising and training staff to use a health information system in

Bangladesh have also been resolved [Gould & Frerichs 1986], and there are slowly increasing numbers of projects using microcomputers for analysing field data [Kanté, Brinkmann & Bocoum-Maiga 1986], and, in some cases, small portable hardware for data collection [Reitmaier, Dupret & Cutting 1987]. Very little work on expert systems and decision support in developing countries has been reported. A team from Médecins sans Frontières working in Chad [Auvert et al. 1985; Auvert et al. 1986] have reported developing a computerised version of previously developed flowcharts [Essex 1980] for diagnosis of tropical diseases. There has also been some work on medical decision support for people in particularly isolated environments such as submarine personnel and astronauts [Robinson et al. 1983; Grams et al. 1986], which are in some ways analogous to the particular problems of developing countries.

5.3 Informatics in The Gambia

The first computer installation in The Gambia, a PDP minicomputer, was commissioned for the Hydromet department in the late 1970s, to collate meteorological data and in particular to provide the necessary information on weather conditions for international air traffic. The Central Statistics Department followed with a Wang mini, and from the early 1980s onwards the number of installations has grown rapidly.

5.3.1 Appropriate Hardware

The question as to what hardware is most suitable for use in tropical conditions has not been intensively studied. The advent of microcomputers considerably increased the feasibility of using computers in an environment where servicing facilities are not readily available. Some microcomputers were modified in an attempt to increase their durability [Anon. 1984]. Experience in the operation of computers in tropical conditions is slowly being gathered [Byass 1987], but it will continue to be difficult for organisations and governments to operate computers in developing countries to the standards expected in other parts of the world until more direct technical support is generally available locally.

5.3.2 Epidemiological Applications

At the U.K. Medical Research Council's (MRC) laboratories in The Gambia, until 1981 data arising from epidemiological and other studies were either analysed by hand or sent to European centres, particularly the London School of Hygiene and Tropical Medicine, for computer analysis. In 1981 the feasibility of on-site data processing was considered, and, although the viability of such an idea was not completely known at that stage, a pilot project was agreed whereby initially two microcomputers would be "tropicalised" [Anon. 1984] and used at Fajara. From 1982 to 1984 these machines worked well, and apart from the useful work they did during this period, they established the usefulness

and feasibility of local data processing.

In the light of this experience, a larger and more powerful system was installed in 1984, with hard disc storage and networked discless workstations [Byass 1987]. This facilitated considerable potential for epidemiological data management and analysis. However, there was little recorded experience of applying computers to field studies in epidemiology at that time, and methodologies that were appropriate both to the technology and the special considerations of epidemiological field studies in a developing country had to be developed.

Because of the off-line methods that had previously been in use, some re-thinking of epidemiological methods, particularly of questionnaire design, had to be considered to facilitate the transition from thinking in terms of records on punched cards to records in an on-line database [Byass 1986]. This also had implications for subject identification, a notoriously difficult aspect of tropical epidemiology. Ethnic and associated linguistic difficulties also arise, whereby apparent ethnic differences may in fact be attributable to variations in the translation of questions into different ethnic tongues.

Having improved our epidemiological methods to this extent, we had a good system for retrospective analysis of epidemiological data. However, the success of the computer system in this respect prompted us to consider the possibility of having computer facilities at rural field stations, to allow

virtual on-line processing facilities in real time as data were collected [Rowan, Byass & Snow 1987]. Thus, in the context of a study of insecticide-treated bed nets [Snow, Rowan & Greenwood 1987], a system was set up at the MRC field station in Farafenni to receive and process weekly surveillance data within the week. Although it was not feasible to design a trial whereby only part of the data was handled in this manner, an analysis of the quality of data obtained showed the methodology to be highly effective. Because the computer system was able to monitor movements in and out of the study cohort, an up-to-date list of children for interview could be produced each week, and as a result field workers successfully completed 99.8% of all interviews.

The weekly questionnaires were relatively simple, with a total of 44 characters per form, in 20 fields. All of them were doubly entered to trap keyboard errors, which were thus detected at a rate of 0.6% of fields entered. After correcting these errors, logical checks performed by the computer revealed a further 0.3% of errors. As a result of the prompt data processing, it was possible to correct 96% of these detected errors by reference to field workers, and where necessary, interviewees, with the result that an exceedingly clean database was immediately available for analysis at the end of the field surveillance period. Similar projects in developing countries had previously noted the bottle-neck effect that data processing can easily generate in such projects [van Ginneken & Muller 1984], and the success of this project represented an important methodological advance.

Subsequently further refinements have been made to the general method, such as the printing of self-adhesive labels for use on questionnaire forms, and used in a number of other studies [Snow & Byass 1988; Byass 1989 A; Byass 1989 B].

5.3.3 Demographic Applications

A further problem facing field investigators in developing countries is often the lack of accurate information on local populations at the individual level. This causes difficulties in actually identifying study subjects, and so it is often necessary to undertake basic demographic surveillance to solve this problem. A computerised method of doing so has now been devised at Farafenni [Stephens et al. 1989] which facilitates the maintenance of a local population census, with regular updates to record vital changes in the population.

5.3.4 Clinical Trial Management

In organising community based clinical trials in developing countries, many similar considerations apply as to epidemiological studies, particularly in terms of personal identification, etc. In addition there are further requirements, dependent on the design of the trial, such as calling subjects to clinics at predetermined intervals.

In our clinical trial of rotavirus vaccine [Hanlon et al. 1987 C], there was a requirement to continuously register newborn infants in the study

area, and to call them for vaccination and follow-up at certain times, some of which were age related, and others to intervals since previous attendances. With a total of almost 500 children in the trial, it would have been a major clerical effort to organise manually, and hence a computer system was established for use in the management of the trial [Byass et al. 1988].

In this trial, where vaccination with the new vaccine was integrated with the EPI structure, it was possible to compare vaccination compliance rates with those in the same community in the period preceding the trial. During the trial the overall compliance rate for clinic visits within one month of the due date was 98%, compared with 59% in the preceding period. Although this obviously represents a lot of work by field staff in requesting mothers to come to clinic at the appropriate times, without the computer system to actually keep track of who should be coming when, it seems unlikely that these very high compliance rates could have been achieved.

5.3.5 Health Services

Computerisation within Government health services in The Gambia has so far been relatively limited. A small computer centre was established at the Medical and Health Department in 1986/7 to handle incoming statistics from health centres in order to facilitate planning and identify problems. There have not so far been any decentralised installations.

However, since one of the major problems of the

health service is a lack of qualified staff, particularly in rural areas, the possibility of decision support systems at health centre level seems an obvious application that could be filled with an appropriate system. It is therefore the development and testing of such a system, which could give support to health centre staff in patient management, that is the major theme of this thesis.

Chapter 6: APPROACHES TO DECISION SUPPORT

6.1 Introduction

Many different approaches to computerised decision support have been used in recent years. The choice of method depends not only on the nature of the decision system being modelled but also on the hardware that is available or practicable for a final implementation.

6.2 Choice of Methodology

The major methodological division in the area of decision support is between so-called artificial intelligence or heuristic methods on the one hand and probabilistic or statistical methods on the other. Both approaches have advantages and disadvantages, which have been extensively rehearsed. It has been noted that interest and activity in the former category has been increasing recently at the expense of the latter [Spiegelhalter & Knill-Jones 1984]. The relatively low impact of statistical methods, despite long gestation periods, has been attributed to inflexibility, poor interfacing and lack of obvious clinical benefit [Friedman & Gustafson 1977]. On the other hand, AI approaches have not been widely implemented other than in research environments, despite having now been available for some time.

6.2.1 Statistical Systems

In general, statistical approaches to clinical decision support rely on relating a set of diagnostic classifications to a set of patient parameters, in such a way that a particular set of the latter enhance statistical support for the presence of certain members of the former, in a particular case. Many of these approaches are based on Bayes' theorem, first postulated by Rev. Thomas Bayes in the eighteenth century [Bayes 1763], as shown in Figure 6.1. This formed the basis of de Dombal's successful work in the 1970s on decision support for diagnosis in acute abdominal presentations [de Dombal et al. 1972] using a set of conditional probabilities from a database of existing abdominal patients. Critics of the method frequently refer to the implied independence of parameters between diagnostic classifications. Some attempts have been made to incorporate interaction terms and thus no longer assume independence [Titterington et al. 1981; Pantin & Merrett 1982]. However, such techniques considerably increase the complexity of the overall system. It has also been argued however [Hilden 1984] that conditional independence is a sufficient but not necessary condition for the validity of conditional independence Bayesian methods. In practice, various systems using this method, but in which true conditional independence is demonstrably absent, have been shown to be valid. The lack of clinical uptake of systems using this approach has been attributed to the failure of researchers in the area to transfer the science of the methods into usable technology [Spiegelhalter & Knill-Jones 1984].

quodque ſolum, certa nitri ſigna præbere, ſed plura concurrere debere, ut de vero nitro producto dubium non relinquatur.

LII. *An Eſſay towards ſolving a Problem in the Doctrine of Chances. By the late Rev. Mr.* Bayes, *F. R. S. communicated by Mr.* Price, *in a Letter to* John Canton, *A. M. F. R. S.*

Dear Sir,

Read Dec. 23, 1763. I Now ſend you an eſſay which I have found among the papers of our deceaſed friend Mr. Bayes, and which, in my opinion, has great merit, and well deſerves to be preſerved. Experimental philoſophy, you will find, is nearly intereſted in the ſubject of it; and on this account there ſeems to be particular reaſon for thinking that a communication of it to the Royal Society cannot be improper.

He had, you know, the honour of being a member of that illuſtrious Society, and was much eſteemed by many in it as a very able mathematician. In an introduction which he has writ to this Eſſay, he ſays, that his deſign at firſt in thinking on the ſubject of it was, to find out a method by which we might judge concerning the probability that an event has to happen, in given circumſtances, upon ſuppoſition that we know nothing concerning it but that, under the ſame circum-

Figure 6.1: Facsimile of Rev. Bayes' original statement of his theorem.

6.2.2 Knowledge-based Systems

Much interest in AI and heuristic methods has originated from the view that it is knowledge rather than data which should form the basis of any decision process, stemming from a desire to make computers behave more like human brains. Acquiring the necessary knowledge is an area in itself that has received considerable attention. Unlike statistical systems, where a complete set of data is required from the outset, a knowledge-based system can start with relatively simple basic knowledge and "learn" from experience as it operates, again rather like a human consultant. Clinical knowledge-based systems can proceed through a consultation less mechanically than statistical systems, as for example in INTERNIST, where initially the system pursues a discriminatory line of enquiry, changing to a confirmatory pursuit of likely outcomes once they begin to emerge [Miller, Pople & Myers 1987]. Rigorous evaluations of knowledge-based systems have not been widely reported, presumably either because the complexity of their reasoning makes objective assessments difficult, or perhaps because their more subjective nature is to some extent incompatible with objective evaluation. It is however true, at the current state of the technology, that running AI-based software brings with it intensive demands on hardware. Although this may be alleviated in the future, it is a major current factor restricting clinical implementations of sophisticated knowledge-based systems. Certainly in terms of health services in developing countries, there is little realistic prospect of AI systems having any major impact in the

immediate future.

6.3 Requirements of the System

Before developing details of a methodology for use in a decision support system for use in a rural African setting, it is necessary to define criteria which the method must satisfy. The system, to be clinically useful, must be able to cover the whole area of health problems that might present at a rural clinic (although referral to a higher centre would be the endpoint of choice for a variety of presentations at the more serious or unusual end of the spectrum). Secondly, there has to be the capability of considering basically independent endpoints in parallel, ideally with interactions although that may not be technically feasible nor essential. Thirdly, a traditional medical diagnosis, with no immediate implications of patient management, would not be the most useful kind of endpoint in this situation. A more valuable approach would be to recommend case management strategies. Fourthly, the system must guide its user through the clinical consultation process, and thus facilitate the elicitation of details relevant to the case. Finally the system in its final implementation would have to be capable of running on sufficiently simple hardware so that it could be used in a health centre. Criteria for suitable hardware would therefore include portability, ruggedness in a tropical environment, independence from mains electricity and reasonable cost.

6.4 Basic Methodology

Irrespective of the theoretical advantages and disadvantages of knowledge-based versus statistical methods, the constraints imposed on the choice of methods by hardware factors dictated the use of statistical methods. Nevertheless, there are considerable arguments in favour of statistical methods, and the existence of hardware constraints in this particular application does not imply "second best" status for non-AI methods. Because the level of health care under consideration is much lower than that in many other decision support systems, the reasoning processes underlying it are also much simpler, and hence seem well suited to a probabilistic approach. Real-time clinical support is sought, and it is also therefore important to retain computational simplicity, and hence rapid response. In view of geographical variations in tropical health problems, the concept of a data-driven system, into which a dataset appropriate to the locality can be inserted, also seems advantageous. This facility would be more difficult to achieve with a knowledge-based system in which the "learning" would have been related to a particular environment, or indeed particular experts.

6.4.1 Bayes' Theorem

Bayes' Theorem [Bayes 1763], in the context of diseases and symptoms, is generally stated in terms of conditional probabilities, where $P(x|y)$ is the probability of x given the presence of y, and $P(\bar{x})$ is the probability of NOT x, as:

$$P(D|S) = \frac{P(S|D) \cdot P(D)}{P(S|D) \cdot P(D) + P(S|\bar{D}) \cdot P(\bar{D})}$$

where D is one of a set of diseases and S one of a set of a symptoms. Thus it is possible to calculate the probability that a particular disease is present given the presence of a particular symptom, from data on the probability of a particular symptom given the disease, and the probability of the disease in general.

6.4.2 Terminology

Following from the requirement to develop a system with management-orientated endpoints, it is important to develop terminology that is not confined to concepts of diseases and symptoms. Accordingly the following definitions have been adopted, and will be used throughout.

INDICATOR - an item of information pertaining to a particular patient's case. Symptoms, signs, histories, laboratory test results, season and other personal details would all be included.

STRATEGY - an action to be taken. Treatments, referrals, undertaking tests, making examinations, would all be included. By implication therefore carrying out certain strategies may generate additional indicators.

CHARACTERISTIC - an item of information analogous to an indicator, but at the patient population level, pertaining to a strategy, rather than to an individual case.

RELEVANCE - the probability that a particular characteristic is present, given that a particular strategy is appropriate, at the patient population level.

USAGE - the unmodified probability that a given strategy is appropriate, at the patient population level.

OCCURRENCE - the unmodified probability that a given characteristic is present, at the patient population level.

ADVISABILITY - the probability that a particular strategy is appropriate in a particular case.

THRESHOLD - the level of advisability beyond which a strategy is selected for implementation.

6.4.3 Basic Theorem

Using the terminology defined above, we can proceed to a basic data system of n strategies $S_1..S_n$ and m characteristics $C_1..C_m$. Each strategy S_i has a corresponding usage U_i and threshold T_i, while each characteristic C_j has a corresponding occurrence O_j. Characteristics and strategies are then related by a set of n x m relevances R_{ij}.

In parallel to the system data, each patient then has a personal set of indicators $I_1..I_x$, where $x \leq m$, and which can be used in conjunction with the system data to generate a patient set of advisabilities $A_1..A_n$, corresponding to strategies $S_1..S_n$.

The theorem in these terms can be expressed as:

$$A_i(S_i|I_j) = \frac{R_{ij}(C_j|S_i) \cdot U_i}{\{R_{ij}(C_j|S_i) \cdot U_i\} + \{O_j \cdot (1 - U_i)\}}$$

This theorem can then be applied repeatedly for each I_j if initially $A_1..A_n$ are made equivalent to $U_1..U_n$ (that is, in the absence of any modifying factors, advisabilities are equivalent to population usages). Thereafter A_i of the previous cycle becomes U_i for the next.

If A_i reaches either 1 or 0, it will remain at that value through any further iterations, and any R_{ij} value of 0 will force the corresponding A_i to 0. It is also possible to build in a non-Bayesian condition whereby if R_{ij} is 1, the corresponding A_i becomes 1. These conditions make it possible to force or prohibit a particular strategy on the basis of an single characteristic.

6.4.4 Algorithm

If each strategy S_i has a Boolean flag G_i associated with it to show whether or not S_i has the capability of generating further indicators, then the overall algorithm for the system can be stated as:

```
FOR 1 TO n
  LET A_i = U_i
ENDFOR

finish=FALSE

DO UNTIL finish
  GET(I_j)
  finish=TRUE
  FOR 1 TO n
    LET U_i = A_i
    CALCULATE(A_i)
    IF G_i AND (A_i > T_i)
      THEN DISPLAY(S_i)
      finish=FALSE
    ENDIF
  ENDFOR
ENDDO

FOR 1 TO n
  IF NOT(G_i) AND (A_i > T_i) THEN DISPLAY(S_i)
ENDFOR
```

6.4.5 Applicability

The above outline gives a methodology which satisfies our requirements. The generalised terminology adopted allows the representation of a sufficiently wide range of clinical entities, such that the whole clinical process can be represented. A number of endpoints (in fact, all strategies in the system) can be considered in parallel. Interactions are not dealt with, but the reliability of conditional independence Bayesian statistics, at least as far as ranking probabilities goes, is likely to be sufficient without true conditional independence. Hilden [1984] has suggested that the likely effects of non-independence are to produce more extreme results, which on a threshold system is unimportant. By generalising from diagnoses to management strategies suitably useful endpoint(s) can be reached. In addition, since strategies can include information-generating activities, such as tests and examinations, the clinical process can be guided by the system, as recommendations are initially made for such strategies, before final endpoints are suggested. Finally, the methodology is relatively simple, and, given the relatively limited nature of the health care setting for which the system is designed, a complete implementation on relatively simple hardware should be possible.

Chapter 7: CLINICAL DATA

7.1 Introduction

As part of its service to the local community, the MRC in The Gambia provides a range of clinical facilities. Principally these are situated at the Fajara site, where a three tier system operates. Less structured clinical services operate from the field stations.

At Fajara, the first level of clinical services is known as the Gate Clinic (so called from the time when this stage took place outside the main gate). Anyone who cares to present themselves at this clinic by 8 a.m. will be seen by a physician or senior dresser in a very brief consultation. This will result either in a prescription from a range of about thirty simple treatments, or referral to the second tier of the system (which happens in about 10% of cases). Up to 200 patients are seen in the Gate Clinic each working day.

The second tier of the system is an out-patients clinic operating along the lines of a U.K. style general practice. Patients referred from the Gate Clinic are seen by a physician in a traditional surgery-style consultation, together with previous patients given return appointments and patients referred from other medical facilities in The Gambia.

The third tier consists of a non-surgical in-patient facility of about 40 beds, roughly half

paediatric and half adult. This unit takes admissions primarily from the out-patients clinic, together with some emergencies after hours.

7.2 The Gate Clinic as a Source of Data

Because of the very superficial nature of Gate Clinic consultations, and the large numbers of patients involved, no formal records are normally kept at this level. However, as a source of data for this project the Senior Clinician (Dr. P.T. Corrah) agreed to record a sample of Gate Clinic consultations for a one-year period (1987). The sample was based on recording approximately the first 1,000 patients attending in each calendar month.

7.2.1 Advantages

One major advantage of using this clinic as a source of data was that, unlike most primary-level clinics in The Gambia, it was staffed mainly by qualified physicians. There was a reasonable expectation therefore that the quality of patient management would be high.

At the same time, the range of treatments used in the Gate Clinic is similar in many respects to that allocated to government health centres, with the possibility of onward referral where necessary. Returning patients and referrals from other facilities are automatically excluded (since they would attend the out-patients clinic directly). Thus Gate Clinic patients are a group of people attending

for medical care at their own instigation, and being managed in a similar fashion to other health centre patients in The Gambia.

7.2.2 Disadvantages

There are however some respects in which the Gate Clinic patients are not entirely representative of general health centre attenders. Fajara is situated in a peri-urban area on the coast, and so the majority of patients are likely not to come from rural communities. On the other hand, because the MRC clinical services enjoy a considerable reputation in The Gambia, there are also some people who self-refer from some distance rather than attending a local health centre.

The MRC operates no obstetric services, and hence morbidity associated with pregnancy is under-represented. Likewise it does not function as an EPI vaccination centre.

It is therefore important to exercise caution in extrapolating from Gate Clinic data; nevertheless as individual patient data it probably represents the best source available in The Gambia.

7.3 Methods of Data Collection

In view of the highly seasonal nature of certain important diseases in The Gambia, it was clearly necessary to undertake data collection over a complete year. It was also necessary to monitor

sufficient cases to obtain relatively precise data on quite rare occurrences, certainly for presentations and managements occurring as rarely as in 1% of patients attending.

A further constraint was that the process of collecting data should not impinge significantly on the smooth running of the Gate Clinic. Since most Gate Clinic consultations only last for less than a minute, it was therefore very important to use a simple form on which to record the essential data. Since traditional clinical concepts of diagnosis have very little direct relevance to this type of situation, the data recorded would concentrate on main features of presentation and management.

A form was therefore devised in collaboration with Dr. Corrah, which is shown in Figure 7.1. Completing the form only involved circling the appropriate age group and sex in the top section, relevant details of presentation in the central section, and management in the lower section. It proved feasible to do this during the course of the consultation without significantly delaying the clinical process. The data thus recorded were subsequently coded on the right hand side of the form and entered into a database.

It was therefore decided to collect data using these forms on approximately the first 1,000 Gate Clinic patients attending each month during 1987. A total of 13,212 consultations were successfully documented in this way, out of a total of 27,824 Gate Clinic consultations during the year. The seasonal patterns of actual attendance and of case recording

Form GC1

M.R.C. GATE CLINIC

FOR COMPUTER CENTRE USE

PATIENT

AGE: (mark one)

1 < 1 month
2 1 - 6 months
3 6 - 12 months
4 1 - 5 years
5 5 - 15 years
6 15 - 40 years
7 > 40 years

SEX: (mark one)

1 male
2 female

serial:

month: ¦__¦__¦

age: ¦__¦

sex: ¦__¦

COMPLAINTS, SYMPTOMS, FINDINGS (mark one or more)

10 fever
11 general pain
12 weakness
13 dizziness
14 weight loss
15 joint pain
16 fits
17 shock
18 trauma
19 rash
20 oedema
21 local swelling
22 loss of appetite
23 anaemia
24 jaundice
25 mental confusion
26 backache
27 headache
28 neck stiffness
29 bulging fontanelle
30 puffy face
31 sore eye
32 ear pain/discharge
33 cough
34 yellow sputum
35 white sputum
36 chest pain
37 dyspnoea
38 haemoptysis
39 vomiting
40 diarrhoea
41 bloody diarrhoea
42 upper abdominal pain
43 lower abdominal pain
44 dysuria
45 haematuria
46 genital discharge/STD
47 dysmenorrhoea
48 amenorrhoea
49 pregnancy

¦__¦__¦
¦__¦__¦
¦__¦__¦
¦__¦__¦
¦__¦__¦
¦__¦__¦
¦__¦__¦

MANAGEMENT (mark one or more)

10 see doctor
11 see surgeon
12 nil
13 aspirin
14 chloroquine
15 vitamins
16 linctus
17 magnesium trisilicate
18 gentian violet
19 iron
20 hibitane
21 folic acid
22 sytron
23 benzyl benzoate
24 benzoic acid
25 tetracycline ointment
26 septrin
27 laxative
28 flagyl
29 calamine
30 kaolin
31 oral rehydration
32 potassium permanganate
33 piperazine
34 ampicillin
35 chloramphenicol
36 tetracycline
37 paracetamol

¦__¦__¦
¦__¦__¦
¦__¦__¦
¦__¦__¦

Figure 7.1: Patient record form used in the MRC Gate Clinic during 1987.

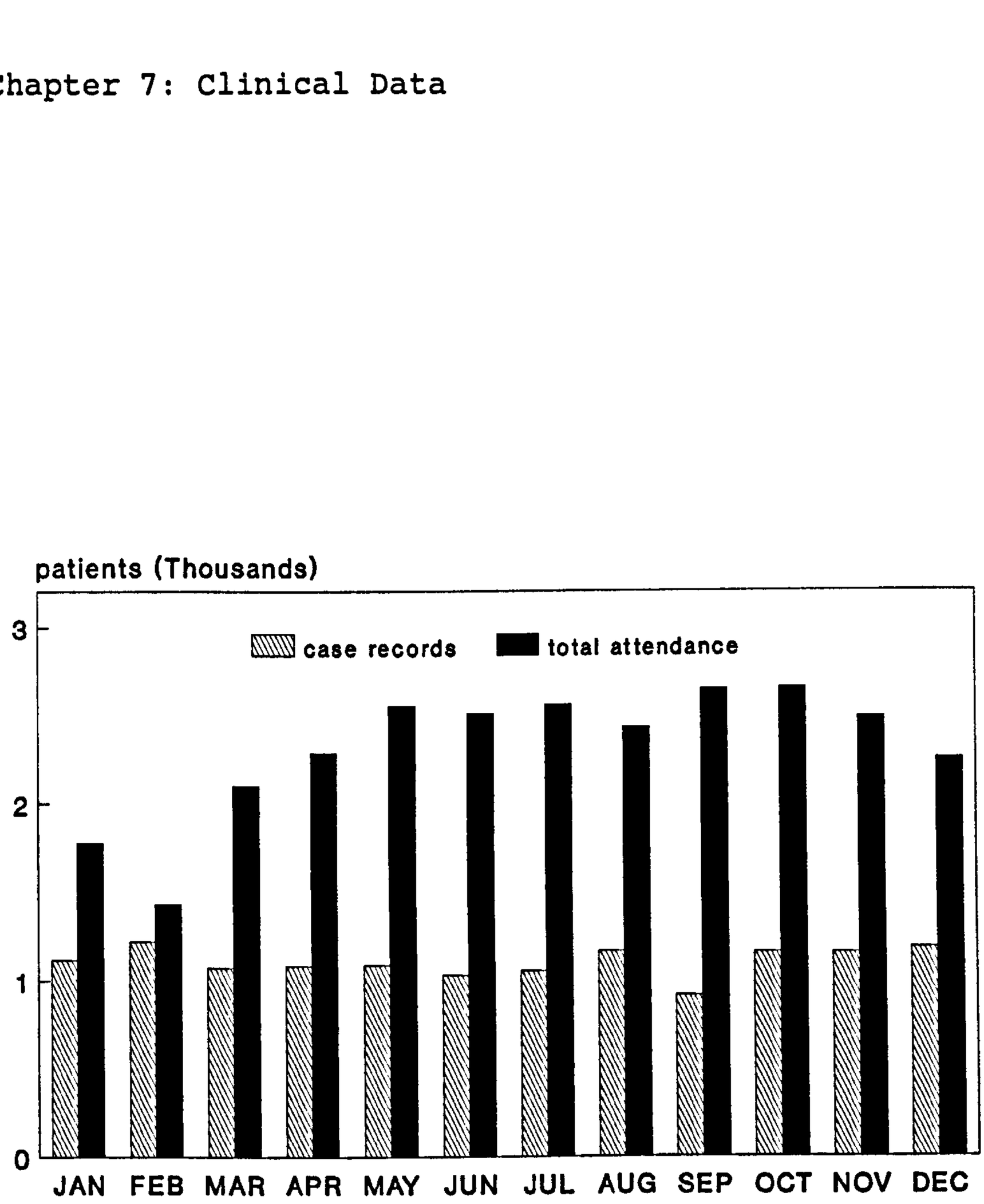


Figure 7.2: Seasonal patterns of MRC Gate Clinic attendance and of case recording during 1987.

are shown in Figure 7.2.

7.4 Results

In order to retain some patient records for later evaluation of systems developed, 10,000 records were selected at random from among the 13,212 collected. The remaining 3,212 records were put aside for later evaluations.

From the database of 10,000 records for analysis, the age and sex structure was determined and is shown in Figure 7.3. Overall 45% of the consultations were with children under 15 years of age, which is very similar to the proportion of under-15 year olds in the general population, quoted as 44% in the 1983 census [Central Statistics Department 1987]. It is interesting to note that boys attended slightly more than girls, possibly reflecting the cultural importance of male children. In the adult groups women attended more frequently, despite the fact that the clinic does not offer specialised obstetric or antenatal care.

7.4.1 Presentations

An overall analysis of clinical signs and symptoms from the clinical records is presented in Table 7.1. These are ranked in order of descending prevalence. As would be expected, the least specific items occurred most frequently. The mean number of presenting items per patient was 2.25 (standard deviation 1.12, range 1 to 6). The same data cross-

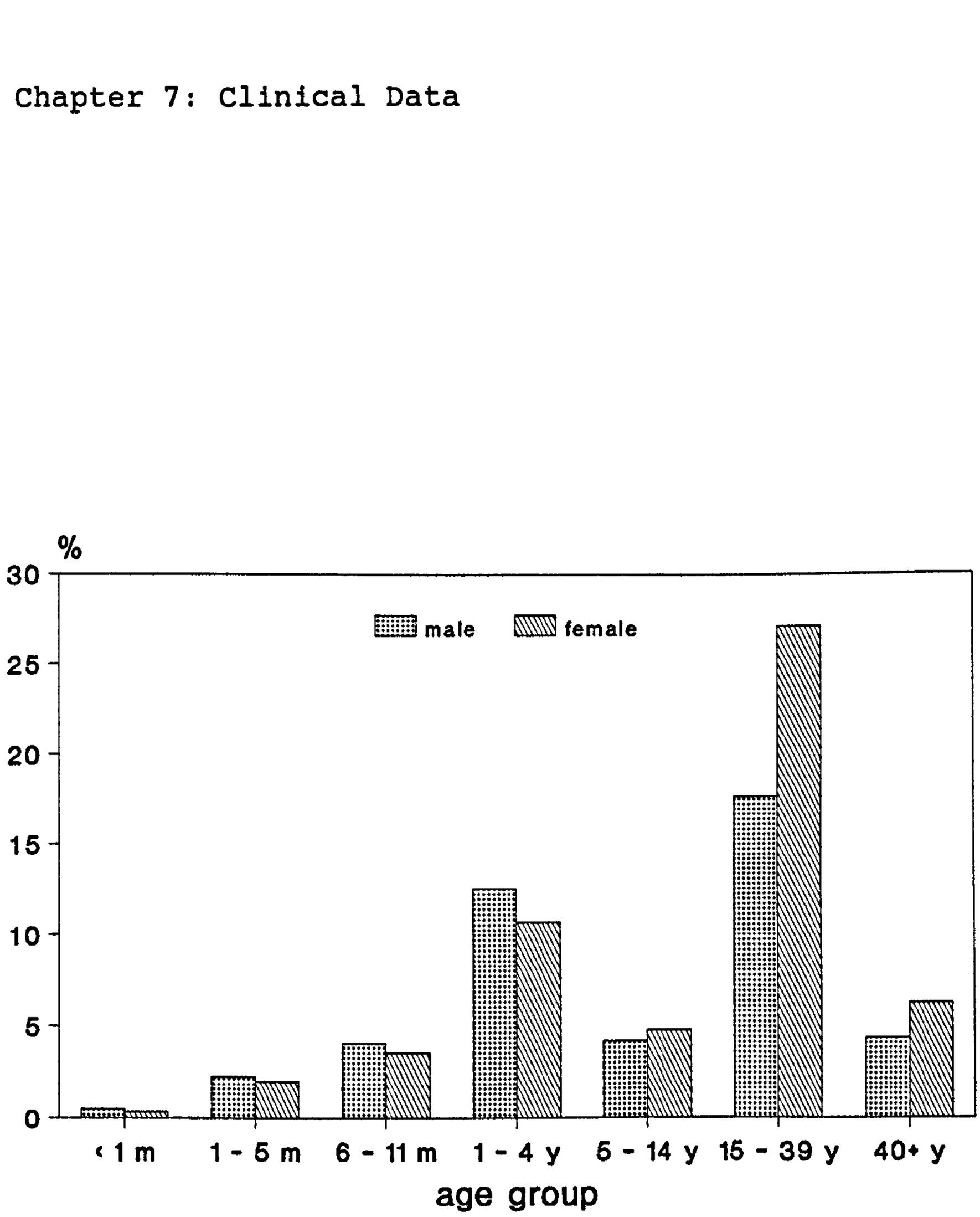


Figure 7.3: Age and sex breakdown of 10,000 Gate Clinic patient records during 1987.

Table 7.1

Overall prevalence of clinical signs and symptoms in 10,000 Gate Clinic patients during 1987.

SIGNS AND SYMPTOMS	PREVALENCE (%)
fever (subjective)	53.5
cough	21.7
general pain	16.1
chest pain	14.4
rash	11.2
headache	10.1
vomiting	9.9
diarrhoea	8.6
upper abdominal pain	8.5
lower abdominal pain	7.4
dizziness	6.7
backache	5.1
joint pain	4.4
white sputum	3.9
sore eyes	3.3
loss of appetite	3.0
dysuria	2.6
weight loss	2.1
genital discharge	2.0
ear pain	1.9
local swelling	1.7
dyspnoea	1.7
weakness	1.5
trauma	1.4
anaemia	1.3
bloody diarrhoea	1.2
yellow sputum	1.1
oedema	0.8
haemoptysis	0.5
amenhorrea	0.3
pregnancy	0.3
dysmenhorrea	0.2
haematuria	0.2
fits	0.2
neck stiffness	0.2
mental confusion	0.2
puffy face	0.1
jaundice	0.1
bulging fontanelle	0.04
shock	0.01

tabulated by age, sex and season are shown in Appendix I.

7.4.2 Managements

The corresponding overall analysis of clinical managements is shown in Table 7.2. Again they are ranked in descending order of occurrence. The mean number of management strategies per patient was 2.37 (standard deviation 0.97, range 1 to 4). These data, cross-tabulated by age, sex and season, are also shown in Appendix I.

7.5 Discussion

These results provide a useful insight to the sort of patients presenting at the primary level, the manner of their presentation, and how competent medical personnel with a limited range of drugs and diagnostic facilities manage such cases.

It is necessary to proceed with caution in extrapolating these results to the general situation in Gambian primary level health facilities. These figures are almost certainly not a model of what actually happens in general, due to the generally lower calibre of health centre staff and frequent problems with supplies of drugs and other consumables. These factors not only influence patient management outcomes but also attendance patterns.

In any case, in setting about the development of decision support for such situations it is not so

Table 7.2

Overall prevalence of management strategies used in 10,000 Gate Clinic patients during 1987.

STRATEGIES	PREVALENCE (%)
aspirin	63.2
vitamins	41.2
chloroquine	20.6
cough linctus	16.4
see doctor	10.6
oral rehydration	8.1
magnesium trisilicate	7.0
septrin	6.2
tetracycline ointment	5.8
paracetamol	5.7
hibitane lotion	5.6
iron tablets	5.4
tetracycline	5.4
flagyl	3.9
chloramphenicol	3.5
benzoic acid	3.5
folic acid	2.1
piperazine	2.0
calamine	1.7
laxatives	1.7
see surgeon	1.7
gentian violet	1.5
benzyl benzoate	0.9
ampicillin	0.4
kaolin	0.1
sytron	0.1
potassium permanganate	0.1

much the generally pertaining situation but rather a "better" situation on which one seeks to base a model. The overall contention therefore is that these data represent a system which is sufficiently close to the general situation to be of realistic interest, but which has several advantages, particularly in terms of expertise and resources, over most Gambian facilities at the same level.

There are however a number of significant omissions from these data in terms of clinical completeness, particularly for example in pregnancy-related morbidity. It will therefore be necessary to introduce other sources of data in some instances in the course of building an overall system.

Chapter 8: ASSESSMENT OF METHODOLOGY

8.1 Introduction

Using the probabilistic approach set out in Chapter 6, together with the Gate Clinic data described in Chapter 7, it is now possible to make an assessment of the methodology. This is intended as a preliminary stage of evaluation before clinical trials.

Methods of evaluating expert and decision support systems are generally poorly defined. Rossi-Mori and Ricci [1988] have suggested various levels at which it may be appropriate to carry out such evaluations. Indeed, they hypothesise that the relative lack of practical success of expert systems in medicine compared with other domains is partly due to a lack of objective and acceptable assessment criteria. The four discrete levels at which they suggest such evaluations might take place start with the efficiency of the system in itself, that is the technical performance of the system outside the context in which it might eventually be used. The second level considers effectiveness in the user's environment, followed thirdly by long term effects on the user's behaviour as a result of using the system. The fourth and final level then considers the impact of the system on the health problems for which it was designed. Thus the present evaluation falls within the scope of the first level of this categorisation, namely assessing the technical efficiency of the system.

8.2 Method of Assessment

In order to make the assessment, the data from 10,000 Gate Clinic cases as described in Chapter 7 were analysed to determine usages, occurrences and relevances of the strategies and characteristics included in the Gate Clinic records (using the terminology defined in Chapter 6 [Byass 1988]). The results of these analyses are set out in detail in Appendix II. Records in which managements other than those defined on the form were excluded.

Using these data and the defined methodology, a system was built up. Whilst the system was limited in clinical scope by the limitations of the parameters available in the Gate Clinic records, it was built with the intention of testing its application to clinical case records in that same format.

Since it was not intended as a system for practical use, the inclusion of user interfacing was not necessary, and in fact the whole system was implemented within the dBase III+ system [de Pace 1987] on an IBM personal computer. Simple dBase command files were written to read patient indicators from a file of clinical records, and then use them to calculate advisabilities for each available strategy, according to the general Bayesian expression:

$$A_i(S_i|I_j) = \frac{R_{ij}(C_j|S_i) \cdot U_i}{\{R_{ij}(C_j|S_i) \cdot U_i\} + \{O_j \cdot (1 - U_i)\}}$$

8.3 Determining Thresholds

The only quantitative parameter not directly available for the model from the Gate Clinic records were the threshold probabilities which had to be reached by strategy advisabilities in order for a particular strategy to be implemented. Very little attention has generally been given to the selection of appropriate thresholds in such systems.

In the absence of a theoretical basis from which to proceed, the following empirical approach was adopted. One hundred clinical cases were selected at random from among the 10,000 used to build the model. For each of these cases, advisabilities for each strategy were calculated using the indicators from the case. For each strategy, the distribution of calculated advisabilities was then considered, and a threshold selected such that a proportion of cases corresponding to the general usage for that particular strategy were above the threshold. The relationship between thresholds thus determined and usages for each strategy was then examined, as shown in Figure 8.1. A relatively well-defined relationship in which

$$\ln(\text{threshold}) \propto \ln(\text{usage}) \ ,$$

resulted from this approach. For the purposes of this test system, a relatively conservative selection of thresholds was taken, as shown by the dotted line in Figure 8.1, whereby

$$\ln(T_i) = (0.5 \times \ln(U_i)) - 0.5$$

Chapter 8: Assessment of Methodology

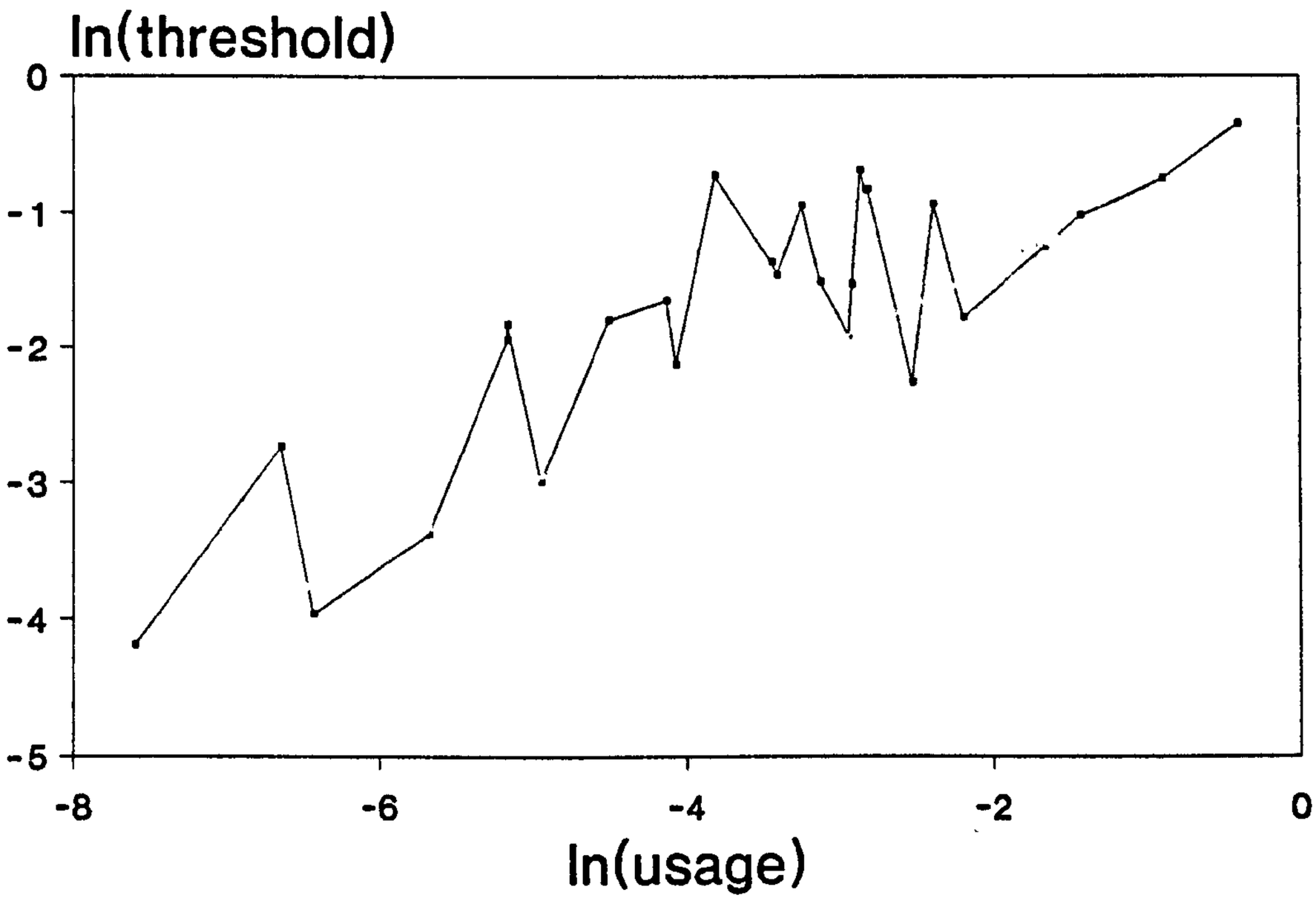


Figure 8.1: Empirical relationship between thresholds and usages, based on 100/10000 Gate Clinic case records. Dotted line shows threshold definition used in this assessment.

The selection of thresholds on this basis included all but 3/26 (11.5%) of the empirically determined thresholds. Clearly the precise choice for a practical implementation would have to be carefully considered and could be slightly different, depending on the aims of the system.

8.4 Basis of Comparisons

For the purposes of this assessment, two separate groups of case records were used. The first group consisted of 500 randomly selected records from among the 10,000 used to build the model. Whilst in some ways there is a danger of circularity in this approach, nevertheless it was considered as an important component in assessing the internal consistency of the system. Secondly, a similar group of 500 from among the 3,212 records not used in building the model was assessed.

Since the range of strategies available in the Gate Clinic records include a number of functionally equivalent, or partially equivalent, options, a comparison based on individual strategies was not considered suitable. Therefore, strategies were functionally grouped as shown in Table 8.1, and the presence of one or more strategies from a particular group in the computer recommendations was taken as "positive" for that group. This was also necessary in part due to inadequacies of the clinic record system, where, for example, the presence of a rash is the only indicator for treatment with one or more of a group of seven strategies (gentian violet, hibitane,

TABLE 8.1

Functional groupings of strategies in the Gate Clinic model.

GROUP	STRATEGY
REFERRAL	see doctor
	see surgeon
ANALGESIC/ANTIPYRETIC	aspirin
	paracetamol
VITAMINS ETC.	vitamins
	linctus
	magnesium trisilicate
	iron tablets
	folic acid
	sytron
	laxatives
	kaolin
SKIN TREATMENTS	gentian violet
	hibitane
	benzyl benzoate
	benzoic acid
	tetracycline ointment
	calamine
	potassium permanganate
MALARIA TREATMENT	chloroquine
ANTHELMINTIC	piperazine
ANTIBIOTICS/AMOEBICIDE	septrin
	ampicillin
	chloramphenicol
	tetracycline
	flagyl
REHYDRATION	oral rehydration

benzyl benzoate, benzoic acid, tetracycline ointment, calamine and potassium permanganate). Thus, although groupings on this basis would be unacceptable in a final system, for the purposes of this evaluation endpoints such as "treatment of skin condition" are valid in their own right.

In the Gate Clinic records, patients referred to a doctor or surgeon had no further details of management noted. Thus, apart from the referral outcome, outcome comparisons exclude those cases which were referred in their original consultation.

8.5 Results

8.5.1 Assessment of 500 cases drawn from the model

The comparison between original clinical managements and computer recommendations in 500 Gate Clinic cases selected at random from among the 10,000 used to build the test system are shown in Table 8.2, classified by the eight functional groups of management strategies used for this comparison. The sensitivity and specificity for the computer recommendations in comparison with the original clinical managements are also shown.

From the group of 500 test cases, 443 (89%) were not originally referred. Of these, 127 (29%) were given equivalent management in the clinic and by the computer system in respect of all eight finctional groups. A further 200 (45%) were equivalent but included additional recommendations. Thus 74%

TABLE 8.2

Comparison of Gate Clinic management and computer recommendations in 500 case records drawn at random from 10,000 used to build the system. Sensitivities and specificities relate to computer recommendations compared with clinical management.

STRATEGY GROUP	% PRESCRIBED		SENSIT.	SPECIF.
	clinic	computer		
REFERRAL	11.4	11.6	54.4	93.9
ANALGESIC/ ANTIPYRETIC	81.5	95.9	98.6	15.9
VITAMINS ETC.	70.2	77.6	87.8	46.2
SKIN TREATMENT	17.2	16.0	86.8	98.6
MALARIA TREATMENT	30.5	34.1	75.6	84.1
ANTHELMINTIC	1.8	2.7	*	97.7
ANTIBIOTICS/ AMOEBICIDE	17.2	29.1	68.4	79.0
REHYDRATION	10.6	23.9	85.1	83.3

Note: * indicates insufficient data

corresponded closely. In the functional groups corresponding to potentially life-saving therapies (referral, malaria treatment and antibiotics/ amoebicide), only 61 cases (12%) who had originally received these therapies in the clinic were not recommended to do so by the computer.

Thus, taking the validity of the original clinical managements as an absolute standard, the test system performed tolerably well in 88% of cases.

8.5.2 Reassessment of discrepant cases

The 61 cases noted above whose management recommendations from the computer system differed in potentially important respects from their original clinical managements were studied in more detail, since they represented a potentially important difference. The reassessment was carried out by making written records of the presentations recorded for these cases in the original clinic records. This set of cases was then presented to the M.R.C.'s Senior Clinician, who was not told at this stage that they constituted a set of discrepant records. He was asked to select management strategies from the set available in the original clinic for each record. In this reassessment, his clinical recommendations concurred with the those of the computer system in 25/61 cases (41%). In 20/61 cases (33%) the reassessment agreed with the original managements, and not with the computer recommendations. In the remaining 16/61 cases (26%) all three recommendations differed.

8.5.3 Assessment of 500 cases outwith the model

A further group of 500 cases for assessment was drawn at random from among the 3,212 cases from the Gate Clinic not used to build the model. The results of this comparison, on the same basis as the comparison of the group of 500 drawn from within the model, are shown in Table 8.3. The results are generally similar to the other group, with 145/451 (32%) exactly equivalent and 199/451 (44%) equivalent with the inclusion of supplementary recommendations. Thus 76% were generally equivalent. Eighty-nine cases (18%) lacked recommendations for potentially life-saving therapies (referral, malaria treatment and antibiotics/amoebicide) in comparison with their original managements.

8.6 Discussion

In view of the relatively ill-defined approaches towards the evaluation of medical expert and decision support systems, it is not easy to put these results into the wider context of such systems. Objective assessments of practical systems have not been widely reported, particularly at the relatively unspecialised medical level at which this system is intended to operate.

de Dombal [1984] in assessing the efficacy of his team's efforts on computer assisted diagnosis of the acute abdomen has reported considerably higher accuracy for his computer system (92%) than for junior doctors (42%). He also claims considerable

TABLE 8.3

Comparison of Gate Clinic management and computer recommendations in 500 case records drawn at random from 3,212 not used to build the system. Sensitivities and specificities relate to computer recommendations compared with clinical management.

STRATEGY GROUP	% PRESCRIBED		SENSIT.	SPECIF.
	clinic	computer		
REFERRAL	9.8	11.8	40.8	91.4
ANALGESIC/ ANTIPYRETIC	82.5	98.7	99.2	3.8
VITAMINS ETC.	69.6	76.5	87.9	49.6
SKIN TREATMENT	16.9	26.2	88.3	90.2
MALARIA TREATMENT	21.1	25.1	62.1	84.8
ANTHELMINTIC	0.2	1.6	*	98.7
ANTIBIOTICS/ AMOEBICIDE	12.6	20.2	57.9	85.2
REHYDRATION	1.3	8.4	*	91.7

Note: * indicates insufficient data

improvements in human performance after some experience of working with the computer system, which he attributes substantially to its use. A more recent report [Uplekar et al. 1988] of a microcomputer system using flowchart logic (similar to that of Essex [1980]) quotes 78% equivalence between a physician and the system in a blind trial. "non-essential" prescriptions, for vitamins etc., were excluded from this comparison, but the precise basis of their comparison is unclear. Auvert et al. [1986 B] have reported subjectively on the acceptable performance of a hand-held system in Chad, but details of performance evaluations are not given.

A direct comparison between this assessment and othe systems is therefore difficult. Furthermore, there are specific factors associated with this assessment which have to be considered in the context of the results obtained. At this stage, the evaluation concerns retrospective consideration of cases, using details of presentation noted during a genuine consultation. However, the comparison is then made between actual clinical management and the computer's retrospective recommendations for the case. This must not be confused with the situation which would pertain in a live clinical trial where the computer, via its operator, would have direct access to the patient in order to elicit any additional details that might be pertinent. In the consultations being considered retrospectively, it is highly probable that, at the original consultation, vague concepts such as "generally unwell" may well have influenced clinical management but went unrecorded.

The relatively low sensitivities obtained for referral, and to a lesser extent for antibiotic, amoebicidal and malaria treatments, may well reflect the influence of clinical impressions of disease severity, rather than the presence or absence of particular signs and symptoms, as determinants of clinical management. Similarly the very low specificity of relatively unimportant managements attained in this test system may well reflect a somewhat arbitrary approach to their use in the Gate Clinic. Indeed, the fact that only 3 out of 10,000 patients were actually recorded to have nil managements supports the view that a large amount of "placebo" prescribing takes place. Indeed it would appear that clinic visits not resulting in any medicine or further care have almost become culturally unacceptable. Nevertheless, all these effects will have tended to reduce the efficacy of the system, by increasing iner-case variability, in comparison with the original Gate Clinic managements, and hence its overall performance appears to be encouraging.

The results of reassessing the discrepant cases are interesting. The fact that in the majority of cases the expert reassessment did not agree with their original management suggests that many of these 61 cases may have represented unusual or difficult cases, or indeed may have been abnormal in some respect, such as mis-coding. Given the generally good agreement between the computer system and clinical recommendations, it does suggest that most of them do not represent "missed" cases on the part of the

computer.

The fact that the results from the set of 500 cases that were not used to build the model are generally comparable in accuracy with the cases drawn from the model supports the view that a database of this type can have genuinely predictive value, rather than merely internal consistency.

The question of the selection of thresholds for such a model is not trivial. The empirical basis as described above which was used here seems to have performed reasonably well, but with some exceptions. Advisabilities for strategies with high usages (such as vitamins and aspirin) do not dichotomise well compared with those for rare strategies. The ratios of their thresholds:usages is not much greater than 1. The result in this assessment seems to have been over-recommendation of such strategies; however the same strategies tend to be widely used, including, as discussed above for "placebo" purposes, and this may have contributed to the effect. It seems likely that in a final system one could considerably reduce the overall level of recommendation of, for example, aspirin, whilst at the same time tying it more closely to specific indications. This might not model existing clinical practice so accurately, but would probably ensure those patients requiring such treatments for specific reasons actually received them. It is probably reasonable to assume that such treatments would continue to be given to other patients on a placebo basis irrespective of computer system recommendations.

Chapter 8: Assessment of Methodology

The overall impression from this preliminary methodological assessment is therefore positive; it seems that this general approach may well be a useful means of modelling patient management at this level of primary care. There are obvious shortcomings in the dataset used in certain specific respects, and a clinically useful system will need to incorporate other sources of data. Nevertheless, given the relatively high degree of subjectivity involved in clinical patient management, and hence an absence of "gold standards" with which to compare computer performance, these results are encouraging.

Chapter 9: SYSTEM DEVELOPMENT

9.1 Introduction

Having established the possible usefulness of a microcomputer decision support system for health care delivery, developed an appropriate methodology, and validated this approach at a preliminary non-clinical level, the next logical step concerns the development of a practical system.

9.2 Data Acquisition

As previously pointed out, a single source of data, such as that from the Gate Clinic, is insufficiently comprehensive for building a complete system. There are however various other sources of relevant data, such as many of the references cited in earlier chapters. The problem thus arises of how to incorporate various different sources of data into an overall model.

9.2.1 Review of methods

The process of data capture in building expert and decision support systems has received much attention. Glasziou and Vermeir [1984] point out however that there has been more preoccupation with deductive methods than with the data structures supporting the various approaches. The derivation of appropriate rules for artificial intelligence-based systems is not a trivial task [Hudson and Estrin 1984]. Medical

knowledge bases for some systems, such as INTERNIST/CADUCEUS [Miller 1984] need to be so large in theory that in practice they are inevitably less comprehensive than they need to be. The need for collaboration between clinical specialists and informatics specialists in the production of a valid set of data has been emphasised [Morton et al. 1984]. The need to accept data from different sources, such as physicians and textbooks, has been recognised and compared [Prust 1986]. Chard [1987] has identified four possible approaches to assembling a useful set of data. The first is to use published data, though he argues this is often incomplete (particularly in respect of frequency information) and may be of only local relevance. Secondly there is the possibility of forming a database from recording local practice, though this is time consuming. Thirdly, direct approaches to "experts" can be made, but may differ widely between individuals. Lastly a "bootstrapping" approach whereby a system learns from its regular use in clinical practice may be possible in some circumstances.

9.2.2 Additional local sources of data

Apart from published material, both from The Gambia and relating to tropical health in Africa generally, there are additional local sources of data.

The MRC Dunn Nutrition Unit's field station at Keneba runs a routine clinic [Lamb et al. 1984] from which a series of presentations from 16,776 paediatric consultations has been made available by Dr. Bill Lamb. Results of analysing these data,

showing major presenting features by age, sex and season, are shown in Appendix III. Corresponding details of management are not available, but would in any case differ from the available range of managements in Government facilities. The cases in this dataset represent all paediatric consultations at Keneba between February 1984 and April 1985.

The paediatric medical ward at RVH is a further important source of data. Whilst patients there, and their management, obviously do not relate directly to health centre patient management, they represent a group of children at the most severe end of the disease spectrum, and who should therefore have been referred from lower level clinics. Statistics from this ward for 1988 have been made available by Dr. David Brewster and are also shown in Appendix III.

9.3 Required precision of data

Given the Bayesian model being used here, the question arises as to what level of precision is required in the probability estimates that form the database. From a set of patient data such as that obtained from the Gate Clinic, relatively precise estimates of proportions for specific presentations and managements can be made, at least in the sense of internal precision for Gate Clinic patients. This is of course particularly true in the case of more common symptoms and treatments.

On the other hand, other sources of data may only yield much cruder estimates of quantitative

parameters. Additionally, the apparent precision of estimates from, for example, the Gate Clinic data, is somewhat misleading in that differences between a specific source, such as the Gate Clinic, and the general case are unknown.

Therefore, having shown reasonable performance in the Gate Clinic model with its relatively high degree of internal precision, it is of considerable interest at this stage to consider the implications of using less precise data. This is essentially the same problem as that of applying an internally consistent and precise model such as the Gate Clinic data to more general situations.

9.3.1 A qualitative model

In order to obtain at least some empirical understanding of these issues it was decided to build and test a deliberately crude model. In order to do this a source of general qualitative data relating to health care in The Gambia was required, and a recently compiled manual for health workers entitled "Health in The Gambia" [Hanlon and Hanlon 1986] was used.

A simple qualitative scale was defined whereby a range of qualitative probabilities from 1 ("almost always") to 0 ("virtually never") was used. Between these extremes A represented "about half", B "fairly common" and C "uncommon".

From reading the book, a set of 24 management strategies and 46 presenting characteristics were

identified. These do not necessarily represent an exhaustive representation of health problems in The Gambia, but form a sufficient selection on which to build the model. Details of all parameters in the model are shown in Appendix IV.

Being a qualitative model, it is not possible to evaluate its performance rigorously in the way that was done for the Gate Clinic model. Nevertheless, a database was formed from the qualitative data, using the quantitative approximations shown in Appendix IV (A=0.5, B=0.05, C=0.005). Thresholds were set in a similar way to the Gate Clinic model, by taking as an approximation the square root of usages. The adoption of these quantitative approximations was somewhat arbitrary. Some suggestions have been made [Kong et al. 1986] as to correlations between commonplace qualitative expressions of probability and their quantitative equivalents. In this case the concept underlying the scale, namely that quantitative equivalents progress logarithmically, seems reasonable on the basis of the Gate Clinic database.

9.3.2 Application of the qualitative model

Following from the qualitative approach to building the model, evaluation has to proceed on a similarly qualitative basis, in other words applying the model to hypothetical cases and considering whether the outcome is "reasonable". This was performed in over 100 cases, using a simple dBase III program to drive the system. This program and a small selection of test cases are shown at the end of Appendix IV. In

general the system appears to have behaved reasonably sensibly. It seems reasonable therefore to infer that quite crude probability estimates can be useful in a system such as this, even though the nature of the system precludes precise evaluation.

9.4 Defining the scope of the system

Before attempting to define probability estimates for a general system, it is necessary to define the scope of the system in terms of management strategies and patient characteristics that will be included.

9.4.1 Selection of management strategies

The availability of management strategies to paramedical staff at rural health centres is governed by a number of different constraints. There is a relatively limited range of pharmaceuticals which are supposed to be stocked by health centres; in practice certain important drugs may from time to time be out of stock. Investigative procedures are constrained by both the facilities and equipment available (for laboratory tests, etc.) and by limitations of staff expertise. Referral, particularly on an urgent basis, may be a problem because of either lack of availability or servicability of transport, or cost.

The selection, or exclusion, of particular management strategies for a prototype system is therefore not entirely straightforward. It is important for the system to be as comprehensive as possible, whilst not making unrealistic management

recommendations. A selection of strategies has therefore been made (Appendix V) on a somewhat subjective basis, but with the intention of modelling Gambian health service policies and practices as closely as possible. They fall into five main categories, as follows:

CATEGORY	DESCRIPTION
A	suggested investigations & enquiries
B	suggested laboratory procedures
C	referral to other facilities, returns
D	advice to the patient
E	prescriptions

Strategies in categories A and B are of the indicator-generating type, whereas C, D and E are final outcome strategies which can be recommended once all available data have been considered.

9.4.2 Selection of patient indicators

The selection of a set of patient indicators for the system is constrained in a similar manner to the selection of strategies. Indicators arising directly from indicator-generating strategies must obviously be included. Again, the overall selection is subjective, but can be categorised into five main groups as follows:

CATEGORY	DESCRIPTION
A	patient's personal details
B	items of patient history
C	specific complaints and symptoms
D	clinical findings
E	test results etc.

9.5 Probability estimates

Having selected appropriate strategies and indicators, it is necessary to derive probability estimates for them and their interdependence (relvances). To arrive at the most comprehensive model, it is clearly necessary to use a variety of data sources, not all of which may be entirely comparable nor of consistent precision. The various estimates that have been derived, and their sources, are also shown in Appendix V, together with the overall database of probabilities derived from them.

9.6 User interface

The target hardware for the prototype is Cambridge Computers' Z88 portable microcomputer. This small portable machine runs the BBC Basic language from a ROM-resident interpreter, and so the BBC Basic language was the obvious one in which to develop the system. An important principle of the design was to make the user interface as simple as possible to operate, so that health centre personel could use the system with a minimum of training related

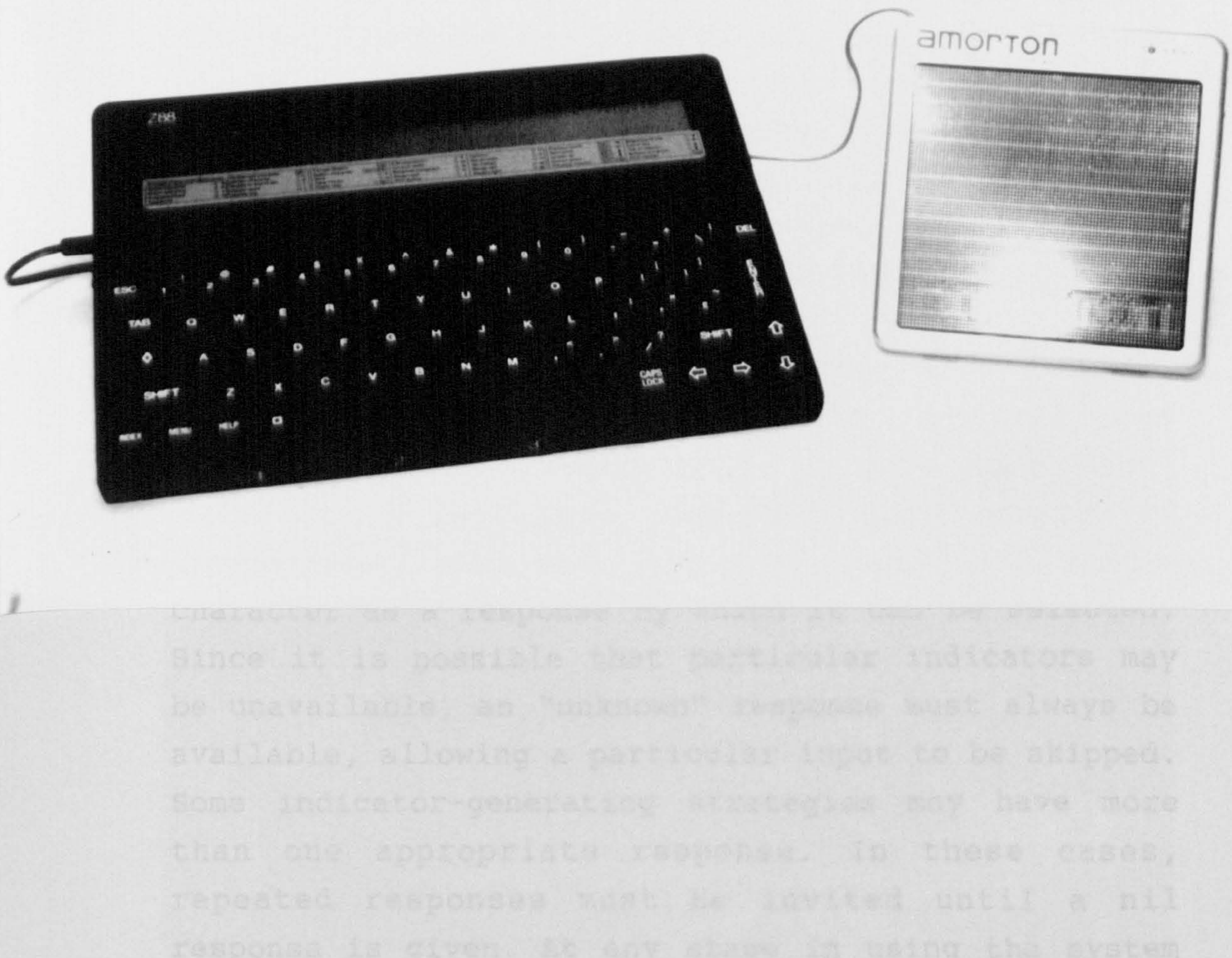


Figure 9.1: Cambridge Computers' Z88 portable microcomputer together with solar power supply.

specifically to the computer.

Four important functions were identified for the display. Since the Z88 display is an LCD type with only 8 lines, economy of space is important. Three of the functions, however, namely: a suggested next action, a selection of possible responses and a resumé of the case so far, were identified as being required simultaneously during the course of a patient consultation. Thus the basic display was designed to function in three windows, one for each of the above functions, during the consultation. The machine together with this display layout is shown in Figure 9.2. The fourth function, that of displaying suggested outcome strategies, can then be done separately after the data input is complete.

It follows from this approach that each strategy needs a descriptor for displaying, as does each patient indicator. Furthermore, to make input easy, only single keystroke responses were considered appropriate. Thus each indicator requires a single character as a response by which it can be selected. Since it is possible that particular indicators may be unavailable, an "unknown" response must always be available, allowing a particular input to be skipped. Some indicator-generating strategies may have more than one appropriate response. In these cases, repeated responses must be invited until a nil response is given. At any stage in using the system the user must be able to abandon the process and start again; this function can be provided via the ESCAPE key.

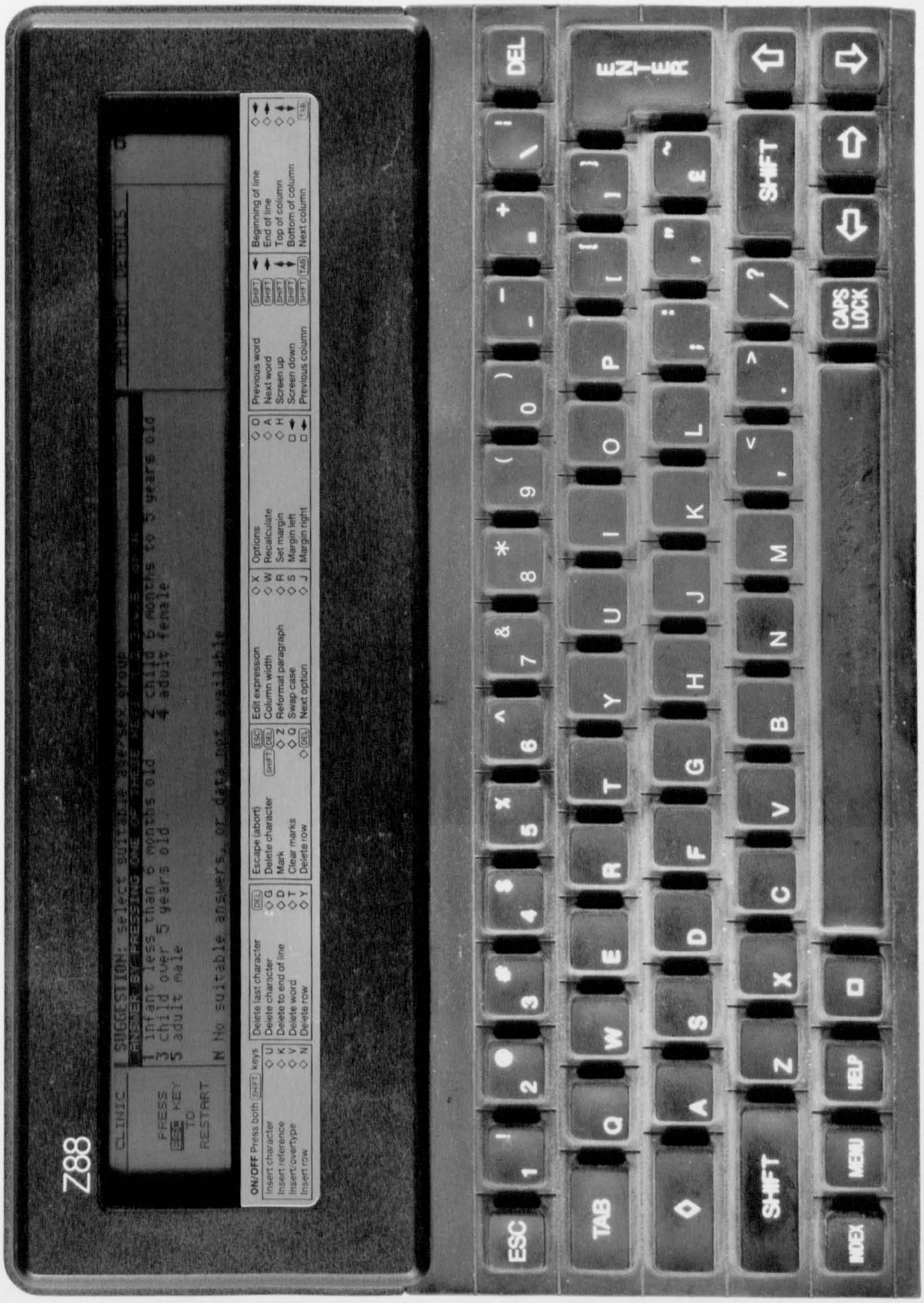


Figure 9.2: The Z88 computer, showing the display split into windows for suggestions, responses and patient details.

9.7 Data interface

Since it is important for the system to be data-driven, for the sake of flexibility and ease of modifying data, the software had to be designed to read separate ASCII data files. The overall database was designed to be split into four parts; strategies, characteristics, relevances and questions. These four data files can then be stored separately from the program itself, and read when the program is loaded. The software developed and the data files derived from the database in Appendix V are shown in Appendix VI.

9.8 Using the system

Having implemented the system as described above on the Z88 computer, its use is very straightforward. A simple users' manual is shown in Appendix VII. The step-by-step output through three examples of patient consultations are shown in Figures 9.3, 9.4 and 9.5.

The first example relates to a child aged 2 years, in the early part of the dry season, presenting with a septic skin rash and a normal temperature. The advice of the system in this case is to check whether the child's vaccinations are up to date, and to give some antiseptic lotion for the rash.

In the second case, a child of the same age presents in the early part of the wet season, seriously ill with a high fever. The system suggests taking a thick blood film and measuring haemoglobin,

but, for the sake of the example, it is assumed that these facilities are unavailable. In this case the system suggests giving chloroquine, septrin and paracetamol.

In the last case, an adult male presents in the later part of the dry season with a genital discharge and a moderate fever. A urine test is suggested by the system, but again it is assumed to be unavailable in this example. The system's recommendations for this man are aspirin and tetracycline.

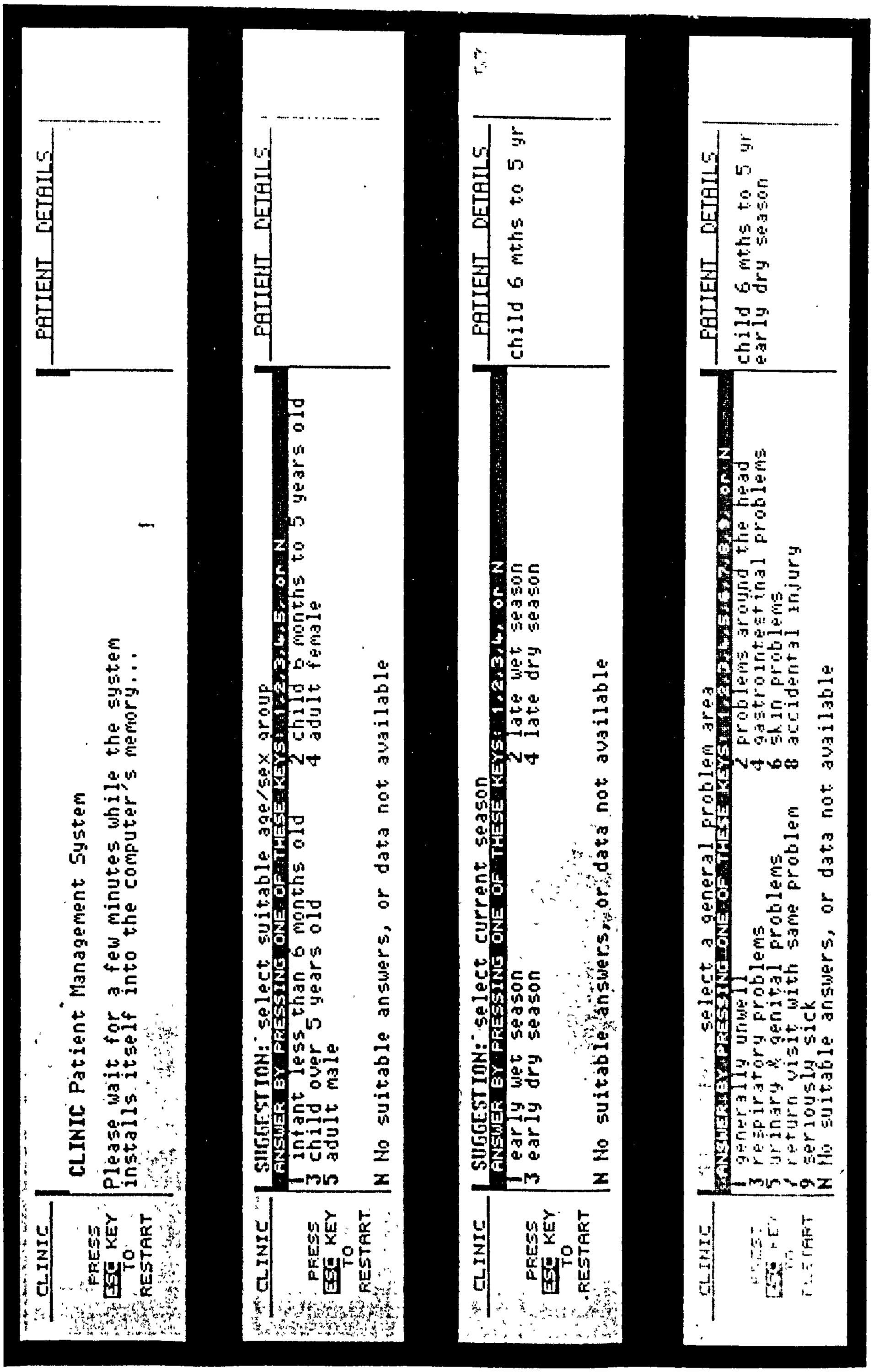


Figure 9.3A: System output for example 1.

CLINIC

PRESS ESC KEY TO RESTART

SUGGESTION: select a general problem area

ANSWER BY PRESSING ONE OF THESE KEYS: 1,2,3,4,5,7,8,9, or N

1 generally unwell
2 problems around the head
3 respiratory problems
4 gastrointestinal problems
5 urinary & genital problems
7 return visit with same problem
8 accidental injury
9 seriously sick

N No suitable answers, or data not available

PATIENT DETAILS

child 6 mths to 5 yr
early dry season
skin problems

CLINIC

PRESS ESC KEY TO RESTART

SUGGESTION: take the patient's temperature

ANSWER BY PRESSING ONE OF THESE KEYS: 1,2,3, or N

1 high fever
2 moderate fever
3 normal temperature

N No suitable answers, or data not available

PATIENT DETAILS

child 6 mths to 5 yr
early dry season
skin problems

CLINIC

PRESS ESC KEY TO RESTART

SUGGESTION: select a skin symptom

ANSWER BY PRESSING ONE OF THESE KEYS: 1,2,3,4, or N

1 sudden rash
2 general rash for some time
3 boils
4 septic rash

N No suitable answers, or data not available

PATIENT DETAILS

child 6 mths to 5 yr
early dry season
skin problems
temperature normal

CLINIC

PRESS ESC KEY TO RESTART

CONSIDER DOING SOME OR ALL OF THE FOLLOWING FOR THIS PATIENT:

check for vaccinations due
give antiseptic lotion

PATIENT DETAILS

child 6 mths to 5 yr
early dry season
skin problems
temperature normal
septic rash

Figure 9.3B: System output for example 1 (cont'd).

```
CLINIC                                                    PATIENT DETAILS

PRESS
ESC KEY
TO
RESTART
          CLINIC Patient Management System

          Please wait for a few minutes while the system
          installs itself into the computer's memory...
```

```
CLINIC                SUGGESTION: select suitable age/sex group          PATIENT DETAILS
                      ANSWER BY PRESSING ONE OF THESE KEYS: 1,2,3,4,5, or N

PRESS                 1 infant less than 6 months old     2 child 6 months to 5 years old
ESC KEY               3 child over 5 years old            4 adult female
TO                    5 adult male
RESTART

                      N No suitable answers, or data not available
```

```
CLINIC                SUGGESTION: select current season                  PATIENT DETAILS          OZ
                      ANSWER BY PRESSING ONE OF THESE KEYS: 1,2,3,4, or N

PRESS                 1 early wet season                  2 late wet season          child 6 mths to 5 yr
ESC KEY               3 early dry season                  4 late dry season
TO
RESTART

                      N No suitable answers, or data not available
```

```
CLINIC                SUGGESTION: select a general problem area          PATIENT DETAILS          OZ
                      ANSWER BY PRESSING ONE OF THESE KEYS: 1,2,3,4,5,6,7,8,9, or N

                      1 generally unwell                  2 problems around the head     child 6 mths to 5 yr
PRESS                 3 respiratory problems              4 gastrointestinal problems    early wet season
ESC KEY               5 urinary & genital problems        6 skin problems
TO                    7 return visit with same problem    8 accidental injury
RESTART               9 seriously sick
                      N No suitable answers, or data not available
```

Figure 9.4A: System output for example 2.

CLINIC

PRESS ESC KEY TO RESTART

SUGGESTION: select a general problem area

ANSWER BY PRESSING ONE OF THESE KEYS: 1,2,3,4,5,6,7,8, or N

1 generally unwell
2 problems around the head
3 respiratory problems
4 gastrointestinal problems
5 urinary & genital problems
6 skin problems
7 return visit with same problem
8 accidental injury

N No suitable answers, or data not available

PATIENT DETAILS

02

child 6 mths to 5 yr
early wet season
seriously sick

CLINIC

PRESS ESC KEY TO RESTART

SUGGESTION: take the patient's temperature

ANSWER BY PRESSING ONE OF THESE KEYS: 1,2,3, or N

1 high fever
2 moderate fever
3 normal temperature

N No suitable answers, or data not available

PATIENT DETAILS

child 6 mths to 5 yr
early wet season
seriously sick

CLINIC

PRESS ESC KEY TO RESTART

SUGGESTION: do a thick blood film

ANSWER BY PRESSING ONE OF THESE KEYS: 1, or N

1 malaria parasitaemia

N No suitable answers, or data not available

PATIENT DETAILS

child 6 mths to 5 yr
early wet season
seriously sick
high fever

CLINIC

PRESS ESC KEY TO RESTART

SUGGESTION: measure haemoglobin

ANSWER BY PRESSING ONE OF THESE KEYS: 1, or N

1 low haemoglobin

N No suitable answers, or data not available

PATIENT DETAILS

child 6 mths to 5 yr
early wet season
seriously sick
high fever

CLINIC

PRESS ESC KEY TO RESTART

CONSIDER DOING SOME OR ALL OF THE FOLLOWING FOR THIS PATIENT:

give chloroquine
give paracetamol
give septrin

PATIENT DETAILS

child 6 mths to 5 yr
early wet season
seriously sick
high fever

Figure 9.4B: System output for example 2 (cont'd).

```
CLINIC                                                    PATIENT DETAILS

PRESS
ESC KEY
TO
RESTART

CLINIC Patient Management System

Please wait for a few minutes while the system
installs itself into the computer's memory...
```

```
CLINIC                                                    PATIENT DETAILS

PRESS
ESC KEY
TO
RESTART

SUGGESTION: select suitable age/sex group
ANSWER BY PRESSING ONE OF THESE KEYS: 1,2,3,4,5, or N
1 infant less than 6 months old      2 child 6 months to 5 years old
3 child over 5 years old             4 adult female
5 adult male

N No suitable answers, or data not available
```

```
CLINIC                                                    PATIENT DETAILS

PRESS
ESC KEY
TO
RESTART

SUGGESTION: select current season
ANSWER BY PRESSING ONE OF THESE KEYS: 1,2,3,4, or N
1 early wet season                   2 late wet season                  adult male
3 early dry season                   4 late dry season

N No suitable answers, or data not available
```

```
CLINIC                                                    PATIENT DETAILS

PRESS
ESC KEY
TO
RESTART

SUGGESTION: select a general problem area
ANSWER BY PRESSING ONE OF THESE KEYS: 1,2,3,4,5,6,7,8,9, or N
1 generally unwell                   2 problems around the head         adult male
3 respiratory problems               4 gastrointestinal problems        late dry season
5 urinary & genital problems         6 skin problems
7 return visit with same problem     8 accidental injury
9 seriously sick
N No suitable answers, or data not available
```

```
CLINIC                                                    PATIENT DETAILS

PRESS
ESC KEY
TO
RESTART

SUGGESTION: select a general problem area
ANSWER BY PRESSING ONE OF THESE KEYS: 1,2,3,4,6,7,8,9, or N
1 generally unwell                   2 problems around the head         adult male
3 respiratory problems               4 gastrointestinal problems        late dry season
6 skin problems                      7 return visit with same problem   urinary/genital pro
8 accidental injury                  9 seriously sick

N No suitable answers, or data not available
```

Figure 9.5A: System output for example 3.

CLINIC

PRESS ESC KEY TO RESTART

SUGGESTION: take the patient's temperature

ANSWER BY PRESSING ONE OF THESE KEYS: 1,2,3, or N

1 high fever
2 moderate fever
3 normal temperature

N No suitable answers, or data not available

PATIENT DETAILS

adult male
late dry season
urinary/genital prob

CLINIC

PRESS ESC KEY TO RESTART

SUGGESTION: select a genitourinary symptom

ANSWER BY PRESSING ONE OF THESE KEYS: 1,2,3, or N

1 blood in urine
2 pain on passing urine
3 genital discharge

N No suitable answers, or data not available

PATIENT DETAILS

adult male
late dry season
urinary/genital prob
moderate fever

CLINIC

PRESS ESC KEY TO RESTART

SUGGESTION: select a genitourinary symptom

ANSWER BY PRESSING ONE OF THESE KEYS: 1,2, or N

1 blood in urine
2 pain on passing urine

N No suitable answers, or data not available

PATIENT DETAILS

adult male
late dry season
urinary/genital prob
moderate fever
genital discharge

CLINIC

PRESS ESC KEY TO RESTART

SUGGESTION: do a urine test

ANSWER BY PRESSING ONE OF THESE KEYS: 1,2,3, or N

1 protein in urine
2 sugar in urine
3 urine infection

N No suitable answers, or data not available

PATIENT DETAILS

adult male
late dry season
urinary/genital prob
moderate fever
genital discharge

CLINIC

PRESS ESC KEY TO RESTART

CONSIDER DOING SOME OR ALL OF THE FOLLOWING FOR THIS PATIENT:

give aspirin
give tetracycline

PATIENT DETAILS

adult male
late dry season
urinary/genital prob
moderate fever
genital discharge

Figure 9.5B: System output for example 3 (cont'd).

Chapter 10: Evaluation of the Prototype System

10.1 Introduction

As discussed in Chapter 8, the assessment of medical decision support systems is an important but complex issue. In this particular medical domain, the difficulties are especially great because of the relative imprecision of clinical decision making. The implication of this is that for many patients there is no single correct management. Therefore, in a particular case there may be two or more equally valid overall managements, and indeed in reality the choice between different approaches may be determined by factors such as availability of certain drugs.

In making any comparison between the recommendations of a decision support system and an expert, therefore, the fundamental determinant is not so much a question of whether the two approaches to a particular case are identical, but whether or not the patient could be expected to proceed to an equally satisfactory outcome using both approaches. Because of the transitory nature of the consultation process at the health centre level, assessing outcome in individual patients is not realistic, and in any case individual patients cannot be simultaneously managed in two different ways.

Inevitably therefore an evaluation has to be partially subjective, in so far as "equivalence" has to be assigned to different patient managements in

particular cases.

10.2 Designing the Evaluation

Within the present project, undertaking a full-scale multi-centre clinical evaluation such as that of Adams et al. [1986] was not possible. Nevertheless, it was considered important to quantify the performance of the prototype system as precisely as possible, so that at least a clear indication could be reached as to whether the approach would justify future large-scale investigation.

A fundamental question in any evaluation of this sort concerns the source of comparison. In rural health centres themselves, there is some reason to doubt the general level of clinical performance, and so a comparison against existing health centre practice would not be helpful. On the other hand, better medical practitioners do not generally deal with clinics at this level.

In the absence of a more appropriate alternative therefore it was necessary to resort to the MRC's Senior Clinician, Dr. P.T. Corrah, working in the Gate Clinic, as the reference. Whilst this had some disadvantages, for example in that neither the patients nor clinical managements in the MRC Gate Clinic exactly mirror those in health centres, it provided a single source of high quality clinical experience and practice.

The question as to how the comparisons should be

made was initially resolved by planning for Dr. Corrah to use a check-list as shown in Figure 10.1 (which was closely related to the design of the prototype system) for each consultation, and for patients then to proceed with another copy for a second consultation using the prototype system. However, at the pilot stage it rapidly became obvious that this was an unworkable approach. A large proportion of patients seemed to get the idea that, having seen the doctor and been written up for appropriate treatment, if on the second encounter they gave a totally different history then they might get additional treatment. Reluctantly therefore the idea of more than one consultation per patient was dropped, and it was decided to make the comparison using the checklists filled in by Dr. Corrah as subsequent input to the prototype system, comparing the output with his clinical management on a case-by-case basis.

In considering the necessary size of the trial, the basic outcome would be the proportion of case managements that were equivalent between the clinician and the prototype system. A sample size of 300 permits the estimation of a proportion of 0.9 within 95% confidence limits of 0.86 to 0.94, and on this basis it was decided to collect details of approximately 300 cases for comparison.

10.3 Results

A total of 325 cases were documented by Dr. Corrah at the Gate Clinic during one week. These were

GATE CLINIC COMPUTER ASSESSMENT

Tick boxes relevant to this patient's presentation:

PATIENT
- ☐ infant under 6 months
- ☐ child 6 mths to 5 yrs
- ☐ child over 5 yrs
- ☐ adult female
- ☐ adult male
- ☐ early wet season
- ☐ late wet season
- ☐ early dry season
- ☐ late dry season

GENERAL
- ☐ general pain/fatigue
- ☐ recent fevers
- ☐ low wt./wt. loss
- ☐ current/recent fits
- ☐ accidental injury
- ☐ seriously sick
- ☐ malnourished
- ☐ overweight
- ☐ dehydrated
- ☐ anaemic
- ☐ semi/unconscious
- ☐ swelling/oedema
- ☐ jaundice

PROBLEM
- ☐ generally unwell
- ☐ problems of the head
- ☐ respiratory problems
- ☐ gastrointestinal problems
- ☐ urinary/genital problems
- ☐ skin problems
- ☐ returned, not better

TEMPERATURE
- ☐ high fever
- ☐ moderate fever
- ☐ normal

HEAD
- ☐ headache
- ☐ ear ache/infection
- ☐ eye sore/infected
- ☐ poor vision
- ☐ stiff neck/font'lle
- ☐ mental confusion
- ☐ sore throat

RESPIRATORY
- ☐ cough
- ☐ chest pain
- ☐ rapid breathing
- ☐ wheezing
- ☐ chest indrawing
- ☐ yellow/bloody sputum

ADULT FEMALES
- ☐ pregnant ‹ 6 mths
- ☐ pregnant › 6 mths
- ☐ abn. vaginal bleeding
- ☐ amenhorrea › 2 mths
- ☐ just deliv./aborted
- ☐ prev. difficult preg.
- ☐ can't get pregnant
- ☐ lactating

GASTROINTESTINAL
- ☐ diarrhoea
- ☐ diarrhoea with blood
- ☐ upper abdominal pain
- ☐ lower abdominal pain
- ☐ vomiting
- ☐ severe constipation
- ☐ worms

SKIN
- ☐ sudden rash
- ☐ rash for some time
- ☐ boils
- ☐ septic rash
- ☐ burns

URINARY/GENITAL
- ☐ blood in urine
- ☐ pain on urinating
- ☐ genital discharge

Assuming only the following managements are available, tick those you would choose for this patient:

TESTS
- ☐ thick blood film
- ☐ thin blood film
- ☐ haemoglobin
- ☐ white cell count
- ☐ urine test
- ☐ stool parasitology

REFERRALS
- ☐ refer to hospital urgently
- ☐ refer to hospital
- ☐ refer to ante-natal clinic
- ☐ refer to TB clinic
- ☐ refer to family planning
- ☐ return to clinic

PRESCRIPTIONS
- ☐ antiseptic lotion
- ☐ aspirin
- ☐ bendrofluazide
- ☐ chloroquine
- ☐ chlorpheniramine
- ☐ cough syrup
- ☐ ephedrine
- ☐ iron tablets
- ☐ folic acid tablets
- ☐ laxatives
- ☐ mag. trisilicate
- ☐ niclosamide
- ☐ oral rehydration
- ☐ paracetamol
- ☐ penicillin V
- ☐ phenobarbitone
- ☐ piperazine
- ☐ septrin
- ☐ sulfadimidine
- ☐ tetracycline
- ☐ antib. eye oint.
- ☐ thiabendazole
- ☐ vitamins

ADVICE
- ☐ improve diet
- ☐ lose weight
- ☐ rest
- ☐ check vaccinations

Figure 10.1: Checklist used for the evaluation.

TABLE 10.1: Details of 40 cases in which clinical management and prototype recommendations were non-equivalent.

[A] Omissions by the prototype system (32/40 cases)

OMISSION	CASES	PRESENTATION
referral	6	skin complaints
	5	gastrointestinal complaints
	1	haematuria
	1	piles
	1	shortness of breath
antibiotic	10	septic rash
	1	accidental injury
chloroquine	1	recent fever and diarrhoea
	2	recent fever and vomiting
anthelmintic	4	abdominal pain

[B] Over-reactions by the prototype system (4/40)

OVER-REACTION	CASES	PRESENTATION
referral & antibiotics	4	chest pain/rapid breathing

[C] Other discrepancies (4/40 cases)

SOURCE	CASES	PRESENTATION
outside scope of system	1	blocked nose -> nasal drops
	1	swollen testis -> aspirin
	1	undescended testis -> refer
	1	chicken pox -> calamine

subsequently fed through the prototype system on the basis of the presentations recorded on the checklists, and the output compared with the patients' original managements. Individual cases were either classified as the same, equivalent or having potentially important differences. Overall 285/325 cases (87.7%, 95% C.I. 84.1% to 91.3%) were classified as the same or equivalent. Determining which cases were the same (in all 78/325, 24.0%) was very straightforward. The question of equivalence was more difficult. Guidelines for possible equivalence were (a) treatments with similar functionality (e.g. two different antibiotics) unless one or other was either clearly superior or contraindicated in a particular case; (b) omission or inclusion of one or two palliative treatments; (c) the inclusion by the decision aid of one or two additional suggested strategies that would not have been either irrelevant or inappropriate for the patient, but were not actually given. A summary of the 40 non-equivalent cases is shown in Table 10.1. Basic reasons for non-equivalence were (a) the omission by the decision aid of a potentially important strategy; (b) a gross over-reaction in terms of recommendations for a particular case and (c) other anomalies.

10.4 Discussion

The interpretation of these data is not simple. Apart from the problem of judging equivalence, it is of course not fair to assume that the original clinical management was 100% correct, and so the basis of comparison is somewhat "soft". Certainly it

would be wrong to generalise these results to the conclusion that 1 in 8 patients would do worse if the prototype system were used in place of Dr. Corrah. One could equally well argue that the system probably got the "correct" answer in half of the 40 non-equivalent cases, in which case the overall performances of the clinician and the system against the mythical standard of "correctness" would be equal at 94% each.

Taking a more realistic view point, this evaluation should perhaps be regarded as a test of this approach to decision support in general. From this point of view, it would be reasonable to draw the conclusion, judging by the results of this preliminary evaluation, that a full clinical trial of such a system might be worthwhile.

It is also clear from the breakdown of non-equivalent cases that a proportion of them could be dealt with by minor additions or modifications to the database. For example, some additional clarification of severity of septic rash might be helpful to determine the need for antibiotics. Equally, it seems, in Dr. Corrah's practice, that lower respiratory symptoms are less strongly associated with referral than in the prototype system. The fact that the analysis of non-equivalent cases in this way, which is relatively simple to undertake, points fairly clearly to specific problems in the database is encouraging. It would mean that a generally available system could be adjusted relatively simply to local variations and requirements, and tested in this way against a local expert.

Chapter 10: Evaluation of the Prototype System

Inevitably there are going to be occasional cases that are highly unusual and would fall outside the scope of the system. However, in the health centre context they would probably represent a very small proportion of total cases - approximately 1% in this evaluation.

The overall conclusion therefore from the development and evaluation of the prototype system is that it represents a feasible approach to improving patient management at the health centre level. The extent and nature of health improvements that might result from its use remain hypothetical, and would have to be further investigated before any recommendation for the widespread use of such a system could be made.

Chapter 11: DISCUSSION

11.1 Introduction

In considering the possible benefits and relevance of computer decision support in health care delivery systems for a country such as The Gambia, one has to consider not only potential computer applications but also the nature of the health service itself. It has been suggested [Mandil 1989] that health informatics may provide new solutions to old challenges in the delivery of health care in developing countries. Nevertheless, in many situations the "old challenges" seem to be so basic in their nature - for example a lack of essential resources or personnel - that many health practitioners are sceptical as to the potential benefits of, or necessity for, health informatics.

At the same time, the technologies and methodologies associated with decision support are still under development. In particular, as progress has been made with the systems themselves, their evaluation and validation seems to have become a much more important and difficult issue. This, coupled with technological reluctance in some quarters, has resulted in relatively few implementations of useful decision support systems in health care practice.

Nevertheless, the results of this project suggest that decision support systems may have a role to play in health care in developing countries in the future.

11.2 Delivering Primary Health Care

One of the problems associated with primary health care in developing countries in the last decade or so has been the widespread implementation of programmes, the content of which has largely been based on subjective and untested principles. It is clear that the term "primary health care" has come to mean very different things in developing countries compared with industrialised societies. In the former, the nature of some implementations are so basic as to include only a handful of cheap and simple treatments, often administered fairly indiscriminately. On the other hand, primary care in European countries has generally come to be associated with ready access to highly qualified medical practitioners and sophisticated treatments, together with easy referral to hospitals. It is therefore not surprising that general levels of health continue to show enormous international variation.

Unfortunately the relationship between investment in primary health care and benefits accruing from implemented programmes in developing countries has not been well investigated. Some programmes in developing countries have been costed [Chabot & Waddington 1987; Lamb et al. 1984] but there have been very few thorough evaluations [Greenwood A.M. et al. 1989; Greenwood B.M. et al. 1989 A], primarily because they are very expensive and difficult to carry out effectively [Vaughan, Walt & Ross 1984].

In addition, there appears to have arisen a

tendency to assume that primary health care is (a) beneficial and (b) cost effective, despite the existence of little hard evidence to support this view. Despite earlier refutations [Gowers 1984], it has certainly become clear in The Gambia that the low cost primary health care scheme in most of the country falls far short of the relatively intensive and expensive programme in Keneba, in terms of reducing infant and child mortality [Greenwood B.M. et al. 1989 A; Lamb et al. 1984]. Whether or not there are potential intermediate points where a modestly increased investment in health care would produce significant benefits remains a matter for conjecture, although the addition of malaria chemoprophylaxis to primary health care in the Farafenni area produced significant benefits for only the additional cost of the Maloprim used [Greenwood B.M. et al. 1988].

Meanwhile, much subjective effort continues to be directed towards priorities for health care planning [Monekosso 1984; Feachem, Graham & Timæus 1989]. Nevertheless, there is an increasing awareness that good primary health care schemes do depend on good background information and good monitoring systems for their success [Feachem, Graham & Timæus 1989; Gibbons 1984]. Coupled with this however is the necessity of community motivation [Akenzua, Ozigbo-Esere & Osuhor 1984] and in particular the need to look at the problems at the rural level, where very little research has actually taken place [Mäkelä 1987]. The potential applications of good data on the health of a population have included enhancing the effectiveness of central planning for pharmaceuticals

[Osore 1989]. A further important factor for the success of primary health care has been identified as the integration of hospital and primary care facilities into a complementary whole, rather than a coexistence as competing components of the health service [Hardie 1984; Turner 1985].

The perceived need for improved data within haelth care systems in turn suggests that there may be applications for appropriate computer systems - with the emphasis on appropriate. The recently increased availability of small, portable computers has been suggested as a method of acquiring better quality health data [Lun 1989], and certainly encouraging applications have been described [Osborne 1984; van de Merwe 1984; Crisan, Keita & Cantrelle 1988; Birkett 1988]. However, the ability to collect and use health information must not be confused with the need to do so in any given context.

The virtually complete lack of medical audit procedures at the primary health care level in developing countries makes it difficult to assess the extent to which some of the obvious shortcomings in health care systems are due to inadequacies in personnel and training, rather than, for example, unavailability of essential drugs. This in turn makes the possible impact of decision support systems difficult to predict. Whilst the field of health informatics represents many different and potentially interesting possible solutions to problems of health care delivery, notably by assisting in the various levels of decision making from patient management to central planning, what impact might such solutions

have on community health? This, to a large extent, remains an unanswered question.

11.3 Appropriate Decision Support

Deciding on what constitutes appropriate decision support within the context of health care delivery systems such as those discussed above is not easy. In many instances there are no clear guidelines on which decisions, for example in patient management, are supposed to be made [Scherrer & Borst 1989]. In their widest sense, decision support systems include everything from a simple flowchart, to systems based on sophisticated technology. Flowchart-type approaches have been widely implemented but infrequently evaluated [Essex 1975] but, from a technological point of view, are obviously appropriate. However, their relative inflexibility of use has some drawbacks, particularly in that once a paticular branch of the chart is followed, other parallel branches tend to be ignored.

The prospect of computerised decision support potentially solves the problem of the inflexibility of flowcharts, but immediately raises a different problem, that of the technology itself. Many people would take the view that the introduction of computer technology into health centres in developing countries would inevitably cause more problems than it could solve. Certainly this would have been true until very recently, as computer systems would have required constant power supplies, air-conditioning, etc. However, the developments in the last few years

of small portable systems that do not depend on mains power represents a major change. Systems are now available which are not technologically very different from pocket calculators, and which certainly, in principle, could be appropriate for health centre use. An example of this is the Z88 and its solar power supply that was used for the development of the prototype system in this project.

If it is accepted that computer hardware might have a part to play in decision aids for health care, there remains the major question of how to implement a suitable system on the hardware. Basic methodologies for experimental medical decision support systems have been developed in a number of contexts, but often in situations where the computational capacity available was not a major constraint [Myers 1983]. In many cases, systems have been devoted to specialist areas, such as the acute abdomen [Wilson et al. 1977; Edwards & Davies 1984], or jaundice [Knill-Jones et al. 1973]. Many implementations have made use of Bayesian methods [Bayes 1763], which, despite continued criticism, have provided interesting results whilst being computationally manageable. This contrasts with artificial intelligence or knowledge-based methods which are of potential interest in this field but whose implementational difficulties persist. Various attempts have been made to improve on the basic Bayesian methodology, largely by attempting to compensate for the conditional independence of probabilities which Bayes' theorem assumes [Ludwig & Heilbronn 1983; Seroussi 1986]. However, very few comparisons of methodologies have been made at a

practical level [Fox, Barber & Bardhan 1980]. There is therefore no obviously optimal methodology for clinical decision support at this stage. The choice of a Bayesian approach for this project was also therefore somewhat arbitrary, except that, because of the environment for which it was intended, the relative computational simplicity of a Bayesian system became a major factor.

Choosing a methodology is however only the first step in building a decision support system. A system depends just as crucially on the data associated with it as with the methodology used to manipulate the data. This aspect presents serious problems, particularly in the context of a health service in which there is little reliable information. Whilst there are certain deliberate constraints on health centres, such as the range of drugs with which they are supposed to be supplied, in many cases these have arisen on a purely subjective basis. There have been very few carefully conducted trials of patient management at the rural population level in Africa [Campbell et al. 1988] from which to derive meaningful data for decision support. Levels in the health service at which various tasks should be performed are not well defined even in more sophisticated settings [Crandall 1984], and certainly criteria for referral are often vague [Mitchell & Porter 1984]. The concepts of medical audit and efficient use of available resources are becoming more important in industrialised societies [Todd 1984 A; Todd 1984 B; Todd 1984 C; Todd 1984 D; Somers 1983] but remain almost uninvestigated in most tropical countries. Whilst it has been suggested that

hard, quantitative data perform best in decision support systems [Leaper et al. 1972], our findings suggest that, at least at the relatively general level of health care with which we are dealing, qualitative estimates can play a useful part [Kong et al. 1986]. This is fortunate, since for many aspects of tropical health care there exist almost no useful data. Even though some data can usefully be collected, such as the Gate Clinic database described earlier, this is inevitably not exactly equivalent to what pertains in a rural health centre. On the other hand, it is virtually impossible to gather useful data at rural health centres for two reasons. Firstly, one of the aims behind the development of decision support at this level is to improve standards of patient management, and so collecting data pertaining to existing poor standards would not be particularly helpful. Secondly, the data collection exercise in itself would almost certainly have a major impact on the subject of observation. Thus it became obvious in this study that a useful database would of necessity be an amalgam of quantitative and qualitative data, compiled from a variety of sources. In addition, poorly defined issues such as the actual and desirable extents of "placebo" prescribing have to be addressed. In practice, it seems that very few patients leave health facilities empty-handed, and the concept of emotional and psychological support as a component of therapy is virtually ignored [Srinivasan & Srinivasa Murthy 1986]. However, the extent to which this practice should be modelled in a decision support system is doubtful, and the prototype system therefore tries to link prescriptions more

specifically to presentations. A further issue in building such systems arises from the lack of clear policy in many patient management issues. For example, in the United Kingdom it was suggested in 1987 that aspirin should no longer be given to children under the age of 12 (except for the treatment of rheumatic conditions) because of its association with Reye's syndrome [Committee for the Safety of Medicines 1987]. Despite this, aspirin continues to be given to children in many developing countries, The Gambia included. The prototype system however has been designed to favour paracetamol rather than aspirin in children, even though this is not yet a stated health service policy.

11.4 Evaluating Decision Support

During the period of this study, there has been a shift of interest away from the design of decision support towards its evaluation, and indeed validating and evaluating decision support systems has almost become a speciality in its own right. Evaluation in general has been defined by the United Nations as "a process which attempts to determine as systematically as possible the relevance, effectiveness and impact of activities in the light of their objectives" [Ford & Sohm 1982]. Very few evaluations of medical decision support systems have met this definition, including unfortunately the evaluation of the prototype system in this project. As discussed above, even a general evaluation of a health care programme is very difficult to achieve in rural Africa, and similar difficulties apply to the evaluation of a

decision aid within such a programme. Many treatises on the general subject of evaluating expert systems have been published in recent years, but the subject remains relatively poorly defined [Gaschnig et al. 1983; Liebowitz 1986; Wyatt 1987; Miller 1988; Hollnagel 1989].

In general terms, it can be argued that the evaluation of decision support systems should be analogous to the evaluation and licensing procedures that are well-established for new drug products. Indeed, questions of legal liability associated with the routine use of decision aids may well arise [Kilian 1988; Brahams & Wyatt 1989], in which case evaluatory procedures could be very important. However, just as testing procedures for new drug products pass through a series of different stages, it is similarly possible to consider the evaluation of decision support systems at a number of different levels [Rossi-Mori & Ricci 1988]. The initial stages, of laboratory testing the system, are relatively starightforward if the system is built from a set of quantitative data which is assumed to be correct for the purposes of the evaluation [de Dombal et al. 1971 A; de Dombal et al. 1971 B]. This was essentially the case in the evaluation of the pilot Gate Clinic system [Byass & Corrah 1989]. However, once more subjective data and criteria are used, for example in the qualitative system described earlier, even this level of evaluation becomes difficult, at least on a quantitative basis.

It has been argued that evaluation of a system should be undertaken in different setting from that

in which it was developed, as has been described with a system developed in Denmark and evaluated in Mexico [Boom et al. 1986]. However, this may not always be possible, depending on the nature of the system. The balance between "ordinary" and "difficult" cases in an evaluation has also been raised together with the need to remove both pro- and anti-computer biases [Chandrasekaran 1983].

The whole field of evaluation has been dominated by the search for the elusive "gold standard". However, it has also been noted that many clinical problems do not have a single correct answer [Shortliffe 1987]. Whilst there is clearly a place for comparative case-by-case evaluation procedures, the interpretation of such investigations does indeed depend heavily on a true "gold standard". In practice, depending on the intended domain of the system, there may not exist any definable "gold standard", and indeed this appears to be the case in this project, where the whole area of health care and patient management that falls within the scope of the system is relatively ill-defined. Attempts at evaluation in such cases can in fact lead to a circularity in which the standard is inextricably linked with the building of the system itself. In our case, even the possibility of an evaluation against a panel of "experts", such as has been used effectively in other contexts [Quaglini et al. 1984; Quaglini et al. 1988], is difficult in that potential paramedical users are not experts in health care, and health care experts are generally physicians who approach issues of patient management from a different viewpoint.

Chapter 11: Discussion

As discussed earlier, the inconsistency with which patients at this level report their complaints is a further difficulty with respect to evaluation, in that the scope for trials consisting of double consultations for comparative purposes is very limited.

It seems therefore that there may be contexts in which the search for the "gold standard" is unrealistic. Similarly, the quest for 100% concordance between decision support systems and the source of comparison may be inappropriate, although this does not imply that such a comparison should not be made. In some ways, there is an analogy with medical education, in which the "experts" (faculty members) seek to inculcate their knowledge and practice into new "decision aids" (their students). In this analogy, the evaluation consists of examinations undertaken by the students, depending on the results of which they progress to independent practice. However, there is not an expectation that students who are to graduate should necessarily score 100% in all their examinations, and in practice very few, if any, do so.

In terms of evaluating decision aids therefore, it may in some cases be more appropriate to concentrate on evaluating the effects of using the system rather than on its inherent accuracy, although this approach has been more the subject of discussion than action: it has however been attempted [Adams et al. 1986]. This shortcoming is explained largely by the difficulties and expense of designing and undertaking such evaluations, which indeed also precluded such an

approach in this study. Two fundamental problems arise in designing such an evaluation: firstly the hypothetical effects of using the system, which are to be measured, have to identified in order to be investigated, and secondly a "placebo" group has to be arranged in such a way as to permit a valid comparison. Further safeguards have to be incorporated to avoid potentially serious sources of bias. The so-called "Hawthorne" effect, whereby performance is altered by observation, has to be considered [Roethligsburger & Dickson 1939]. The effects of using a system on the general approach to clinical work may also be significant, and in this respect it is important that the "placebo" system is selected appropriately, for example to include collecting patient data without using it for decision support [Adams et al. 1986].

Thus, whilst it must be admitted that a theoretically ideal evaluation may not always be possible for new decision support systems, it is clear that the development of a new system, which subjectively appears to work, is not a satisfactory end point, even though it has in some cases been presented as such [Auvert et al. 1986 B].

11.5 Conclusions

Medical decision support systems are generally regarded by medical professionals either as a potentially interesting field of study and development, or as an irrelevance; few people maintain a neutral position. Thus, for example, the

moderate performance of a system directed at the acute abdomen was given the interpretation that Bayesian statistics could play no useful role in such a system [Sutton 1989]; and, despite refutations of this extraordinary extrapolation [Murray 1989, Wyatt 1989], a subsequent Lancet editorial concluded that computer diagnostic systems were too simplistic to be useful [Anon. 1989]. This illustrates the sometimes irrational approaches that have been made to the subject.

Despite recognition in principle of the roles that clinical computer systems might make in health services, they have frequently been ignored in favour of adminstrative information systems [Massey 1988]. Various reasons have been put forward as to why effort and progress have been relatively small. Clinicians may resent what they perceive to be an interfering computer system in their exclusive domain [Siegel & Alexander 1984]. Even relatively proven systems have in some cases not proved popular [Batson 1984] and multifarious reasons have been suggested for these obstacles to progress [de Dombal 1987].

At the same time, significant benefits other than those primarily intended have been attributed to decision support systems. Their possible contributions to medical education, rather in the same way that medical personnel learn by working alongside more experienced colleagues, has been recognised [Myers 1983] and the use of clinical predictions in public health planning has also been studied [McNeil & Hanley 1981]. Developing better methods of formalising medical knowledge has also

been cited as a benefit of decision support research [Kulikowski 1983; Duda & Shortliffe 1983].

General attitudes as to the potential role of computer systems in clinical medicine have softened somewhat from original views that they might completely emulate, or even supersede, physicians; but many people still believe that such systems may have useful roles to play in particular settings, and in educational and training situations [Salamon 1989].

In many ways the setting of the rural African health centre appears to be particularly suited, at least in principle, to the use of decision support systems. This project has shown that worthwhile systems can be implemented on hardware than is feasible in that setting. Having overcome that hurdle, the facts that (a) human expertise is actually in short supply in rural Africa, (b) on-the-job training for paramedical staff is difficult for logistic reasons, (c) in most health centres the luxury of a trusted colleague's second opinion is unavailable and (d) subjective opinions suggest that scarce treatment resources are not always best matched to patients, form a strong case for the need for decision aids. Whilst in this study it has not been possible to establish whether or not health benefits would accrue from the use of the prototype system, the preliminary evaluations reported suggest that at least a field trial of a system along the lines of the prototype would be feasible and worthwhile. However, until such an evaluation has taken place, it would be wrong to assume that

the hypothetical benefits to health care of using such a system would necessarily be shown. As has been pointed out in this context, "the feasibility of a technique never implies either its utility or its desirability" [Grémy 1988].

11.6 Possible Future Developments

As suggested above, the results of this study indicate that a field trial of a system similar to the prototype would be worthwhile. The question remains as to how such a trial should be designed. One of the best examples of field trials of decision support systems to date [Adams et al. 1986] may be helpful to consider. Considerations as to how such a trial could fit appropriately into rural health centres must also be addressed.

One possibility, since health centres are supposed to keep crude tallies of case numbers, would be to introduce two different computer systems, both of which purported to facilitate record keeping. Thus both could, in a similar fashion, be designed to collect patient data. However, one system could go on to also make management suggestions. If both systems were, for the purposes of the trial, implemented on laptop portables with hard disc storage, it would also be possible to keep a log of every key-press on the machine in a totally transparent background process, and these data could simply be downloaded by the investigator from time to time.

This type of approach should minimise the effects

of making the observation, allow accumulation of detailed data on case presentations at the health centre level, and finally allow the assessment of the effects of the management suggestions given by that version of the system on the performance of users. The extent of appropriate patient management with and without decision support could also be evaluated within this framework if a sample of records were submitted to a suitable group of independent reviewers. This type of trial would still be one step removed from assessing the effects of such a system on the health of the community, but it would provide important data on the practice of patient management at the health centre level, and the extent to which such behaviour might be influenced by decision support.

REFERENCES

Adams, I.D., Chan, M., Clifford, P.C., Cooke, W.M., Dallos, V., de Dombal, F.T., Edwards, M.H., Hancock, D.M., Hewett, D.J., McIntyre, N., Somerville, P.G., Spiegelhalter, D.J., Wellwood, J., Wilson, D.H., (1986), Computer aided diagnosis of acute abdominal pain: a multicentre study. British Medical Journal, 293, 800-804.

Agbalajobi, F., (1983), Indigenisation of health informatics through adaptation. In: Health Informatics in Developing Countries: Experiences and Viewpoints, pp. 173-180, eds. A. Fernandez Perez de Talens et al.; North-Holland, Amsterdam.

Alonso, P.L., Bowman, A., Marsh, K., Greenwood, B.M., (1987), The accuracy of the clinical histories given by mothers of seriously ill African children. Annals of Tropical Paediatrics, 7, 187-189.

Akenzua, G.I., Ozigbo-Esere, I.J.M., Osuhor, P.C., (1984), Community response to primary health care: Obadan project in Bendel state of Nigeria. Journal of Tropical Paediatrics, 30, 310-312.

Anon., (1984), Climatised computers. African Technical Review, June, 29-30.

Anon., (1989), Computer-assisted diagnosis (Editorial). Lancet ii, 1371.

References

Auvert, B., Gilbos, V., Aegeter, Ph., Du, Le Thi Huong, Boutin, Ph., Philippe, A.M., Benillouche, E., van Look, F., Emanuelli, X., (1985), An expert system as an aid to decision making by para-medical personnel in developing countries. Medical Decision Making: Diagnostic Strategies and Expert Systems, pp. 81-84, eds. J.H. van Bemmel, F. Grémy, J. Zvarova; North-Holland, Amsterdam.

Auvert, B., Aegeter, Ph., Gilbos, V., Benillouche, E., Boutin, P., Desve, G., Landre, M-F., Bos, D., (1986 A), TROPICAID: a portable expert system for medical decision aid in developing countries. Proceedings of Medinfo-86, pp. 222-224, eds. R. Salamon, B. Blum, M. Jorgensen; North-Holland, Amsterdam.

Auvert, B., Aegerter, Ph., van Look, F., Du, Le Thi Huong, Boutin, Ph., Monier, J.L., Emmanuelli, X., Gilbos, V., Benillouche, E., (1986 B), A hand-held decision-aid system designed for rural health workers. Computers and Biomedical Research, 19, 80-89.

Barnett, G.O., Souder, D., Beaman, P., Hupp, J., (1981), MUMPS - an evolutionary commentary. Computers and Biomedical Research, 14, 112-118.

Batson, E., (1984), Computer as consultant: application of artificial intelligence in diagnosis. Postgraduate Medicine, 75, 211-214.

References

Bayes, T., (1763), A problem in the doctrine of chances. Philosophical Transactions of the Royal Society, 53, 370-418.

Bijlmer, H.A., Alphen, van L., Greenwood, B.M., Brown, J., Schneider, G., Hughes, A., Menon, A., Zanen, H.C., Valkenburg, H.A., (1990), The epidemiology of Haemophilus influenzae meningitis in children under 5 years of age in The Gambia, West Africa. Jounal of Infectious Diseases, {IN PRESS}.

Billewicz, W.Z., McGregor, I.A., (1981), The demography of two West African (Gambian) villages, 1951-75. Journal of Biosocial Science, 13, 219-240.

Birkett, N.J., (1988), Computer-aided personal interviewing. American Journal of Epidemiology, 127, 684-690.

Boom, R., Gonzalez, C., Fridman, L., Ayala, J.F., Realpe, J.L., Morales, P., Quintero, R., (1986), Looking for "indicants" in the differential diagnosis of jaundice. Medical Decision Making, 6, 36-41.

Bradley, A.K., Greenwood, B.M., Greenwood, A.M., Marsh, K., Byass, P., Tulloch, S., Hayes, R., (1986), Bed-nets (mosquito-nets) and morbidity from malaria. Lancet, ii, 204-207.

Brahams, D., Wyatt, J., (1989), Decision aids and the law. Lancet, ii, 632-634.

References

Byass, P., (1986), The design of computer forms for tropical medical research. Methods of Information in Medicine, 25, 229-232.

Byass, P., (1987), Computers in Africa: appropriate technology? Computer Bulletin, 3, 17.

Byass, P., (1988), A probabilistic approach to health care delivery in tropical Africa, in: Rienhoff, O., Piccolo, U., & Schneider, B. (eds.), Lecture Notes in Medical Informatics 36: Expert Systems and Decision Support in Medicine (Springer-Verlag, Berlin) pp. 136-141.

Byass, P., Hanlon, P., Hanlon, L., Marsh, V., Greenwood, B.M., (1988), Microcomputer management of a vaccine trial. Computers in Biology and Medicine, 18, 179-195.

Byass, P., (1989 A), Choosing and using a microcomputer for tropical epidemiology: I. Preliminary considerations. Journal of Tropical Medicine and Hygiene, 92, 282-287

Byass, P., (1989 B), Choosing and using a microcomputer for tropical epidemiology: II. Study implementation. Journal of Tropical Medicine and Hygiene, 92, 330-337.

Byass, P., Corrah, P.T., (1989), Assessment of a probabilistic decision support methodology for tropical health care. In: B. Barber, D. Cao, D. Qin, G. Wagner (Eds.), Proceedings of Medinfo-89, North-Holland, Amsterdam, 995-1000.

References

Campbell, H., Byass, P., Greenwood, B.M., (1987), Bed-nets and malaria suppression. Lancet, i, 859-860.

Campbell, H., Byass, P., Forgie, I.M., O'Neill, K.P., Lloyd-Evans, N., Greenwood, B.M., (1988), Trial of co-trimoxazole versus procaine penicillin with ampicillin in treatment of community-acquired pneumonia in young Gambian children. Lancet, ii, 1182-1184.

Campbell, H., Byass, P., Lamont, A.C., Forgie, I.M., O'Neill, K.P., Lloyd-Evans, N., Greenwood, B.M., (1989), Assessment of clinical criteria for identification of severe acute lower respiratory tract infections in children. Lancet, i, 297-299.

Campbell, H., Byass, P., Greenwood, B.M., (1990), Acute lower respiratory infections in Gambian children: maternal perception of illness. Annals of Tropical Paediatrics, {IN PRESS}.

Central Statistics Department, (1987), The Republic of The Gambia population and housing census 1983, General Report, Vol. 1. Banjul, The Gambia.

Chabot, J., Waddington, C., (1987), Primary health care is not cheap: a case study from Guinea Bissau. International Journal of Health Services, 17, 387-409.

Chandrasekaran, B., (1983), On evaluating AI systems for medical diagnosis. The AI Magazine, Summer 1983, 34-37.

References

Chard, T., (1987), Self-learning for a Bayesian knowledge base: how long does it take for the machine to educate itself? Methods of Information in Medicine, **26**, 185-188.

Chen, L.C., (1986), Primary health care in devloping countries: overcoming operational, technical and social barriers. Lancet, ii, 1260-1265.

Committee for the Safety of Medicines, (1987), Reye's syndrome and aspirin. British Medical Journal, **292**, 1590.

Crandall, L.A., Santulli, W.P., Radelet, M.L., Kilpatrick, K.E., Lewis, D.E., (1984), Physician assistants in primary care: patient assignment and task delegation. Medical Care, **22**, 268-282.

Crisan, C., Keita, L., Cantrelle, P., (1988), Observation demographique suivie avec des micro-ordinateurs portables sur le terrain: une experience en Guinée. Presented at the African Population Conference, Dakar, November 1988.

Cross, E.R., Sheffield, C., Perrine, R., Pazzaglia, G., (1984), Predicting areas endemic for schistosomiasis using weather variables and a Landsat database. Military Medicine, **149**, 542-544.

Cumper, G., (1987), The resource requirements for basic health care in developing countries, with special reference to Africa. Journal of Tropical Paediatrics, 33, supplement, 18-25.

References

de Dombal, F.T., Horrocks, J.C., Staniland, J.R., Gill, P.W., (1971 A), Simulation of clinical diagnosis: a comparative study. British Medical Journal, 2, 575-577.

de Dombal, F.T., Horrocks, J.C., Staniland, J.R., Guillou, P.J., (1971 B), Production of artificial "case-histories" by using a small computer. British Medical Journal, 2, 578-581.

de Dombal, F.T., Leaper, D.J., Staniland, J.R., McCann, A.P., Horrocks, J.C., (1972), Computer aided diagnosis of acute abdominal pain. British Medical Journal, 2, 9-13.

de Dombal, F.T., (1984 A), Computer based assistance for medical decision making. Gastroenterologie Clinique et Biologique, 8, 135-137.

de Dombal, F.T., (1984 B), Computer-assisted diagnosis of acute abdominal pain: the British experience. Revue d'Epidémiologie et de Santé Publique, 32, 50-56.

de Dombal, F.T., (1984 C), The O.M.G.E. acute abdominal pain survey - progress report 1982. Scandinavian Journal of Gastroenterology, 19, (suppl.), 28-40.

de Dombal, F.T., (1987), Computer-aided decision support - the obstacles to progress. Methods of Information in Medicine, 26, 183-184.

References

de Pace, M., (1987), dBase III plus. BSP Professional Books, Oxford.

Duda, R.O., Shortliffe, E.H., (1983), Expert systems research. Science, 220, 261-268.

Edwards, F.H., Davies, R.S., (1984), Use of a Bayesian algorithm in the computer-assisted diagnosis of appendicitis. Surgery, Gynaecology and Obstetrics, 158, 219-222.

El Kholy, A., Mandil, S.H., (1983), Microcomputers and health improvement in developing countries. WHO Chronicle, 37, 163-165.

Elstein, A.S., Bordage, G., (1979), Psychology of clinical reasoning. In: Health Psychology: A Handbook, eds. Stone, G.C., Cohen, F., Adler, N.E.; Jossey Bass, San Francisco.

Essex, B.J., (1975), Approach to rapid problem solving in clinical medicine. British Medical Journal, 3, 34-36.

Essex, B.J., (1980), Diagnostic pathways in clinical medicine. Churchill-Livingstone, Edinburgh.

Feachem, R.G., Graham, W.J., Timæus, I.M., (1989), Identifying health problems and health research priorities in developing countries. Journal of Tropical Medicine and Hygiene, 92, 133-191.

References

Fischhoff, B., Slovic, P., Lichtenstein, S., (1977), Knowing with certainty: the appropriateness of extreme confidence. Journal of Experimental Psychology: Human Perception and Performance, 3, 552-564.

Fitzgerald, S., Gowers, P., (1983), Blueprint for success: the Gambian immunization programme. World Health Forum, 4, 79-82.

Ford, A.N., Sohm, E.D., (1982), United Nations system cooperation in developing evaluation by governments. Joint Inspection Unit, United Nations, Geneva.

Fox, J., Barber, D., Bardhan, K.D., (1980), Alternatives to Bayes: a quantitative comparison with rule-based diagnostic inference. Methods of Information in Medicine, 19, 210-215.

Friedman, R.B., Gustafson, D.H., (1977), Computers in clinical medicine: a critical review. Computers in Biomedical Research, 10, 199-204.

Gamble, D.P., (1952), Infant mortality rates in rural areas of The Gambian Protectorate. Journal of Tropical Medicine and Hygiene, 55, 145-149.

Gaschnig, J., Klahr, P., Pople, H., Shortliffe, E, Terry, A., (1983), Evaluation of expert systems: Issues and case studies. In: Building Expert Systems, F. Hayes-Roth, D.A. Waterman & D.B. Lenat (Eds.), Addison-Wesley, London, 241-280.

References

Gibbons, G., (1984), The role of information in primary health care. Public Health Review, 12, 372-377.

Gillett, J.D., (1987), The harnessing of artificial satellites for the prevention of disease in the tropics: flights of fancy or of fact? Transactions of the Royal Society of Tropical Medicine and Hygiene, 81, 350-351.

Glasziou, P., Vermeir, D., (1984), Information analysis for medical expert systems. Methods of Information in Medicine, 23, 126-134.

Goh-Rowland, S.G.J., Lloyd-Evans, N., Williams, K., Rowland, M.G.M., (1985), The etiology of diarrhoea studied in the community in young urban Gambian children. Journal of Diarrhoeal Disease Research, 3, 7-13.

Gomaa, R.A., (1983), Experience of Egypt in health informations systems and activities. Health Informatics in Developing Countries: Experiences and Viewpoints, pp. 65-70, eds. A. Fernandez Perez de Talens et al.; North-Holland, Amsterdam.

Gowers, P.R.S., (1984), Primary health care in The Gambia. Lancet, ii, 1396.

Gould, J.B., Frerichs, R.R., (1986), Training faculty in Bangladesh to use a microcomputer for public health: follow-up report. Public Health Reports, 101, 616-623.

References

Grams, R.R., Massey, J.K., Jin, Ze Ming, Hickey, S., (1986), Medical diagnostic support for spacecraft. Journal of Medical Systems, 10, 185-194.

Greenwood, A.M., Greenwood, B.M., Bradley, A.K., Williams, K., Shenton, F.C., Tulloch, S., Byass, P., Oldfield, F.S.J., (1987), A prospective study of the outcome of pregnancy in a rural area of The Gambia. Bulletin of the World Health Organisation, 65, 635-643.

Greenwood, A.M., Bradley, A.K., Byass, P., Greenwood, B.M., Snow, R.W., Bennett, S., Hatib-N'jie, A.B., (1989), Evaluation of a primary health care programme in The Gambia: I. Its impact on the outcome of pregnancy. Journal of Tropical Medicine and Hygiene, {IN PRESS}.

Greenwood, B.M., Greenwood, A.M., Bradley, A.K., Tulloch, S., Hayes, R., Oldfield, F.S.J., (1987 A), Deaths in infancy and early childhood in a well-vaccinated, rural, West African population. Annals of Tropical Paediatrics, 7, 91-99.

Greenwood, B.M., Bradley, A.K., Greenwood, A.M., Byass, P., Jammeh, K., Marsh, K., Tulloch, S., Oldfield, F.S.J., Hayes, R., (1987 B), Mortality and morbidity from malaria among children in a rural area of The Gambia, West Africa. Transactions of the Royal Society of Tropical Medicine and Hygiene, 81, 478-486.

References

Greenwood, B.M., Greenwood, A.M., Bradley, A.K., Williams, K., Hassan-King, M., Shenton, F.C., Wall, R.A., Hayes, R.J., (1987 C), Factors influencing susceptibility to meningococcal disease during an epidemic in The Gambia, West Africa. Journal of Infection, 14, 167-184.

Greenwood, B.M., Bradley, A.K., Greenwood, A.M., Oldfield, F.S.J., (1987 D), A record system for drug administration by illiterate village health workers. Transactions of the Royal Society of Tropical Medicine and Hygiene, 81, 534-535.

Greenwood, B.M., Greenwood, A.M., Bradley, A.K., Snow, R.W., Byass, P., Hayes, R.J., N'jie, A.B.H., (1988), A comparison of two drug strategies for the control of malaria within a primary health care programme in The Gambia, West Africa. Lancet, i, 1121-1127.

Greenwood, B.M., Bradley, A.K., Byass, P., Greenwood, A.M., Menon, A., Snow, R.W., Hayes, R.J., Hatib-N'jie, A.B., (1989 A), Evaluation of a primary health care programme in The Gambia: II. Its impact on mortality and morbidity in young children. Journal of Tropical Medicine and Hygiene, {IN PRESS}.

Greenwood, B.M., Greenwood, A.M., Snow, R.W., Byass, P., Bennett, S., Hatib-N'jie, A.B., (1989 B), Malaria chemoprophylaxis given by traditional birth attendants improves the outcome of pregnancy in primagravidae. Transactions of the Royal Society of Tropical Medicine and Hygiene, {IN PRESS}.

References

Grémy, F., (1988), Human meaning of medical informatics: reflections about its future and trends. Presented at the P.L. Reichertz Memorial Congress, Hannover, September 1988.

Hall, A.J., Inskip, H.M., Loik, F., Day, N.E., O'Conor, G., Bosch, X., Muir, C.S., Parkin, M., Muñoz, N., Tomatis, L., Greenwood, B., Whittle, H., Ryder, R., Oldfield, F.S.J., N'Jie, A.B.H., Smith, P.G., Coursaget, P., (1987), The Gambia Hepatitis Intervention Study. Cancer Research 47, 5782-5787.

Hall, A.J., Inskip, H.M., Loik, F., Chotard, J., Jawara, M., Vall-Mayans, M., Greenwood, B.M., Whittle, H.C., N'jie, A.B.H., Cham, K., Bosch, F.X., Muir, C.S., (1989), Hepatitis B vaccine in the expanded programme of immunisation: the Gambian experience. Lancet, i, 1057-1060.

Hanlon, P., Hanlon, L., (1986), Health in The Gambia. Action Aid, Banjul, The Gambia.

Hanlon, P. Hanlon, L., Marsh, V., Byass, P., Shenton, F., Sanders, R.C., Hassan-King, M., Greenwood, B.M., (1987 A), Epidemiology of rotavirus in a periurban Gambian community. Annals of Tropical Paediatrics, 7, 238-243.

Hanlon, P., Hanlon, L., Marsh, V., Byass, P., Sillah, H., Hayes, R., Whittle, H.C., Greenwood, B.M., (1987 B), Serological comparisons of approaches to polio vaccination in The Gambia. Lancet, i, 800-801.

References

Hanlon, P., Hanlon, L., Marsh, V., Byass, P., Shenton, F., Hassan-King, M., Jobe, O., Sillah, H., Hayes, R., M'Boge, B.H., Whittle, H.C., Greenwood, B.M., (1987 C), Trial of an attenuated bovine rotavirus vaccine (RIT 4237) in Gambian infants. Lancet, i, 1342-1345.

Hanlon, P., Byass, P., Yamuah, M., Hayes, R., Bennett, S., M'Boge, B.H., (1988), Factors influencing vaccination compliance in peri-urban Gambian children. Journal of Tropical Medicine and Hygiene, 91, 29-33.

Hardie, M., (1984), Hospitals and primary health care (PHC). International Nursing Review, 31, 43-46.

Hilden, J., (1984), Statistical diagnosis based on conditional independence does not require it. Computers in Biology and Medicine, 14, 429-435.

Hollnagel, E., (1989), Evaluation of expert systems. In: Topics in Expert System Design, G. Guida & C. Tasso (Eds.), Elsevier Science Publishers, Amsterdam, 377-416.

Horrocks, J.C., McCann, A.P., Staniland, J.R., Leaper, D.J., de Dombal, F.T., (1972), Computer-aided diagnosis: description of an adaptable system, and operational experience with 2,034 cases. British Medical Journal, 2, 5-9.

Hudson, D.L., Estrin, T., (1984), Derivation of rule-based knowledge from established medical outlines. Computers in Biology and Medicine, 14, 3-13.

References

Hutchinson, P., (1982), Rainfall variations in The Gambia since 1886. World Meteorological Organisation report, Banjul.

Kanté, B., Brinkmann, U.K., Bocoum-Maiga, S., (1986), Medical applications of personal computer systems in Mali. Proceedings of Medinfo-86, pp. 1043-1045, eds. R. Salamon, B.Blum, M. Jorgensen; North-Holland, Amsterdam.

Kilian, W., (1988), Liability for deficient medical expert systems. Presented at the P.L. Reichertz Memorial Congress, Hannover, September 1988.

Kleinmuntz, B., (1968), The processing of clinical information by man and machine. In: Formal Representation of Human Judgment, ed. Kleinmuntz; John Wiley, New York.

Kleinmuntz, B., (1984), Diagnostic problem solving by computer: a historical review and the current state of the science. Computers in Biology and Medicine, 14, 255-270.

Knill-Jones, R.P., Stern, R.B., Girmes, D.H., Maxwell, J.D., Thompson, R.P.H., Williams, R., (1973), Use of sequential Bayesian model in diagnosis of jaundice by computer. British Medical Journal, 1, 530-533.

Kolata, G., (1982), How can computers get common sense? Science, 217, 1237-1238.

References

Kong, A., Barnett, G.O., Mosteller, F., Youtz, C., (1986), How medical professionals evaluate expressions of probability. New England Journal of Medicine, 315, 740-744.

Kulikowski, C.A., (1983), Expert medical consultation systems. Journal of Medical Systems, 7, 229-234.

Lamb, W.H., Foord, F.A., Lamb, C.M.B., Whitehead, R.G., (1984), Changes in maternal and child mortality rates in three isolated Gambian villages over ten years. Lancet, ii, 912-914.

Leaper, D.J., Horrocks, J.C., Staniland, J.R., de Dombal, F.T., (1972), Computer-assisted diagnosis of abdominal pain using "estimates" provided by clinicians. British Medical Journal, 4, 350-354.

Ledley, R.S., Lusted, L., (1959), Reasoning foundations of medical diagnosis. Science, 130, 9-22.

Liebowitz, J., (1986), Useful approach for evaluating expert systems. Expert Systems, 3, 86-96.

Lindsay, S.W., Gibson, M.E., (1988), Bednets revisited - old idea, new angle. Parasitology Today, 4, 270-272.

Lowe, G.D.N., (1975), The land resources of The Gambia and their development, Vol. 3, Rural Society and the economics of agricultural development. Ministry of Overseas Development, Land Resources Division, Surbiton, Surrey.

References

Ludwig, D., Heilbronn, D., (1983), The design and testing of a new approach to computer-aided differential diagnosis. Methods of Information in Medicine, 22, 156-166.

Lun, K.C., (1989), Hand-held computers. World Health, August/September 1989, 9-11.

Mahler, H., (1983), Primary health care: health for all and the role of doctors. Tropical Doctor, 13, 146-148.

Mäkelä, M., (1987), General practice research from developing countries: health or medicine? Family Practice, 4, 134-137.

Mandil, S.H., (1989), Health Informatics. World Health, August/September 1989, 2-5.

Massey, J., (1988), An injection of new blood in the hospital ward. Computing, 6th October 1988, 28-29.

McGregor, I.A., Smith, D.A., (1952), A health, nutrition and parasitological survey in a rural village (Keneba) in West Kiang, Gambia. Transactions of the Royal Society of Tropical Medicine and Hygiene, 46, 403-427.

McNeil, B.J., Hanley, J.A., (1981), Statistical approaches to clinical predictions. New England Journal of Medicine, 21, 1292-1294.

References

Menon, A., Snow, R.W., Otoo, L., Greenwood, B.M., (1987), Decline in sensitivity of Plasmodium falciparum to chloroquine in The Gambia. Lancet, i, 1029-1030.

Mill, J., (1986), Software support that spans the whole world. Computing, October 9th, 16-17.

Miller, P.L., (1988), Evaluation of artificial intelligence systems in medicine. In: Selected Topics in Medical Artificial Intelligence, P.L. Miller (Ed.), Springer-Verlag, Berlin, 202-211.

Miller, R.A., Pople, H.E., Myers, J.D., (1982), INTERNIST-1, an experimental computer-based diagnostic consultant for general internal medicine. New England Journal of Medicine, 307, 468-376.

Miller, R.A., (1984), INTERNIST-1/CADUCEUS: problems facing expert consultation programs. Methods of Information in Medicine, 23, 9-14.

Mitchell, J.R.A., Porter, J.E., (1984), Wasting resources in referrals to hospital. Lancet, ii, 1468-1469.

Moffatt, D.J., Anderson, I.P., Williams, J.B., (1975), The land resources of The Gambia and their development, Vol. 2, The physical environment, Section A. Ministry of Overseas Development, Land Resources Division, Surbiton, Surrey.

References

Monekosso, G.L., (1984), Essential health care: a framework for its definition and implementation in health districts. Tropical Doctor, 14, 146-150.

Morley, D., (1987), Medical needs of African children - can they be met by the year 2000? Journal of Tropical Paediatrics, 33, supplement, 9-12.

Morton, B.A., Teather, D., du Boulay, G., (1984), Statistical modelling and diagnostic aids. Medical Decision Making, 4, 339-348.

Murray, G.D., (1989), Computer-assisted diagnosis in acute abdominal pain. Lancet, ii, 1102-1103.

Myers, J.D., (1983), The computer as a diagnostic consultant. Journal of the Florida Medical Association, 70, 1000-1004.

O'Brien, R.C., Channing, M., (1986), The global structure of the electronic information services industry. Oxford Surveys in Information Technology, 3, 175-210.

Ochoa, F.R., (1983), Is there a computers "impact" in the developing countries? La Santé Publique, XXVI, 147-158.

Osborne, S.F., (1984), Medical diagnosis aboard submarines. Journal of Occupational Medicine, 26, 110-114.

References

Osore, H., (1989), Estimating drug requirements using morbidity data-based method: cumulative country experience. Tropical Doctor, 19, 90-94.

Otoo, L.N., Snow, R.W., Menon, A., Byass, P., Greenwood, B.M., (1988), Immunity to malaria in young Gambian children after a two-year period of chemoprophylaxis. Transactions of the Royal Society of Tropical Medicine and Hygiene, 82, 59-65.

Pantin, C.F.A., Merrett, T.G., (1982), Allergy screening using a microcomputer. British Medical Journal, 2, 483-487.

Pickering, H., Lamb, W.H., (1985), Urban and rural differences in seasonal stress in The Gambia. Proceedings of XIII International Congress on Nutrition, Brighton, Libbey & Co., London, 1986.

Prust, R.M., (1986), Diagnostic knowledge base construction. Medical Informatics, 11, 83-88.

Pryor, T.A., Warner, H.R., (1972), Some approaches to computerised diagnosis. In: Computer Diagnosis and Diagnostic Methods, p. 241, ed. Jacquez, A.; Thomas, Springfield, Illinois.

Quaglini, S., Stefanelli, M., Barosi, G., Berzuini, A., (1984), ANAEMIA: an expert consultation system. Computers and Biomedical Research, 19, 13-27.

References

Quaglini, S., Stefanelli, M., Barosi, G., Berzuini, A., (1988), A performance evaluation of the expert system ANAEMIA. Computers and Biomedical Research, 21, 307-323.

Reitmaier, P., Dupret, A., Cutting, W.A.M., (1987), Better health data with a portable microcomputer at the periphery: and anthropometric survey in Cape Verde. Bulletin of the World Health Organisation, 65, 651-657.

Rienhoff, O., Piccolo, U., Schneider, B., (Eds.), (1988), Expert systems and decision support in medicine. Lecture Notes in Medical Informatics, volume 36, Springer-Verlag, Berlin.

Robinson, K.D., Ryack, B.L., Moeller, G., Post, R., Schroeder, W., (1983), A computer-based diagnostic/patient management system for isolated environments. Methods of Information in Medicine, 22, 131-134.

Roemer, M.I., Montoya-Aguilar, C., Quality assessment and assurance in primary health care. Offset Publication no. 105, WHO, Geneva.

Roethligsburger, F.J., Dickson, W.J., (1939), Management and the worker. Harvard University Press, Cambridge, Massachusetts.

References

Rossi-Mori, A., Ricci, F.L., (1988), On the assessment of medical expert systems, in: Rienhoff, O., Piccolo, U. & Schneider, B. (eds.), Lecture Notes in Medical Informatics 36: Expert Systems and Decision Support in Medicine (Springer-Verlag, Berlin) pp. 292-297.

Rowan, K.M., Byass, P., Snow, R.W., (1987), On-line tropical epidemiology - a case-study from The Gambia. Methods of Information in Medicine, 26, 73-76.

Rowland, M.G.M., Goh, S.G.J., Tulloch, S., Dunn, D.T., Hayes, R.J., (1985), Growth and weaning in urban Gambian children. In "child Health in the Tropics", Sixth Nutricia-Cow and Gate Symposium, pp 9-18, eds. Eeckels, R.E., Ransome-Kuti, O., Kroonenberg, C.C.; Martinus Nijhoff Publishers, Dordrecht.

Salamon, R., (1989), Expert systems in medicine. World Health, August/September 1989, 12-13.

Savage, L.J., (1954), The Foundations of Statistics. John Wiley, New York.

Savage, L.J., (1972), Diagnosis and the Bayesian viewpoint. In: Computer Diagnosis and Diagnostic Methods, p. 131, ed. Jacquez, A.; Thomas, Springfield, Illinois.

Scherrer, J-R., Borst, F., (1989), A common standard. World Health, August/September 1989, 24-25.

References

Seroussi, B., (1986), Computer-aided diagnosis of acute abdominal pain when taking into account interactions. Methods of Information in Medicine, 25, 194-198.

Shires, D.B., (1983), Health information systems applications in technologically lesser-developed countries: an overview. In: Health Informatics in Developing Countries: Experiences and Viewpoints, pp. 57-63, eds. A. Fernandez Perez de Talens et al.; North-Holland, Amsterdam.

Shortliffe, E., (1987), Computer programs to support medical decisions. Journal of the American Medical Association, 258, 61-6.

Siegel, C., Alexander, M.J., (1984), Acceptance and impact of the computer in clinical decisions. Hospital and Community Psychiatry, 35, 773-775.

Snow, R.W., Rowan, K.M., Greenwood, B.M., (1987), A trial of permethrin-treated bed nets in the prevention of malaria in Gambian children. Transactions of the Royal Society of Tropical Medicine and Hygiene, 81, 563-567.

Snow, R.W., Bradley, A.K., Hayes, R., Byass, P., Greenwood, B.M., (1987), Does woodsmoke protect against malaria? Annals of Tropical Medicine and Parasitology, 81, 449-451.

References

Snow, R.W., Rowan, K.M., Lindsay, S.W., Greenwood, B.M., (1988 A), A trial of bed nets (mosquito nets) as a malaria control strategy in a rural area of The Gambia. Transactions of the Royal Society of Tropical Medicine and Hygiene, 82, 212-215.

Snow, R.W., Phillips, A., Lindsay, S.W., Greenwood, B.M., (1988 B), How best to treat bed nets with insecticide in the field. Transactions of the Royal Society of Tropical Medicine and Hygiene, 82, 647-648.

Snow, R.W., Lindsay, S.W., Hayes, R.J., Greenwood, B.M., (1988 C), Permethrin treated bed nets (mosquito nets) prevent malaria in The Gambia. Transactions of the Royal Society of Tropical Medicine and Hygiene, 82, 838-842.

Snow, R.W., Byass, P., (1988), Computerised morbidity surveillance in the field. Proceedings of the African Population Conference, Dakar, pp. 1.2.31-1.2.38; International Union for the Scientific Study of Population, Liège.

Somers, A.R., (1983), And who shall be the gatekeeper? The role of the primary physician in the health care delivery system. Inquiry, 20, 301-313.

Speigelhalter, D.J., Knill-Jones, R.P., (1984), Statistical and knowledge-based approaches to clinical decision-support systems, with an application in gastroenterology. Journal of the Royal Statistical Society, Series A, 147, 35-77.

References

Srinivasan, K., Srinivasa Murthy, R., (1986), Multiple somatic complaints in primary health care settings in tropical countries. Tropical Doctor, 16, 18-21.

Stephens, J., Alonso, P.L., Byass, P., Snow, R.W., (1989), Tropical epidemiology: a system for continuous demographic monitoring of a study population. Methods of Information in Medicine, 28, 155-159

Sutton, G.C., (1989), How accurate is computer-aided diagnosis? Lancet, ii, 905-908.

Times Books, (1987), The Times Atlas of the World. London.

Titterington, D.M., Murray, G.D., Murray, L.S., Spiegelhalter, D.J., Skene, A.M., Habbema, J.D., Gelpke, D.J., (1981), Comparison of discrimination techniques applied to a complex data set of head injured patients. Journal of the Royal Statistical Society, Series A, 144, 145-175.

Todd, J.W., (1984 A), Wasted resources: referrals to hospital. Lancet, ii, 1089.

Todd, J.W., (1984 B), Wasted resources: investigations. Lancet, ii, 1146-1147.

Todd, J.W., (1984 C), Wasted resources: prescribing in general practice. Lancet, ii, 1204-1205.

References

Todd, J.W., (1984 D), Wasted resources: hospital treatment. Lancet, ii, 1266.

Turner, J., (1985), Primary health care in India. Lancet, i, 408-409.

Uplekar, M.W., Antia, N.H., Dhumale, P.S., Sympmed I: computer program for primary health care. British Medical Journal, 297, 841-843.

van Bemmel, J.H., Shortliffe, E.H., (1986), Medical Informatics - from art to science. Proceedings of Medinfo-86, pp. vii-xv, eds. Salamon, R., Blum, B., Jorgensen, M.; Elsevier, Amsterdam.

van de Merwe, J.P., (1984), Differentiation between diseases using a programmable hand-held calculator and Bayes' theorem: application to lower gastrointestinal tract disorders. Computers in Biology and Medicine, 14, 471-489.

van Ginneken, J.K., Muller, A.S., (eds.), (1984), Maternal and child health in rural Kenya. Croom-Helm, London.

Vaughan, J.P., Walt, G., Ross, D., (1984), Evaluation of primary health care: approaches, comments and criticisms. Tropical Doctor, 14, 56-60.

Vesikari, T., Isolaura, E., Delem, A., d'Hondt, E., Andre, F.E., Zissis, G., (1984), Protection of infants against rotavirus diarrhoea by RIT 4237 attenuated bovine rotavirus strain vaccine. Lancet, i, 977-81.

References

Warner, H.R., Toronto, A.F., Veasy, L.G., Stephenson, R., (1961), A mathematical approach to medical diagnosis. Journal of the American Medical Association, 177, 177-183.

Werner, D., (1977), Where there is no doctor. Macmillan Tropical Community Health Manuals, London.

Whittle, H.C., Hanlon, P., O'Neill, K., Hanlon, L., Marsh, V., Jupp, E., Aaby, P., (1988), Trials of high-dose Edmonston-Zagreb measles vaccine in The Gambia: antibody responses and side effects. Lancet, ii, 811-814.

Wilson, D.H., Wilson, P.D., Walmsley, R.G., Horrocks, J.C., de Dombal, F.T., (1977), Diagnosis of acute abdominal pain in the accident and emergency department. British Journal of Surgery, 64, 250-254.

World Health Organisation, (1981), Global strategy for health for all by the year 2000. "Health for All" series, no. 3,WHO, Geneva.

World Health Organisation, (1985), Case management of acute respiratory infections in children in developing countries. WHO/RSD/85.15, Geneva.

World Health Organisation, (1988 A), Strengthening ministries of health for primary health care. Technical report series no. 766, WHO, Geneva.

References

World Health Organisation, (1988 B), Informatics and telematics in health: present and potential uses. ISBN 92 4 156117 3, WHO, Geneva.

World Health Organisation, (1988 C), World Directory of Medical Schools, 6th edition. WHO, Geneva.

Wyatt, J., (1987), The evaluation of clinical decision support systems: a discussion of the methodology used in the ACORN project. In: J. Fox & R. Engelbrecht (Eds.), Proceedings of the European Conference of Artificial Intelligence in Medicine, Heidelberg; Springer-Verlag, Berlin, 15-24.

Wyatt, J., (1989), Computer-assisted diagnosis in acute abdominal pain. Lancet, ii, 1103.

APPENDICES

Appendix I: Summary of 10,000 Gate Clinic records
(a) presentations by age, sex & season
(b) management by age, sex & season

Appendix II: Data used for the test model: usages, thresholds, occurrences & relevances

Appendix III: Additional sources of data
(a) Keneba paediatric clinic
(b) RVH paediatric statistics 1988

Appendix IV: Qualitative model derived from "Health in The Gambia"

Appendix V: Details of the database for the prototype system

Appendix VI: Software and data files for the prototype system

Appendix VII: User's manual for the prototype system

Appendix VIII: Related publications

Appendix I: Summary of 10,000 Gate Clinic records

Presentations by age, sex & season

	n	fever	general pain	weakness	dizziness	weight loss	joint pain	fits	shock	trauma	rash
CASES	10000	5349	1607	149	673	211	438	22	1	138	1124
AGE GROUP											
< 1 month	83	64				1					9
	.8%	1.2%				.5%					.8%
1 - 5 months	423	330	6	1		8				1	67
	4.2%	6.2%	.4%	.7%		3.8%				.7%	6.0%
6 - 11 months	759	592	12	4		34	2	1		6	107
	7.6%	11.1%	.7%	2.7%		16.1%	.5%	4.5%		4.3%	9.5%
1 - 4 years	2310	1614	141	20	9	57	17	9		33	357
	23.1%	30.2%	8.8%	13.4%	1.3%	27.0%	3.9%	40.9%		23.9%	31.8%
5 - 14 years	890	476	76	5	43	11	24	3	1	29	116
	8.9%	8.9%	4.7%	3.4%	6.4%	5.2%	5.5%	13.6%	100.0%	21.0%	10.3%
15 - 39 years	4475	1985	1012	89	500	78	285	7		62	414
	44.8%	37.1%	63.0%	59.7%	74.3%	37.0%	65.1%	31.8%		44.9%	36.8%
40 + years	1060	288	360	30	121	22	110	2		7	54
	10.6%	5.4%	22.4%	20.1%	18.0%	10.4%	25.1%	9.1%		5.1%	4.8%
SEX											
male	4533	2491	585	63	150	85	172	13		79	548
	45.3%	46.6%	36.4%	42.3%	22.3%	40.3%	39.3%	59.1%		57.2%	48.8%
female	5467	2858	1022	86	523	126	266	9	1	59	576
	54.7%	53.4%	63.6%	57.7%	77.7%	59.7%	60.7%	40.9%	100.0%	42.8%	51.2%
SEASON											
early rains	2690	1601	292	26	171	49	103	3		34	334
	26.9%	29.9%	18.2%	17.4%	25.4%	23.2%	23.5%	13.6%		24.6%	29.7%
late rains	2190	1215	394	14	154	53	96	12		42	232
	21.9%	22.7%	24.5%	9.4%	22.9%	25.1%	21.9%	54.5%		30.4%	20.6%
early dry	2660	1300	465	69	170	55	117	5	1	29	290
	26.6%	24.3%	28.9%	46.3%	25.3%	26.1%	26.7%	22.7%	100.0%	21.0%	25.8%
late dry	2460	1233	456	40	178	54	122	2		33	268
	24.6%	23.1%	28.4%	26.8%	26.4%	25.6%	27.9%	9.1%		23.9%	23.8%

Appendix I: Summary of 10,000 Gate Clinic records
Presentation by age, sex & season

	n	oedema	local swelling	loss of appetite	anaemia	jaundice	mental confusion	backache	headache	neck stiffness	bulging fontanelle
CASES	10000	84	173	302	130	12	18	513	1005	20	4
AGE GROUP											
< 1 month	83			1	1						
	.8%			.3%	.8%						
1 - 5 months	423	1	3	4	1	1			2		2
	4.2%	1.2%	1.7%	1.3%	.8%	8.3%			.2%		50.0%
6 - 11 months	759	1	11	38	14			1	5	1	2
	7.6%	1.2%	6.4%	12.6%	10.8%			.2%	.5%	5.0%	50.0%
1 - 4 years	2310	19	35	136	42	2		8	87	2	
	23.1%	22.6%	20.2%	45.0%	32.3%	16.7%		1.6%	8.7%	10.0%	
5 - 14 years	890	7	15	25	3	5		22	135	1	
	8.9%	8.3%	8.7%	8.3%	2.3%	41.7%		4.3%	13.4%	5.0%	
15 - 39 years	4475	39	95	80	53	3	14	339	633	10	
	44.8%	46.4%	54.9%	26.5%	40.8%	25.0%	77.8%	66.1%	63.0%	50.0%	
40 + years	1060	17	14	18	16	1	4	143	143	6	
	10.6%	20.2%	8.1%	6.0%	12.3%	8.3%	22.2%	27.9%	14.2%	30.0%	
SEX											
male	4533	46	93	127	42	6	14	204	331	6	2
	45.3%	54.8%	53.8%	42.1%	32.3%	50.0%	77.8%	39.8%	32.9%	30.0%	50.0%
female	5467	38	80	175	88	6	4	309	674	14	2
	54.7%	45.2%	46.2%	57.9%	67.7%	50.0%	22.2%	60.2%	67.1%	70.0%	50.0%
SEASON											
early rains	2690	19	45	108	16	3	6	114	264	2	
	26.9%	22.6%	26.0%	35.8%	12.3%	25.0%	33.3%	22.2%	26.3%	10.0%	
late rains	2190	13	29	63	60	1	3	98	228	5	
	21.9%	15.5%	16.8%	20.9%	46.2%	8.3%	16.7%	19.1%	22.7%	25.0%	
early dry	2660	29	37	65	33	5	5	153	256	8	4
	26.6%	34.5%	21.4%	21.5%	25.4%	41.7%	27.8%	29.8%	25.5%	40.0%	100.0%
late dry	2460	23	62	66	21	3	4	148	257	5	
	24.6%	27.4%	35.8%	21.9%	16.2%	25.0%	22.2%	28.8%	25.6%	25.0%	

Appendix I: Summary of 10,000 Gate Clinic records
Presentation by age, sex & season

	n	puffy face	sore eyes	ear pain	cough	yellow sputum	white sputum	chest pain	dyspnoea	haemo-ptysis	vomiting
CASES	10000	14	331	187	2173	111	391	1436	170	50	985
AGE GROUP											
< 1 month	83		8	1	25	1		1			13
	.8%		2.4%	.5%	1.2%	.9%		.1%			1.3%
1 - 5 months	423		23	9	143		1	31	3	2	69
	4.2%		6.9%	4.8%	6.6%		.3%	2.2%	1.8%	4.0%	7.0%
6 - 11 months	759	2	53	20	234	1	4	71	8		146
	7.6%	14.3%	16.0%	10.7%	10.8%	.9%	1.0%	4.9%	4.7%		14.8%
1 - 4 years	2310	3	91	61	637	3	42	331	33	3	513
	23.1%	21.4%	27.5%	32.6%	29.3%	2.7%	10.7%	23.1%	19.4%	6.0%	52.1%
5 - 14 years	890	3	37	23	190	11	36	103	12	1	68
	8.9%	21.4%	11.2%	12.3%	8.7%	9.9%	9.2%	7.2%	7.1%	2.0%	6.9%
15 - 39 years	4475	4	90	64	740	73	238	729	73	31	150
	44.8%	28.6%	27.2%	34.2%	34.1%	65.8%	60.9%	50.8%	42.9%	62.0%	15.2%
40 + years	1060	2	29	9	204	22	70	170	41	13	26
	10.6%	14.3%	8.8%	4.8%	9.4%	19.8%	17.9%	11.8%	24.1%	26.0%	2.6%
SEX											
male	4533	9	150	91	1057	55	163	642	95	32	486
	45.3%	64.3%	45.3%	48.7%	48.6%	49.5%	41.7%	44.7%	55.9%	64.0%	49.3%
female	5467	5	181	96	1116	56	228	794	75	18	499
	54.7%	35.7%	54.7%	51.3%	51.4%	50.5%	58.3%	55.3%	44.1%	36.0%	50.7%
SEASON											
early rains	2690	1	134	51	633	19	119	361	57	11	313
	26.9%	7.1%	40.5%	27.3%	29.1%	17.1%	30.4%	25.1%	33.5%	22.0%	31.8%
late rains	2190		69	40	475	14	76	270	32	9	220
	21.9%		20.8%	21.4%	21.9%	12.6%	19.4%	18.8%	18.8%	18.0%	22.3%
early dry	2660	9	69	48	591	48	127	427	36	16	244
	26.6%	64.3%	20.8%	25.7%	27.2%	43.2%	32.5%	29.7%	21.2%	32.0%	24.8%
late dry	2460	4	59	48	474	30	69	378	45	14	208
	24.6%	28.6%	17.8%	25.7%	21.8%	27.0%	17.6%	26.3%	26.5%	28.0%	21.1%

Appendix I: Summary of 10,000 Gate Clinic records
Presentations by age, sex & season

	n	diarrhoea	bloody diarrhoea	upper abdominal pain	lower abdominal pain	dysuria	haematuria	genital discharge	dysmen-horrea	amen-horrea	pregnancy
	10000										
CASES		859	121	846	735	260	23	200	22	28	30
AGE GROUP	83										
< 1 month	.8%	31		2							
	423	3.6%		.2%							
1 - 5 months	4.2%	100	4	3	8	6					
	759	11.6%	3.3%	.4%	1.1%	2.3%					
6 - 11 months	7.6%	176	9	18	7	3					
	2310	20.5%	7.4%	2.1%	1.0%	1.2%					
1 - 4 years	23.1%	420	57	141	63	12	3	2			
	890	48.9%	47.1%	16.7%	8.6%	4.6%	13.0%	1.0%			
5 - 14 years	8.9%	40	8	78	67	7	4	9	1	2	
	4475	4.7%	6.6%	9.2%	9.1%	2.7%	17.4%	4.5%	4.5%	7.1%	
15 - 39 years	44.8%	80	36	477	540	214	13	178	18	22	29
	1060	9.3%	29.8%	56.4%	73.5%	82.3%	56.5%	89.0%	81.8%	78.6%	96.7%
40 + years	10.6%	12	7	127	50	18	3	11	3	4	1
		1.4%	5.8%	15.0%	6.8%	6.9%	13.0%	5.5%	13.6%	14.3%	3.3%
SEX	4533										
male	45.3%	437	76	395	185	87	12	111			
	5467	50.9%	62.8%	46.7%	25.2%	33.5%	52.2%	55.5%			
female	54.7%	422	45	451	550	173	11	89	22	28	30
		49.1%	37.2%	53.3%	74.8%	66.5%	47.8%	44.5%	100.0%	100.0%	100.0%
SEASON	2690										
early rains	26.9%	321	30	173	173	51	7	34	5	6	8
	2190	37.4%	24.8%	20.4%	23.5%	19.6%	30.4%	17.0%	22.7%	21.4%	26.7%
late rains	21.9%	156	20	196	154	54	2	29	6	7	2
	2660	18.2%	16.5%	23.2%	21.0%	20.8%	8.7%	14.5%	27.3%	25.0%	6.7%
early dry	26.6%	196	35	220	211	73	6	80	6	7	7
	2460	22.8%	28.9%	26.0%	28.7%	28.1%	26.1%	40.0%	27.3%	25.0%	23.3%
late dry	24.6%	186	36	257	197	82	8	57	5	8	13
	21.7%	29.8%	30.4%	26.8%	31.5%	34.8%	28.5%	22.7%	28.6%	43.3%	

Appendix I: Summary of 10,000 Gate Clinic records
Managements by age, sex & season

	n	see doctor	see surgeon	nil	aspirin	chloro-quine	vitamins	linctus	magnesium trisil.	gentian violet	iron
CASES	10000	1059	169	3	6316	2060	4115	1638	696	150	537
AGE GROUP											
< 1 month	83	15			54	46	13	20		5	
	.8%	1.4%			.9%	2.2%	.3%	1.2%		3.3%	
1 - 5 months	423	54	3		306	187	94	107		19	
	4.2%	5.1%	1.8%		4.8%	9.1%	2.3%	6.5%		12.7%	
6 - 11 months	759	80	1		566	295	185	153	1	21	8
	7.6%	7.6%	.6%		9.0%	14.3%	4.5%	9.3%	.1%	14.0%	1.5%
1 - 4 years	2310	236	10		1575	804	783	387	9	67	26
	23.1%	22.3%	5.9%		24.9%	39.0%	19.0%	23.6%	1.3%	44.7%	4.8%
5 - 14 years	890	77	21	1	555	220	344	171	49	21	18
	8.9%	7.3%	12.4%	33.3%	8.8%	10.7%	8.4%	10.4%	7.0%	14.0%	3.4%
15 - 39 years	4475	447	105	2	2613	444	2201	626	509	14	409
	44.8%	42.2%	62.1%	66.7%	41.4%	21.6%	53.5%	38.2%	73.1%	9.3%	76.2%
40 + years	1060	150	29		647	64	495	174	128	3	76
	10.6%	14.2%	17.2%		10.2%	3.1%	12.0%	10.6%	18.4%	2.0%	14.2%
SEX											
male	4533	565	75	2	2763	1029	1651	756	277	75	132
	45.3%	53.4%	44.4%	66.7%	43.7%	50.0%	40.1%	46.2%	39.8%	50.0%	24.6%
female	5467	494	94	1	3553	1031	2464	882	419	75	405
	54.7%	46.6%	55.6%	33.3%	56.3%	50.0%	59.9%	53.8%	60.2%	50.0%	75.4%
SEASON											
early rains	2690	221	47		1895	755	1121	467	154	63	139
	26.9%	20.9%	27.8%		30.0%	36.7%	27.2%	28.5%	22.1%	42.0%	25.9%
late rains	2190	222	40	1	1465	667	793	391	138	19	107
	21.9%	21.0%	23.7%	33.3%	23.2%	32.4%	19.3%	23.9%	19.8%	12.7%	19.9%
early dry	2660	402	41	1	1489	356	1022	442	170	40	127
	26.6%	38.0%	24.3%	33.3%	23.6%	17.3%	24.8%	27.0%	24.4%	26.7%	23.6%
late dry	2460	214	41	1	1467	282	1179	338	234	28	164
	24.6%	20.2%	24.3%	33.3%	23.2%	13.7%	28.7%	20.6%	33.6%	18.7%	30.5%

Appendix I: Summary of 10,000 Gate Clinic records
Managements by age, sex & season

	n	hibitane	folic acid	sytron	benzyl benzoate	benzoic acid	tetracyc. ointment	septrin	laxative	flagyl	calamine
CASES	10000	563	206	10	91	346	576	623	173	385	168
AGE GROUP											
< 1 month	83	7					8			13	
	.8%	1.2%					1.4%			3.4%	
1 - 5 months	423	31	1		4	7	31	36	2	29	14
	4.2%	5.5%	.5%		4.4%	2.0%	5.4%	5.8%	1.2%	7.5%	8.3%
6 - 11 months	759	54	16	3	15	8	79	98	1	37	13
	7.6%	9.6%	7.8%	30.0%	16.5%	2.3%	13.7%	15.7%	.6%	9.6%	7.7%
1 - 4 years	2310	250	29	7	23	46	206	261	3	97	71
	23.1%	44.4%	14.1%	70.0%	25.3%	13.3%	35.8%	41.9%	1.7%	25.2%	42.3%
5 - 14 years	890	57	7		13	35	62	62	11	23	14
	8.9%	10.1%	3.4%		14.3%	10.1%	10.8%	10.0%	6.4%	6.0%	8.3%
15 - 39 years	4475	135	137		35	230	151	146	133	162	49
	44.8%	24.0%	66.5%		38.5%	66.5%	26.2%	23.4%	76.9%	42.1%	29.2%
40 + years	1060	29	16		1	20	39	20	23	24	7
	10.6%	5.2%	7.8%		1.1%	5.8%	6.8%	3.2%	13.3%	6.2%	4.2%
SEX											
male	4533	274	58	6	48	185	267	338	86	151	77
	45.3%	48.7%	28.2%	60.0%	52.7%	53.5%	46.4%	54.3%	49.7%	39.2%	45.8%
female	5467	289	148	4	43	161	309	285	87	234	91
	54.7%	51.3%	71.8%	40.0%	47.3%	46.5%	53.6%	45.7%	50.3%	60.8%	54.2%
SEASON											
early rains	2690	199	31	4	33	78	211	185	40	126	65
	26.9%	35.3%	15.0%	40.0%	36.3%	22.5%	36.6%	29.7%	23.1%	32.7%	38.7%
late rains	2190	114	47	2	17	90	142	112	35	79	17
	21.9%	20.2%	22.8%	20.0%	18.7%	26.0%	24.7%	18.0%	20.2%	20.5%	10.1%
early dry	2660	136	45	2	24	91	119	182	35	99	42
	26.6%	24.2%	21.8%	20.0%	26.4%	26.3%	20.7%	29.2%	20.2%	25.7%	25.0%
late dry	2460	114	83	2	17	87	104	144	63	81	44
	24.6%	20.2%	40.3%	20.0%	18.7%	25.1%	18.1%	23.1%	36.4%	21.0%	26.2%

Appendix I: Summary of 10,000 Gate Clinic records
Managements by age, sex & season

	n	kaolin	oral rehydrat.	potassium permang.	piperazine	ampi-cillin	chloram-phenicol	tetra-cycline	para-cetamol
CASES	10000	12	809	11	198	37	353	539	565
AGE GROUP									
< 1 month	83		28		1		1		
	.8%		3.5%		.5%		.3%		
1 - 5 months	423		97		7	4	21		2
	4.2%		12.0%		3.5%	10.8%	5.9%		.4%
6 - 11 months	759	2	154	1	15	3	33		
	7.6%	16.7%	19.0%	9.1%	7.6%	8.1%	9.3%		
1 - 4 years	2310	4	386	2	94	9	193	3	17
	23.1%	33.3%	47.7%	18.2%	47.5%	24.3%	54.7%	.6%	3.0%
5 - 14 years	890	1	37	3	37	4	35	17	37
	8.9%	8.3%	4.6%	27.3%	18.7%	10.8%	9.9%	3.2%	6.5%
15 - 39 years	4475	4	97	5	36	16	55	446	432
	44.8%	33.3%	12.0%	45.5%	18.2%	43.2%	15.6%	82.7%	76.5%
40 + years	1060	1	10		8	1	15	73	77
	10.6%	8.3%	1.2%		4.0%	2.7%	4.2%	13.5%	13.6%
SEX									
male	4533	4	410	5	93	16	188	249	213
	45.3%	33.3%	50.7%	45.5%	47.0%	43.2%	53.3%	46.2%	37.7%
female	5467	8	399	6	105	21	165	290	352
	54.7%	66.7%	49.3%	54.5%	53.0%	56.8%	46.7%	53.8%	62.3%
SEASON									
early rains	2690	7	299	8	50	5	81	101	51
	26.9%	58.3%	37.0%	72.7%	25.3%	13.5%	22.9%	18.7%	9.0%
late rains	2190	1	136		44	2	29	58	73
	21.9%	8.3%	16.8%		22.2%	5.4%	8.2%	10.8%	12.9%
early dry	2660	2	192	2	57	24	112	190	230
	26.6%	16.7%	23.7%	18.2%	28.8%	64.9%	31.7%	35.3%	40.7%
late dry	2460	2	182	1	47	6	131	190	211
	24.6%	16.7%	22.5%	9.1%	23.7%	16.2%	37.1%	35.3%	37.3%

Appendix II: Data used for the test model: usages, thresholds, occurrences & relevances

	usage	thres-hold	AGE						
			< 1 m	1-5 m	6-11 m	1-4 y	5-14 y	15-39 y	40+ y
occurrence			0.0091	0.0462	0.0843	0.2192	0.0850	0.4449	0.1112
see doctor	0.1126	0.2035	0.0117	0.0538	0.0842	0.2258	0.0667	0.4271	0.1311
see surgeon	0.0057	0.0458	0.0000	0.0227	0.0000	0.0461	0.1387	0.7649	0.0234
aspirin	0.6673	0.4955	0.0099	0.0521	0.0971	0.2395	0.0867	0.4071	0.1076
chloroquine	0.2419	0.2983	0.0234	0.0936	0.1487	0.3725	0.1101	0.2205	0.0310
vitamins	0.4105	0.3886	0.0032	0.0231	0.0452	0.1682	0.0786	0.5449	0.1367
linctus	0.1891	0.2638	0.0133	0.0703	0.0968	0.2333	0.1059	0.3734	0.1066
mag trisil	0.0791	0.1706	0.0000	0.0000	0.0017	0.0150	0.0717	0.7278	0.1832
gentian violet	0.0057	0.0458	0.0231	0.1151	0.1849	0.4845	0.0701	0.0937	0.0234
iron	0.0586	0.1468	0.0000	0.0000	0.0157	0.0449	0.0338	0.7600	0.1461
hibitane	0.0320	0.1085	0.0206	0.0699	0.1070	0.4240	0.0823	0.2558	0.0410
folic acid	0.0221	0.0902	0.0000	0.0059	0.0835	0.1488	0.0300	0.6502	0.0835
sytron	0.0013	0.0219	0.0000	0.0000	0.3048	0.7082	0.0000	0.0000	0.0000
benzyl benzoate	0.0105	0.0622	0.0000	0.0374	0.1758	0.2630	0.1635	0.3517	0.0127
benzoic acid	0.0328	0.1098	0.0000	0.0161	0.0242	0.1604	0.0884	0.6389	0.0722
tetracyc oint	0.0536	0.1404	0.0197	0.0639	0.1548	0.3145	0.1032	0.2756	0.0689
septrin	0.0534	0.1402	0.0000	0.0665	0.1899	0.4072	0.0864	0.2125	0.0371
laxative	0.0071	0.0511	0.0000	0.0000	0.0190	0.0185	0.0934	0.8146	0.0564
flagyl	0.0441	0.1274	0.0359	0.0836	0.1076	0.2301	0.0598	0.4217	0.0628
calamine	0.0157	0.0760	0.0000	0.0839	0.1004	0.3686	0.0839	0.3202	0.0418
kaolin	0.0016	0.0243	0.0000	0.0000	0.1633	0.3288	0.0850	0.3337	0.0834
O.R.F.	0.0925	0.1845	0.0371	0.1281	0.2079	0.4543	0.0470	0.1125	0.0129
potass permang	0.0005	0.0136	0.0000	0.0000	0.0000	0.2630	0.2720	0.5339	0.0000
piperazine	0.0171	0.0793	0.0077	0.0384	0.0848	0.4781	0.2157	0.1535	0.0234
ampicillin	0.0034	0.0354	0.0000	0.1155	0.0769	0.2708	0.1175	0.3926	0.0392
chloramphenicol	0.0389	0.1196	0.0034	0.0677	0.0915	0.5488	0.0948	0.1555	0.0372
tetracycline	0.0573	0.1452	0.0000	0.0000	0.0000	0.0069	0.0300	0.8114	0.1518
paracetamol	0.0601	0.1487	0.0000	0.0022	0.0000	0.0241	0.0680	0.7543	0.1514

Appendix II: Data used for the test model: usages, thresholds, occurrences & relevances

	usage	thres-hold	------SEX------- male	female	----------SEASON---------- early-rains-late		early--dry--late	
occurrence			0.4418	0.5582	0.2634	0.2266	0.2759	0.2341
see doctor	0.1126	0.2035	0.5195	0.4809	0.2035	0.2246	0.3849	0.1871
see surgeon	0.0057	0.0458	0.2325	0.7639	0.3466	0.1868	0.2759	0.1848
aspirin	0.6673	0.4955	0.4287	0.5713	0.2897	0.2444	0.2446	0.2213
chloroquine	0.2419	0.2983	0.4913	0.5086	0.3546	0.3317	0.1754	0.1383
vitamins	0.4105	0.3886	0.3807	0.6194	0.2683	0.2015	0.2606	0.2696
linctus	0.1891	0.2638	0.4584	0.5414	0.2843	0.2411	0.2739	0.2007
mag trisil	0.0791	0.1706	0.3966	0.6027	0.2231	0.1917	0.2483	0.3365
gentian violet	0.0057	0.0458	0.4185	0.5778	0.3928	0.1391	0.2759	0.1848
iron	0.0586	0.1468	0.2179	0.7821	0.2607	0.2069	0.2542	0.2788
hibitane	0.0320	0.1085	0.4901	0.5111	0.3622	0.1813	0.2845	0.1726
folic acid	0.0221	0.0902	0.2859	0.7148	0.1311	0.2625	0.2322	0.3760
sytron	0.0013	0.0219	0.6117	0.3864	0.4052	0.2092	0.2122	0.1981
benzyl benzoate	0.0105	0.0622	0.5133	0.4891	0.3763	0.2007	0.2391	0.1873
benzoic acid	0.0328	0.1098	0.5105	0.4901	0.2008	0.2487	0.2852	0.2648
tetracyc oint	0.0536	0.1404	0.4599	0.5405	0.3735	0.2334	0.2162	0.1769
septrin	0.0534	0.1402	0.5353	0.4641	0.2713	0.1778	0.3255	0.2245
laxative	0.0071	0.0511	0.4480	0.5582	0.3710	0.2585	0.1671	0.2044
flagyl	0.0441	0.1274	0.3797	0.6215	0.3434	0.2091	0.2452	0.2033
calamine	0.0157	0.0760	0.4362	0.5618	0.3691	0.1097	0.2847	0.2356
kaolin	0.0016	0.0243	0.3313	0.6629	0.5762	0.0850	0.1724	0.1609
O.R.F.	0.0925	0.1845	0.5087	0.4912	0.3505	0.1823	0.2494	0.2179
potass permang	0.0005	0.0136	0.7952	0.2233	0.7902	0.0000	0.2759	0.0000
piperazine	0.0171	0.0793	0.5167	0.4864	0.2619	0.2385	0.2614	0.2382
ampicillin	0.0034	0.0354	0.3508	0.6567	0.0775	0.0800	0.6979	0.1584
chloramphenicol	0.0389	0.1196	0.5213	0.4778	0.2133	0.0915	0.3355	0.3593
tetracycline	0.0573	0.1452	0.4557	0.5446	0.1563	0.1151	0.3770	0.3518
paracetamol	0.0601	0.1487	0.3529	0.6464	0.0898	0.1470	0.4164	0.3463

Appendix II: Data used for the test model: usages, thresholds, occurrences & relevances

	usage	thres-hold	fever	general pain	weakness	dizzi-ness	weight loss	joint pain	fits
occurrence			0.5635	0.1775	0.0167	0.0802	0.0246	0.0507	0.0026
see doctor	0.1126	0.2035	0.5230	0.1111	0.0304	0.0468	0.0748	0.0386	0.0196
see surgeon	0.0057	0.0458	0.3262	0.0218	0.0000	0.0464	0.0229	0.0231	0.0000
aspirin	0.6673	0.4955	0.6731	0.2186	0.0142	0.0811	0.0152	0.0659	0.0004
chloroquine	0.2419	0.2983	0.9493	0.1650	0.0060	0.0610	0.0185	0.0321	0.0005
vitamins	0.4105	0.3886	0.6063	0.2780	0.0298	0.1543	0.0324	0.0744	0.0003
linctus	0.1891	0.2638	0.6499	0.1219	0.0076	0.0404	0.0049	0.0223	0.0000
mag trisil	0.0791	0.1706	0.2301	0.1232	0.0116	0.0866	0.0183	0.0167	0.0000
gentian violet	0.0057	0.0458	0.7118	0.0218	0.0000	0.0225	0.0000	0.0000	0.0000
iron	0.0586	0.1468	0.7558	0.3350	0.0516	0.3550	0.0337	0.1370	0.0000
hibitane	0.0320	0.1085	0.4455	0.0288	0.0041	0.0123	0.0041	0.0124	0.0000
folic acid	0.0221	0.0902	0.7216	0.3156	0.0714	0.3397	0.0535	0.1074	0.0000
sytron	0.0013	0.0219	0.9970	0.0956	0.0000	0.0000	0.2025	0.0000	0.0000
benzyl benzoate	0.0105	0.0622	0.5152	0.0118	0.0000	0.0000	0.0124	0.0377	0.0000
benzoic acid	0.0328	0.1098	0.3058	0.0644	0.0120	0.0242	0.0080	0.0201	0.0040
tetracyc oint	0.0536	0.1404	0.4594	0.0566	0.0000	0.0196	0.0024	0.0098	0.0000
septrin	0.0534	0.1402	0.4907	0.0469	0.0025	0.0149	0.0123	0.0049	0.0000
laxative	0.0071	0.0511	0.5714	0.2050	0.0369	0.1853	0.0000	0.0371	0.0000
flagyl	0.0441	0.1274	0.5290	0.0568	0.0119	0.0447	0.0865	0.0120	0.0000
calamine	0.0157	0.0760	0.6784	0.0339	0.0084	0.0000	0.0083	0.0084	0.0083
kaolin	0.0016	0.0243	0.4226	0.0777	0.0000	0.0000	0.0000	0.0000	0.0000
O.R.F.	0.0925	0.1845	0.8145	0.0827	0.0028	0.0128	0.0142	0.0071	0.0000
potass permang	0.0005	0.0136	0.2254	0.2485	0.0000	0.0000	0.0000	0.2636	0.0000
piperazine	0.0171	0.0793	0.5174	0.0228	0.0000	0.0310	0.0230	0.0154	0.0000
ampicillin	0.0034	0.0354	0.5801	0.0365	0.0000	0.0000	0.0000	0.0000	0.0000
chloramphenicol	0.0389	0.1196	0.8156	0.1323	0.0135	0.0136	0.0744	0.0000	0.0000
tetracycline	0.0573	0.1452	0.5330	0.1518	0.0184	0.0437	0.0092	0.0276	0.0000
paracetamol	0.0601	0.1487	0.4951	0.2082	0.0285	0.1380	0.0175	0.0307	0.0000

Appendix II: Data used for the test model: usages, thresholds, occurrences & relevances

	usage	thres-hold	trauma	rash	oedema	local swelling	loss of appetite	anaemia	jaundice
occurrence			0.0071	0.1051	0.0084	0.0132	0.0318	0.0165	0.0012
see doctor	0.1126	0.2035	0.0234	0.0386	0.0653	0.0387	0.0363	0.0270	0.0107
see surgeon	0.0057	0.0458	0.1153	0.0240	0.0460	0.1158	0.0000	0.0000	0.0000
aspirin	0.6673	0.4955	0.0045	0.0882	0.0008	0.0111	0.0303	0.0174	0.0000
chloroquine	0.2419	0.2983	0.0022	0.0490	0.0000	0.0027	0.0485	0.0246	0.0000
vitamins	0.4105	0.3886	0.0035	0.0889	0.0022	0.0164	0.0550	0.0129	0.0000
linctus	0.1891	0.2638	0.0000	0.0425	0.0000	0.0000	0.0209	0.0035	0.0000
mag trisil	0.0791	0.1706	0.0017	0.0150	0.0000	0.0050	0.0317	0.0050	0.0000
gentian violet	0.0057	0.0458	0.0230	0.7154	0.0230	0.0926	0.0000	0.0000	0.0000
iron	0.0586	0.1468	0.0022	0.0337	0.0000	0.0090	0.0360	0.1352	0.0000
hibitane	0.0320	0.1085	0.0041	0.9219	0.0082	0.0124	0.0123	0.0000	0.0000
folic acid	0.0221	0.0902	0.0000	0.0062	0.0000	0.0000	0.0298	0.2927	0.0000
sytron	0.0013	0.0219	0.0000	0.0000	0.0000	0.0000	0.1003	0.4062	0.0000
benzyl benzoate	0.0105	0.0622	0.0000	0.9409	0.0000	0.0000	0.0000	0.0000	0.0000
benzoic acid	0.0328	0.1098	0.0040	0.9437	0.0000	0.0121	0.0120	0.0121	0.0000
tetracyc oint	0.0536	0.1404	0.0368	0.3318	0.0000	0.0074	0.0246	0.0025	0.0000
septrin	0.0534	0.1402	0.0000	0.1307	0.0000	0.0222	0.0247	0.0025	0.0000
laxative	0.0071	0.0511	0.0000	0.0192	0.0185	0.0000	0.0184	0.0000	0.0000
flagyl	0.0441	0.1274	0.0060	0.0539	0.0000	0.0030	0.0867	0.0180	0.0000
calamine	0.0157	0.0760	0.0000	0.9399	0.0000	0.0000	0.0000	0.0000	0.0000
kaolin	0.0016	0.0243	0.0000	0.1642	0.0000	0.0000	0.0815	0.0000	0.0000
O.R.F.	0.0925	0.1845	0.0000	0.0384	0.0000	0.0014	0.0499	0.0014	0.0000
potass permang	0.0005	0.0136	0.0000	0.7988	0.0000	0.0000	0.0000	0.0000	0.0000
piperazine	0.0171	0.0793	0.0154	0.0387	0.0000	0.0000	0.1002	0.0154	0.0000
ampicillin	0.0034	0.0354	0.0000	0.1175	0.0000	0.0000	0.0383	0.0000	0.0000
chloramphenicol	0.0389	0.1196	0.0034	0.1489	0.0034	0.0475	0.1051	0.0000	0.0000
tetracycline	0.0573	0.1452	0.0046	0.0620	0.0046	0.0484	0.0115	0.0023	0.0000
paracetamol	0.0601	0.1487	0.0000	0.0352	0.0044	0.0110	0.0307	0.0110	0.0000

Appendix II: Data used for the test model: usages, thresholds, occurrences & relevances

	usage	thres-hold	mental confusion	backache	headache	neck stiffness	bulging fontan.	puffy face	sore eyes
occurrence			0.0012	0.0582	0.1141	0.0024	0.0005	0.0018	0.0370
see doctor	0.1126	0.2035	0.0036	0.0246	0.0585	0.0107	0.0044	0.0114	0.0152
see surgeon	0.0057	0.0458	0.0000	0.0000	0.0701	0.0000	0.0000	0.0225	0.0461
aspirin	0.6673	0.4955	0.0008	0.0732	0.1469	0.0016	0.0000	0.0008	0.0326
chloroquine	0.2419	0.2983	0.0000	0.0321	0.1656	0.0011	0.0000	0.0011	0.0245
vitamins	0.4105	0.3886	0.0023	0.1036	0.1707	0.0019	0.0000	0.0009	0.0244
linctus	0.1891	0.2638	0.0000	0.0320	0.0962	0.0000	0.0000	0.0000	0.0195
mag trisil	0.0791	0.1706	0.0017	0.0450	0.0616	0.0034	0.0000	0.0000	0.0033
gentian violet	0.0057	0.0458	0.0000	0.0000	0.0460	0.0234	0.0000	0.0000	0.0695
iron	0.0586	0.1468	0.0000	0.1775	0.2360	0.0000	0.0000	0.0000	0.0068
hibitane	0.0320	0.1085	0.0042	0.0082	0.0125	0.0000	0.0000	0.0000	0.0206
folic acid	0.0221	0.0902	0.0000	0.0714	0.1311	0.0000	0.0000	0.0000	0.0000
sytron	0.0013	0.0219	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
benzyl benzoate	0.0105	0.0622	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0250
benzoic acid	0.0328	0.1098	0.0000	0.0121	0.0282	0.0000	0.0000	0.0000	0.0080
tetracyc oint	0.0536	0.1404	0.0000	0.0123	0.0319	0.0000	0.0000	0.0000	0.6142
septrin	0.0534	0.1402	0.0000	0.0123	0.0271	0.0000	0.0000	0.0000	0.0197
laxative	0.0071	0.0511	0.0000	0.0926	0.0932	0.0000	0.0000	0.0000	0.0000
flagyl	0.0441	0.1274	0.0000	0.0269	0.0329	0.0000	0.0000	0.0000	0.0119
calamine	0.0157	0.0760	0.0000	0.0167	0.0501	0.0000	0.0000	0.0000	0.0167
kaolin	0.0016	0.0243	0.0000	0.0837	0.0000	0.0000	0.0000	0.0000	0.0000
O.R.F.	0.0925	0.1845	0.0014	0.0099	0.0542	0.0000	0.0000	0.0000	0.0270
potass permang	0.0005	0.0136	0.0000	0.0000	0.2738	0.0000	0.0000	0.0000	0.0000
piperazine	0.0171	0.0793	0.0000	0.0078	0.0080	0.0000	0.0000	0.0000	0.0232
ampicillin	0.0034	0.0354	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0392
chloramphenicol	0.0389	0.1196	0.0000	0.0102	0.0610	0.0000	0.0000	0.0000	0.0169
tetracycline	0.0573	0.1452	0.0000	0.0482	0.0713	0.0000	0.0000	0.0000	0.0023
paracetamol	0.0601	0.1487	0.0000	0.0745	0.1228	0.0022	0.0000	0.0000	0.0087

Appendix II: Data used for the test model: usages, thresholds, occurrences & relevances

	usage	thres-hold	ear pain	cough	yellow sputum	white sputum	chest pain	dyspnoea	haemo-ptysis
occurrence			0.0161	0.2424	0.0133	0.0430	0.1538	0.0170	0.0059
see doctor	0.1126	0.2035	0.0035	0.2469	0.0351	0.0351	0.1698	0.0808	0.0431
see surgeon	0.0057	0.0458	0.0695	0.0213	0.0000	0.0000	0.0243	0.0000	0.0000
aspirin	0.6673	0.4955	0.0184	0.2870	0.0111	0.0528	0.1750	0.0091	0.0012
chloroquine	0.2419	0.2983	0.0016	0.2353	0.0016	0.0262	0.0888	0.0022	0.0005
vitamins	0.4105	0.3886	0.0158	0.1861	0.0045	0.0527	0.1686	0.0083	0.0010
linctus	0.1891	0.2638	0.0049	0.8918	0.0376	0.1848	0.4642	0.0279	0.0028
mag trisil	0.0791	0.1706	0.0017	0.0601	0.0050	0.0167	0.1250	0.0100	0.0000
gentian violet	0.0057	0.0458	0.0463	0.1148	0.0000	0.0000	0.0000	0.0000	0.0000
iron	0.0586	0.1468	0.0023	0.1394	0.0045	0.0518	0.1486	0.0292	0.0000
hibitane	0.0320	0.1085	0.0289	0.1197	0.0041	0.0042	0.0332	0.0041	0.0000
folic acid	0.0221	0.0902	0.0060	0.0834	0.0060	0.0119	0.1016	0.0119	0.0000
sytron	0.0013	0.0219	0.0000	0.0932	0.0000	0.0000	0.1065	0.0000	0.0000
benzyl benzoate	0.0105	0.0622	0.0000	0.0508	0.0000	0.0000	0.0381	0.0000	0.0000
benzoic acid	0.0328	0.1098	0.0081	0.0562	0.0000	0.0080	0.0361	0.0000	0.0000
tetracyc oint	0.0536	0.1404	0.0123	0.1153	0.0000	0.0099	0.0442	0.0025	0.0000
septrin	0.0534	0.1402	0.1334	0.3282	0.0099	0.0148	0.1457	0.0321	0.0000
laxative	0.0071	0.0511	0.0000	0.0922	0.0000	0.0369	0.1300	0.0187	0.0000
flagyl	0.0441	0.1274	0.0150	0.1286	0.0030	0.0120	0.0328	0.0000	0.0030
calamine	0.0157	0.0760	0.0000	0.1266	0.0000	0.0167	0.0754	0.0000	0.0000
kaolin	0.0016	0.0243	0.0000	0.1667	0.0000	0.0000	0.0000	0.0000	0.0000
O.R.F.	0.0925	0.1845	0.0029	0.1609	0.0000	0.0171	0.0755	0.0000	0.0014
potass permang	0.0005	0.0136	0.0000	0.2424	0.0000	0.0000	0.2768	0.0000	0.0000
piperazine	0.0171	0.0793	0.0077	0.0851	0.0077	0.0153	0.0459	0.0000	0.0000
ampicillin	0.0034	0.0354	0.0000	0.5846	0.2324	0.1556	0.3890	0.0000	0.0000
chloramphenicol	0.0389	0.1196	0.0339	0.3895	0.0338	0.0576	0.2712	0.0237	0.0067
tetracycline	0.0573	0.1452	0.0092	0.3312	0.0896	0.1404	0.3014	0.0483	0.0092
paracetamol	0.0601	0.1487	0.0022	0.1226	0.0153	0.0329	0.1622	0.0197	0.0022

Appendix II: Data used for the test model: usages, thresholds, occurrences & relevances

	usage	thres-hold	vomiting	diarrhoea	bloody diarr.	upper abd. pain	lower abd. pain	dysuria	haema-turia
occurrence			0.1129	0.0988	0.0146	0.0913	0.0764	0.0261	0.0026
see doctor	0.1126	0.2035	0.1825	0.0994	0.0140	0.0632	0.0573	0.0223	0.0185
see surgeon	0.0057	0.0458	0.0238	0.0225	0.0000	0.0224	0.1381	0.0925	0.0228
aspirin	0.6673	0.4955	0.1196	0.1048	0.0085	0.0377	0.0565	0.0203	0.0000
chloroquine	0.2419	0.2983	0.2516	0.2009	0.0027	0.0594	0.0267	0.0016	0.0000
vitamins	0.4105	0.3886	0.1059	0.0754	0.0109	0.0940	0.0882	0.0254	0.0006
linctus	0.1891	0.2638	0.0683	0.0369	0.0028	0.0299	0.0209	0.0028	0.0000
mag trisil	0.0791	0.1706	0.0383	0.0084	0.0033	0.6945	0.2081	0.0033	0.0000
gentian violet	0.0057	0.0458	0.0931	0.1161	0.0000	0.0465	0.0000	0.0000	0.0000
iron	0.0586	0.1468	0.0428	0.0089	0.0000	0.0405	0.1484	0.0270	0.0022
hibitane	0.0320	0.1085	0.0166	0.0247	0.0000	0.0040	0.0165	0.0165	0.0000
folic acid	0.0221	0.0902	0.0894	0.0300	0.0000	0.0417	0.1372	0.0239	0.0000
sytron	0.0013	0.0219	0.3040	0.0988	0.0000	0.0000	0.0000	0.0000	0.0000
benzyl benzoate	0.0105	0.0622	0.0247	0.0254	0.0000	0.0252	0.0124	0.0000	0.0000
benzoic acid	0.0328	0.1098	0.0079	0.0120	0.0000	0.0242	0.0240	0.0041	0.0000
tetracyc oint	0.0536	0.1404	0.0394	0.0393	0.0074	0.0221	0.0098	0.0049	0.0000
septrin	0.0534	0.1402	0.1455	0.1678	0.1281	0.0395	0.0691	0.0765	0.0049
laxative	0.0071	0.0511	0.0191	0.0557	0.0000	0.2598	0.2970	0.0000	0.0000
flagyl	0.0441	0.1274	0.1851	0.4331	0.0805	0.0389	0.2838	0.1016	0.0000
calamine	0.0157	0.0760	0.0503	0.0925	0.0084	0.0081	0.0000	0.0000	0.0000
kaolin	0.0016	0.0243	0.0847	0.8213	0.0000	0.0799	0.3295	0.0000	0.0000
O.R.F.	0.0925	0.1845	0.4942	0.7135	0.0896	0.0370	0.0342	0.0114	0.0000
potass permang	0.0005	0.0136	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
piperazine	0.0171	0.0793	0.1235	0.0693	0.0000	0.4853	0.2775	0.0078	0.0000
ampicillin	0.0034	0.0354	0.0398	0.0378	0.0000	0.0000	0.0764	0.0775	0.0000
chloramphenicol	0.0389	0.1196	0.3251	0.3251	0.0811	0.0169	0.0271	0.0034	0.0000
tetracycline	0.0573	0.1452	0.0368	0.0276	0.0298	0.0276	0.2965	0.2531	0.0023
paracetamol	0.0601	0.1487	0.0680	0.0505	0.0328	0.2894	0.3221	0.0768	0.0000

Appendix II: Data used for the test model: usages, thresholds, occurrences & relevances

	usage	thres-hold	genital discharge	dysmen-orrhoea	amen-orrhoea	pregnancy
occurrence			0.0240	0.0028	0.0036	0.0029
see doctor	0.1126	0.2035	0.1042	0.0012	0.0012	0.0023
see surgeon	0.0057	0.0458	0.0232	0.1403	0.3041	0.0694
aspirin	0.6673	0.4955	0.0069	0.0020	0.0024	0.0012
chloroquine	0.2419	0.2983	0.0000	0.0000	0.0000	0.0000
vitamins	0.4105	0.3886	0.0051	0.0032	0.0039	0.0026
linctus	0.1891	0.2638	0.0007	0.0000	0.0014	0.0021
mag trisil	0.0791	0.1706	0.0117	0.0017	0.0017	0.0000
gentian violet	0.0057	0.0458	0.0000	0.0000	0.0000	0.0000
iron	0.0586	0.1468	0.0090	0.0091	0.0182	0.0225
hibitane	0.0320	0.1085	0.0000	0.0000	0.0000	0.0000
folic acid	0.0221	0.0902	0.0000	0.0121	0.0241	0.0716
sytron	0.0013	0.0219	0.0000	0.0000	0.0000	0.0000
benzyl benzoate	0.0105	0.0622	0.0000	0.0000	0.0000	0.0000
benzoic acid	0.0328	0.1098	0.0040	0.0000	0.0000	0.0000
tetracyc oint	0.0536	0.1404	0.0049	0.0025	0.0000	0.0000
septrin	0.0534	0.1402	0.0124	0.0000	0.0025	0.0025
laxative	0.0071	0.0511	0.0000	0.0000	0.0000	0.0000
flagyl	0.0441	0.1274	0.1106	0.0000	0.0000	0.0030
calamine	0.0157	0.0760	0.0000	0.0000	0.0000	0.0000
kaolin	0.0016	0.0243	0.0000	0.0000	0.0000	0.0000
O.R.F.	0.0925	0.1845	0.0000	0.0000	0.0000	0.0028
potass permang	0.0005	0.0136	0.0000	0.0000	0.0000	0.0000
piperazine	0.0171	0.0793	0.0000	0.0000	0.0000	0.0000
ampicillin	0.0034	0.0354	0.0388	0.0000	0.0000	0.0775
chloramphenicol	0.0389	0.1196	0.0034	0.0000	0.0000	0.0000
tetracycline	0.0573	0.1452	0.1519	0.0093	0.0023	0.0000
paracetamol	0.0601	0.1487	0.0461	0.0022	0.0067	0.0132

Appendix III: Additional sources of data: Keneba paediatric clinic

	TOTAL CONSULTATIONS	gastrointestinal						fever	malaria	anaemia
		colic	diarrhoea	dysentery	chronic diarrhoea	vomiting	TOTAL			
CASES	16776	560	1081	96	47	611	2395	1913	786	551
AGE GROUP										
< 1 month	275	17	6	1		7	31	35	2	
	1.6%	3.0%	0.6%	1.0%		1.1%	1.3%	1.8%	0.3%	
1-5 months	1658	47	197	9	6	76	335	252	7	16
	9.9%	8.4%	18.2%	9.4%	12.8%	12.4%	14.0%	13.2%	0.9%	2.9%
6-11 months	2348	48	274	13	10	106	451	274	26	93
	14.0%	8.6%	25.3%	13.5%	21.3%	17.3%	18.8%	14.3%	3.3%	16.9%
1-4 years	7845	214	539	61	28	259	1101	774	253	415
	46.8%	38.2%	49.9%	63.5%	59.6%	42.4%	45.9%	40.5%	32.2%	75.3%
5+ years	4650	234	65	12	3	163	477	578	498	27
	27.7%	41.8%	6.0%	12.5%	6.4%	26.7%	19.9%	30.2%	63.4%	4.9%
SEX										
male	8258	276	565	49	26	302	1218	989	423	299
	49.2%	49.3%	52.3%	51.0%	55.3%	49.4%	50.9%	51.7%	53.8%	54.3%
female	8518	284	516	47	21	309	1177	924	363	252
	50.8%	50.7%	47.7%	49.0%	44.7%	50.6%	49.1%	48.3%	46.2%	45.7%
SEASON										
early rains	3894	128	275	23	9	162	597	553	262	97
	23.2%	22.9%	25.4%	24.0%	19.1%	26.5%	24.9%	28.9%	33.3%	17.6%
late rains	4677	166	194	18	4	185	567	640	491	183
	27.9%	29.6%	17.9%	18.8%	8.5%	30.3%	23.7%	33.5%	62.5%	33.2%
early dry	3833	139	308	23	18	159	647	289	29	168
	22.8%	24.8%	28.5%	24.0%	38.3%	26.0%	27.0%	15.1%	3.7%	30.5%
late dry	4372	127	304	32	16	115	594	431	4	103
	26.1%	22.7%	28.1%	33.3%	34.0%	18.8%	24.8%	22.5%	0.5%	18.7%

Appendix III: Additional sources of data: Keneba paediatric clinic

	TOTAL CONSULTATIONS	respiratory disease					infections			
		cold	cough	bronchitis	pneumonia	TOTAL	chicken pox	mumps	measles	others
CASES	16776	898	1602	411	183	3094	80	59	47	85
AGE GROUP										
< 1 month	275	17	27	6	5	55			2	1
	1.6%	1.9%	1.7%	1.4%	2.7%	1.8%			4.3%	1.2%
1-5 months	1658	137	259	74	21	491	7		4	
	9.9%	15.3%	16.2%	18.0%	11.5%	15.9%	8.8%		8.5%	
6-11 months	2348	148	220	103	46	517	11	2	10	12
	14.0%	16.4%	13.7%	25.1%	25.1%	16.7%	13.8%	3.4%	21.3%	14.1%
1-4 years	7845	492	692	177	81	1442	52	27	15	44
	46.8%	54.8%	43.2%	43.1%	44.3%	46.6%	65.0%	45.8%	31.9%	51.8%
5+ years	4650	104	404	51	30	589	10	30	16	28
	27.7%	11.6%	25.2%	12.4%	16.4%	19.0%	12.5%	50.8%	34.0%	32.9%
SEX										
male	8258	410	704	192	85	1391	47	35	27	58
	49.2%	45.7%	43.9%	46.7%	46.4%	45.0%	58.8%	59.3%	57.4%	68.2%
female	8518	488	898	219	98	1703	33	24	20	27
	50.8%	54.3%	56.1%	53.3%	53.6%	55.0%	41.2%	40.7%	42.6%	31.8%
SEASON										
early rains	3894	145	272	109	16	542	7	44		26
	23.2%	16.1%	17.0%	26.5%	8.7%	17.5%	8.8%	74.6%		30.6%
late rains	4677	203	398	122	56	779		15	2	28
	27.9%	22.6%	24.8%	29.7%	30.6%	25.2%		25.4%	4.3%	32.9%
early dry	3833	226	418	78	35	757	2		44	13
	22.8%	25.2%	26.1%	19.0%	19.1%	24.5%	2.5%		93.6%	15.3%
late dry	4372	324	514	102	76	1016	71		1	14
	26.1%	36.1%	32.1%	24.8%	41.5%	32.8%	88.8%		2.1%	16.5%

Appendix III: Additional sources of data: Keneba paediatric clinic

	TOTAL CONSULTATIONS	oral pathology					conjunctivitis	tonsillitis	ear infections	general aches
		gingivitis	thrush	ulcers	dental	TOTAL				
CASES	16776	126	40	45	37	248	1103	132	282	1040
AGE GROUP										
< 1 month	275		11			11	26		1	3
	1.6%		27.5%			4.4%	2.4%		0.3%	0.3%
1-5 months	1658		13	1		14	138	10	31	14
	9.9%		32.5%	2.2%		5.6%	12.5%	7.6%	11.0%	1.3%
6-11 months	2348	4	9	7	3	23	215	15	64	35
	14.0%	3.2%	22.5%	15.6%	8.1%	9.3%	19.5%	11.4%	22.7%	3.4%
1-4 years	7845	82	6	28	9	125	552	59	148	299
	46.8%	65.1%	15.0%	62.2%	24.3%	50.4%	50.0%	44.7%	52.5%	28.8%
5+ years	4650	40	1	9	25	75	172	48	38	689
	27.7%	31.7%	2.5%	20.0%	67.6%	30.2%	15.6%	36.4%	13.5%	66.3%
SEX										
male	8258	70	17	23	24	134	507	63	170	540
	49.2%	55.6%	42.5%	51.1%	64.9%	54.0%	46.0%	47.7%	60.3%	51.9%
female	8518	56	23	22	13	114	596	69	112	500
	50.8%	44.4%	57.5%	48.9%	35.1%	46.0%	54.0%	52.3%	39.7%	48.1%
SEASON										
early rains	3894	22	11	6	4	43	342	22	61	279
	23.2%	17.5%	27.5%	13.3%	10.8%	17.3%	30.9%	16.7%	21.6%	26.8%
late rains	4677	29	9	14	7	59	103	18	77	496
	27.9%	23.0%	22.5%	31.1%	18.9%	23.7%	9.3%	13.6%	27.3%	47.7%
early dry	3833	32	7	18	10	67	295	39	61	141
	22.8%	25.4%	17.5%	40.0%	27.0%	27.0%	26.7%	29.5%	21.6%	13.6%
late dry	4372	43	13	7	16	79	363	53	83	124
	26.1%	34.1%	32.5%	15.6%	43.2%	31.9%	32.9%	40.2%	29.4%	11.9%

Appendix III: Additional sources of data: Keneba paediatric clinic

	TOTAL CONSULTATIONS	skin conditions					trauma
		impetigo	fungal	abcess	others	TOTAL	
CASES	16776	793	319	502	684	2298	263
AGE GROUP							
< 1 month	275	11	8	4	22	45	
	1.6%	1.4%	2.5%	0.8%	3.2%	2.0%	
1-5 months	1658	25	35	13	46	119	3
	9.9%	3.2%	11.0%	2.6%	6.7%	5.2%	1.1%
6-11 months	2348	96	27	59	102	284	7
	14.0%	12.1%	8.5%	11.8%	14.9%	12.4%	2.7%
1-4 years	7845	476	128	282	360	1246	119
	46.8%	60.0%	40.1%	56.2%	52.6%	54.2%	45.2%
5+ years	4650	185	121	144	154	604	134
	27.7%	23.3%	37.9%	28.7%	22.5%	26.3%	51.0%
SEX							
male	8258	356	151	236	303	1046	138
	49.2%	44.8%	47.3%	47.0%	44.3%	45.5%	52.5%
female	8518	437	168	266	381	1252	125
	50.8%	53.2%	52.7%	53.0%	55.7%	54.5%	47.5%
SEASON							
early rains	3894	228	35	181	194	638	26
	23.2%	28.8%	11.0%	36.1%	28.4%	27.8%	9.9%
late rains	4677	153	38	139	122	452	34
	27.9%	19.3%	11.9%	27.7%	17.8%	19.7%	12.9%
early dry	3833	204	117	65	230	616	76
	22.8%	25.7%	36.7%	12.9%	33.6%	26.8%	28.9%
late dry	4372	208	127	117	138	590	127
	26.1%	26.2%	39.8%	23.3%	20.2%	25.7%	48.3%

Appendix III: Additional sources of data:
RVH paediatric statistics 1988

	n	%
ADMISSIONS		
TOTAL	3254	100.0
AGE GROUP		
< 6 months	885	27.2
6-12 months	472	14.5
1-4 years	1513	46.5
5+ years	387	11.9
SEASON		
early rains	789	24.2
late rains	1096	33.7
early dry	719	22.1
late dry	646	19.9
MAJOR DIAGNOSES		
malaria - total	943	29.0
- cerebral	483	14.8
A.R.I. - total	689	21.2
- pneumonia	436	13.4
- bronchiolitis	182	5.6
diarrhoeal disease	481	14.8
malnutrition	450	13.8
severe anaemia	388	11.9
meningitis	99	3.0
DEATHS	384	11.8

Appendix III: Additional sources of data:
RVH paediatric statistics 1988

	n	%
DEATHS		
TOTAL	384	100.0
MAJOR CAUSES OF DEATH		
malaria	103	26.8
malnutrition	67	17.4
A.R.I.	42	10.9
diarrhoeal disease	31	8.1
meningitis	29	7.6
CASE FATALITY RATES		
meningitis	29/99	29.3
malnutrition	67/450	14.9
malaria	103/943	10.9
diarrhoeal disease	31/481	6.4
A.R.I.	42/689	6.1
severe anaemia	11/388	2.8

AGE AT DEATH BY CAUSE (months)

	mean	s.d.	n
malaria	40.8	24.0	103
malnutrition	19.0	10.7	67
A.R.I.	15.7	24.4	42
diarrhoeal disease	12.0	11.6	31
meningitis	6.0	4.8	29

Appendix III: Additional sources of data:
RVH paediatric statistics 1988

SEASONALITY

	early rains		late rains		early dry		late dry	
	n	%	n	%	n	%	n	%
deaths	103	26.8	149	38.8	69	18.0	63	16.4
malaria	141	15.0	548	58.1	207	22.0	47	5.0
A.R.I.	178	25.8	180	26.1	142	20.6	189	27.4
diarrhoeal disease	180	37.4	107	22.2	107	22.2	87	18.1
malnutrition	136	30.2	165	36.7	74	16.4	75	16.7
severe anaemia	43	11.1	202	52.1	112	28.9	31	8.0

(meningitis not available)

Appendix IV: Qualitative model derived from "Health in The Gambia"

Basis of the qualitative model

A set of management strategies and patient indicators were taken from "Health in The Gambia" [Hanlon & Hanlon 1986]. Corresponding usages, occurrences and relevances, as detailed below, were determined qualitatively from the same text, using the following scale:

QUALITATIVE DESCRIPTOR	DESCRIPTION	APPROXIMATE QUANTITATIVE EQUIVALENT
1	almost always	100%
A	about half	50%
A-		20%
B+		10%
B	fairly common	5%
B-		2%
C+		1%
C	uncommon	0.5%
C-		0.2%
0	virtually never	0

Appendix IV: Qualitative model derived from "Health in The Gambia"

Characteristics used in the qualitative model

DESCRIPTOR	DESCRIPTION	OCCURRENCE
INFANT	age less than 1 year	A-
CHILD	age 1 to 14 years	A-
ADULT_MALE	male 15 years and over	A-
ADULT_FEM	female 15 years and over	A-
EARLY_RAIN	early rainy season	A-
LATE_RAIN	late rainy season	A
EARLY_DRY	early dry season	A-
LATE_DRY	late dry season	B+
FATIGUE	general fatigue and/or pain	A-
COUGH	cough	A-
HEADACHE	headache	A-
FEVER	subjective fever	A-
RAPID_BR	increased respiratory rate	B
INDRAWING	chest indrawing	B
EAR_INF	ear ache or infection	B
DARK_SPUT	yellow/bloody sputum	B-
HAEMATURIA	haematuria	B-
U_T_I	urinary tract infection	B
MALNOUR	malnutrition	B+
L_WEIGHT	low weight or loss of weight	B+
DIARR	diarrhoea	A-
DIAR_BLD	bloody diarrhoea	B
DEHYD	clinical dehydration	B-
LOW_AB_PN	lower abdominal pain	B
GENIT_DIS	genital discharge	B+
ANAEMIC	clinical anaemia	B+
SICKLER	sickle cell disease	C
FITS	current or very recent fits	C-
COMATOSE	semi-conscious or unconscious	C-
OEDEMA	generalised oedema	B-
EYE_INF	eye soreness or infection	B
POOR_VIS	poor vision	B
NECK_S_BF	neck stiffness or raised fontanelle	C
BURN_TRAUM	accidental injury	B-
SEPT_SKIN	septic skin condition	B+
RINGWORM	ringworm or other skin fungus	B-
BF_POS	malaria-positive thick bllod film	B+
RETURN	previously came with same problem	B+
EARLY_PREG	less than 6 months pregnant	B
LATE_PREG	6 months or more pregnant	B
AB_VAG_BL	abnormal vaginal bleeding	C
AMENHORREA	amenhorrea two months or more	C
REC_DEL	recently delivered/aborted	C
DIFF_PREG	previous difficult pregnancy	C
INFERT	unsuccessful in conceiving	C+
LACT	currently lactating	B

Appendix IV: Qualitative model derived from "Health in The Gambia"

Strategies used in the qualitative model

DESCRIPTOR	DESCRIPTION	USAGE
refer_urgent	may need urgent referral	B
refer	refer to larger centre	B
refer_ANC	refer to ante-natal clinic	B
refer_FPC	refer to family planning	B-
refer_TBC	refer to TB clinic	B
return_visit	ask to come back	B+
rest	suggest resting	B
improve_diet	suggest dietary improvement	A-
vitamins	give vitamins	A-
aspirin	give aspirin	B+
paracetamol	give paracetamol	B+
ORF	give oral rehydration	A-
iron&folic_acid	give iron and folic acid	B
tet_tox	check tetanus vaccination	B
antibiotics	give oral antibiotics	B+
flagyl	give flagyl	B-
chloroquine	give chloroquine	B+
chemoprophylaxis	give malaria chemoprophylaxis	B
antib_eye_oint	give antibiotic eye ointment	B-
antibiotic_ointment	give antibiotic skin ointment	B-
gentian_violet	give gentian violet	B+
benzoic_acid_oint	give benzoic acid ointment	B-
vaccinate	check vaccinations	B+
treat_schisto	give schisto treatment	B-

strategy	usage	infant	child	adult_male	adult_fem	early_rain	late_rain	early_dry	late_dry
occurrence		A-	A-	A-	A-	A-	A	A-	B+
refer_urgent	B	A-	A-	B+	A	A-	A	A-	B+
refer	B	A-	A-	A-	A-	A-	A	A-	B+
refer_ANC	B	0	0	0	1	A-	A	A-	B+
refer_FPC	B-	0	0	A-	A	A-	A	A-	B+
refer_TBC	B	A-	A-	A-	A-	A-	A	A-	B+
return_visit	B+	A-	A-	A-	A-	A-	A	A-	B+
rest	B	A-	A-	A-	A-	A-	A	A-	B+
improve_diet	A-	B+	A	A-	A-	A	A	B+	B+
vitamins	A-	B+	A	A	B+	A	A	B+	B+
aspirin	B+	B	B	A	A	A-	A	A-	B+
paracetamol	B+	A	A	B	B	A-	A	A-	B+
ORF	A-	A	A	A-	A-	A-	A	A-	B+
iron&folic_acid	B	A-	A-	A-	A	A-	A	A-	B+
tet_tox	B	B+	B+	B+	A	A-	A	A-	B+
antibiotics	B+	A-	A-	A-	A-	A-	A	A-	B+
flagyl	B-	A-	A-	A-	A-	A-	A	A-	B+
chloroquine	B+	A-	A	A-	A-	A	A	B+	B+
chemoprophylaxis	B	B+	A-	B+	A-	A	A	B+	B+
antib_eye_oint	B-	A	A-	A-	A-	A-	A	A-	B+
antibiotic_ointment	B-	A-	A-	A-	A-	A	A	B+	B+
gentian_violet	B+	A-	A-	A-	A-	A	A	B+	B+
benzyl_benzoate	B-	A-	A-	A-	A-	A-	A	A-	B+
vaccinate	B+	1	0	0	0	A-	A	A-	B+
treat_schisto	B-	B	A	A-	A-	A-	A	A-	B+

strategy	fatigue	cough	headache	fever	rapid_br	indrawing	ear_inf	dark_sput	haematuria	u_t_i
occurrence	A-	A-	A-	A-	B	B	B	B-	B-	B
refer_urgent	A-	A-	A-	A-	B+	B+	B+	B	B-	B-
refer	A-	A-	A-	A-	B	B	B+	B	B	B
refer_ANC	A-	A-	A-	A-	B	B	B	B-	B-	B-
refer_FPC	A-	A-	A-	A-	B	B	B	B-	B-	B-
refer_TBC	A-	A	A-	A-	B	B	B	A-	B-	B-
return_visit	A-	A-	A-	A-	B+	B+	B	B	B-	B-
rest	A	A-	A-	A-	B	B	B	B-	B-	B-
improve_diet	A-	A-	A-	A-	B	B	B	B-	B-	B-
vitamins	A	A-	A-	A-	B	B	B	B-	B-	B-
aspirin	A	A-	A	A	B	B	B+	B	B	B
paracetamol	A-	A-	A-	A	B	B	B+	B-	B	B
ORF	A-	A-	A	A-	B	B	B	B-	B-	B-
iron&folic_acid	A	A-	A-	A-	B	B	B	B-	B	B
tet_tox	A-	A-	A-	A-	B	B	B	B-	B-	B-
antibiotics	A-	A-	A-	A	A-	A-	B+	B	B	B
flagyl	A-	A-	A-	A-	B	B	B	B-	B-	B-
chloroquine	A-	A-	A	A	B	B	B	B-	B-	B-
chemoprophylaxis	A-	A-	A-	A-	B	B	B	B-	B-	B-
antib_eye_oint	A-	A-	A-	A-	B	B	B	B-	B-	B-
antibiotic_ointment	A-	A-	A-	A-	B	B	B	B-	B-	B-
gentian_violet	A-	A-	A-	A-	B	B	B	B-	B-	B-
benzyl_benzoate	A-	A-	A-	A-	B	B	B	B-	B-	B-
vaccinate	A-	A-	A-	A-	B	B	B	B-	B-	B-
treat_schisto	A-	A-	A-	A-	B	B	B	B-	1	B-

strategy	malnour	l_weight	diarr	diar_bld	dehyd	low_ab_pn	genit_dis	anaemic	sickler	fits
occurrence	B+	B+	A-	B	B-	B	B+	B+	C	C-
refer_urgent	A-	A-	A-	B+	B+	B+	B+	A-	B+	B-
refer	A-	A-	A-	B+	B-	B+	A-	A-	B-	C-
refer_ANC	B+	B+	A-	B	B-	B	B+	B+	C	C-
refer_FPC	B+	B+	A-	B	B-	B	B+	B+	B	C-
refer_TBC	A-	A	A-	B	B-	B	B+	B+	C	C-
return_visit	A-	A-	A-	B	B	B	B+	B+	B	C
rest	B+	B+	A-	B	B-	B	B+	B+	C+	C
improve_diet	A	A	A-	B	B-	B	B+	A	C+	C-
vitamins	A-	A-	A-	B	B-	B	B+	A	C+	C-
aspirin	B+	B+	A-	B	B-	B+	A-	B+	B-	B-
paracetamol	B+	B+	A-	B	B-	B+	B+	B+	B-	B-
ORF	A-	A-	A	A-	A	B+	B+	B+	C	C-
iron&folic_acid	B+	B+	A-	B	B-	B	B+	1	B	C-
tet_tox	B+	B+	A-	B	B-	B	B+	B+	C	C-
antibiotics	A-	B+	A-	B	B-	B+	A-	B+	C	B-
flagyl	B+	B+	A	A	B-	A-	B+	B+	C	C-
chloroquine	A-	B+	A-	B	B-	B	B+	A	C	B-
chemoprophylaxis	B+	B+	A-	B	B-	B	B+	A-	B	C-
antib_eye_oint	B+	B+	A-	B	B-	B	B+	B+	C	C-
antibiotic_ointment	B+	B+	A-	B	B-	B	B+	B+	C	C-
gentian_violet	B+	B+	A-	B	B-	B	B+	B+	C	C-
benzyl_benzoate	B+	B+	A-	B	B-	B	B+	B+	C	C-
vaccinate	B+	B+	A-	B	B-	B	O	B+	C	O
treat_schisto	B+	B+	A-	B	B-	A-	B+	B+	C	C-

Appendix IV: Qualitative model derived from "Health in The Gambia"

strategy	comatose	oedema	eye_inf	poor_vis	neck_s_bf	burn_traum	sept_skin	ringworm	bf_pos	return
occurrence	C-	B-	B	B	C	B-	B+	B-	B+	B+
refer_urgent	B-	B	B	B	B	B	B+	B-	A-	B+
refer	C-	B	B	B+	C	B	B+	B-	B+	A-
refer_ANC	C-	B	B	B	C	B-	B+	B-	B+	B+
refer_FPC	C-	B-	B	B	C	B-	B+	B-	B+	B+
refer_TBC	C-	B-	B	B	C	B-	B+	B-	B+	A-
return_visit	C	B	B	B	C	B-	B+	B-	B+	A-
rest	C-	A-	B	B	C	B-	B+	B-	B+	B+
improve_diet	C-	B-	B	B	C	B-	B+	B-	B+	B+
vitamins	C-	B-	B	B+	C	B-	A-	B-	B+	B+
aspirin	B-	B-	B+	B	C+	B+	B+	B-	A-	B+
paracetamol	B-	B-	B+	B	C+	B+	B+	B-	A-	B+
ORF	B-	B-	B	B	C+	B	B+	B-	B+	B+
iron&folic_acid	C-	B-	B	B	C	B-	B+	B-	A-	B+
tet_tox	C-	B-	B	B	C	A	B+	B-	B+	B+
antibiotics	B-	B-	B+	B	B	B	A-	B-	B+	B+
flagyl	C-	B-	B	B	C	B-	B+	B-	B+	B+
chloroquine	B-	B-	B	B	C	B-	B+	B-	A	B+
chemoprophylaxis	C-	B-	B	B	C	B-	B+	B-	B+	B+
antib_eye_oint	C-	B-	1	B	C	B-	B+	B-	B+	B+
antibiotic_ointment	C-	B-	B	B	C	B	A	B	B+	B+
gentian_violet	C-	B-	B	B	C	B+	A	B	B+	B+
benzyl_benzoate	C-	B-	B	B	C	B-	B+	1	B+	B+
vaccinate	0	B-	B	B	C	B-	B+	B-	B-	B+
treat_schisto	C-	B-	B	B	C	B-	B+	B-	B+	B+

Appendix IV: Qualitative model derived from "Health in The Gambia"

strategy	early_preg	late_preg	ab_vag_bl	amenhorrea	rec_del	diff_preg	infert	lact
occurrence	B	B	C	C	C	C	C+	B
refer_urgent	B+	B+	B	C	C+	B-	C+	B
refer	B	B	C+	B	C+	B	B+	B
refer_ANC	A	A	C-	B	B	B	C+	B
refer_FPC	0	0	0	C	B	C+	C+	A
refer_TBC	B	B	C	C	C	C	C+	B
return_visit	B	B	C	C	C	C	C+	B
rest	B+	B+	B+	C	C+	B-	C+	B
improve_diet	B+	B+	C	B-	C+	C+	B-	B+
vitamins	B+	B+	C	B-	C+	C+	B-	B+
aspirin	B	B	B-	C	C+	C	C+	B
paracetamol	B	B	B-	C	C+	C	C+	B
ORF	B	B	C	C	C	C	C+	B
iron&folic_acid	A-	A-	B+	C+	B-	B-	B-	B
tet_tox	A-	A	C	C	C	B-	C+	B
antibiotics	B	B	B	C	C	C	C+	B
flagyl	B	B	C	C	C	C	C+	B
chloroquine	B+	B+	C	C	C	C	C+	B
chemoprophylaxis	A-	A-	C	C	C	A-	C+	B
antib_eye_oint	B	B	C	C	C	C	C+	B
antibiotic_ointment	B	B	C	C	C	C	C+	B
gentian_violet	B	B	C	C	C	C	C+	B
benzyl_benzoate	B	B	C	C	C	C	C+	B
vaccinate	0	0	0	0	0	0	0	0
treat_schisto	B	B	C	C	C	C	C+	B

Appendix IV: Qualitative model derived from "Health in The Gambia"

Examples of output from the qualitative model

```
PATIENT    -> infant, late_dry, diarr, fever,
MANAGEMENT -> paracetamol, ORF, vaccinate,

PATIENT    -> infant, late_dry, cough, rapid_br, indrawing,
MANAGEMENT -> antibiotics, vaccinate,

PATIENT    -> infant, late_dry, fever, bf_pos,
MANAGEMENT -> paracetamol, chloroquine,

PATIENT    -> child, early_rain, fever,
MANAGEMENT -> improve_diet, vitamins, paracetamol, chloroquine,

PATIENT    -> child, late_dry, neck_s_bf, fever,
MANAGEMENT -> refer_urgent, paracetamol, ORF, antibiotics,
              chloroquine,

PATIENT    -> child, late_dry, sickler,
MANAGEMENT -> refer_urgent, return_visit, improve_diet, vitamins,
              paracetamol, iron&folic_acid, chemoprophylaxis,

PATIENT    -> child, late_dry, fits,
MANAGEMENT -> refer_urgent, paracetamol, antibiotics,
              chloroquine,

PATIENT    -> child, early_dry, cough, fatigue, ringworm,
MANAGEMENT -> benzoic_acid_oint,

PATIENT    -> adult_fem, late_rain, early_preg, cough, fatigue,
MANAGEMENT -> refer_ANC, aspirin, iron&folic_acid, tet_tox,

PATIENT    -> adult_fem, late_dry, u_t_i, fever, low_ab_pn,
MANAGEMENT -> aspirin, antibiotics,

PATIENT    -> adult_male, early_rain, genit_dis, fever,
MANAGEMENT -> vitamins, aspirin, antibiotics, chloroquine,

PATIENT    -> adult_fem, late_preg, ab_vag_bl,
MANAGEMENT -> refer_urgent, refer_ANC, rest, aspirin,
              iron&folic_acid, tet_tox, antibiotics,

PATIENT    -> adult_fem, early_rain, infert,
MANAGEMENT -> refer, improve_diet,
```

Appendix IV: Qualitative model derived from "Health in The Gambia"

dBase III program to drive the qualitative model

```
set talk off
use database

set print on
? "PATIENT    -> "
set print off

* set initial advisabilities to usages
store 1 to c
do while c <= reccount()
 goto c
 if c<10
  store "A"+str(recno(),1) to aname
 else
  store "A"+str(recno(),2) to aname
 endif
 store usge to &aname
 store c+1 to c
enddo

* ask for patient indicators until told to quit
* and update advisabilities for each one
store " " to pis
do while pis<>"quit" .and. pis<>"QUIT"
 accept "patient indicator code: [or QUIT] " to pis
 if pis<>"quit" .and. pis<>"QUIT"
  set print on
  ?? pis+', '
  set print off
  1
  store &pis to occ
  store 1 to c
```

Appendix IV: Qualitative model derived from "Health in The Gambia"

```
* calculate new set of advisabilities
do while c <= reccount()
 goto c
 if c<10
  store "A"+str(recno(),1) to aname
 else
  store "A"+str(recno(),2) to aname
 endif
 store ((&pis*&aname)/((&pis*&aname)+(occ*(1-&aname)))) to &aname
 if &aname>thrs
  ? strt,&aname
 endif
 store c+1 to c
enddo

 endif
enddo * drop out of loop on "quit"

* produce output
store 1 to c
set print on
? "MANAGEMENT -> "
do while c <= reccount()
 goto c
 if c<10
  store "A"+str(recno(),1) to aname
 else
  store "A"+str(recno(),2) to aname
 endif
 if &aname>thrs
  ?? trim(strt)+', '
 endif
 store c+1 to c
enddo
?
set print off
return
```

Appendix V: Details of the database for the prototype system: strategies

STRATEGIES SELECTED FOR THE SYSTEM

		code name
GROUP A: SUGGESTED INVESTIGATIONS AND ENQUIRIES		
1	determine patient's age and sex	WASX
2	determine the current season	WSES
3	for adult women, their reproductive history	REPH
4	determine general nature of presenting problem	GENP
5	measure temperature	TKTP
6	determine symptoms of general illness	GILL
7	get details of problems associated with the head	HEAD
8	get details of respiratory problems	RESP
9	get details of gastrointestinal problems	GAST
10	get details of genitourinary problems	GEUR
11	get details of skin problems	SKIN
GROUP B: SUGGESTED LABORATORY PROCEDURES		
12	do a thick blood film	TKBF
13	do a thin blood film	TNBF
14	measure haemoglobin	HGLB
15	do a white cell count	DWCC
16	test urine for protein and sugar	URTS
17	do stool microscopy to identify parasites	STPR
GROUP C: REFERRAL TO OTHER FACILITIES, RETURNS		
18	refer to a doctor or hospital urgently	RFHU
19	refer to a doctor or hospital	RFHO
20	refer to an ante-natal clinic	RANC
21	refer to a TB clinic	RTBC
22	refer to a family planning clinic	RFPC
23	ask to return to the health centre	REVT

Appendix V: Details of the database for the prototype system: strategies

GROUP D: ADVICE TO THE PATIENT

24	improve diet	IMPD
25	lose weight	LSWT
26	take rest	REST
27	check for any vaccinations that are due	CVAC

GROUP E: PRESCRIPTIONS

28	antiseptic lotion	ANLO
29	aspirin	ASPR
30	bendrofluazide	BEND
31	chloroquine	CHLO
32	chlorpheniramine	CHLP
33	cough syrup	COSY
34	ephedrine	EPHD
35	ferrous sulphate	IRON
36	folic acid	FOAC
37	laxatives	LAXT
38	magnesium trisilicate	MGTS
39	niclosamide	NICL
40	oral rehydration fluid	OREF
41	paracetamol	PARA
42	penicillin V	PENV
43	phenobarbitone	PHBA
44	piperazine	PIPZ
45	septrin	SEPT
46	sulfadimidine	SULF
47	tetracycline	TETR
48	tetracycline eye ointment	TEOI
49	thiabendazole	THBZ
50	vitamins	VITS

Appendix V: Details of the database for the prototype system: indicators

INDICATORS SELECTED FOR THE SYSTEM

GROUP A: PATIENT'S PERSONAL DETAILS

1 infant less than 6 months old
2 child 6 months to 5 years old
3 child over 5 years
4 adult female
5 adult male
6 early rainy season
7 late rainy season
8 early dry season
9 late dry season

GROUP B: ITEMS OF PATIENT HISTORY

10 generally unwell
11 problems associated with the head
12 respiratory problems
13 gastrointestinal problems
14 urinary and genital problems
15 skin problems
16 return visit with the same problem
17 pregnant, less than 6 months
18 pregnant, over 6 months
19 abnormal vaginal bleeding
20 amenhorrea for 2 months or more
21 recently delivered or aborted
22 previous difficult pregnancy
23 unsuccessful in conceiving
24 lactating

Appendix V: Details of the database for the prototype system: indicators

GROUP C: SPECIFIC COMPLAINTS AND SYMPTOMS

25 general pain/fatigue
26 has been feverish
27 low weight or loss of weight
28 current or very recent fits
29 accidental injury
30 diarrhoea
31 diarrhoea with blood
32 upper abdominal pain
33 lower abdominal pain
34 vomiting
35 worms
36 burns
37 sore throat
38 headache
39 ear ache/infection
40 eye soreness/infection
41 poor vision
42 cough
43 chest pain
44 blood in urine
45 pain on passing urine
46 genital discharge
47 sudden rash
48 general rash for some time
49 severe constipation

GROUP D: CLINICAL FINDINGS

50 seriously sick
51 malnourished
52 overweight
53 dehydration
54 anaemia

55 semi-conscious or unconscious
56 general swelling/oedema
57 jaundice
58 neck stiffness and/or raised fontanelle
59 mental confusion
60 rapid breathing
61 wheezing
62 chest indrawing
63 yellow or bloody sputum
64 boils
65 septic rash
66 high fever
67 moderate fever
68 temperature normal

GROUP E: TEST RESULTS, ETC.

69 sickle cell disease
70 urine infection
71 malaria parasitaemia
72 low haemoglobin
73 iron deficient
74 folate deficient
75 high white cell count
76 protein in urine
77 sugar in urine
78 roundworm or threadworm
79 hookworm, trichuris or strongyloides
80 tapeworm

Appendix V: Details of the database for the prototype system: data summary

SUMMARY OF DATA BY STRATEGY

Probabilities in many instances are expressed on a scale from A to K, with approximate quantitative equivalents as follows:

A: 1, B: 0.5, C: 0.2, D: 0.1, E: 0.05, F: 0.02, G: 0.01,

H: 0.005, I: 0.002, J: 0.001, K: 0.

Sources of data are referred to as follows:

a: Gate Clinic database
b: Keneba clinic data
c: R.V.H. paediatric ward data
d: "Health in The Gambia" [Hanlon and Hanlon 1986]
e: Dr. A. Hughes, Consultant Pathologist, R.V.H.
f: "Where there is no doctor" [Werner 1977]

1. **WASX** - to be used once for every consultation. Usage A.

2. **WSES** - to be used once for every consultation. Usage A.

3. **REPH** - to be used for all adult women. Usage C^a.

4. **GENP** - to be used for every consultation. Usage A.

5. **TKTP** - to be used once for every consultation. Usage A.

6. **GILL** - to be used when indicator 10 is selected from strategy 4. Usage B^a.

7. **HEAD** - to be used when indicator 11 is selected from strategy 4. Usage C^a.

8. **RESP** - to be used when indicator 12 is selected from strategy 4. Usage C[a].

9. **GAST** - to be used when indicator 13 is selected from strategy 4. Usage C[a].

10. **GEUR** - to be used when indicator 14 is selected from strategy 4. Usage C[a].

11. **SKIN** - to be used when indicator 15 is selected from strategy 4. Usage C[a].

12. **TKBF** - to be used where there is a possibility of the patient having malaria. Usage C. More likely to be required in children, in the wet season, in patients generally unwell, having fevers, difficulty breathing, semi-conscious, anaemic[d,e].

13. **TNBF** - to be used where there are clinical signs of anaemia. Usage D. More likely to be required in women and children, in the wet season and in patients generally unwell[e].

14. **HGLB** - to be used to assess possible anaemic conditions. Usage C. More likely to be required in pale patients, women and children, in the wet season, in pregnancy, in known sicklers and in severe malaria[d,e].

15. **DWCC** - to be used in suspected infections. Usage E[d,e].

16. **URTS** - to be used in suspected urinary infections and pregnancy. Usage D[d,e].

17. **STPR** - to be used to find and identify intestinal parasites. Usage E. More likely to be required for patients with abdominal pain, diarrhoea, anaemia and in children[d,e,f].

18. **RFHU** - to be used for potentially life-threatening conditions. Usage E. More likely to be required in infants and young children, pregnant women, in the rainy season, in cases of fits, serious injuries, chest pain, loss of consciousness, neck stiffness, raised fontanelle, yellow or bloody sputum, malaria parasitaemia, protein and/or sugar in urine and seriously ill patients[a,b,c,d,e,f].

19. **RFHO** - to be used for serious and/or persistent conditions. Usage D. More likely to be required in infants, children and pregnant women, in the rainy season, in patients returning with the same problem, in cases of gynaecological problems, weight loss or malnutrition, poor vision, genital discharge, mental confusion, sickle cell disease, protein and/or sugar in urine and in seriously ill patients[a,b,c,d,e,f].

20. **RANC** - to be used for all pregnant or possibly pregnant women. Usage D[a].

21. **RTBC** - to be used for possible cases of tuberculosis. Usage E. More likely for patients who are generally unwell, losing weight, cough and respiratory problems[d,f].

22. **RFPC** - to be used for women who have recently delivered or aborted, have had previous difficulties in pregnancy or are lactating. Usage D[d].

23. **REVT** - to be used to follow up cases which might have potentially serious developments. Usage E. More likely to be used in infants and young children, infections, malnutrition, etc. [a,b,c,d,e,f]

24. **IMPD** - to be used for conditions with possible dietary causes or consequences. Usage D. More likely to be used in children and pregnant or lactating women, in the rainy season, in cases with low weight or loss of weight, diarrhoea and/or vomiting, persistent rashes, malnutrition, anaemia and intestinal parasites[d,f].

25. **LSWT** - to be used for overweight adults. Usage G[d,f].

26. **REST** - to be used for generally ill patients and in pregnancy. Usage D. More likely in pregnant women, women recently delivered or aborted, in cases of anaemia, general swelling and oedema[d,f].

27. **CVAC** - to be used in infants and young children who are not seriously ill. Usage C[a].

28. **ANLO** - to be used for minor skin complaints. Usage D. More likely to be used in children and in the rainy season[a].

29. **ASPR** - to be used for pain and/or fever. Not for use in young children or in cases of upper abdominal pain. Usage C[a,d,f].

30. **BEND** - to be used as a diuretic in adults with oedema. Usage H[a].

31. **CHLO** - to be used for the treatment of malaria. Usage C. More likely to be used in children and during the rainy season. Essential if malaria parasites are found in a blood film[a,d,f].

32. **CHLP** - to be used in cases of allergic reactions. Usage G[f].

33. **COSY** - to be used for cough. Usage C[a].

34. **EPHD** - to be used for asthmatics. Usage F[d,f].

35. **IRON** - to be used in iron-deficient anaemia and pregnancy. Usage D. More likely to be used in rainy season[a,d,f].

36. **FOAC** - to be used in folate-deficient anaemia and pregnancy. Usage E[a,d,f].

37. **LAXT** - to be used occasionally in adults with severe constipation. Usage G[f].

38. **MGTS** - to be used for upper abdominal pain and discomfort. Usage E[a].

39. **NICL** - to be used for tapeworm infestations. Usage G[d,f].

40. **OREF** - to be used in diarrhoea and dehydration. Usage D. More likely to be used for children and in the rainy season[a,d,f].

41. **PARA** - to be used for pain and/or fever. Suitable for children and for upper abdominal pain. Usage C[a,d,f].

42. **PENV** - to be used for relatively mild infections. Usage E. More likely to be used in children and in the rainy season[a,d,f].

43. **PHBA** - to be used to control serious fits. Usage $H^{d,f}$.

44. **PIPZ** - to be used for roundworm or threadworm infestations. Usage $F^{a,d,f}$.

45. **SEPT** - to be used for respiratory and other serious infections. Usage D. More likely to be used in children and in the rainy season^{a,d,f}.

46. **SULF** - to be used for urinary and skin infections. Usage $E^{a,d,f}$.

47. **TETR** - to be used for infections, e.g. STDs, in non-pregnant adults. Usage $E^{a,d,f}$.

48. **TEOI** - to be used for eye infections. Usage $E^{a,d,f}$.

49. **THBZ** - to be used for hookworm, trichuris and strongyloides infestations. Usage $F^{a,d,f}$.

50. **VITS** - to be used for vitamin deficiencies and general illnesses of no obvious cause. Usage $C^{a,d,f}$.

Appendix V: Details of the database for the prototype system: database

COMPLETE DATABASE FOR THE SYSTEM

(A) dBase III database of occurrences, usages and relevances

Each record in the following database relates to a particular characteristic, specified in field 52, with an occurrence as specified in field 51. Fields 1 to 50 contain relevances for particular characteristics for each strategy field.

Structure for database: D:database.dbf
Number of data records: 82
Date of last update : 19/01/90

Field	Field Name	Type	Width	Dec
1	WASX	Character	1	
2	WSES	Character	1	
3	REPH	Character	1	
4	GENP	Character	1	
5	TKTP	Character	1	
6	GILL	Character	1	
7	HEAD	Character	1	
8	RESP	Character	1	
9	GAST	Character	1	
10	GEUR	Character	1	
11	SKIN	Character	1	
12	TKBF	Character	1	
13	TNBF	Character	1	
14	HGLB	Character	1	
15	DWCC	Character	1	
16	URTS	Character	1	
17	STPR	Character	1	
18	RFHU	Character	1	
19	RFHO	Character	1	
20	RANC	Character	1	
21	RTBC	Character	1	
22	RFPC	Character	1	

Appendix V: Details of the database for the prototype system: database

23	REVT	Character	1
24	IMPD	Character	1
25	LSWT	Character	1
26	REST	Character	1
27	CVAC	Character	1
28	ANLO	Character	1
29	ASPR	Character	1
30	BEND	Character	1
31	CHLO	Character	1
32	CHLP	Character	1
33	COSY	Character	1
34	EPHD	Character	1
35	IRON	Character	1
36	FOAC	Character	1
37	LAXT	Character	1
38	MGTS	Character	1
39	NICL	Character	1
40	OREF	Character	1
41	PARA	Character	1
42	PENV	Character	1
43	PHBA	Character	1
44	PIPZ	Character	1
45	SEPT	Character	1
46	SULF	Character	1
47	TETR	Character	1
48	TEOI	Character	1
49	THBZ	Character	1
50	VITS	Character	1
51	OCCR	Character	1
52	CHAR	Character	20
** Total **			72

Appendix V: Details of the database for the prototype system: database

	INDICATOR	OCCR	WASX	WSES	REPH	GENP
1	infant < 6 months	D	K	D	K	D
2	child 6 mths to 5 years	B	K	B	K	B
3	child over 5 years	C	K	C	K	C
4	adult female	C	K	C	A	C
5	adult male	C	K	C	K	C
6	early wet season	C	C	K	C	C
7	late wet season	C	C	K	C	C
8	early dry season	C	C	K	C	C
9	late dry season	D	D	K	D	D
10	generally unwell	B	B	B	B	B
11	problems of the head	C	C	C	C	C
12	respiratory problems	C	C	C	C	C
13	gastrointestinal problems	C	C	C	C	C
14	urinary/genital problems	C	C	C	C	C
15	skin problems	C	C	C	C	C
16	returned not better	D	D	D	D	D
17	pregnant < 6 months	E	E	E	K	E
18	pregnant > 6 months	E	E	E	K	E
19	abnormal vaginal bleeds	G	G	G	K	G
20	amenhorrea > 2 months	F	F	F	K	F
21	just delivered/aborted	F	F	F	K	F
22	prev. difficult pregnancy	F	F	F	K	F
23	can't get pregnant	F	F	F	K	F
24	lactating	D	D	D	K	D
25	general pain/fatigue	C	C	C	C	C
26	recent fevers	D	D	D	D	D
27	low weight/losing weight	E	E	E	E	E
28	current/recent fits	H	H	H	H	H
29	accidental injury	G	G	G	G	G
30	diarrhoea	C	C	C	C	C
31	diarrhoea with blood	E	E	E	E	E

Appendix V: Details of the database for the prototype system: database

	INDICATOR	OCCR	WASX	WSES	REPH	GENP
32	upper abdominal pain	D	D	D	D	D
33	lower abdominal pain	D	D	D	D	D
34	vomiting	E	E	E	E	E
35	worms	F	F	F	F	F
36	burns	G	G	G	G	G
37	sore throat	F	F	F	F	F
38	headache	C	C	C	C	C
39	ear ache/infection	E	E	E	E	E
40	eye soreness/infection	E	E	E	E	E
41	poor vision	F	F	F	F	F
42	cough	C	C	C	C	C
43	chest pain	F	F	F	F	F
44	blood in urine	F	F	F	F	F
45	pain on urinating	E	E	E	E	E
46	genital discharge	E	E	E	E	E
47	sudden rash	G	G	G	G	G
48	rash for some time	D	D	D	D	D
49	severe constipation	F	F	F	F	F
50	seriously sick	D	D	D	D	D
51	malnourished	E	E	E	E	E
52	overweight	G	G	G	G	G
53	dehydration	F	F	F	F	F
54	anaemia	D	D	D	D	D
55	semi- or unconscious	G	G	G	G	G
56	swelling or oedema	G	G	G	G	G
57	jaundice	H	H	H	H	H
58	neck stiff/raised font'le	I	I	I	I	I
59	mental confusion	F	F	F	F	F
60	rapid breathing	D	D	D	D	D
61	wheezing	E	E	E	E	E
62	chest indrawing	E	E	E	E	E

Appendix V: Details of the database for the prototype system: database

	INDICATOR	OCCR	WASX	WSES	REPH	GENP
63	yellow/bloody sputum	G	G	G	G	G
64	boils	G	G	G	G	G
65	septic rash	E	E	E	E	E
66	high fever	E	E	E	E	E
67	moderate fever	D	D	D	D	D
68	temperature normal	B	B	B	B	B
69	sickle cell disease	G	G	G	G	G
70	urine infection	F	F	F	F	F
71	malaria parasites	D	D	D	D	D
72	low haemoglobin	E	E	E	E	E
73	iron deficient	E	E	E	E	E
74	folate deficient	E	E	E	E	E
75	high white cell cnt.	D	D	D	D	D
76	protein in urine	F	F	F	F	F
77	sugar in urine	H	H	H	H	H
78	roundworm/threadworm	F	F	F	F	F
79	hookworm etc.	F	F	F	F	F
80	tapeworm	G	G	G	G	G
81	USAGE		A	A	C	A
82	INDICATOR-GENERATING*		1	1	2	2

* coded as follows:

1 generates a single indicator
2 may generate several indicators
0 not indicator-generating

Appendix V: Details of the database for the prototype system: database

continued..

	TKTP	GILL	HEAD	RESP	GAST	GEUR	SKIN	TKBF	TNBF	HGLB
1	D	D	D	D	D	D	D	C	C	D
2	B	B	B	B	B	B	B	B	B	B
3	C	C	C	C	C	C	C	C	D	C
4	C	C	C	C	C	C	C	D	C	C
5	C	C	C	C	C	C	C	D	D	C
6	C	C	C	C	C	C	C	C	D	C
7	C	C	C	C	C	C	B	B	B	B
8	C	C	C	C	C	C	C	C	C	B
9	D	D	D	D	D	D	D	D	D	D
10	B	A	B	B	B	B	B	B	B	B
11	C	C	A	C	C	C	C	B	C	C
12	C	C	C	A	C	C	C	B	C	C
13	C	C	C	C	A	C	C	C	C	C
14	C	C	C	C	C	A	C	C	C	C
15	C	C	C	C	C	C	A	C	C	C
16	D	D	D	D	D	D	D	D	C	C
17	E	E	E	E	E	E	E	D	D	C
18	E	E	E	E	E	E	E	D	D	C
19	G	G	G	G	G	G	G	G	G	C
20	F	F	F	F	F	F	F	F	D	D
21	F	F	F	F	F	F	F	F	D	D
22	F	F	F	F	F	F	F	F	F	F
23	F	F	F	F	F	F	F	F	D	D
24	D	D	D	D	D	D	D	D	C	C
25	C	C	C	C	C	C	C	C	C	C
26	D	D	D	D	D	D	D	C	D	D
27	E	E	E	E	E	E	E	E	E	E
28	H	H	H	H	H	H	H	B	H	H
29	G	G	G	G	G	G	G	G	G	G
30	C	C	C	C	C	C	C	C	C	C
31	E	E	E	E	E	E	E	E	E	D

Appendix V: Details of the database for the prototype system: database

	TKTP	GILL	HEAD	RESP	GAST	GEUR	SKIN	TKBF	TNBF	HGLB
32	D	D	D	D	D	D	D	D	D	D
33	D	D	D	D	D	D	D	D	D	D
34	E	E	E	E	E	E	E	E	E	E
35	F	F	F	F	F	F	F	F	F	E
36	G	G	G	G	G	G	G	G	G	G
37	F	F	F	F	F	F	F	F	F	F
38	C	C	C	C	C	C	C	B	C	C
39	E	E	E	E	E	E	E	E	E	E
40	E	E	E	E	E	E	E	E	E	E
41	F	F	F	F	F	F	F	F	F	F
42	C	C	C	C	C	C	C	C	C	C
43	F	F	F	F	F	F	F	F	F	F
44	F	F	F	F	F	F	F	F	F	F
45	E	E	E	E	E	E	E	E	E	E
46	E	E	E	E	E	E	E	E	E	E
47	G	G	G	G	G	G	G	G	G	G
48	D	D	D	D	D	D	D	D	D	D
49	F	F	F	F	F	F	F	F	F	F
50	D	D	D	D	D	D	D	B	B	C
51	E	E	E	E	E	E	E	C	C	E
52	G	G	G	G	G	G	G	G	G	G
53	F	F	F	F	F	F	F	F	F	F
54	D	D	D	D	D	D	D	C	B	B
55	G	G	G	G	G	G	G	C	D	C
56	G	G	G	G	G	G	G	G	G	G
57	H	H	H	H	H	H	H	D	H	H
58	I	I	I	I	I	I	I	E	I	I
59	F	F	F	F	F	F	F	E	F	F
60	D	D	D	D	D	D	D	C	C	D
61	E	E	E	E	E	E	E	D	E	E
62	E	E	E	E	E	E	E	D	E	E

Appendix V: Details of the database for the prototype system: database

	TKTP	GILL	HEAD	RESP	GAST	GEUR	SKIN	TKBF	TNBF	HGLB
63	G	G	G	G	G	G	G	G	G	G
64	G	G	G	G	G	G	G	G	G	G
65	E	E	E	E	E	E	K	F	F	F
66	K	E	E	E	E	E	E	B	E	D
67	K	D	D	D	D	D	D	B	D	C
68	K	B	B	B	B	B	B	D	B	B
69	G	G	G	G	G	G	G	C	C	C
70	F	F	F	F	F	F	F	F	F	F
71	D	D	D	D	D	D	D	K	D	C
72	E	E	E	E	E	E	E	C	E	K
73	E	E	E	E	E	E	E	E	K	E
74	E	E	E	E	E	E	E	E	K	E
75	D	D	D	D	D	D	D	D	D	D
76	F	F	F	F	F	F	F	F	F	F
77	H	H	H	H	H	H	H	H	H	H
78	F	F	F	F	F	F	F	F	F	F
79	F	F	F	F	F	F	F	F	F	F
80	G	G	G	G	G	G	G	G	G	G
81	A	C	C	C	C	C	C	C	D	C
82	1	2	2	2	2	2	2	1	2	1

Appendix V: Details of the database for the prototype system: database

continued..

	DWCC	URTS	STPR	RFHU	RFHO	RANC	RTBC	RFPC	REVT	IMPD
1	D	D	E	C	C	K	E	K	C	D
2	B	B	B	B	B	K	B	K	B	B
3	C	C	C	D	C	K	C	K	C	C
4	C	C	D	C	C	B	C	B	C	B
5	C	C	D	D	D	K	C	K	C	C
6	C	C	C	C	C	C	C	C	C	C
7	C	C	C	B	B	C	C	C	B	B
8	C	C	C	C	C	C	C	C	C	C
9	D	D	D	D	D	D	D	D	D	D
10	B	B	B	B	B	B	B	B	B	B
11	C	C	C	C	C	C	C	C	C	C
12	B	C	C	B	C	C	C	C	C	C
13	B	C	B	C	C	C	C	C	C	C
14	B	B	C	C	C	C	C	C	C	C
15	C	C	C	C	C	C	C	C	C	C
16	C	C	C	D	C	D	D	D	C	C
17	C	C	E	E	E	A	E	K	D	D
18	C	C	E	D	D	A	E	K	D	D
19	G	G	G	C	C	C	G	G	G	G
20	F	F	F	F	E	A	F	F	E	C
21	F	D	F	F	F	K	F	A	E	D
22	F	F	F	F	F	F	F	D	E	F
23	F	F	F	F	C	F	F	D	E	D
24	D	D	D	F	F	D	D	C	D	C
25	C	C	C	D	D	C	C	C	C	C
26	D	C	D	E	D	D	C	D	D	D
27	E	E	B	E	D	E	B	E	C	A
28	B	H	K	A	K	H	H	H	B	K
29	G	G	G	E	E	G	G	G	D	G
30	C	C	B	C	C	C	C	C	C	B
31	D	E	C	D	D	E	E	E	C	D

Appendix V: Details of the database for the prototype system: database

	DWCC	URTS	STPR	RFHU	RFHO	RANC	RTBC	RFPC	REVT	IMPD
32	D	D	D	D	D	D	D	D	D	D
33	D	D	C	C	C	D	D	D	D	D
34	E	E	D	E	E	E	E	E	D	D
35	F	F	C	F	F	F	F	F	F	E
36	G	G	G	F	F	G	G	G	G	G
37	E	F	F	F	F	F	F	F	F	F
38	C	C	C	C	C	C	C	C	C	C
39	E	E	E	E	E	E	E	E	E	E
40	E	E	E	E	E	E	E	E	E	E
41	F	F	F	F	B	F	F	F	F	E
42	C	C	C	C	C	C	B	C	C	C
43	D	F	F	E	E	F	E	F	E	F
44	D	B	F	F	E	F	F	F	E	F
45	C	B	F	E	E	E	E	E	E	E
46	E	E	E	E	E	E	E	E	E	E
47	G	G	G	F	G	G	G	G	G	G
48	D	D	D	E	E	D	D	D	D	C
49	F	F	F	G	G	F	F	F	F	E
50	C	C	D	C	C	D	D	D	C	D
51	E	E	C	D	D	E	C	E	C	A
52	G	G	G	H	H	G	H	G	G	G
53	F	F	F	E	E	F	F	F	E	F
54	D	D	C	D	D	D	D	C	C	B
55	C	G	G	A	K	K	K	K	K	G
56	G	G	G	G	G	G	G	G	D	G
57	H	H	H	F	F	H	H	H	E	G
58	C	I	I	A	K	K	K	K	K	K
59	F	F	F	F	E	F	F	F	D	F
60	C	D	D	D	C	D	D	D	C	D
61	E	E	E	E	D	E	E	E	D	E
62	E	E	E	D	E	E	E	E	D	E

Appendix V: Details of the database for the prototype system: database

	DWCC	URTS	STPR	RFHU	RFHO	RANC	RTBC	RFPC	REVT	IMPD
63	G	G	G	F	E	E	C	G	G	G
64	G	G	G	G	G	G	G	G	G	G
65	F	F	F	F	E	E	E	E	E	E
66	D	D	E	D	D	E	E	E	D	E
67	C	C	D	D	D	D	D	D	D	D
68	C	C	B	D	C	B	B	B	B	B
69	G	G	G	D	D	G	G	G	D	G
70	D	K	F	F	E	F	F	F	F	F
71	D	D	D	C	D	D	D	D	D	D
72	E	D	D	E	E	E	E	D	E	D
73	E	E	D	E	D	E	E	E	E	D
74	E	E	E	E	D	E	E	E	E	D
75	K	C	D	D	D	D	D	D	D	D
76	F	K	F	F	E	F	F	F	D	F
77	H	K	H	E	E	H	H	H	E	H
78	F	F	K	F	F	F	F	F	F	F
79	F	F	K	F	F	F	F	F	F	F
80	G	G	K	G	G	G	G	G	G	G
81	E	D	E	E	D	D	E	D	E	D
82	1	2	2	0	0	0	0	0	0	0

Appendix V: Details of the database for the prototype system: database

continued..

	LSWT	REST	CVAC	ANLO	ASPR	BEND	CHLO	CHLP	COSY	EPHD
1	K	E	A	D	K	K	D	D	D	K
2	K	C	A	B	K	K	B	B	B	B
3	K	C	K	C	D	K	C	C	C	C
4	B	B	K	C	B	B	C	C	C	C
5	B	C	K	C	B	B	C	C	C	C
6	C	C	C	C	C	C	B	C	C	C
7	C	C	C	B	C	C	B	C	C	C
8	C	C	C	C	C	C	D	C	C	C
9	D	D	D	D	D	D	E	D	D	D
10	B	B	B	B	B	B	B	B	B	B
11	C	C	C	C	C	C	C	C	C	C
12	C	B	C	C	C	C	C	C	B	B
13	C	C	C	C	K	C	C	C	C	C
14	C	C	C	C	C	C	C	C	C	C
15	C	C	C	B	C	C	C	C	C	C
16	C	C	D	D	D	D	D	D	D	D
17	K	D	K	E	E	D	D	E	E	E
18	K	B	K	E	E	D	D	E	E	E
19	G	D	K	G	G	G	G	G	G	G
20	K	E	K	F	F	F	F	F	F	F
21	K	D	K	F	F	F	F	F	F	F
22	K	F	K	F	F	F	F	F	F	F
23	K	D	K	F	F	F	F	F	F	F
24	K	C	K	D	F	D	C	D	D	D
25	C	C	C	C	B	C	C	C	C	C
26	D	C	D	D	B	D	B	C	D	D
27	K	D	E	E	E	K	E	E	E	E
28	K	B	K	K	C	K	B	G	K	K
29	G	C	K	C	C	K	G	G	G	G
30	K	C	C	C	C	K	C	C	C	C
31	K	D	K	E	E	K	E	E	E	E

Appendix V: Details of the database for the prototype system: database

	LSWT	REST	CVAC	ANLO	ASPR	BEND	CHLO	CHLP	COSY	EPHD
32	D	D	D	D	K	D	D	D	D	D
33	D	D	D	D	D	D	D	D	D	D
34	K	D	K	E	K	K	E	E	E	E
35	K	F	F	F	F	F	F	F	E	F
36	G	G	G	D	D	G	G	G	G	G
37	F	F	F	F	E	F	F	F	F	F
38	C	C	C	C	B	C	B	C	C	C
39	E	E	E	E	D	E	E	E	E	E
40	E	E	E	E	E	E	E	E	E	E
41	F	F	F	F	F	F	F	F	F	F
42	C	C	C	C	C	C	C	C	B	C
43	F	E	F	F	D	F	F	F	F	F
44	F	F	K	F	F	F	F	F	F	F
45	E	E	E	F	C	E	E	E	E	E
46	E	E	E	F	C	E	E	E	E	E
47	G	G	G	F	G	G	G	B	G	G
48	D	D	D	B	C	D	D	D	D	D
49	F	F	F	F	F	F	F	F	F	F
50	D	C	K	D	D	D	C	D	E	D
51	K	E	E	E	E	E	D	E	E	E
52	B	G	G	G	G	F	G	G	G	G
53	K	F	K	F	F	K	F	F	F	F
54	K	C	D	D	D	K	D	D	D	D
55	K	G	K	G	G	K	E	K	K	K
56	G	C	G	G	G	C	G	G	G	G
57	K	C	H	H	J	K	F	H	H	H
58	K	C	K	K	I	K	F	K	K	K
59	F	F	F	F	F	F	E	F	F	F
60	D	D	D	D	D	D	C	D	C	C
61	E	E	E	E	E	E	D	E	C	B
62	E	E	K	E	E	E	D	E	D	E

Appendix V: Details of the database for the prototype system: database

	LSWT	REST	CVAC	ANLO	ASPR	BEND	CHLO	CHLP	COSY	EPHD
63	K	F	K	G	G	G	G	D	G	G
64	K	G	G	G	F	G	G	G	G	G
65	E	E	E	B	E	E	E	E	E	E
66	K	D	K	E	C	K	C	E	E	E
67	K	D	D	D	C	D	C	D	D	D
68	B	B	B	B	C	B	C	B	B	B
69	K	D	G	G	G	G	C	G	G	G
70	F	F	F	F	D	F	F	F	F	F
71	K	D	D	D	C	D	A	D	D	D
72	K	D	E	E	E	E	D	E	E	E
73	K	D	E	E	E	E	E	E	E	E
74	K	D	E	E	E	E	E	E	E	E
75	K	D	D	D	D	D	D	D	D	D
76	F	F	F	F	F	F	F	F	F	F
77	H	H	H	H	H	H	H	H	H	H
78	F	F	F	F	F	F	F	F	F	F
79	F	F	F	F	F	F	F	F	F	F
80	G	G	G	G	G	G	G	G	G	G
81	G	D	C	D	C	H	C	G	C	F
82	0	0	0	0	0	0	0	0	0	0

Appendix V: Details of the database for the prototype system: database

continued..

	IRON	FOAC	LAXT	MGTS	NICL	OREF	PARA	PENV	PHBA	PIPZ
1	E	E	K	K	K	D	C	C	D	D
2	C	C	K	K	B	B	B	B	B	B
3	C	C	C	D	C	C	C	C	C	C
4	B	B	C	B	C	C	E	D	C	C
5	C	C	C	C	C	C	E	D	C	C
6	C	C	C	C	C	C	C	C	C	C
7	B	B	C	C	C	C	C	C	C	C
8	C	C	C	C	C	C	C	C	C	C
9	D	D	D	D	D	D	D	D	D	D
10	B	B	B	B	B	B	B	B	B	B
11	C	C	C	C	C	C	C	C	C	C
12	B	B	C	C	C	C	C	B	C	C
13	C	C	C	B	C	B	B	C	C	C
14	C	C	C	C	C	C	C	B	C	C
15	C	C	C	C	C	C	C	C	C	C
16	D	D	D	D	D	D	D	D	D	D
17	B	B	K	D	K	E	E	E	E	K
18	B	B	K	D	K	E	E	E	E	K
19	G	G	K	G	K	G	G	G	G	K
20	C	C	K	F	K	F	F	F	F	K
21	C	C	F	F	F	F	F	F	F	F
22	F	F	F	F	F	F	F	F	F	F
23	C	C	F	F	F	F	F	F	F	F
24	C	C	D	D	K	D	C	D	E	D
25	C	C	C	C	C	C	B	C	C	C
26	D	D	D	D	D	C	B	C	D	D
27	E	E	E	E	D	E	E	E	E	D
28	H	H	K	K	K	H	D	H	D	K
29	F	G	K	G	G	G	D	D	G	G
30	C	C	K	C	C	B	C	C	C	B
31	E	E	K	E	E	B	E	E	E	D

Appendix V: Details of the database for the prototype system: database

	IRON	FOAC	LAXT	MGTS	NICL	OREF	PARA	PENV	PHBA	PIPZ
32	D	D	K	B	D	D	B	D	D	D
33	D	D	K	C	C	C	C	D	D	C
34	E	E	E	D	E	B	D	E	E	D
35	D	E	F	F	D	F	F	F	F	D
36	G	G	G	G	G	G	E	F	G	G
37	F	F	F	F	F	F	D	C	F	F
38	C	C	C	C	C	B	B	C	C	C
39	E	E	E	E	E	E	B	B	E	E
40	E	E	E	E	E	E	E	B	E	E
41	F	F	F	F	F	F	F	F	F	F
42	C	C	C	C	C	C	C	B	C	C
43	F	F	F	F	F	F	D	D	F	F
44	F	F	F	F	F	F	F	F	F	F
45	E	E	E	E	E	E	C	D	E	E
46	E	E	E	E	E	E	D	E	E	E
47	G	G	G	G	G	G	G	G	G	G
48	D	D	D	D	D	D	C	C	D	D
49	F	F	C	F	F	F	F	F	F	F
50	D	D	F	D	D	D	D	C	D	D
51	E	E	K	E	E	E	E	D	E	D
52	G	G	G	G	G	G	G	G	G	G
53	F	F	K	F	F	A	F	F	F	F
54	B	B	K	D	C	D	D	D	D	C
55	K	K	K	K	K	G	G	G	G	K
56	G	G	G	G	G	G	G	G	G	G
57	H	H	H	H	H	H	H	H	H	H
58	K	K	K	K	K	I	E	B	I	I
59	F	F	F	F	F	F	F	F	F	F
60	D	D	D	D	D	D	D	C	D	D
61	E	E	E	E	E	E	E	D	E	E
62	E	E	E	E	E	E	E	D	E	E

Appendix V: Details of the database for the prototype system: database

	IRON	FOAC	LAXT	MGTS	NICL	OREF	PARA	PENV	PHBA	PIPZ
63	G	G	G	G	G	G	G	G	G	G
64	G	G	G	G	G	G	F	E	G	G
65	E	E	E	E	E	E	E	C	E	E
66	E	E	K	E	E	D	C	D	D	E
67	D	D	D	D	D	D	C	C	D	D
68	B	B	B	B	B	B	C	B	B	B
69	C	C	G	G	G	G	D	G	G	G
70	F	F	F	F	F	F	D	D	F	F
71	C	C	D	D	D	D	B	D	C	D
72	B	B	E	E	E	E	E	E	E	E
73	A	B	E	E	E	E	E	E	E	E
74	B	A	E	E	E	E	E	E	E	E
75	D	D	D	D	D	D	D	C	D	D
76	F	F	F	F	F	F	F	F	F	F
77	H	H	H	H	H	H	H	H	H	H
78	F	F	F	F	F	F	F	F	F	A
79	E	F	F	F	F	F	F	F	F	F
80	F	G	G	G	A	G	G	G	G	G
81	D	E	G	E	G	D	C	E	H	F
82	0	0	0	0	0	0	0	0	0	0

continued..

	SEPT	SULF	TETR	TEOI	THBZ	VITS
1	C	K	K	D	K	D
2	B	K	K	B	B	B
3	C	C	K	C	C	C
4	D	C	B	C	C	C
5	D	C	B	C	C	C
6	C	C	C	C	C	C
7	C	C	C	C	C	C
8	C	C	C	C	C	C
9	D	D	D	D	D	D
10	B	B	B	B	B	B
11	C	C	C	B	C	C
12	B	C	C	C	C	C
13	C	B	C	C	B	C
14	C	B	B	C	C	C
15	C	B	C	C	C	C
16	D	D	D	D	D	D
17	E	K	K	E	K	D
18	E	K	K	E	K	D
19	G	G	K	G	K	F
20	F	K	K	F	K	C
21	F	F	F	F	F	C
22	F	F	F	F	F	F
23	F	F	F	F	F	C
24	D	K	K	F	K	C
25	C	C	C	F	C	C
26	C	C	D	D	D	D
27	E	E	E	E	D	C
28	C	K	K	H	K	K
29	E	F	G	G	G	G
30	C	B	C	C	B	C
31	C	C	E	E	D	E

Appendix V: Details of the database for the prototype system: database

	SEPT	SULF	TETR	TEOI	THBZ	VITS
32	D	D	D	D	D	D
33	D	D	D	D	D	D
34	E	D	E	E	D	E
35	F	F	F	F	C	D
36	F	G	G	G	G	D
37	E	F	E	F	F	F
38	C	C	C	C	C	C
39	D	E	E	E	E	E
40	E	E	E	B	E	E
41	F	F	F	D	F	C
42	C	C	C	C	C	C
43	C	F	F	F	F	F
44	E	F	F	F	F	F
45	D	C	C	E	E	F
46	D	E	B	E	E	E
47	G	G	G	G	G	G
48	D	C	D	D	D	C
49	F	F	F	F	F	F
50	C	D	D	D	D	E
51	C	E	E	E	E	C
52	G	G	G	G	G	G
53	F	F	F	F	F	F
54	D	D	D	D	C	C
55	D	K	G	G	K	K
56	G	G	G	G	G	G
57	H	H	H	H	H	H
58	B	K	I	I	K	K
59	F	F	F	F	F	D
60	C	D	D	D	D	D
61	E	E	E	E	E	E
62	C	E	E	E	E	E

Appendix V: Details of the database for the prototype system: database

	SEPT	SULF	TETR	TEOI	THBZ	VITS
63	D	G	G	G	G	G
64	C	G	G	G	G	D
65	E	C	E	E	E	D
66	C	E	D	E	E	E
67	C	D	C	D	D	D
68	D	B	C	B	B	B
69	G	G	G	G	G	D
70	D	C	C	F	F	F
71	C	D	D	D	D	D
72	E	E	E	E	E	D
73	E	E	E	E	E	C
74	E	E	E	E	E	E
75	C	D	D	D	D	D
76	F	F	F	F	F	F
77	H	H	H	H	H	H
78	F	F	F	F	F	F
79	F	F	F	F	A	F
80	G	G	G	G	G	G
81	D	E	E	E	F	C
82	0	0	0	0	0	0

(B) dBase III database of strategy descriptors

This database contains full text descriptors of strategies represented in fields 1 to 50 of the preceding database.

```
Structure for database: D:stradesc.dbf
Number of data records:      50
Date of last update   : 27/01/90
Field  Field Name  Type        Width    Dec
    1  STDESC      Character      30
** Total **                      31


Record#  STDESC
      1  select suitable age/sex group
      2  select current season
      3  select reproductive history
      4  select a general problem area
      5  take the patient's temperature
      6  select a general symptom
      7  select a symptom from the head
      8  select a respiratory symptom
      9  select a gastrointestinal symp
     10  select a genitourinary symptom
     11  select a skin symptom
     12  do a thick blood film
     13  do a thin blood film
     14  measure haemoglobin
     15  do a white cell count
     16  do a urine test
     17  do stool parasitology
     18  refer to hospital urgently
     19  refer to hospital
```

20 refer to ante natal clinic
21 refer to TB clinic
22 refer to family planning
23 ask to return to health centre
24 advise improving diet
25 advise to lose weight
26 advise to rest
27 check for vaccinations due
28 give antiseptic lotion
29 give aspirin
30 give bendrofluazide
31 give chloroquine
32 give chlorpheniramine
33 give cough syrup
34 give ephedrine
35 give iron tablets
36 give folic acid tablets
37 give laxatives
38 give magnesium trisilicate
39 give niclosamide
40 give oral rehydration fluids
41 give paracetamol
42 give penicillin V
43 give phenobarbitone
44 give piperazine
45 give septrin
46 give sulfadimidine
47 give tetracycline
48 give antibiotic eye ointment
49 give thiabendazole
50 give vitamins

C) dBase III database of suggestion responses by strategy and characteristic numbers

Each record in the following database relates response strings and response texts for the user interface to strategy and characteristic numbers.

Structure for database: D:question.dbf
Number of data records: 80
Date of last update : 19/01/90

Field	Field Name	Type	Width	Dec
1	SNO	Numeric	3	
2	CNO	Numeric	3	
3	RESP	Character	1	
4	TEXT	Character	30	
** Total **			38	

Record#	SNO	CNO	RESP	TEXT
1	1	1	1	infant less than 6 months old
2	1	2	2	child 6 months to 5 years old
3	1	3	3	child over 5 years old
4	1	4	4	adult female
5	1	5	5	adult male
6	2	6	1	early wet season
7	2	7	2	late wet season
8	2	8	3	early dry season
9	2	9	4	late dry season
10	3	17	1	pregnant less than 6 months
11	3	18	2	pregnant more than 6 months
12	3	19	3	abnormal vaginal bleeding
13	3	20	4	amenhorrea for 2 months & more

14	3	21	5	recently delivered or aborted
15	3	22	6	previous difficult pregnancy
16	3	23	7	unsuccessful in conceiving
17	3	24	8	lactating
18	4	10	1	generally unwell
19	4	11	2	problems around the head
20	4	12	3	respiratory problems
21	4	13	4	gastrointestinal problems
22	4	14	5	urinary & genital problems
23	4	15	6	skin problems
24	4	16	7	return visit with same problem
25	4	29	8	accidental injury
26	4	50	9	seriously sick
27	5	66	1	high fever
28	5	67	2	moderate fever
29	5	68	3	normal temperature
30	6	25	1	general pain and fatigue
31	6	26	2	has been feverish
32	6	27	3	low weight or loss of weight
33	6	28	4	current or very recent fits
34	6	53	5	dehydrated
35	6	54	6	anaemic and/or pale
36	6	55	7	semi-conscious or unconscious
37	6	56	8	general swelling or oedema
38	6	57	9	jaundice
39	7	38	1	headache
40	7	39	2	ear ache/infection
41	7	40	3	eye soreness/infection
42	7	41	4	poor vision
43	7	58	5	stiff neck/raised fontanelle
44	7	59	6	mental confusion
45	7	37	7	sore throat
46	8	42	1	cough
47	8	43	2	chest pain
48	8	60	3	rapid breathing

49	8	61	4	wheezing
50	8	62	5	chest indrawing
51	8	63	6	yellow or bloody sputum
52	9	30	1	diarrhoea
53	9	31	2	diarrhoea with blood
54	9	32	3	upper abdominal pain
55	9	33	4	lower abdominal pain
56	9	34	5	vomiting
57	9	49	6	severe constipation
58	9	51	7	malnourished
59	9	52	8	overweight
60	9	35	9	worms
61	10	44	1	blood in urine
62	10	45	2	pain on passing urine
63	10	46	3	genital discharge
64	11	47	1	sudden rash
65	11	48	2	general rash for some time
66	11	64	3	boils
67	11	65	4	septic rash
68	11	36	5	burns
69	12	71	1	malaria parasitaemia
70	13	69	1	sickle cell disease
71	13	73	2	iron deficiency
72	13	74	3	folate deficiency
73	14	72	1	low haemoglobin
74	15	75	1	high white cell count
75	16	76	1	protein in urine
76	16	77	2	sugar in urine
77	16	70	3	urine infection
78	17	78	1	roundworm or threadworm
79	17	79	2	hookworm trichuris etc.
80	17	80	3	tapeworm

Appendix VI: Software and data files for the prototype system

PROTOTYPE SYSTEM: BBCBASIC PROGRAM FOR THE Z88

```
10 REM Program for Bayesian algorithm using data from ASCII
     files
20 REM Peter Byass August 1988
30 :
40 REM ***** SET UP SYSTEM ***********************************
50 :
60 ON ERROR GOTO 10 : REM restart on error
70 *NAME CLINIC SYSTEM    : REM name for index panel
80 a$=CHR$(1) : REM video introduction string for special
     effects
90 REM B bold, G grey, R reverse, S scrolling, T tiny, U
     underlined
100 :
110 REM ***** SET UP DATA STRUCTURES ***************************
120 :
130 nostrats=50 : REM upper limit of strategy reference numbers
140 nochcts=80 : REM upper limit of characteristic reference
     numbers
150 noqus=80 : REM upper limit of questions
160 DIM thresh(nostrats) : REM strategy thresholds
170 DIM usage(nostrats) : REM strategy usages
180 DIM indgen%(nostrats) : REM indicator generating flags
190 DIM st$(nostrats) : REM array of strategy descriptors
200 DIM occur(nochcts) : REM array of characteristic occurrences
210 DIM ch$(nochcts) : REM array of characteristic descriptors
220 DIM relevs(nochcts,nostrats) : REM array of relevs (nochcts
     x nostrats)
230 DIM adv(nostrats) : REM array of advisabilities
240 DIM qs%(noqus) : REM array of question strategy nos
250 DIM qc%(noqus) : REM array of question characteristic nos
260 DIM qresp$(noqus) : REM array of question responses
```

Appendix VI: Software and data files for the prototype system

```
270 DIM qtext$(noqus) : REM array of question descriptors
280 DIM code(11) : REM probability code values
290 DIM qused%(noqus) : REM array of selected flags
300 :
310 REM ***** MAIN PROGRAM *************************************
320 :
330 PROCinitialise : PROCreset : PROCmessage
340 PROCread_strats : PROCread_chcts : PROCread_relevs :
      PROCread_qus
350 ON ERROR GOTO 360
360 REPEAT
370 PROCinitialise : PROCreset
380 endpoint=FALSE
390 REPEAT
400   PROCresults
410 UNTIL endpoint=TRUE
420 UNTIL TRUE=FALSE
430 END
440 :
450 REM ***** END OF MAIN PROGRAM *******************************
460 :
470 REM ***** FUNCTION TO RETURN DATA ITEM FROM ASCII FILE *****
480 :
490 DEFFN_read
500 LOCAL data$,byte$,byte
510 data$=""
520 REPEAT
530   byte=BGET#compat
540   IF byte=&1A THEN CLOSE#compat : endfile=TRUE
550   IF byte=&0A OR byte=&0D THEN endline=TRUE
560   IF NOT(byte=&0A OR byte=&0D OR byte=&2C) THEN
        data$=data$+CHR$(byte)
570 UNTIL byte=&0D OR byte=&2C OR byte=&1A
580 =data$
590 :
```

Appendix VI: Software and data files for the prototype system

```
600 REM ***** INTRODUCTORY MESSAGE DISPLAY ************************
610 :
620 DEFPROCmessage
630 PROCwin(5) : CLS
640 PRINT : PRINT a$+"B CLINIC"+a$+"B Patient Management System"
650 PRINT : PRINT "Please wait for a few minutes while the
      system"
660 PRINT "installs itself into the computer's memory..."
670 ENDPROC
680 :
690 REM ***** READ STRATEGIES FILE ********************************
700 :
710 DEFPROCread_strats
720 compat=OPENIN("STRATF.DAT") : endfile=FALSE
730 REPEAT
740   IF NOT endfile THEN index%=VAL(FN_read)
750   IF NOT endfile THEN usage(index%)=code(ASC(FN_read)-65)
760   IF NOT endfile THEN indgen%(index%)=VAL(FN_read)
780   IF NOT endfile THEN st$(index%)=FN_read
790   PRINT TAB(55,5);index%;
800 UNTIL endfile
810 PRINT TAB(55,5);SPC(5);
820 ENDPROC
830 :
840 REM ***** READ CHARACTERISTICS FILE ***************************
850 :
860 DEFPROCread_chcts
870 compat=OPENIN("CHCTF.DAT") : endfile=FALSE
880 REPEAT
890   IF NOT endfile THEN index%=VAL(FN_read)
900   IF NOT endfile THEN occur(index%)=code(ASC(FN_read)-65)
910   IF NOT endfile THEN ch$(index%)=FN_read
920   PRINT TAB(55,5);index%;
930 UNTIL endfile
940 PRINT TAB(55,5);SPC(5);
```

```
 950 ENDPROC
 960 :
 970 REM ***** READ RELEVANCES FILES ******************************
 980 :
 990 DEFPROCread_relevs
1000 compat=OPENIN("RELEVF.DAT") : endfile=FALSE
1010 REPEAT
1020   IF NOT endfile THEN index%=VAL(FN_read) : endline=FALSE
1030   FOR sno=1 TO nostrats
1040     IF NOT endline AND NOT endfile THEN
         relevs(index%,sno)=code(ASC(FN_read)-65)
1050   NEXT sno
1060   PRINT TAB(55,5);index%;
1070 UNTIL endfile
1080 PRINT TAB(55,5);SPC(5);
1090 ENDPROC
1100 :
1110 REM ***** READ QUESTIONS FILE *********************************
1120 :
1130 DEFPROCread_qus
1140 compat=OPENIN("QUSF.DAT") : index%=0 : endfile=FALSE
1150 REPEAT
1160   IF NOT endfile THEN qs%(index%)=VAL(FN_read)
1170   IF NOT endfile THEN qc%(index%)=VAL(FN_read)
1180   IF NOT endfile THEN qresp$(index%)=FN_read
1190   IF NOT endfile THEN qtext$(index%)=FN_read
1200   PRINT TAB(55,5);index%;
1210   index%=index%+1
1220 UNTIL endfile
1230 PRINT TAB(55,5);SPC(5);
1240 ENDPROC
1250 :
1260 REM ***** RESET INITIAL PARAMETERS FOR A NEW CONSULTATION **
1270 :
1280 DEFPROCreset
```

```
1290 CLS
1300 FOR index%=0 TO nostrats
1310   adv(index%)=usage(index%)
1320   thresh(index%)=SQR(usage(index%))
1330 NEXT index%
1340 FOR index%=0 TO noqus
1350   qused%(index%)=qs%(index%)
1360 NEXT index%
1370 code(0)=1 : code(1)=0.5 : code(2)=0.2 : code(3)=0.1 :
       code(4)=0.05
1380 code(5)=0.02 : code(6)=0.01 : code(7)=0.005 : code(8)=0.002
1390 code(9)=0.001 : code(10)=0
1400 ENDPROC
1410 :
1420 REM ***** SETUP SCREEN WINDOWS, ETC. **************************
1430 :
1440 DEFPROCinitialise
1450 CLS : PROCwin(7) : CLS : PRINT a$+"U"+"  CLINIC  "+a$+"U"
1460 PRINT : PRINT "   PRESS " : PRINT "  "+a$+"RESC"+a$+"R KEY"
       : PRINT "    TO" : PRINT "  RESTART"
1470 PRINT
       a$+"7#3"+CHR$(102)+CHR$(32)+CHR$(52)+CHR$(40)+CHR$(129)
1480 PRINT
       a$+"7#4"+CHR$(33)+CHR$(32)+CHR$(100)+CHR$(33)+CHR$(131)
1490 PRINT
       a$+"7#5"+CHR$(33)+CHR$(33)+CHR$(100)+CHR$(39)+CHR$(131)
1500 PRINT a$+"2C3"+a$+"2G+"+a$+"S"+a$+"2C4"+a$+"2C5"+a$+"2G+";
1510 PROCwin(3) : PRINT a$+"U  PATIENT  DETAILS  "+a$+"U" :
       PROCwin(4)
1520 ENDPROC
1530 :
1540 REM ***** SELECT SCREEN WINDOW x ******************************
1550 :
1560 DEF PROCwin(x)
1570 PRINT a$+"2G+";
```

```
1580 PRINT a$+"2H4"+a$+"2G-"
1590 PRINT a$+"2H"+STR$(x);
1600 PRINT a$+"2G-";
1610 ENDPROC
1620 :
1630 REM ***** FIND NEXT ENQUIRY OR ELSE DO FINAL OUTPUT ********
1640 :
1650 DEFPROCresults
1660 topino=0 : a=1
1670 REPEAT
1680   IF indgen%(a)>=1 AND adv(a)>=thresh(a) THEN topino=a
1690   a=a+1
1700 UNTIL topino>0 OR a=nostrats
1710 IF topino > 0 THEN PROCenq(topino) ELSE PROCsout
1720 ENDPROC
1730 :
1740 REM ***** DISPLAY SUGGESTED OUTCOME STRATEGIES **************
1750 :
1760 DEFPROCsout
1770 PROCwin(4) : CLS : PRINT a$+"B CONSIDER DOING SOME OR ALL OF
       THE FOLLOWING FOR THIS PATIENT: "+a$+"B";
1780 PROCwin(5) : CLS
1790 rxflag=FALSE
1800 rflag=1
1810 FOR a=0 TO nostrats
1820   IF adv(a)>thresh(a) AND indgen%(a)=0 THEN rflag=rflag+1 :
       PRINT TAB((rflag MOD 2)*35,rflag DIV 2);st$(a) :
       rxflag=TRUE
1830 NEXT a
1840 IF NOT rxflag THEN PRINT : PRINT "no suggestions offered"
1850 endpoint=TRUE
1860 GOTO 1850 : REM loop until ESC pressed
1870 ENDPROC
1880 :
1890 REM ***** PROCESS AN INDICATOR-GENERATING STRATEGY *********
```

```
1900 :
1910 DEFPROCenq(s)
1920 PROCwin(4) : PRINT a$+"B SUGGESTION: "+a$+"B"+st$(s)
1930 PROCwin(5) : CLS : PRINT a$+"T"+a$+"R ANSWER BY PRESSING ONE
       OF THESE KEYS: ";SPC(29);a$+"R"+a$+"T" : rs$=""
1940 posflag=1
1950 FOR index%=0 TO noqus
1960   IF qused%(index%)=s THEN posflag=posflag+1 :
       rs$=rs$+qresp$(index%) : PRINT TAB((posflag MOD
       2)*35,posflag DIV 2);a$+"B"+qresp$(index%)+"
       "+a$+"B"+qtext$(index%);
1970 NEXT
1980 PRINT TAB(0,6);a$+"BN "+a$+"B"+"No suitable answers, or data
       not available"
1990 PRINT TAB(39,0);a$+"R"+a$+"T";
2000 FOR index%=1 TO LEN(rs$)
2010   PRINT MID$(rs$,index%,1)+",";
2020 NEXT index%
2030 PRINT " or N"+a$+"R"+a$+"T";
2040 in$=GET$
2050 IF ASC(in$)>96 AND ASC(in$)<123 THEN in$=CHR$(ASC(in$)-32)
2060 IF in$="N" THEN adv(s)=0 : ENDPROC
2070 pos%=INSTR(rs$,in$)
2080 IF pos%=0 THEN PROCinperr(s) ELSE PROCselch(s,in$)
2090 ENDPROC
2100 :
2110 REM ***** TRAP ILLEGAL INPUT **********************************
2120 :
2130 DEFPROCinperr(s)
2140 PROCwin(4) : CLS : PRINT CHR$(7)+"Wrong input!     Press any
       key to continue";
2150 in$=GET$
2160 PROCenq(s)
2170 ENDPROC
2180 :
```

```
2190 REM ***** PROCESS A SELECTED PATIENT INDICATOR **************
2200 :
2210 DEFPROCselch(s,in$)
2220 PROCwin(3)
2230 index%=-1
2240 REPEAT
2250   index%=index%+1
2260 UNTIL qs%(index%)=s AND qresp$(index%)=in$
2270 sc=qc%(index%)
2280 qused%(index%)=0
2290 PRINT ch$(sc);
2300 PROCwin(4) : CLS : PROCwin(5) : CLS : PROCwin(3)
2310 PROCcalc(sc)
2320 ENDPROC
2330 :
2340 REM ***** RECALCULATE ADVISABILITIES USING INDICATOR i *****
2350 :
2360 DEFPROCcalc(i)
2370 FOR a=0 TO nostrats
2380   IF ((relevs(i,a)*adv(a))+(occur(i)*(1-adv(a)))<>0) AND
       (relevs(i,a)<>1) THEN
       adv(a)=(relevs(i,a)*adv(a))/(relevs(i,a)
       *adv(a)+occur(i)*(1-adv(a)))
2390   IF (relevs(i,a)=0)OR(relevs(i,a)=1) THEN
       adv(a)=relevs(i,a)
2400 NEXT a
2410 ENDPROC
2420 :
```

Appendix VI: Software and data files for the prototype system

DBASE III PROGRAM TO CONVERT DATABASES (Appendix V) TO DELIMITED ASCII FILES SUITABLE FOR THE PRECEDING PROGRAM

```
* dBase III program to build prototype data files
* PB 25/10/89

clear all

* use DATABASE.DBF and STRADESC.DBF to build a delimited ASCII
*   file of strategies called STRATF.DAT

use database
select 2
use stradesc
select 1
set talk off
set alte to stratf.dat
set alte on
store 1 to fno
do while field(fno) <> "OCCR"
 store field(fno) to fn
 ?? str(fno,2)+','
 locate for char = "USAGE"
 ?? &fn+','
 locate for char = "INDIC"
 ?? &fn+','
 select 2
 store str(fno,2) to rno
 &rno
 ?? stdesc
 select 1
 store fno+1 to fno
 ?
enddo
set alte off
```

```
* use DATABASE.DBF to build a delimited ASCII file of
*   characteristics called CHCTF.DAT

clear all
use database
set alte to chctf.dat
set alte on
do while recno() <= reccount()-2
 ?? str(recno(),3)+','+occr+','+char
 ?
 skip
enddo
set alte off


* use DATABASE.DBF to build a delimited ASCII file of relevances
*   called RELEVF.DAT

clear all
use database
set alte to relevf.dat
set alte on
do while recno() <= reccount()-2
 store 1 to fno
 ?? str(recno(),3)
 do while field(fno) <> "OCCR"
  store field(fno) to fn
  ?? ','+&fn
  store fno+1 to fno
 enddo
 ?
 skip
enddo
set alte off
```

```
* use QUESTION.DBF to build a delimited ASCII file of questions
*   for the user interface called QUSF.DAT

clear all
use question
set alte to qusf.dat
set alte on
do while .not. eof()
  ?? str(sno,3)+','+str(cno,3)+','+resp+','+text
  ?
  skip
enddo
set alte off

return
```

Appendix VI: Software and data files for the prototype system

STRATEGY DATA FILE "STRATF.DAT"

```
 1,A,1,select suitable age/sex group
 2,A,1,select current season
 3,C,2,select reproductive history
 4,A,2,select a general problem area
 5,A,1,take the patient's temperature
 6,C,2,select a general symptom
 7,C,2,select a symptom from the head
 8,C,2,select a respiratory symptom
 9,C,2,select a gastrointestinal symp
10,C,2,select a genitourinary symptom
11,C,2,select a skin symptom
12,C,1,do a thick blood film
13,D,2,do a thin blood film
14,C,1,measure haemoglobin
15,E,1,do a white cell count
16,D,2,do a urine test
17,E,2,do stool parasitology
18,E,0,refer to hospital urgently
19,D,0,refer to hospital
20,D,0,refer to ante natal clinic
21,E,0,refer to TB clinic
22,D,0,refer to family planning
23,E,0,ask to return to health centre
24,D,0,advise improving diet
25,G,0,advise to lose weight
26,D,0,advise to rest
27,C,0,check for vaccinations due
28,D,0,give antiseptic lotion
29,C,0,give aspirin
30,H,0,give bendrofluazide
31,C,0,give chloroquine
32,G,0,give chlorpheniramine
```

```
33,C,0,give cough syrup
34,F,0,give ephedrine
35,D,0,give iron tablets
36,E,0,give folic acid tablets
37,G,0,give laxatives
38,E,0,give magnesium trisilicate
39,G,0,give niclosamide
40,D,0,give oral rehydration fluids
41,C,0,give paracetamol
42,E,0,give penicillin V
43,H,0,give phenobarbitone
44,F,0,give piperazine
45,D,0,give septrin
46,E,0,give sulfadimidine
47,E,0,give tetracycline
48,E,0,give antibiotic eye ointment
49,F,0,give thiabendazole
50,C,0,give vitamins
```

Appendix VI: Software and data files for the prototype system

CHARACTERISTIC DATA FILE "CHCTF.DAT"

```
 1,D,infant < 6 months
 2,B,child 6 mths to 5 yr
 3,C,child over 5 years
 4,C,adult female
 5,C,adult male
 6,C,early wet season
 7,C,late wet season
 8,C,early dry season
 9,D,late dry season
10,B,generally unwell
11,C,problems of the head
12,C,respiratory problems
13,C,gastrointestinal prb
14,C,urinary/genital prob
15,C,skin problems
16,D,returned not better
17,E,pregnant < 6 months
18,E,pregnant > 6 months
19,G,ab. vaginal bleeding
20,F,amenhorrea > 2 mths
21,F,just delivered/abort
22,F,prev. difficult preg
23,F,can't get pregnant
24,D,lactating
25,C,general pain/fatigue
26,D,recent fevers
27,E,low wt/losing wt
28,H,current/recent fits
29,G,accidental injury
30,C,diarrhoea
31,E,diarrhoea with blood
32,D,upper abdominal pain
```

```
33,D,lower abdominal pain
34,E,vomiting
35,F,worms
36,G,burns
37,F,sore throat
38,C,headache
39,E,ear ache/infection
40,E,eye soreness/infect.
41,F,poor vision
42,C,cough
43,F,chest pain
44,F,blood in urine
45,E,pain on urinating
46,E,genital discharge
47,G,sudden rash
48,D,rash for some time
49,F,severe constipation
50,D,seriously sick
51,E,malnourished
52,G,overweight
53,F,dehydration
54,D,anaemia
55,G,semi- or unconscious
56,G,swelling or oedema
57,H,jaundice
58,I,neck stiff/font'lle
59,F,mental confusion
60,D,rapid breathing
61,E,wheezing
62,E,chest indrawing
63,G,yellow/bloody sputum
64,G,boils
65,E,septic rash
66,E,high fever
67,D,moderate fever
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68,B,temperature normal
69,G,sickle cell disease
70,F,urine infection
71,D,malaria parasites
72,E,low haemoglobin
73,E,iron deficient
74,E,folate deficient
75,D,high white cell cnt.
76,F,protein in urine
77,H,sugar in urine
78,F,roundworm/threadworm
79,F,hookworm etc.
80,G,tapeworm
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RELEVANCE DATA FILE "RELEVF.DAT"

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 1,K,D,K,D,D,D,D,D,D,D,D,C,C,D,D,D,E,C,C,K,E,K,C,D,K,E,A,D,K,K,D,D,D,K,E,E,K,K,K,D,C,C,D,D,C,K,K,D,K,D
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22,F,F,K,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,D,E,F,K,F,K,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F
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68,B,B,B,B,K,B,B,B,B,B,B,D,B,B,C,C,B,D,C,B,B,B,B,B,B,B,B,B,C,B,C,B,B,B,B,B,B,B,B,B,C,B,B,B,D,B,C,B,B,B
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74,E,E,E,E,E,E,E,E,E,E,E,E,K,E,E,E,E,E,D,E,E,E,E,D,K,D,E,E,E,E,E,E,E,E,B,A,E,E,E,E,E,E,E,E,E,E,E,E,E,E
75,D,D,D,D,D,D,D,D,D,D,D,D,D,K,C,D,D,D,D,D,D,D,D,K,D,D,D,D,D,D,D,D,D,D,D,D,D,D,D,C,D,D,C,D,D,D,D,D
76,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,K,F,F,E,F,F,F,D,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F
77,H,H,H,H,H,H,H,H,H,H,H,H,H,H,H,K,H,E,E,H,H,H,E,H,H,H,H,H,H,H,H,H,H,H,H,H,H,H,H,H,H,H,H,H,H,H,H,H,H
78,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,K,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,A,F,F,F,F,F,F
79,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,K,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,E,F,F,F,F,F,F,F,F,F,F,F,F,A,F
80,G,G,G,G,G,G,G,G,G,G,G,G,G,G,G,G,K,G,G,G,G,G,G,G,G,G,G,G,G,G,G,G,G,G,F,G,G,G,A,G,G,G,G,G,G,G,G,G,G
```

Appendix VI: Software and data files for the prototype system

QUESTIONS DATA FILE "QUSF.DAT"

```
1,  1,1,infant less than 6 months old
1,  2,2,child 6 months to 5 years old
1,  3,3,child over 5 years old
1,  4,4,adult female
1,  5,5,adult male
2,  6,1,early wet season
2,  7,2,late wet season
2,  8,3,early dry season
2,  9,4,late dry season
3, 17,1,pregnant less than 6 months
3, 18,2,pregnant more than 6 months
3, 19,3,abnormal vaginal bleeding
3, 20,4,amenhorrea for 2 months & more
3, 21,5,recently delivered or aborted
3, 22,6,previous difficult pregnancy
3, 23,7,unsuccessful in conceiving
3, 24,8,lactating
4, 10,1,generally unwell
4, 11,2,problems around the head
4, 12,3,respiratory problems
4, 13,4,gastrointestinal problems
4, 14,5,urinary & genital problems
4, 15,6,skin problems
4, 16,7,return visit with same problem
4, 29,8,accidental injury
4, 50,9,seriously sick
5, 66,1,high fever
5, 67,2,moderate fever
5, 68,3,normal temperature
6, 25,1,general pain and fatigue
6, 26,2,has been feverish
6, 27,3,low weight or loss of weight
```

```
 6, 28,4,current or very recent fits
 6, 53,5,dehydrated
 6, 54,6,anaemic and/or pale
 6, 55,7,semi-conscious or unconscious
 6, 56,8,general swelling or oedema
 6, 57,9,jaundice
 7, 38,1,headache
 7, 39,2,ear ache/infection
 7, 40,3,eye soreness/infection
 7, 41,4,poor vision
 7, 58,5,stiff neck/raised fontanelle
 7, 59,6,mental confusion
 7, 37,7,sore throat
 8, 42,1,cough
 8, 43,2,chest pain
 8, 60,3,rapid breathing
 8, 61,4,wheezing
 8, 62,5,chest indrawing
 8, 63,6,yellow or bloody sputum
 9, 30,1,diarrhoea
 9, 31,2,diarrhoea with blood
 9, 32,3,upper abdominal pain
 9, 33,4,lower abdominal pain
 9, 34,5,vomiting
 9, 49,6,severe constipation
 9, 51,7,malnourished
 9, 52,8,overweight
 9, 35,9,worms
10, 44,1,blood in urine
10, 45,2,pain on passing urine
10, 46,3,genital discharge
11, 47,1,sudden rash
11, 48,2,general rash for some time
11, 64,3,boils
11, 65,4,septic rash
```

```
11, 36,5,burns
12, 71,1,malaria parasitaemia
13, 69,1,sickle cell disease
13, 73,2,iron deficiency
13, 74,3,folate deficiency
14, 72,1,low haemoglobin
15, 75,1,high white cell count
16, 76,1,protein in urine
16, 77,2,sugar in urine
16, 70,3,urine infection
17, 78,1,roundworm or threadworm
17, 79,2,hookworm trichuris etc.
17, 80,3,tapeworm
```

"CLINIC" PATIENT MANAGEMENT SYSTEM: USER GUIDE

INTRODUCTION

The **CLINIC** system is designed to help in deciding how patients at health centre clinics should be managed. The system uses a small Z88 computer to make suggestions, based on information entered about the patient.

Please remember that **CLINIC** has been designed to make recommendations only: you should not necessarily follow all of the recommendations that it makes if you do not think that they would help the patient.

CLINIC has been specially designed so that it is easy to use even if you are not very familiar with computers. All of the answers that you need to give it can be entered by pressing a single key - you don't need to be able to type well.

SWITCHING ON

The Z88 computer has internal batteries, and can also receive external power, for example from a solar panel. To switch it on, find the two larger keys marked "SHIFT" and press them both simultaneously.

If it is on, then the same operation (pressing both "SHIFT" keys simultaneously) will switch it off.

Appendix VII: User's manual for the prototype system

If, while it is switched on, a small symbol appears in the bottom right hand corner of the display with the message "LO BAT", it means that the batteries are low and need replacing, or alternatively an external power source needs to be connected.

THE DISPLAY

The **CLINIC** display is divided into separate sections, or windows. At the left hand end of the display, there is a small window which displays the name **CLINIC**, together with the message "PRESS **ESC** KEY TO RESTART". The **ESC** or "ESCAPE" key is found at the top left hand corner of the keyboard. At any time it is pressed, the system will return to the position where it is ready to start a new consultation.

At the right hand side of the **CLINIC** display, there is a window headed "PATIENT DETAILS". At the start of a consultation, this window is blank apart from the heading. During the consultation, details that you have entered about the patient will appear in this window as a record of the case.

In the centre, there is a large area which is split into a "SUGGESTION" window at the top and a "RESPONSE" window at the bottom. In the suggestion window, you will find a suggestion as to what to do next in the course of the consultation. The first suggestion is always "select suitable age/sex group". However, later on in the consultation suggestions do not always come up in the same order: the **CLINIC** system decides which suggestions might be suitable for a particular patient.

Appendix VII: User's manual for the prototype system

The window below the suggestion shows possible responses that might be appropriate. Some suggestions have many possible responses, while others only have a few. Each response has a number next to it, and so to select a particular response, it is simply necessary to press the number key on the top row of the keyboard that corresponds to your chosen response. For every suggestion, there is the possibility of pressing "**N**" instead of a number if you think that none of the responses shown are suitable or if you do not know the correct response to the suggestion. This may happen, for example, if the suggestion involves a laboratory test that you do not have the facilities to undertake. The "**N**" key is found near the bottom of the keyboard, in the middle.

UNDERTAKING A CONSULTATION

A **CLINIC** consultation always starts from the same point, which is reached by pressing **ESC**. The first suggestion is to enter a suitable response for the age and sex group of the patient. After a response is entered, details of the response appear in the "patient details" window, and there is a brief pause while the **CLINIC** system considers what to suggest next. For some suggestions, there may be more than one relevant response. In this case, the **CLINIC** system will give the same suggestion again, with the same selection of responses, except that any already chosen will no longer be available. To go on to the next suggestion in this situation, when no more of the responses shown are relevant, simply press the "**N**" key. The total number of suggestions made in a

particular consultation will vary, but, when the **CLINIC** system has made all the suggestions it considers relevant, the display will change, and the message "CONSIDER DOING SOME OR ALL OF THE FOLLOWING FOR THIS PATIENT" will be shown at the top. Under this message there will be a list of patient management ideas which you may wish to consider for this particular patient. These may include items of advice, suggestions for referrals to other health facilities, and suggested prescriptions. It is important to remember that these are only intended as suggestions, and you may not think that all are suitable for the patient. Equally, you may have some particular reason for managing a patient in a different way. However, it is likely, for most patients, that at least some of the suggestions made will be appropriate for their complaints.

Remember that at any time in the consultation, if you have made mistakes in entering responses, or got confused in some other way, pressing the **ESC** key will take you back to the beginning and allow you to start again with the consultation.

from abroad

Computers in Africa: appropriate technology?

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The introduction of technology to developing countries has always been a contentious issue: is it appropriate to short-circuit steps in a nation's industrial and technical development by importing hard-learnt experience, or should countries work up to home-grown industrial and technical revolutions in their own good time? Protagonists of the former view would argue that it is pointless repeatedly to invent the wheel; the other camp would argue that imported technology forms an unsustainable basis for on-going development.

Against this background, how does computer technology fit into the Africa of the mid-80s? Just as there are a myriad of computer applications in developed countries, there are potentially many useful applications here. Certainly in the commercial sector there are many small and medium sized businesses which could benefit from computerised accounting and other administrative functions. Many sections of government could benefit similarly. So, if the principle of importing already developed technology is acceptable, what are the problems, and why are computers still relatively scarce in many parts of the continent?

Probably the largest single problem is the lack of available support, both in terms of hardware and software, and in training facilities for personnel. In The Gambia for example, there is not one computer dealer or agent. True, certain manufacturers offer some facilities on a regional (that is, West African) basis – but considering the difficulties of regional communications and travel, Europe is in many ways 'nearer'. Another significant problem is the lack of infrastructural support – notably clean power supplies – in many cases. This is not an insoluble problem, but in the absence of locally based support and expertise the solutions may be difficult to find.

Experience of minicomputer installations in these circumstances has not been encouraging. Traditional minis are sufficiently complex and bulky to require on-site maintenance – and so if the nearest dealer is several countries and over 1,000 km away, the prospects for a reliable computer operation with minimum down-time are not good. In addition, backup power supplies for such systems are often designed for relatively short interruptions and would not normally service air-conditioners and terminals – so faced with long cuts during the working day productivity using such a system can fall dramatically unless full uninterruptible power supply *and* generator facilities are available and working.

Whilst until recently an organisation requiring significant data processing power only had the option of a minicomputer system, with all its attendant problems in the African environment, this situation has rapidly changed. Microcomputers, at least at first sight, provide a solution to many of these problems. Certainly in The Gambia, 1986 has seen an almost exponential growth of microcomputer imports. They are portable, and so for servicing there is the new option of sending the machine by air to the dealer rather than *vice versa*. Furthermore, most organisations are likely to need, and be able to afford, more than one machine, so that the failure of one unit may be less catastrophic. The provision of backup power, while still necessary, is easier because of lower power consumption. However, all problems are still not solved. Potential users, who will probably not have in-house computer expertise, are faced with selecting and obtaining a system from overseas with no reliable and unbiased local advice. In addition, their chances of locally recruiting trained, qualified and experienced staff are very slim. Imported personnel are extremely costly to maintain. It is therefore not surprising that there are still relatively few organisations here which have been able to establish and sustain an effective computer facility. Our experience at the UK Medical Research Council's station in The Gambia has revealed a number of relevant issues that may be of interest in similar circumstances elsewhere. If a potential user genuinely has sufficient data for processing to justify a computer system, then, given the lack of other support, a professionally qualified system manager will not only be justified but essential. Such a person will also need to have basic hardware and fault-finding skills – at least to the level of identifying faulty boards. A number of microcomputers represent an inherently more flexible and reliable system than a single mini, and the choice has to be for the simplest system capable of meeting requirements. For example, micros with separate rather than integral monitors are less of a problem if the monitor goes down. Disc drives are the most environmentally sensitive part of the system. We have experienced floppy discs clogging up with all-pervasive Saharan dust during the dry season and growing moulds on the magnetic surface during the wet season! Hard disc drives, although inherently higher technology, have proved more reliable inside their sealed housings, providing that power failures during write operations can be avoided.

Our solution has been to install a LAN linking over 40 micros with disc facilities housed centrally in a controlled environment. We have used the TorchNet system, employing BBC micros with Z80 second processors as workstations. The network runs Torch's enhanced CP/M-80 and Unix concurrently. We now have a two year record of 24-hour, 7-day operation with an up-time of over 95%. Thus our conclusion is that a system of networked micros is a satisfactory solution to our particular problems. It demonstrates that computers *can* be appropriate for Africa – and so the answer to my title has to be 'it depends . . '. Appropriate computer technology can become as indispensible here as in Europe – but hardware that is inappropriate can become a grotesquely expensive white elephant, again just as in Europe. The difference between Europe and Africa lies in the criteria for appropriateness. My impression is that there will be a vast demand for computer systems in Africa in the near future as more people gain an understanding of the possibilities. What is needed is appropriate commercial support for appropriate products – and that, at present, is not forthcoming.

A PROBABILISTIC APPROACH TO HEALTH CARE DELIVERY IN TROPICAL AFRICA

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ABSTRACT

Many health care delivery systems in tropical Africa suffer from a shortage of expert manpower. Computerised decision support systems which are both clinically relevant and technologically feasible could therefore be very useful. This paper describes a probabilistic methodology developed to meet these criteria, which is currently being used to produce a micro-computer decision support system for the rural African health centre.

ZUSAMMENFASSUNG

Vielen Programmen für öffentliche Gesundheitspflege in den tropischen Gebieten Afrikas mangelt es an erfahrener Arbeitskraft. Unter diesen Umständen könnte ein Computerentscheidungsunterstützungssystem, das technologisch möglich und auch klinisch anwendbar ist, sehr nützlich sein. In diesen Beitrag wird eine mögliche Methodologie beschrieben, die diese Verhältnisse in Betracht nimmt. Diese Arbeitsweise wird gegenwärtig verwendet, um ein Mikrocomputer-System als Entscheidungshilfe in ländlichen Gesundheits-Kliniken Afrikas vorzulegen.

INTRODUCTION

Given the wide range and scope of expert and decision support systems that have been developed during the last decade, a current priority should be the selection of areas of human activity in which such systems might play an important rôle. An obvious criterion for selection is whether or not a particular field suffers from a shortage of skilled and trained manpower, and one of its most obvious fulfilments is in the area of health care delivery in developing

countries, particularly in sub-Saharan Africa. The dramatic effects of a near-ideal, though arguably unrealistic, primary health care delivery system in a group of rural Gambian villages have been demonstrated[1]. Hence an appropriate decision support system that could improve health care delivery would be of considerable benefit.

On the other hand, rural African health services are not highly computerised nor technologically based, and so special technical criteria need to be applied to potential decision support systems[2]. Furthermore, the medical realities of the rural African situation are grossly different from primary care in Europe and North America, from where many medical expert systems have emerged.

Various attempts have been made to present appropriate health care materials in an assimilable format, such as flowcharts,[3,4] but these are somewhat unwieldy to use in the clinic setting, and preclude simultaneous assessment of concurrent conditions which are located on different branches of the flowchart tree. Furthermore, they do not have the necessary flexibility to cater for factors such as seasonality of disease. Computer implementations based on flowcharts have been developed[5] but do not entirely overcome these problems.

PRE-REQUISITE CRITERIA AND THEIR IMPLICATIONS

A number of essential requirements for an appropriate methodology were therefore identified. Firstly, a system must cover the whole area of health problems experienced at a rural clinic (although referral to a higher level of care would be an acceptable endpoint). Secondly, the possibility of two or more concurrent conditions must be catered for (ideally including interactions, but at least independently). Thirdly, a traditional medical diagnosis would not be the most useful endpoint: courses of action are required. Fourthly, the system must guide its user through the entire clinical consultation process from start to finish. Fifthly, the system must be capable of implementation on a small, portable microcomputer, and finally the facility of adjusting the knowledge base to allow for local conditions will be important in terms of general applicability.

The fifth requirement effectively precluded true artificial intelligence (AI) solutions with current technology. The second requirement precluded a flowchart-based approach, and so a probabilistic approach based on Bayes' theorem appeared to be a

suitable compromise. The final requirement implied a data-driven system, and, to keep both the algorithm and data structure reasonably simple, all matters relating to a consultation would need structurally similar representations. Since the first, third and fourth requirements implied the need for information about a wide range of often unassociated issues to be contained in the same data structure, it rapidly became clear that terms such as "diagnosis" and "disease" carried unhelpful preconceptions, and hence a neutral terminology was defined for the system.

DEFINITION OF TERMS

INDICATOR - an item of information pertaining to a particular patient's case. Symptoms, signs, histories, laboratory test results, season and personal details would all be included.

STRATEGY - an action to be taken. Treatments, referrals, undertaking tests, making examinations would all be included. Hence some strategies might generate further indicators.

CHARACTERISTIC - an item of information analogous to an indicator, but pertaining to a strategy rather than a patient.

RELEVANCE - the probability that a particular characteristic is present, given that a particular strategy is appropriate.

USAGE - the unmodified probability that a given strategy is appropriate, at the patient population level.

OCCURRENCE - the unmodified probability of a given indicator, at the patient population level.

ADVISABILITY - the probability that a given strategy is appropriate in a particular case.

THRESHOLD - the level of advisability beyond which a particular strategy is implemented.

Appendix VIII: Related publications

[Byass 1988]

METHOD

Starting from Bayes' theorem,[6] which can be expressed as

$$P(D|S) = \frac{P(S|D).P(D)}{P(S|D).P(D) + P(S|\bar{D}).P(\bar{D})}$$

(where D=disease, S=symptom and $\bar{D}$=no disease)
we can proceed using the above definitions to a basic data system of n strategies $S_1..S_n$ and m characteristics $C_1..C_m$. Each strategy S_i has a corresponding usage U_i and threshold T_i, while each characteristic C_j has a corresponding occurrence O_j. Characteristics and strategies are related by a set of nxm relevances R_{ij}.

A patient then has a set of indicators $I_1..I_x$, where $x \leqslant m$, and which can be used to generate a set of advisabilities $A_1..A_n$, corresponding to $S_1..S_n$.

The basic theorem in these terms can be expressed as

$$A_i(S_i|I_j) = \frac{R_{ij}(C_j|S_i) \cdot U_i}{\{R_{ij}(C_j|S_i) \cdot U_i\} + \{O_j \cdot (1 - U_i)\}}$$

which can be applied repeatedly for each I_j if initially $A_1..A_n$ are made equivalent to $U_1..U_n$ (that is, in the absence of any modifying factors advisabilities are equivalent to population usages) and thereafter A_i of the previous cycle becomes U_i for the next.

If A_i reaches either 1 or 0, it will remain at that value through any further iterations, and any R_{ij} value of 0 will force the corresponding A_i to 0. A non-Bayesian condition has also been built into the system whereby if R_{ij} is 1, A_i becomes 1. These conditions make it possible to force or prohibit a particular strategy on the basis of a specific characteristic.

If each S_i has a Boolean flag G_i showing whether or not S_i can generate further indicators, then the overall algorithm becomes

```
FOR 1 TO n LET A_i = U_i ENDFOR
finish=FALSE
  DO UNTIL finish
    GET(I_j)
    finish=TRUE
    FOR 1 TO n
      LET U_i = A_i
      CALCULATE(A_i)
```

```
      IF G_i AND (A_i > T_i) THEN DISPLAY(S_i) : finish=FALSE
    ENDFOR
  ENDDO
  FOR 1 TO n
    IF NOT(G_i) AND (A_i > T_i) THEN DISPLAY(S_i)
  ENDFOR
```

DISCUSSION

Adopting the methodology outlined above, it has become possible to develop a system which fulfils the defined requirements. Repeatedly calculating the advisabilities of a set of n strategies allows concurrent conditions to be considered simultaneously in the iterations towards final strategies, and is hence an improvement on the branch-by-branch traversal of a tree system which a flowchart provides.

The inclusion of the widest possible range of items under the general classification of indicators and characteristics admits maximum flexibility to the system. For example, having different seasons as indicators arising from the consultation (and a corresponding indicator-generating strategy of "what season?") allows very important seasonal profiles of diseases such as malaria to be incorporated. Determination of basic clinical data such as the age and sex of the patient can be forced by including appropriate strategies whose relevance is 1, and further relevant non-treatment strategies can emerge during the consultation, whilst irrelevancies are avoided. Thus guidance through the whole process of the clinical consultation is provided, as an integral part of the system. Similarly strategies that are obviously inappropriate in a particular case, such as gynaecological procedures on male patients, can easily be excluded using relevances of 0.

Initial work based on the Gambian health service suggests that a system with perhaps 50 strategies and 100 characteristics will be able to model the normal work of a rural health centre, which would normally be operated by a dresser/dispenser. This is largely determined by the relatively small number of treatments, tests and examinations available in the health centres rather than by the system itself, although clearly if the medical sophistication increased the size of the data would increase correspondingly.

However, it is possibly at the dresser/dispenser level that such a system will have the greatest impact since it may serve as an on-the-job training facility for less experienced staff and as a "second opinion" for more experienced personnel. Since, in either case, health centres are often situated in very remote locations with no communication facilities to larger centres, both of these functions may prove to be useful.

Currently work is proceeding to assemble a set of data to drive the system, which will be based on over 20,000 clinic consultations in The Gambia together with other sources of published and unpublished data on relevant health issues, after which field testing of the system will be able to proceed.

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REFERENCES

1. Lamb, W.H., Foord, F.A., Lamb, C.M.B., Whitehead, R.G., "Changes in Maternal and Child Mortality Rates in Three Isolated Gambian Villages over Ten Years", Lancet, 1984, ii, 912.

2. Byass, P. "Computers in Africa - Appropriate Technology?", Computer Bulletin, 1987, 3, 17.

3. Essex, B.J., "Diagnostic Pathways in Clinical Medicine", Churchill-Livingstone, Edinburgh, 1981.

4. Essex, B.J., "Management of Obstetric Emergencies in a Health Centre", Churchill-Livingstone, Edinburgh, 1981.

5. Auvert, B., Aegeter, P., Van Look., F., et al., "A Hand-Held Decision-Aid System Designed for Rural Health Workers", Comput. Biomed. Res., 1986, 19, 80.

6. Bayes, T., "A Problem in the Doctrine of Chances", Phil. Trans. Roy. Soc., 1764, 53, 370.

Appendix VIII: Related publications

[Byass et al. 1988]

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MICROCOMPUTER MANAGEMENT OF A VACCINE TRIAL

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Abstract—A microcomputer system used for the management of a trial of rotavirus vaccine in The Gambia is described. This system facilitated call and recall of infants due for vaccination. The resulting compliance is reported and compared retrospectively with vaccination records in the same community.

Microcomputers Health management Developing countries Primary health care Vaccination compliance

INTRODUCTION

In community-based health activities throughout the world increasing emphasis is being placed on preventive medicine. This usually involves the identification of at-risk individuals, who are required to attend a clinic for vaccination or screening. Systems to facilitate this activity are important to family practitioners and researchers worldwide, and are doubly important in a developing country where general infrastructures are much poorer. Few accounts of health-related applications of microcomputer technology in developing countries have been published (for example [1–3]).

We report here on the application of a microcomputer to the management of a trial of a rotavirus vaccine in The Gambia. Rotavirus is an important pathogen in children, particularly in the developing world. It is established as a major cause of severe childhood diarrhoea [4, 5]. The clinical and microbiological aspects of this trial are described elsewhere [6]. This paper describes issues relating to the organisation and management of data within the trial.

The trial took place in Bakau, The Gambia. Bakau is a peri-urban area of over 14 000 total population situated about 15 km from the capital, Banjul, on the Atlantic coast. The population has been described in detail by Pickering [7]. Most of the population comprises low wage earners and their dependents, living in compounds of variable size. Housing is typically mud or brick with corrugated metal roofing, and the community has a piped, chlorinated water supply running to a number of strategically placed standpipes. Diarrhoea is an established problem resulting on average in six episodes per year in children under two years of age [8]. A Government health centre with dresser/dispenser, nurse/midwife and two community health nurses is available to the population and was used as a base for this study.

The trial was designed to compare a new oral vaccine with a placebo, and at the same time to try to assess any potentially detrimental effect of simultaneous administration of oral rotavirus and oral polio vaccines. Three doses of the vaccine were administered, integrated within the existing Expanded Programme of Immunisation (EPI). The first dose was given at ten weeks of age with two further doses at four-weekly intervals. A cohort of 433 newly-born infants was recruited from the start of the study on 1 January 1985 until it ended in February 1986. Infants were allocated randomly to three immunisation groups. Group A

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Appendix VIII: Related publications

[Byass et al. 1988]

received three doses of oral rotavirus and oral polio vaccines, group B three doses of placebo and oral polio vaccine and group C three doses of oral rotavirus and intramuscular polio vaccines. The investigators remained blind to the oral vaccine groups (A and B).

Serological samples were requested at first and second vaccinations, four weeks after the third vaccination and subsequently at 78 weeks of age. Anthropometric data (weight and length) were collected at first and second vaccinations and at 30, 39, 52, 65, 78, 91 and 104 weeks of age. Vaccination and anthropometry clinics were held weekly. Since rotavirus is normally seen in The Gambia in a clearly defined annual epidemic in the early part of the dry season [8], twice-weekly morbidity data were collected during the epidemic period on all the cohort, to minimise recall errors, and weekly data during the remainder of the year.

METHODS

1. *Data processing facilities*

Computerised data processing was seen to be highly desirable because of the relatively large amount of data being generated by the trial. Similarly, it was necessary to incorporate day-to-day management of the trial within the overall data system, rather than dealing with data on a purely retrospective basis, since otherwise the management of age-related events longitudinally in a continuously recruited cohort would have been very complex. Since large mini- and mainframe computers are not a realistic proposition in our situation [9] there was a clear need to devise a suitable microcomputer based system.

Torch Computers' enhancement to the BBC microcomputer was used in conjunction with the dBase II database management system, running under the CP/M operating system. Although our particular configuration used hard discs, the system as described below could equally well be operated on a floppy disc system.

2. *Enumeration*

Prior to the start of the study, a complete map of the area was drawn detailing all componds (discrete residential units comprising several buildings and containing up to 200 people sharing varying degrees of kinship). Personal details of all residents (name, date of birth, sex) were recorded by a fieldworker and each person was given a six-digit identification number (made up of three digits relating to the compound of residence, and three digits as a personal identifier within the compound). These data were entered into a census database.

3. *Birth registration*

In the absence of rigorous official vital registration, it was necessary for field workers to actively identify new births to mothers resident in the study area, occurring at Bakau health centre, at the Royal Victoria Hospital, Banjul, or at home. Mothers were then approached for informed consent to their babies' participation in the study. The next available census identification number for the appropriate compound was then allocated to the infant.

4. *Computerised vaccination record and clinic call system*

From the registration of births, records of identification number, name, date of birth, sex and field worker assigned to the case were compiled for each infant. (Note that identification number, as described above, constitutes the "home address" which is not otherwise a formalised concept in this society.) Thus, the computer system was required to accept new subjects in this format on an on-going basis throughout the study, together with subsequent data relating to vaccinations, anthropometry, morbidity and clinic visits. Outputs comprised clinic call lists and other management aids, all in accordance with the basic study design. Call lists were generated for each weekly clinic indicating which children were due for vaccination, blood sampling and anthropometry. The list contained details of each child as well as the initial of the field worker responsible for each case. Each field worker then took a copy of the list, identified his or her own cases from it, and made home visits asking the mothers to bring their children on the clinic day. The inter-relations of these requirements are shown conceptually in Fig. 1.

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[Byass et al. 1988]

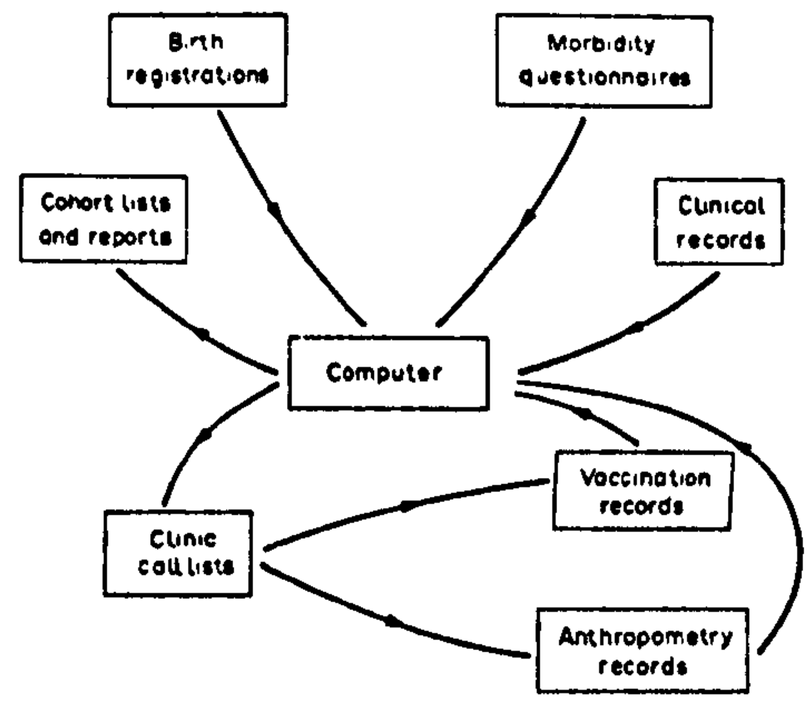

Fig. 1. Conceptual data system.

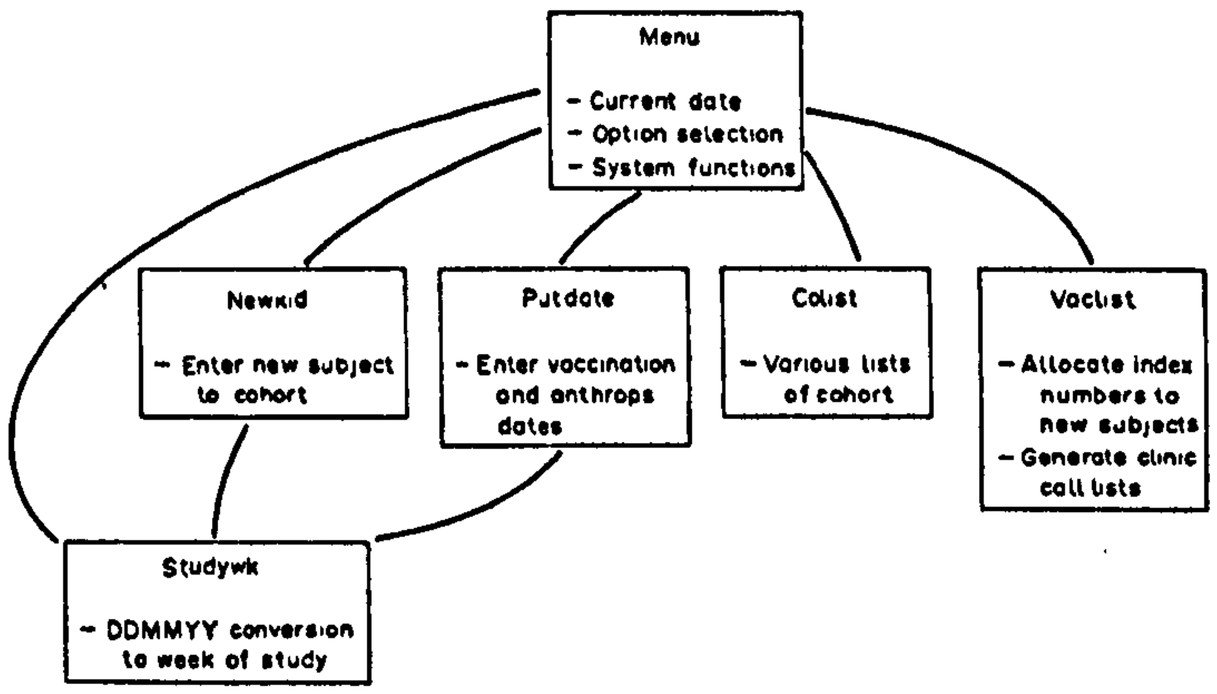

Fig. 2. Modular structure of the vaccination records package.

There was an additional requirement for clinical staff responsible for the project, who were inexperienced in the use of computers, to be able to interact with the system on a continuous basis and with a minimum of specialist advice. It was therefore necessary to provide a user-friendly interface.

The entire system was implemented within dBase II [10, 11], because of the ease of implementation, and in spite of non-optimal run-time efficiency, rather than producing a custom-written compiled program. The system was top-down decomposed into a set of modules (dBase II command files) as shown schematically in Fig. 2. The full code of this system is shown in the Appendix. The most complex part of the system was that which generated the weekly clinic call list on the basis of data entered up to that point. To make this as straightforward as possible, dates were internally represented as a number of weeks from the start of the study, but conventionally presented to the user interface (DD/MM/YY). A conversion routine used by several modules was included (module STUDYWK). All subjects were automatically allocated a vaccine number in the week before their first vaccination fell due, as part of the preparation of the clinic call list (module VACLIST). These numbers corresponded to numbered vials of vaccine which had been blindly randomised by the manufacturer, and thus determined into which of the three treatment groups a subject fell.

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[Byass et al. 1988]

For vaccinations, a child was called every week from the week in which the vaccination was first due, until a date of vaccination was entered onto the computer. Subjects known to be irrevocably lost to follow-up during the study were given vaccination dates of 00/00/00 to prevent continuous recall. For anthropometric data, it was arranged so that if a subject defaulted until the next scheduled anthropometry fell due, he or she would no longer be called for the previous one and a date of 00/00/00 was automatically entered for this call. For the sections of the call list relating to subjects due for anthropometry, spaces were provided for weight and length. One copy of the call list each week with these data inscribed thus formed the anthropometric records from the clinic.

The remaining modules dealt with more straightforward functions of subject registration (module NEWKID), entry of vaccination and anthropometry dates (module PUTDATE), and listings of the cohort in varying detail, and sorted on a choice of keys (module COLIST). In addition to the main user menu, system functions were built in to the main module (module MENU), such as automatic backup of the database on every run and a facility to restore from backup if necessary; we consider these features to be important given as the system was designed to be operated by non-specialists.

5. Morbidity and clinical data

Morbidity data were collected during regular home visits by field workers. These visits were made weekly except in the epidemic period when they were made twice weekly. A form was designed, consisting of questions on recent morbidity, feeding practices and temperature [12]. These forms were field-coded and subsequently entered into the computer. (A specimen of the form is available from the authors.)

The project clinicians held daily clinics open to all children in the cohort, and any consultations relating to diarrhoea were recorded on another computer form. All these records of morbidity and clinical episodes of diarrhoea were identified by the child's identification number and could thus be linked to the vaccination records.

RESULTS

We have analysed the records from the trial for a 12-month period, from 1 January to 31 December 1985, in terms of compliance with the various components of the study. Since the main objective of the study was the trial of the vaccine rather than a trial of methods, there is no formal control group (that is, using a non-computerised system) as we wished to conduct the entire study in the most efficient manner possible. However, we have made a retrospective study of vaccination records in the same community in a period preceding the trial in order to give some data for a comparative assessment of vaccine compliance.

The results for compliance within the study are presented in Table 1, and for the retrospective study of the pre-trial period in Table 2. A comparison between the two groups for vaccination status, within one month of dates on which vaccination should have been given, showed the vaccination compliance to be significantly higher during the trial than during the previous year for all vaccinations ($\chi^2 = 90$, 88 and 71 respectively for first, second and third vaccinations, 1 d.f., $p < 0.001$ in all cases). Restricting the comparison to the response to the first call in the trial with the previous one-month completion rate still showed significant differences for the first two vaccinations ($\chi^2 = 7.7$ and 4.9 respectively, 1 d.f., $p < 0.01$ and $p < 0.05$). Although both the first-call vaccination compliance in the trial and the within-one-month vaccination compliance in the preceding period fall off over the first three vaccinations, in neither case was this significant ($\chi^2 = 2.8$ and 0.1 respectively, 2 d.f.). The anthropometry call made at 39 weeks in the vaccination trial also showed a significantly higher one-month completion rate than the one-month compliance rate for measles and yellow fever vaccination (scheduled for 36 weeks) in the pre-trial period ($\chi^2 = 34$, 1 d.f., $p < 0.001$).

DISCUSSION

In this study we have shown that a system based on computerisation of data and the use

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Table 1. Compliance with various elements of the trial for subjects first called during 1985.

	Number eligible	Came at 1st call	Came at 2nd call	Came within one month	Came after one month
1st vaccination (birth + 10 weeks)	338 (100%)	273 (81%)	42 (12%)	332 (98%)	6 (2%)
2nd vaccination (1st vacc + 4 weeks)	294 (100%)	237 (81%)	36 (12%)	293 (100%)	1 (0%)
3rd vaccination (2nd vacc + 4 weeks)	250 (100%)	189 (76%)	43 (17%)	248 (99%)	2 (1%)
Blood sample (3rd vacc + 4 weeks)	216 (100%)	160 (74%)	40 (19%)	214 (99%)	2 (1%)
30 week anthrops (birth + 30 weeks)	174 (100%)	112 (64%)	34 (20%)	167 (96%)	7 (4%)
39 week anthrops (birth + 39 weeks)	106 (100%)	57 (54%)	31 (29%)	101 (95%)	5 (5%)
All visits	1378 (100%)	1028 (75%)	226 (16%)	1355 (98%)	23 (2%)

Table 2. Vaccination compliance (including attendance at vaccination clinics irrespective of vaccine availability) in a group of 153 Bakau children, 1982–1983.

	Total attended	Within 1 month of due date	More than 1 month late	Not attended
1st vaccination (birth + 10 weeks)	151 (99%)	104 (68%)	47 (31%)	2 (1%)
2nd vaccination (1st vacc + 4 weeks)	143 (93%)	101 (66%)	42 (27%)	10 (7%)
3rd vaccination (2nd vacc + 4 weeks)	128 (84%)	90 (59%)	38 (25%)	25 (16%)
4th vaccination (birth + 9 months)	103 (67%)	63 (41%)	40 (26%)	50 (33%)
All visits	525 (86%)	358 (59%)	167 (27%)	87 (14%)

of clinic call lists achieved better compliance for vaccination than a voluntary attendance system in operation previously. We believe that two factors contributed to this result. Firstly, the computer system allowed more stringent follow-up on vaccine defaulters, and secondly an active system of calling mothers to clinics was more effective than the existing procedures. We cannot easily separate these effects. The improvement in compliance on a single call suggests that active calling is an important factor, whilst the very small numbers of children who defaulted by more than one month suggests that rigorous follow-up is also very important. The trend towards falling compliance with successive vaccinations is interesting and we are studying this and related issues separately. A system of calling on the first due date could reasonably be implemented without the use of a computer and we suggest that this could be a worthwhile intervention in EPI, and could be a useful additional function of community health nurses. In terms of managing a trial, however, we have found the computer system to be invaluable and would recommend a similar approach in other situations. The system described here could also be modified to cover many community health situations, for example well-baby clinics within general practice.

Considering the design of the system, we believe that we were justified in developing, within a database management system, a package which exactly met our specific needs. The alternative strategy, of having a generalised package which can be tailored to a particular study (for example, the MIRACLE system [13]) has some attractions, particularly for a non-programmer. However, the overheads and resources demanded by a package rise very steeply with increasing generality. Thus we have a package with around 400 lines of code as compared with MIRACLE's 10 000 lines. Our system can therefore operate conveniently on

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a small microcomputer, and is thus more appropriate in many circumstances, for example in the conduct of field trials in developing countries.

SUMMARY

One of the problems both of large-scale community epidemiology and of public health delivery is getting subjects to the clinic at the appropriate time. The problem is heightened in developing countries as a result of poorer infrastructures. This study demonstrates that one way in which these difficulties can be alleviated is to apply a microcomputer in a management role. The use of a computerised call system, backed up with effective field work, resulted in very high compliance rates. Previously the vaccination compliance in the same community, assessed retrospectively, was reasonably good, but a significant improvement was seen during the trial. Although this cannot be attributed entirely to the computer system, it is difficult to see how the same effect could have been achieved without it. The fact that a small microcomputer can be used for such an application means that this approach could be applied in almost any situation.

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REFERENCES

1. J. R. Flikeid, D. R. Mackintosh and G. B. Cook, Clinical microcomputer software for developing countries, *Proceedings of MEDINFO-86*, Salamon, Blum and Jorgenson, Eds, p. 296, North-Holland, Amsterdam (1986).
2. B. Kante, U. K. Brinkmann and S. Bocoum Maiga, Medical applications of personal computer systems in Mali, *Proceedings of MEDINFO-86*, Salamon, Blum and Jorgenson, Eds, p. 304, North-Holland, Amsterdam (1986).
3. K. M. Rowan, P. Byass and R. W. Snow, On-line tropical epidemiology—a case-study from The Gambia, *Meth. Inf. Med.* 26, 73–76 (1987).
4. W.H.O. Scientific Working Group, Rotavirus and other viral diarrhoeas, *Bull. W.H.O.* 58, 183–198 (1980).
5. A. Z. Kapikian, R. G. Wyatt, H. B. Greenberg, H. R. Kalica, H. W. Kim, C. D. Brandt, W. J. Rodriguez, R. H. Parrott and R. M. Charrock, Approaches to immunisation of infants and young children against gastroenteritis due to rotaviruses, *Rev. Inf. Dis.* 2, 459–467 (1980).
6. P. Hanlon, L. Hanlon, V. Marsh, P. Byass, F. Shenton, M. Hassan-King, O. Jobe, H. Sillah, R. Hayes, B. H. M'Boge, H. C. Whittle and B. M. Greenwood, A trial of an attenuated bovine rotavirus vaccine (RIT 4237) in Gambian infants, *Lancet* I, 1342–1345 (1987).
7. H. Pickering, Social and economic factors associated with diarrhoea and growth in young children: child health in urban Africa, *Soc. Sci. Med.* 21, 121–127 (1985).
8. M. G. M. Rowland, S. G. H. Goh, K. Williams, A. D. Campbell, G. M. Beards, R. C. Sanders and T. H. Flewett, Epidemiological aspects of rotavirus infection in young Gambian children, *Ann. Trop. Paed.* 5, 23–28 (1985).
9. P. Byass, Computers in Africa—appropriate technology?, *Comput. Bull.* 3, 17 (1987).
10. Ashton-Tate, *dBase II Assembly Language Relational Database Management System*, California (1982).
11. M. de Pace, *Working with dBase II*, Granada, London (1984).
12. P. Byass, The design of computer forms for tropical medical research, *Meth. Inf. Med.*, 25, 229–232 (1984).
13. H. P. Sinn, A. Altendorf and A. Estelmann, MIRACLE: a time-oriented data validation and analysis system for clinical research, *Meth. Inf. Med.* 23, 139–142 (1984).

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From 1978 to 1981 he worked in technical education in Sierra Leone, and subsequently lectured at Bedford College of Higher Education, U.K., until 1984. He then returned to West Africa, since when he has headed the computer section at the U.K. Medical Research Council's Laboratories in The Gambia. In addition to analysing epidemiological studies, his research interests include applications of computers to field studies and to primary health care.

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About the Author—PHILIP HANLON graduated in parasitology from the University of Glasgow in 1975 and qualified in medicine in 1978. He was awarded an M.D., also from Glasgow, in 1987.

He held a number of hospital jobs in Scotland between 1978 and 1984, when he joined the staff of the Medical Research Council in The Gambia to lead a trial of rotavirus vaccine. In 1987 he returned to Glasgow to work in community medicine.

Dr Hanlon holds the diploma of the Royal College of Obstetrics and Gynaecology and is a member of the Royal College of Physicians and of the Royal College of General Practitioners.

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About the Author—LESLEY HANLON qualified in medicine from the University of Glasgow in 1980.

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In 1965 Dr Greenwood left the U.K. to work in Nigeria and most of the rest of his career has been spent in West Africa. For ten years he worked at Ahmadu Bello University, Zaria, Nigeria. Since 1980 he has been director of the Medical Research Council Laboratories in The Gambia. His research has been conducted on various aspects of the infectious diseases which are still important in West Africa such as malaria, meningococcal meningitis and pneumonia.

Dr Greenwood is a Fellow of the Royal College of Physicians of London and of the Royal Society of Tropical Medicine and Hygiene.

APPENDIX: CODE FOR VACCINATION CALL SYSTEM AS IMPLEMENTED IN dBASE II

```
* ROTAVIRUS VACCINE TRIAL
*
* COMPUTERISED CLINIC CALL LIST SYSTEM
*
* Medical Research Council, Fajara, The Gambia
*
* November 1984
*
*
* Main module is MENU, calling NEWKID, PUTDATE, COLIST and VACLIST;
* also STUDYWK is called from several modules for date processing.
*
* Details of children and vaccinations are stored in a database
* called COHORT with the following structure:
*
*
*    FIELD     NAME       TYPE  WIDTH      COMMENT
*     001      NUMBER       C     006     child's cohort number
*     002      NAME1        C     006     child's first name
*     003      NAME2        C     006     child's second name
*     004      SEX          C     001     child's sex
*     005      DOB          C     008     child's date of birth DD/MM/YY
*     006      VNO          C     003     vaccination number
*     007      BTHWK        N     003     study week of child's birth
*     008      FW           C     001     field worker for the child
*     009      VACC1        C     008     date of first vaccination
*     010      VACC2        C     008     date of second vaccination
*     011      VACC3        C     008     date of third vaccination
*     012      VWK1         N     003     study week of first vaccination
*     013      VWK2         N     003     study week of second vaccination
*     014      VWK3         N     003     study week of third vaccination
*     015      BLEED3       C     008     date of third bleed
*     016      ANTH30       C     008     date of 30 week anthrops
*     017      ANTH39       C     008     date of 39 week anthrops
```

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```
*     018     ANTH52      C     008     date of 52 week anthrops
*     019     ANTH65      C     008     date of 65 week anthrops
*     020     ANTH78      C     008     date of 78 week anthrops
*     021     ANTH91      C     008     date of 91 week anthrops
*     022     ANTH104     C     008     date of 104 week anthrops
*
*
* Three report formats are used for printouts:
*
*     COHORT  - lists number, name1, name2, sex, doh, vno and fw
*     FULLCOH - as COHORT plus full dates of vaccinations and anthrops
*     COHANTH - as COHORT plus spaces to write in weight and height data
*
*
*
*
* MODULE MENU1 *
        ----

* initialise and get date
erase
@ 1,27 say "ROTAVIRUS VACCINE TRIAL"
set talk off
store '  /  /  ' to today
@ 12,25 say "Today's date  (DD/MM/YY)  " get today picture "##/##/8#"
read

* calculate current week of study
store today to day
do studywk
store studywk to thiswk
set date to &today

* main menu loop
do while t
     erase
     @ 1,27 say "ROTAVIRUS VACCINE TRIAL"
     ?
     ? "           A. ENTER NEW CHILD"
     ? "           B. ENTER FIRST VACCINATION DATES"
     ? "           C. ENTER SECOND VACCINATION DATES"
     ? "           D. ENTER THIRD VACCINATION DATES"
     ? "           E. ENTER THIRD BLEED DATES"
     ? "           F. ENTER 30 WEEK ANTHROPS DATES"
     ? "           G. ENTER 39 WEEK ANTHROPS DATES"
     ? "           H. ENTER 52 WEEK ANTHROPS DATES"
     ? "           I. ENTER 65 WEEK ANTHROPS DATES"
     ? "           J. ENTER 78 WEEK ANTHROPS/4TH BLEED DATES"
     ? "           K. ENTER 91 WEEK ANTHROPS DATES"
     ? "           L. ENTER 104 WEEK ANTHROPS DATES"
     ? "           M. LIST COHORT"
     ? "           N. WEEKLY CLINIC LIST"
     ? "           R. RESTORE AFTER CRASH"
     ? "           Q. QUIT"
     ?
     store ' ' to opt
     ?
@ 22,40 say "ENTER LETTER " get opt picture "A"
read

* act on menu choice
do case

     * for A, call NEWKID
```

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[Byass et al. 1988]


```
case opt = 'A'
     do newkid

* for B to L, call PUTDATE exporting opt
case opt >= 'B' .and. opt <= 'L'
     do putdate

* for M, call COLIST
case opt = 'M'
     do colist

* for N, call VACLIST
case opt = 'N'
     do vaclist

* for R, restore database from backup
case opt = 'R'
     erase
     ? "RESTORING FROM BACKUP FILE"
     use cohort.bak
     copy to cohort
     use cohort
     index on number to cohort


* for Q, back up and quit
case opt = 'Q'
     erase
     ? "BACKING UP..."
     ?
     copy to cohort.bak
          quit

          * for anything else, redisplay menu
          otherwise
               loop
     endcase
enddo


* MODULE NEWKID *
        ------

* open the cohort file indexed on cohort number
use cohort index cohort
erase

*initialise variables
store 'X' to tno
store ' ' to ok

* repeatedly request new cohort number
do while tno <> ' '
     erase
     store '      ' to tno
     @ 4,5  say "BAKAU ROTAVIRUS COHORT"
     @ 6,10 say "NUMBER       " get tno picture "######"
     read

* close file and go back to main menu if no number entered
if tno = ' '
     use
     return
endif
```

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[Byass et al. 1988]


```
* try to find record for number entered
find &tno

* if number not already in the cohort, get confirmation
* for adding it to the database, else ask for another number
if # = 0
     @ 8,15 say "NEW NUMBER - OK?  Y/N " get ok picture "A"
     read
     if ok = 'Y' .or. ok = 'y'
          append blank
     else
          loop
     endif
endif

* get details for added blank record
@ 10,10 say "FIRST NAME    " get name1 picture "AAAAAA"
@ 12,10 say "SECOND NAME   " get name2 picture "AAAAAA"
@ 14,10 say "DATE OF BIRTH " get dob picture "##/##/8#"
@ 16,10 say "SEX           " get sex picture "A"
@ 18,10 say "FIELD WORKER  " get fw picture "A"
read

* fill in cohort number
replace number with tno

* fill in week of birth
store dob to day
do studywk
replace bthwk with studywk
enddo
```

```
* MODULE PUTDATE *
        -------

* open database file
use cohort index cohort

* select field to enter and title according to opt (imported from MENU)
do case
     case opt = 'B'
          store 'VACC1' to field
          store "'FIRST VACCINATION'" to title
     case opt = 'C'
          store 'VACC2' to field
          store "'SECOND VACCINATION'" to title
     case opt = 'D'
          store 'VACC3' to field
          store "'THIRD VACCINATION'" to title
     case opt = 'E'
          store 'BLEED3' to field
          store "'THIRD BLEED'" to title
     case opt = 'F'
          store 'ANTH30' to field
          store "'30 WEEK ANTHROPS'" to title
     case opt = 'G'
          store 'ANTH39' to field
          store "'39 WEEK ANTHROPS'" to title
case opt = 'H'
     store 'ANTH52' to field
     store "'52 WEEK ANTHROPS'" to title
case opt = 'I'
     store 'ANTH65' to field
     store "'65 WEEK ANTHROPS'" to title
case opt = 'J'
```

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```
          store 'ANTH78' to field
          store "'78 WEEK ANTHROPS/FOURTH BLEED'" to title
     case opt = 'K'
          store 'ANTH91' to field
          store "'91 WEEK ANTHROPS'" to title
     case opt = 'L'
          store 'ANTH104' to field
          store "'104 WEEK ANTHROPS'" to title
endcase

*initialise variables
store 'Y' to cont
store '      ' to tno

* repeatedly get cohort number and date for selected option
do while cont = 'Y' .or. cont = 'y'
     store ' ' to cont
     store '      ' to tno
     erase

     * get cohort number
     @  5,10 say &title +' RECORD'
     @ 10,10 say 'NUMBER    ' get tno picture "######"
     read
     * check number selected is in database, else ask again
     find &tno
     if # = 0
          loop
     endif

     * get date and update database
     @ 15,10 say 'DATE OF '+&title get &field picture "##/##/##"
     @ 20,15 say ' Another entry? Y/N ' get cont picture 'A'
     read

     * if recording a vaccination date, calculate week as well

     * first vaccination
     if opt = "B"
          store &field to day
          do studywk
          replace vwk1 with studywk
     endif

     * second vaccination
     if opt = "C"
          store &field to day
          do studywk
          replace vwk2 with studywk
     endif

     * third vaccination
     if opt = "D"
          store &field to day
          do studywk
          replace vwk3 with studywk
     endif
enddo
return
```

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[Byass et al. 1988]


```
* MODULE COLIST *
        ------

* menu of available lists
do while t
     erase
     @ 1,27 say "COHORT LISTS"
     ?
     ?
     ? "            A. BRIEF LIST BY NUMBER"
     ? "            B. BRIEF LIST BY NAME"
     ? "            C. BRIEF LIST BY DATE OF BIRTH"
     ? "            D. BRIEF LIST BY FIELD WORKER"
     ? "            E. FULL LIST BY NUMBER"
     ? "            F. FULL LIST BY NAME"
     ? "            G. FULL LIST BY DATE OF BIRTH"
     ? "            H. FULL LIST BY FIELD WORKER"
     ?
     ? "            M. RETURN TO MAIN MENU"
     ?
     store ' ' to lopt
     ?
     @ 22,40 say "ENTER LETTER " get lopt picture "A"
     read

     * index according to list selected
     erase
     ? "SORTING..."
     ?
     use cohort
     set heading to COHORT LIST

     * print selected list
     do case
          case lopt = "A"
               index on number to temp
               use cohort index temp
               report form cohort to print
          case lopt = "B"
               index on name2+name1 to temp
               use cohort index temp
               report form cohort to print
          case lopt = "C"
               index on $(dob,7,2)+$(dob,4,2)+$(dob,1,2) to temp
               use cohort index temp
               report form cohort to print
          case lopt = "D"
               index on fw+number to temp
               use cohort index temp
               report form cohort to print
          case lopt = "E"
               index on number to temp
               use cohort index temp
               report form fullcoh to print
          case lopt = "F"
               index on name2+name1 to temp
               use cohort index temp
               report form fullcoh to print
          case lopt = "G"
               index on $(dob,7,2)+$(dob,4,2)+$(dob,1,2) to temp
               use cohort index temp
               report form fullcoh to print
          case lopt = "H"
               index on fw+number to temp
```

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[Byass et al. 1988]


```
        use cohort index temp
        report form fullcoh to print
    case lopt = "M"
        return
    otherwise
                loop
        endcase
enddo
* MODULE VACLIST *
         -------

erase
? "WEEKLY CLINIC CALL LISTS"
?

* ask how many copies of the call list are required
store 1 to copies
@ 5,1 say "How many copies to print? " get copies picture "##"
read
?

* initialise variables
store str(thiswk,3) to strwk
store 0 to count

* allocate vaccination numbers to children who do not already have
* a number, and who are now ten weeks old and therefore need a
* number to be called for first vaccination - numbers being given
* sequentially by date of birth, and alphabetical order of names for
* children born on the same day

? "Allocating numbers to new entries...."
use cohort

* make all blank vaccination numbers 999 to put them at the end of
* the database when it is indexed on vaccination number, date of
* birth and name
replace vno with '999' for vno = '   '
index on vno+$(dob,7,2)+$(dob,4,2)+$(dob,1,2)+name1+name2 to temp

* copy indexed database to a temporary file, then overwrite the
* original with the sorted version and delete temporary files
use cohort index temp
copy to temp
use temp
copy structure to cohort
use cohort
append from temp
use cohort
delete file temp.ndx
delete file temp

* using the sorted file, fill in vaccination numbers equivalent to
* record numbers for those without valid vaccination numbers who
* are at least ten weeks old, make blank for less than 10 weeks old
replace vno with str(#,3) for vno = '999' .and. bthwk+10 <= thiswk
replace vno with '   ' for vno = '999'

* restore index file on cohort number
index on number to cohort
use cohort index cohort

* exclude anthrops defaulters from being called repeatedly by
* inserting dummy dates of 00/00/00
```

Appendix VIII: Related publications

[Byass et al. 1988]


```
? "Excluding long term anthrops defaulters...."
?
replace anth30 with '00/00/00' for bthwk + 39 <= thiswk .and. anth30 = '  '
replace anth39 with '00/00/00' for bthwk + 52 <= thiswk .and. anth39 = '  '
replace anth52 with '00/00/00' for bthwk + 65 <= thiswk .and. anth52 = '  '
replace anth65 with '00/00/00' for bthwk + 78 <= thiswk .and. anth65 = '  '
replace anth78 with '00/00/00' for bthwk + 91 <= thiswk .and. anth78 = '  '
replace anth91 with '00/00/00' for bthwk + 104 <= thiswk .and. anth91 = '  '

* print vaccination call lists
erase
do while count <> copies
     set eject off

     * list for first vaccination/anthrops
     set heading to FIRST VACCINATIONS DUE IN WEEK &strwk
     report form cohanth to print for bthwk+10 <= thiswk .and. ;
          vacc1 = '  '

     * list for second vaccination/anthrops
     set heading to SECOND VACCINATIONS DUE IN WEEK &strwk
     report form cohanth for vwk1+4 <= thiswk .and. vacc2 = '  ' ;
          .and. vwk1 <> 0

     * list for third vaccination
     set heading to THIRD VACCINATIONS DUE IN WEEK &strwk
     report form cohort for vwk2+4 <= thiswk .and. vacc3 = '  ' ;
          .and. vwk2 <> 0

     * list for third bleed/anthrops
     set heading to THIRD BLEED DUE IN WEEK &strwk
     report form cohanth for vwk3+4 <= thiswk .and. bleed3 = '  ' ;
          .and. vwk3 <> 0

* list for 30 week anthrops
set heading to 30 WEEK ANTHROPS DUE IN WEEK &strwk
report form cohanth for bthwk+30 <= thiswk .and. anth30 = '  '

* list for 39 week anthrops
set heading to 39 WEEK ANTHROPS DUE IN WEEK &strwk
report form cohanth for bthwk+39 <= thiswk .and. anth39 = '  '

* list for 52 week anthrops
set heading to 52 WEEK ANTHROPS DUE IN WEEK &strwk
report form cohanth for bthwk+52 <= thiswk .and. anth52 = '  '

* list for 65 week anthrops
set heading to 65 WEEK ANTHROPS DUE IN WEEK &strwk
report form cohanth for bthwk+65 <= thiswk .and. anth65 = '  '

* list for 78 week anthrops
set heading to 78 WEEK ANTHROPS DUE IN WEEK &strwk
report form cohanth for bthwk+78 <= thiswk .and. anth78 = '  '

* list for 91 week anthrops
set heading to 91 WEEK ANTHROPS DUE IN WEEK &strwk
report form cohanth for bthwk+91 <= thiswk .and. anth91 = '  '

* list for 104 week anthrops
set heading to 104 WEEK ANTHROPS DUE IN WEEK &strwk
report form cohanth for bthwk+104 <= thiswk .and. anth104 = '  '

* update count of lists, start new page
store count+1 to count
```

Appendix VIII: Related publications

[Byass et al. 1988]


```
     set eject on
     eject
enddo
return
* MODULE STUDYWK *
        -------

* import day in DD/MM/YY format and export numeric week of study
* (calculated from 01/01/85) as studywk

* dummy day of 00/00/00 gets studywk of 999
if day = "00/00/00"
     store 999 to studywk
     return

* otherwise calculate studywk
else
     * deal with the year
     store 1 to studywk
     if $(day,7,2) = '86'
          store studywk+52 to studywk
     endif
     if $(day,7,2) = '87'
          store studywk+104 to studywk
     endif
     if $(day,7,2) = '88'
          store studywk+156 to studywk
     endif

     * deal with the month
     store $(day,4,2) to month
     do case
     case month = '01'
          store 0 to julday
     case month = '02'
          store 31 to julday
     case month = '03'
          store 59 to julday
     case month = '04'
          store 90 to julday
     case month = '05'
          store 120 to julday
     case month = '06'
          store 151 to julday
     case month = '07'
          store 181 to julday
     case month = '08'
          store 212 to julday
     case month = '09'
          store 243 to julday
     case month = '10'
          store 273 to julday
     case month = '11'
          store 304 to julday
     case month = '12'
          store 334 to julday
endcase

     * deal with the day
     store julday+val($(day,1,2)) to julday

     * work out week of study from julian date
     store studywk+julday/7 to studywk
     return
endif
```

COMPUTERISED MORBIDITY SURVEILLANCE IN THE FIELD

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1. INTRODUCTION

The assessment of morbidity is an essential component of health planning, assessment and research (Ross & Vaughan, 1984). Cross-sectional surveys of populations to describe morbidity-related parameters, such as the number of stools positive for a particular diarrhoeal pathogen or the number of blood films positive for malaria parasites, are interesting epidemiological questions; however they do not necessarily indicate levels of clinically significant disease. The use of data relating to attendances at health centres for particular diseases are well known for being unrepresentative of the picture of clinical disease at the population level. Furthermore they are heavily influenced by perceptions of disease severity, accuracy of diagnosis by community health workers without laboratory facilities and completeness of recording under the very demanding, busy conditions often prevailing. Where reliable health centre data do exist they reflect a population's perception of what is clinically important since they represent cases regarded in the community as being sufficiently serious to seek treatment. For health planning and policy making this source of data can be very useful.

Assessments of disease-specific interventions, however, have generally relied upon sub-clinical epidemiological measures or passive case-detection data from health centres which may be heavily biased. Alternatively, and preferably, carefully controlled trials can be used to assess the true impact of such interventions, before scarce resources are committed to particular strategies. Interventions are often assessed both in terms of preventing deaths from a particular cause (i.e. reduction in disease-specific mortality rates) and of reducing occurrence of a particular disease (i.e. reduction in disease-specific morbidity).

Accurate determination of cause-specific mortality by means of post-mortem interviews requires large populations to be followed over long periods of time and hence a sophisticated and expensive surveillance system is required, particularly in countries where statutory death registration systems are not well developed. However, appropriate techniques have been

developed and tested. (Alonso et al., 1987).

Morbidity from a disease is normally a much more frequent occurrence than mortality from the same disease and hence assessment of morbidity requires smaller numbers of people to be kept under surveillance. However, the surveillance usually needs to be much more intensive.

In Farafenni, The Gambia, we have devised a system of monitoring large numbers of children for clinical episodes of malaria. The primary objective was to determine the number of clinical episodes of malaria suffered by children during trials of various interventions against the disease. It was assumed that a large proportion of clinical attacks would not be seen at health posts and health centres, and hence more active surveillance was indicated. We describe here some of the methods employed in this surveillance and discuss how these techniques might be applied to other intervention trials.

2. THE STUDY AREA

During 1981 the United Kingdom Medical Research Council set up a population laboratory in the town of Farafenni, The Gambia, which is situated in a rural area on the North bank of the River Gambia. Forty-two villages in the surrounding area were selected for study, and, following an enumeration of their 12,500 inhabitants fortnightly vital registration records have been used to update the initial census and to detect all childhood and pregnancy-related deaths. The identification and monitoring of a defined population in this way has made available an up-to-date sampling frame for other longitudinal studies related to health care utilisations, clinical and pathophysiological characteristics of diseases, epidemiology and sociology. Studies have concentrated on malaria-specific interventions and their delivery through The Gambia's Primary Health Care system (Greenwood, B.M. et al., 1987 A; Greenwood, B.M. et al., 1987 B, Greenwood, A.M. et al., 1987; Menon et al., 1988). During the course of these studies the system of active surveillance for morbid episodes of malaria was set up.

3. DATA PROCESSING

When the work started in 1981 the possibilities of local computerised data processing in such a remote situation were not clearly defined, and so, as a starting point, a small experimental computer facility was established at the MRC's main base in The Gambia, near Banjul, about 160 km from Farafenni (Anon., 1984). Whilst this was an improvement on the pre-existing situation, when questionnaires were shipped to London, it was still not ideal. Initial experiences of data processing, combined with technological advances, led to the

point where, in 1984, it was decided to localise data processing onto computers at Farafenni. All subsequent data generated by these studies were processed at the field station, a few kilometres from the study villages and from where the studies were managed. Localising the data processing rather than using the central facility at Fajara (160km from Farafenni) was beneficial for several reasons. Firstly it enabled investigators to manage data collection and quality control on a real time basis as studies progressed. Secondly, feedback on the progress of the project and on any problems was rapidly available. Thirdly, intermediate assessments and analyses could be made.

4. COMPUTER-MANAGED MORBIDITY SURVEILLANCE

As an example of computerised morbidity surveillance, we will refer to a study of insecticide treated bed nets (Snow et al., 1987), which is one of several studies carried out at Farafenni using this methodology.

This trial was carried out in a village 27km west of the Farafenni field station. Five field staff were recruited to conduct all the data collection in the field. All were male, with secondary school education and fluent in the local languages. Two further members of the team were recruited to act as computer operators and field supervisors, based in Farafenni. All the staff underwent two training sessions to familiarise them with survey techniques and specific training in the conduct of interviews, including careful translation of questions and entry of responses on the questionnaires used in the trial.

All the data for the study were processed on microcomputers running under CP/M-80 and using dBase II data base management system (Ashton-Tate, 1984; de Pace, 1984). The hardware system, described in detail elsewhere (Byass, 1987), comprised BBC microcomputers fitted with Torch Z80 second processors. A small network of four such machines with a 20MB hard disc was actually in use at the field station to handle several studies simultaneously; however, the data system described in this example could be implemented on a standalone microcomputer with floppy discs. The decision to use a database management system was made to minimise programming effort and to give investigators ease and flexibility of access to data. This was recognised to be a compromise in terms of run-time efficiency, as compared to customised programs, but this was not a major consideration given the size of the study and the volume of the data involved.

4.1 Registration

The field staff completed a full census of the study

population. Name, sex, date of birth and ethnic group were recorded for each person onto computer-generated blank forms. These forms were pre-coded with village, compound and individual numbers (village letter code, 2 digit compound number followed by a three digit personal number). The completed forms were entered (2076 individuals) and formed a census database with additional fields for compound of current residence (taking into account migrations within the study area) and status (resident within the study area, permanently moved away or dead). These two fields, initially blank, were then updated from regular vital registration during the study. The census database was then used to list children eligible to join the study (all those 1 to 9 years old). The parents of these children were then asked if they would allow their children to enter the trial. Updating the list of children with this information enabled the census database to be modified into a study cohort register of all the children for whom informed consent had been obtained. This group of children were then randomised to receive either the treatment or the placebo and the cohort register was updated with information concerning treatment group and details of the bed nets used by each study child.

4.2 Weekly surveillance

Weekly morbidity surveillance for the entire cohort of 389 children was carried out during 18 weeks of the rainy season, during which most malaria transmission occurs. Surveillance was carried out using weekly questionnaires administered by field staff to the mothers or usual guardians of the study children. Each field worker had two training sessions in the correct way to administer the questionnaire, followed by two trial weeks of administration. A manual was produced to accompany the questionnaire, explaining each question carefully, potential pitfalls and definitions. This covered, for example, details of what constituted "visiting for social reasons" as an explanation of absence, and what was intended to be included as "normal" activities. The form used for the weekly surveillance is shown in Figure 1. It was a simple, one page, precoded design expressly intended for computer processing (Byass 1986). It covered four major issues:

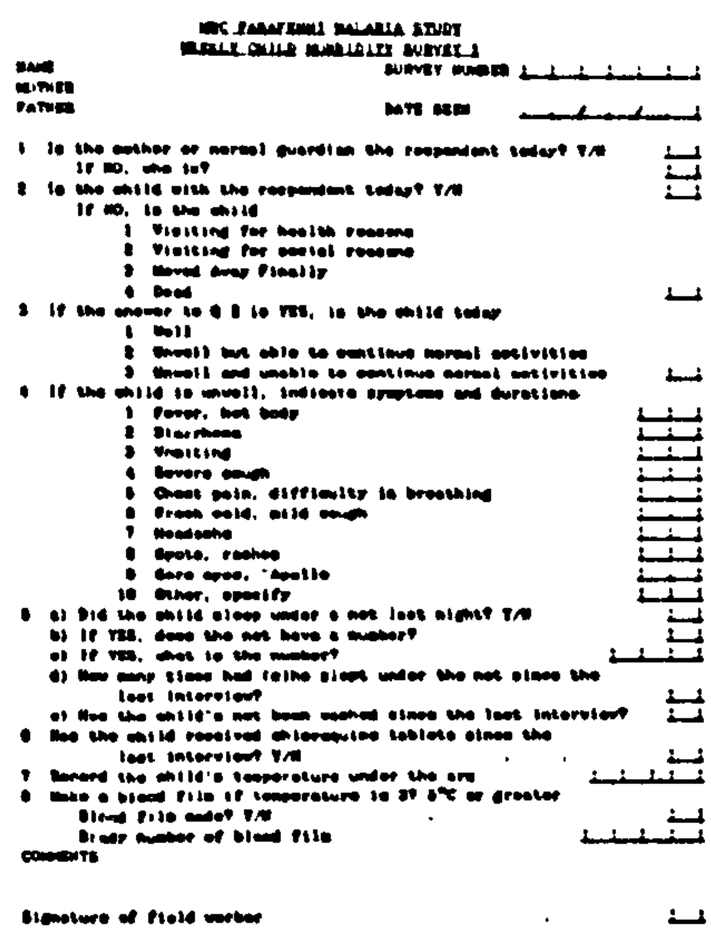
1) Is the child present for the interview; if not where is he?

2) Is the child unwell today; if so, with what symptoms?

3) Did the child use the intervention over the last week?

4) Has the child got a raised axillary temperature?

Field staff completed these questionnaires on their study children between Monday and Thursday of each week (Figure 2). The morbidity forms were returned to Farafenni every Thursday



NMC PARAFFINNI MALARIA STUDY
MORBIDITY SURVEY 1

NAME
MOTHER
FATHER

SURVEY NUMBER
DATE SEEN

1 Is the mother or normal guardian the respondent today? Y/N
If NO, who is?
2 Is the child with the respondent today? Y/N
If NO, is the child
1 Visiting for health reasons
2 Visiting for social reasons
3 Moved away finally
4 Dead
3 If the answer to Q 2 is YES, is the child today
1 Well
2 Unwell but able to continue normal activities
3 Unwell and unable to continue normal activities
4 If the child is unwell, indicate symptoms and durations
1 Fever, hot body
2 Diarrhoea
3 Vomiting
4 Severe cough
5 Chest pain, difficulty in breathing
6 Fresh cold, mild cough
7 Headache
8 Spots, rashes
9 Sore eyes, Apollo
10 Other, specify
5 a) Did the child sleep under a net last night? Y/N
b) If YES, does the net have a number?
c) If YES, what is the number?
d) How many times had (s)he slept under the net since the last interview?
e) Has the child's net been washed since the last interview?
6 Has the child received chloroquine tablets since the last interview? Y/N
7 Record the child's temperature under the arm
8 Make a blood film if temperature is 37.5°C or greater
Blood film made? Y/N
Study number of blood film
COMMENTS

Signature of field worker

Fig. 1: Morbidity Form

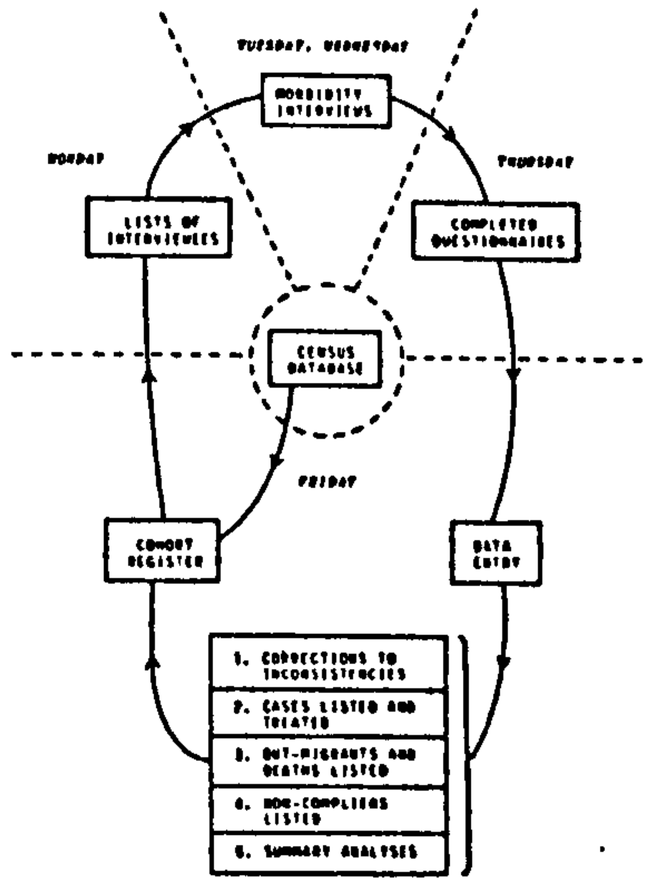


Fig. 2: Data System

morning. On the same day they were entered into the computer twice, and the two versions automatically checked for keyboard errors, by the computer operators that day. The single corrected file was then subjected to various logical and range checks, including isolation of incorrectly answered and unanswered questions. All problems were listed together with the identity of the originating field worker. The cohort numbers in the morbidity file were matched to the register file and any children for whom a morbidity record did not exist were listed and children who were recorded as out-migrating from the study area or who had died during the previous week were automatically deleted from the cohort register. Each field worker's forms were identified by an individual code letter and so any queries arising from these various operations could be made available to each field worker on each Friday morning. Inconsistencies in the data could therefore be corrected whilst the interview was still fresh in the field worker's mind. This enabled both immediate data quality control and continual reinforcement of training in the collection of field data. Also on the Friday lists of study children to be seen the following

week were produced for the field staff. Lists of children with positive blood films for the week were used to update a separate cases file and to list children needing treatment with chloroquine. Lists of children who had not used the intervention that week were produced so that they could be followed up by field staff the following week. Finally a complete analysis of children lost to follow-up and morbid episodes by age, ethnic group and treatment group for the week was made.

Rapid turn over of the data from the field enabled careful monitoring of the intervention being tested, the children in the trial and the quality of the data being collected. Data from additional cross-sectional surveys was also entered at Farafenni and checked and managed in the same way as described above.

CONCLUSIONS

The use of microcomputers in the field has been shown to improve coverage rates (Byass et al., 1988, Rowan et al.,1987). For example, of a total of 6681 interviews scheduled for resident children in our trial, 230 (4.4%) were not conducted because the child was absent and none were missed by accident. Similarly, very low levels of error rates have been demonstrated. Errors and inconsistencies in the data can be corrected very quickly, in the case of our trial within the weekly cycle. Also quality control of the data can be routinely monitored. It is often cited that data processing is a major bottleneck for field studies, as for example by Van Ginneken & Muller, 1984. The processing of morbidity data in situ not only relieves this problem but also enables assessment of the progress of a trial and immediate highlighting of problem areas which require immediate investigation.

This system of monitoring febrile and morbid episodes during an intervention trial represents both a considerable saving in management effort and a considerable increase in efficiency. It requires a team of field investigators, two computer operators and a microcomputer with a data management package. Although our cohort of children was small, with 10 field staff and 2 computer staff 1000 children could be followed in the same way, keeping to the same weekly schedule. Computers are being increasingly used in the tropics and, with suitable back-up power supplies or battery power, are sufficiently robust to withstand the rigours of a rural environment in the tropics.

The surveillance of morbidity as described here specifically relates to malaria, but the onset of fever is common for other infectious diseases (Bell, 1985). Surveillance of other parameters of morbidity, such as investigations of stools from febrile children instead of blood film examination, could be

used in a similar system to actively monitor episodes of other disease. Alternatively, symptom complexes reported by mothers could be used to prompt further investigations.

Active surveillance of morbidity in populations is considerably more expensive than passive case detection methods, but yields data which is demonstrably representative of the population studied. The methodological improvements in active surveillance with field based microcomputers increases the costs of equipment further but saves managerial time. Longitudinal studies can provide excellent data on patterns of cause-specific morbidity and mortality for epidemiological investigations and trials. However, there remains a place for nation-wide estimates of mortality and morbidity, often required for governmental planning, which in less developed countries is not feasible nor practical by means of prospective surveillance and it is in these situations that passive case-detection is most used.

Few studies have been conducted to compare patterns of morbidity described by passive and active surveillance techniques. Methods, like the computerised technique described above, of actively surveying populations for morbid episodes now exist and should be used to evaluate the representativeness of morbidity data collected passively.

REFERENCES

Alonso, P.L., Bowman, A., Marsh, K. and Greenwood, B.M., (1987). The accuracy of clinical histories given by mothers of seriously ill African children. Annals of Tropical Paediatrics, 7, 187-189

Anon., (1984). Climatised Computers. African Technical Review, June 1984, 29-30.

Ashton-Tate Books, (1984). dBase II Assembly Language Relational Database Management System. Culver City, California.

Bell, D., (1985). Lecture Notes on Tropical Medicine. Blackwell Scientific Publishers, Oxford.

Byass, P. (1986). The design of computer forms for tropical medical research. Methods of Information in Medicine, 25, 229-232.

Byass, P. (1987). Computers in Africa: Appropriate technology? Computer Bulletin, 3, 17.

Byass, P., Hanlon, P., Hanlon, L., Marsh, V. and Greenwood, B.M., (1988). Microcomputer management of a vaccine trial. Computers in Biology and Medicine, 18, 3.

Appendix VIII: Related publications
[Snow and Byass 1988]

de Pace, M., (1984). Working with dBase II. Granada, London.

Greenwood, A.M., Greenwood, B.M., Bradley, A.K., Williams, K., Shenton, F., Tulloch, S., Byass, P. and Oldfield, F.S.J., (1987). A prospective survey of the outcome of pregnancy in a rural area of The Gambia, West Africa. Bulletin of the World Health Organisation, 65, 635-643.

Greenwood, B.M., Bradley, A.K., Greenwood, A.M., Byass, P., Jammeh, K., Marsh, K., Tulloch, S., Oldfield, F.S.J. and Hayes, R., (1987 A). Mortality and morbidity from malaria in a rural area of The Gambia, West Africa. Transactions of the Royal Society of Tropical Medicine and Hygiene, 81, 478-486.

Greenwood, B.M., Greenwood, A.M., Bradley, A.K., Tulloch, S., Hayes, R. and Oldfield, F.S.J., (1987 B). Deaths in infancy and early childhood in a well-vaccinated, rural, West African population. Annals of Tropical Paediatrics, 7, 91-99.

Menon, A., Rowan, K.M., Joof, D. and Greenwood, B.M., (1988). Maternal administration of chloroquine: an unexplored aspect of malaria control. Journal of Tropical Medicine and Hygiene (in press).

Ross, D. and Vaughan, P., (1984). Health interview surveys in developing countries: a review with recommendations for future surveys. Evaluation and Planning Centre for Health Care, London.

Rowan, K.M., Byass, P. and Snow, R.W., (1987). On-line tropical epidemiology - a case-study from The Gambia. Methods of Information in Medicine, 26, 73-76.

Snow, R.W., Rowan, K.M. and Greenwood, B.M., (1987). A trial of insecticide treated bed nets in the prevention of malaria in Gambian children. Transactions of the Royal Society of Tropical Medicine and Hygiene, 81, 563-567.

van Ginneken, J.K. and Muller, A.S., (eds), (1984). Maternal and child health in rural Kenya. Croom-Helm, London.

SUMMARY

Suppos que la surveillance de morbidité est importante dans nombreuse domaines de la planification et evaluation de la santé, la methodologie de sell surveillance devienne une question importante. Des problemes concernant l'utilisation des ordinateurs en milieu isolé sont discutés et leur abilité pour faciliter la surveillance de morbidité avec un haut degré d'accord est expliqué.

Appendix VIII: Related publications
[Byass 1989 A]

Journal of Tropical Medicine and Hygiene 1989, 92, 282–287

Choosing and using a microcomputer for tropical epidemiology. I Preliminary considerations

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Summary

Practical considerations involved in ascertaining data processing requirements, starting with the protocol of an epidemiological study, are discussed. These include assessments of both hardware and software requirements. Throughout the paper special emphasis is placed on the problems of conducting an epidemiological study in a tropical environment, with minimal infrastructural, logistic and expert support. The requirements of a hypothetical study protocol are used as an example. This paper covers aspects of data processing required in preparing a project proposal; its sequel considers getting the project under way.

Introduction

Despite the advances in computing in recent years, many epidemiologists working in the tropics are unable to exploit the technology to full benefit. Those worst affected are typically working alone or with a small team in a remote area; workers in larger establishments are generally better off since there is probably sufficient work to justify local professional support for data processing. It is therefore to epidemiologists forced to take responsibility for all aspects of their own data handling that these articles are directed. In view of the difficulties of dealing with essentially practical matters in terms of abstract concepts, a hypothetical epidemiological study will be used as an example throughout.

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The data system

The choice of hardware and software cannot be considered until the epidemiological details of a project have been formulated into a detailed protocol. Once that has been done, a diagram representing the *data system* for the project should be drawn up (Marinez *et al.* 1984). The data system is simply a chart showing all facets of the protocol which are data-related, and the interactions between them. A summary of the protocol of a hypothetical example is shown in Figure 1, and the data system derived from it in Figure 2. It should be emphasized that the data system is useful in deciding whether or not a computer is justified for some or all of a project's data; inclusion of items in a data system does not imply that they must be computerized. Items that should be included comprise all sets of forms, registers, lists, etc. that would be needed for a practical implementation of the protocol. Defining all these data entities from a protocol is, to some extent, a matter of experience in the conduct of epidemiological investigations; certainly at this stage there are no special considerations of data processing methodology.

Data processing requirements

Having defined the data system, the next step is to translate it into discrete requirements for data processing, and to decide whether the magnitude and complexity of the tasks justify using a computer. Working from the protocol and the data system (Figures 1 and 2), the following data tasks can be identified:

Appendix VIII: Related publications

[Byass 1989 A]

> *The efficacy of a new drug X against disease Y in infancy (Y attacks about 30% of infants in the first year of life) is to be tested in a randomised placebo-controlled trial. All children born in the study area will be recruited at birth and sequentially randomised to receive X or placebo in the event of an episode of Y. Recruitment will take place over a one year period, during which 1,000 births are expected, and subjects will be studied for one year or until they experience an outbreak of Y. Episodes of Y will be detected by weekly morbidity surveillance (domiciliary visits by one of 10 field workers). Detected episodes will be treated with X or placebo, and followed up weekly for six weeks, after which the child will exit the trial.*

Figure 1. Summary of hypothetical study protocol.

(1) maintaining a register file with personal details of subjects, which should be continually updated with new births and exits or withdrawals from the study
(2) using the register each week to produce details of children to be visited for weekly surveillance
(3) accumulating morbidity records, including checking and correction procedures
(4) using the morbidity records to list detected cases for follow-up
(5) accumulating follow-up records, including checking and correction procedures.

The magnitude of these tasks can then be estimated from the protocol:

(1) about 20 changes per week
(2) listing an average of 500 children for checking and surveillance per week
(3) collecting and checking an average of 500 morbidity forms per week
(4) listing about three children weekly for follow-up, from morbidity records
(5) collecting and checking about 20 follow-up records per week.

The first point arising from these estimates is that the relatively large volume of morbidity data suggests that a computerized system might be worth while.

Considering each item in terms of both its position in the data system (and hence its relationship with other items) and of its magnitude, (1) and (4) should be handled by a computer system because of their interdependence with the morbidity data in (2) and (3), which themselves justify computerization on grounds of their magnitude. However, item (5) is low in volume and other parts of the data system do not depend upon it; hence it might be handled manually, although the follow-up data may need to be available on-line for later analysis.

At this stage it is possible to estimate the size of the computer files that will need to be created. The two main files in this example are the register and the morbidity records. On the assumption that each record will be about 100 characters, the register file would approximate to 100 characters × 1000 children, which in terms of disc storage capacity is approximately 100 kB (1 kB (kilobyte) = 1024 characters). The total morbidity data will be of similar volume for each of 50 weeks, a total of 5 MB (MB, megabyte, or 1000 kB). This rule-of-thumb estimate is one criterion in choosing hardware.

Estimation of manpower requirements for processing data in such a study is difficult, particularly if the investigation is not sited in an area from which experienced computer data entry clerks can be recruited. Our experience shows that secondary school leavers with education to 'O' level or equivalent standard can reasonably quickly and easily be trained for such work; however, it does take time for keyboard

Appendix VIII: Related publications

[Byass 1989 A]

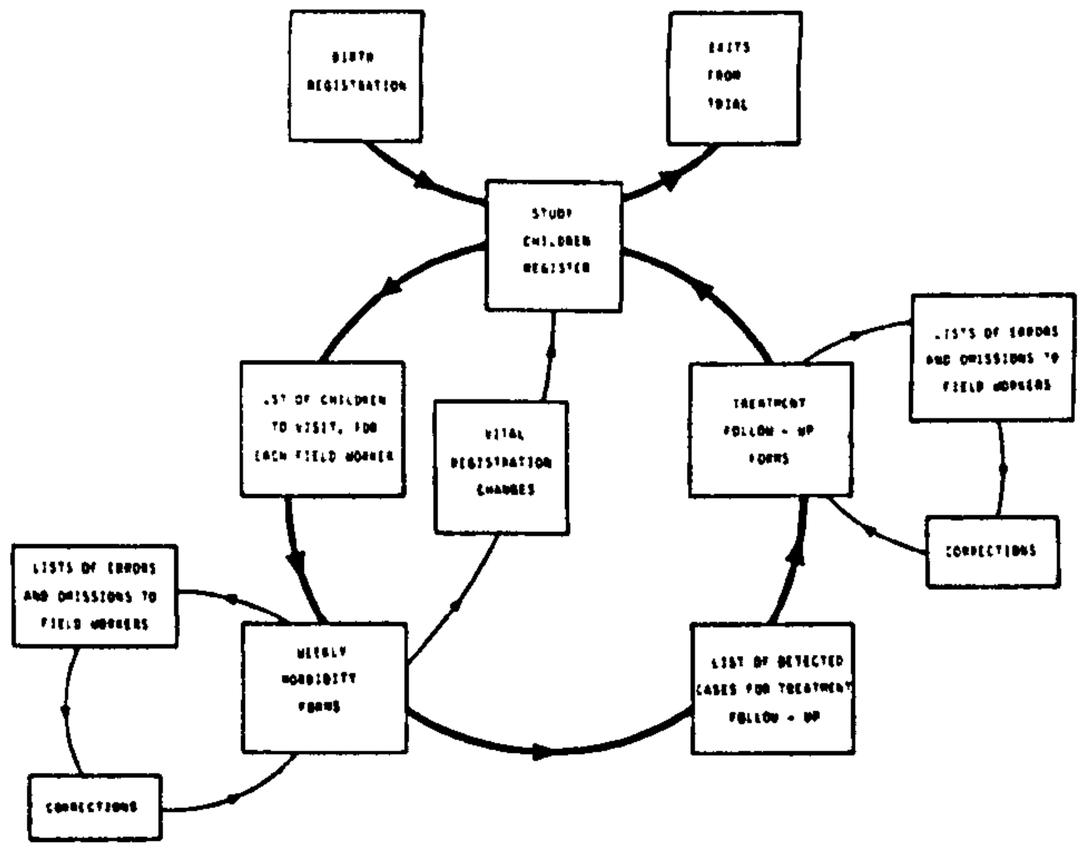

Figure 2. Data system for the hypothetical study. Heavy arrows indicate principal data flows, light arrows secondary flows.

skills to develop speed. In this situation it is particularly important to use double entry procedures to reduce errors, which will be discussed later. On that basis, most operators can handle 100–200 records daily; thus for our example which involves up to 1000 records weekly, two operators would be necessary. In addition a project will make use of computers for writing reports, and possibly administrative functions, in addition to the basic epidemiological data processing. In most cases however these requirements are likely to be relatively small.

Software requirements

The basic requirement for managing a trial of this sort on a microcomputer system is a database management system (DBMS) (Byass 1986). This is particularly so if a professional programmer is not involved with the project, since DBMSs handle aspects such as creating, opening and closing files, sorting and searching, data entry and editing in general terms without requiring programming. The DBMS is, therefore, itself a generalized program consisting of a collection of general data management facilities. In terms of a specific project therefore all that has to be done is to 'customize' the DBMS to the specific details of the investigation.

A DBMS which is widely implemented on microcomputers is Ashton-Tate's dBase II (Ashton-Tate 1982) and its updates, on some operating systems, dBase III, III+ and IV. Many other DBMSs would also be suitable, but one advantage of dBASE is that it has become sufficiently widely used for many third-party guides to have been written (de Pace 1984, 1987). Although DBMSs are frequently used for administrative and financial applications, they are eminently appropriate for epidemiological management and preliminary analyses. Furthermore, most DBMSs accept interactive commands couched in relatively straightforward pseudo-English and are thus accessible to the non-programmer.

The basic concept of a DBMS is that individual records, all having a common structure, are stored in a file (the database). Databases contain records (a record would be, for example, the data from a single morbidity interview), which are made up of fields (a field would be the answer to a single question). Thus, conceptually, a database is a table wherein records form the rows and fields form the columns. The DBMS facilitates traversal of this conceptual table as a means of answering queries or performing updates of the data therein. Any good DBMS also has facilities for output of data in

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text file format (i.e. as a simple list of characters) for input to other software, for example for statistical analysis.

It is important in selecting a DBMS to ensure that it has sufficiently large limits on maximum capacity (number of records, number of fields, etc.) to accommodate the data defined in the data system.

In addition to database software, facilities for tabulation and statistical analysis are necessary. There is a wide variety of such software available and choice depends to a large extent on hardware compatibility. Any worthwhile package, such as the IBM-compatible microcomputer versions of SPSS (SPSS Inc. 1988) and SAS (SAS Institute Inc. 1985), will have the capability to accept data from a text file, which serves as a common link with other software. Some packages may also accept data directly from data management software in other formats. One point about statistical software is that it is not a substitute for understanding statistics: having a package that can perform, for example, logistic regressions, is not useful unless the user understands the statistical principles and can interpret the results correctly.

Some software is emerging, such as Epi-Info (Dean *et al.* 1988), which combines several of these functions into a single package, and which may be particularly suitable for smaller and simpler projects.

Word-processing software is also highly useful, for producing reports, questionnaires, etc., but the choice of package is not critical in terms of data management.

Hardware requirements

Any computer system has built-in software known as the *operating system* which acts as a 'go-between' linking software packages to the machine's hardware. Because of the popularity of the IBM personal computer, and compatible machines from other sources, its operating system, called MS-DOS (Microsoft Inc. 1987), has become a *de facto* standard which will be selected in most new purchases of microcomputers. The fundamental consideration at this stage however is the selection of a single operating system, under which all chosen software packages are able to run. It is then necessary to select hardware which supports the selected operating system.

Only after considering all the above aspects can the question of hardware be addressed. In addition, consideration must be given to the conditions in which the hardware is to operate.

From the data requirements of the project, the magnitude of disc storage required for data can be estimated. As a rule-of-thumb, three or four times the size of the basic data set is reasonable. This gives enough space for working and back-up files. Thus in our example, capacity to store around 20 MB would be appropriate. A further 10 MB or so may be needed to accommodate software, particularly if large statistical packages such as SPSS or SAS are used. Microcomputers increasingly tend to have hard discs (sometimes called Winchester discs) fitted as a standard option, and experience suggests that they are more reliable in harsh environments (Byass 1987) than the previously ubiquitous floppy disc, as well as having much greater capacity (commonly at least 20 MB). Thus, except for very large projects, storage capacity is unlikely to be a problem.

A more critical factor is likely to be the provision of adequate keyboard time; for the example, we have already established a need for two operators who will both need a machine unless shift-working is envisaged. Furthermore, to make use of the computer system for the management of the project a further machine will be required in addition to the two dedicated to data input.

Whatever the data volume requirements for a project, it is always desirable to have at least two identical machines, and preferably one redundant machine, since in many parts of the tropics servicing will not be readily available. Although hard disc drives are not strictly necessary on machines to be used exclusively for data entry, their superior reliability and the desirability of redundant capacity both indicate their installation in all machines. Some larger software packages, particularly for statistical analysis, either require, or run faster with, a maths co-processor, which is available as an option on IBM PCs and compatibles.

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Printers will also be required; basic dot-matrix models are adequate for most aspects of a project but it may be desirable to include one printer capable of higher quality output (either daisy wheel or letter-quality matrix) for producing letters, reports, etc.

A further hardware item which is essential in most situations is an uninterruptable power supply (UPS) to protect equipment and data from the local power supply. UPSs serve a dual function of suppressing spikes and surges as well as maintaining power for a reasonable period of time (depending on their battery capacity and output load) in the event of a mains failure. It is essential to have a UPS that has a sufficient power output (expressed in watts or volt-amps) for the sum of the power requirements of the equipment to which it is to be connected. Having said that, it is not necessarily essential to provide uninterruptable power to less essential parts of the system such as printers unless the mains is of exceptionally poor quality. A UPS is also useful for installations using their own generators since it both stabilizes the supply to the computers and can bridge a change-over between generators.

Adequate supplies of consumables are also necessary. These include printer paper and replacement ribbons, together with magnetic media. Even using a hard disc, it is still *essential* to make back-up copies regularly onto other media to guard against losing data. Many microcomputers use floppy discs for this, and in this case a total of floppy discs equivalent to at least three times the capacity of the hard disc will be needed. A regular two-generation back-up system can then be implemented (current back-up and its predecessor), leaving some discs for archival and miscellaneous uses. It must also be noted that floppy discs should be stored in dust-free conditions at reasonable levels of humidity—they have been known to grow moulds on the magnetic surface during tropical wet seasons, making them unusable and their data irretrievable. Similar arguments apply to tape or cartridge-based systems. For this reason, air conditioning during operation is desirable in many environments, though not absolutely essential provided great care is taken to preserve a clean environment around the computers, and archive storage in dust-free and damp-free conditions is available.

If the opportunity exists to have the whole system unpacked and tested at the place of purchase it is a worthwhile step to take, since it is not unknown for new equipment to malfunction, nor to be lacking minor components such as connecting leads. These problems will probably be much more difficult to rectify in the field.

The makes and models of equipment chosen, in addition to satisfying the above criteria, should depend critically on how servicing will be accomplished and their reputation for reliability. If no reasonable facilities are available in the country where the project is to take place, it is worth finding a dealer elsewhere who is prepared to act on telexes and telegrams describing problems to provide the necessary parts and advice. This may in turn influence the choice of manufacturer. Alternatively, there may be local servicing arrangements for one or two brands of machine, which therefore become likely choices. Compatibility with a home base may be a further consideration.

Thus the choice of hardware is not a simple matter, and certainly should not be made without first considering the data system, the software requirements and the local conditions.

Conclusions

So far the preliminary processes in setting up a computer system for an epidemiological project have been considered. It is most important to consider the various steps in the order set out here in order to finish with a workable system—and not, as so often happens, by starting with the hardware. In the second paper the implementation of the project on the computer system will be considered.

References

Ashton-Tate (1982) *dBase II Assembly Language Relational Database Management System.* (Culver City, California).

Byass P. (1986) The design of computer forms for tropical medical research. *Methods of Information in Medicine* **25**, 229–232.

Byass P. (1987) Computers in Africa—appropriate technology? *Computer Bulletin*, **3**, 17.

Appendix VIII: Related publications
[Byass 1989 A]

Dean J. A., Dean A. G., Burton A. & Dicker R. (1988) *Epi-Info Version 3*, USD Inc., Stone Mountain, Georgia, USA.

de Pace M. (1984) *Working with dBase II*. Granada, London.

de Pace M. (1987) *dBase III Plus*. BSP Professional Books, Oxford.

Marinez Y. N., McMahan C. A., Barnwell G. M. & Wigodsky H. S. (1984) Ensuring data quality in medical research through an integrated data management system. *Statistics in Medicine*, 3, 101–111.

Microsoft Inc. (1987) *DOS 3.30 Reference*, IBM UK, Portsmouth, England.

SAS Institute Inc. (1985) *SAS Introductory Guide*, SAS Institute Inc., Cary, North Carolina, USA.

SPSS Inc. (1988) *SPSS/PC+ V2.0 Base Manual*, SPSS Europe, Gorinchem, The Netherlands.

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Choosing and using a microcomputer for tropical epidemiology. II Study implementation

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Summary

Continuing from the previous paper (Byass 1989), practical considerations in setting up a computer system to assist in the collection of data from an epidemiological project are discussed. Organizing field work so as to facilitate computer processing is considered, together with establishing data entry and checking procedures. The use of the hypothetical example in the first paper is continued here.

Introduction

In the previous paper, the preliminaries to setting up a microcomputer for epidemiological field-work were explored. Assuming the investigator to be on site with a suitable computer system, we now turn to the factors involved in getting the study under way. The use of the hypothetical study as an illustrative example in the first paper will continue.

Identification methodology

In any type of epidemiological study (other than possibly a one-off cross-sectional survey) the precise and unambiguous identification of subjects is a most important issue, whose methodology must be determined before data collection. It is difficult to generalize methods of subject identification since possible strategies depend crucially on social organization and local infrastructures. In many less-developed countries, because of the lack of well defined personal identification procedures, it will often be necessary for the epidemiologist to institute an identification system (Byass 1986; Stephens *et al.* 1989).

The main point of any identification method is to have a unique code for every individual which can be used on all data records relating to a particular subject. By doing this, only the subject register file needs to contain bulky information such as names and addresses, which can be cross-referenced using the identification code as the key.

Our example involves recruitment from birth together with home visits. If the investigator has to implement identification, then the essential components will be the personal identifier for the baby (which might simply be a serial number reflecting recruitment order) and identification of the home address to facilitate visiting.

Questionnaire forms

Before any data collection can start, it is necessary to design questionnaire forms on which to collect the data. In most parts of the tropics, self-administered questionnaires are impracticable so we shall assume that we are designing forms for the use of field staff.

The functions within the study for which forms are required can readily be identified from the data system (Byass 1989). In our example, forms would be needed for birth registration, weekly morbidity interviews, vital registration changes and treatment follow-up. In practice the design and content of the forms are closely related to the database for the study (Byass 1986). All forms must carry the subject's personal identification code. This then links all forms pertaining to an individual in subsequent processing. A second important principle is the physical segregation on the form of data for computer entry from questions, instructions or

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```
Form TF/01          TREATMENT FOLLOW-UP FORM

                                    Serial no:   0322
                          Date (DD/MM/YY): :__:__/__:__/__:__:
Name: .....               Study no: :__:__:__:__:__:__:
                Treatment date (DD/MM/YY): :__:__/__:__/__:__:

1. Are the child and mother available for
                            interview?  Y/N : :__:

   If NO, stop here

2. Has the mother observed the following since treatment?
                                fever       Y/N : :__:
                                vomiting    Y/N : :__:
                                diarrhoea   Y/N : :__:
3. Measure the child's temperature:           :__:__:.:__: °C
4. Field worker's code:                       :__:
```

Figure 1. Questionnaire for treatment follow-up interview.

non-coded responses. The data for entry should be written in boxes with one space per character, usually down the right-hand side of the page, which greatly facilitates data entry procedures (Figure 1).

Once the forms have been designed (a word-processor is the most convenient and flexible tool for this purpose), it is useful to pre-test them prior to the start of data collection by taking a small number of the forms and completing them in the field with a view not to collecting data for analysis, but to highlighting any problems. This leads to modifications in the forms so it is important to have a reference code at the top of a form which incorporates a version number which can be changed whenever a modification is made. If this is not done, several similar but slightly different forms which are not clearly interdistinguishable may, in the worst case, be used interchangeably during the course of a study.

Setting up the databases

Once the forms have been finalized, definition of the database structures is relatively straightforward since they must correspond directly to the forms from which they are to receive data. Database management systems (DBMSs) incorporate a method of specifying the structure of a database file. For each field (i.e. an answer on the questionnaire), a field name, length (number of characters) and data type (for example character or numeric data) need to be specified. A dBase III+ structure (de Pace 1987) corresponding to the questionnaire in Figure 1 is shown in Figure 2.

Data entry

Data entry, the process of transferring data from forms to database files, is another function normally supported within the DBMS. Most DBMSs implement this by the VDU display of an empty record, which can be filled in from the keyboard. Rather than use the main database files directly for data entry, which exposes it to risks of accidental corruption, it is preferable to use a temporary file of the same structure for the entry of a batch—perhaps a few hundred records. To minimize errors introduced in the data entry process it is highly desirable to enter batches of data twice, ideally by two operators. It is then relatively easy for the computer to compare the two supposedly identical files and list discrepancies between them (a process known as verification). This list can then be checked against the original questionnaires to see which version is correct in each case, and then corrections can be made to the database files. Either one file can be corrected and the other abandoned, or, to be even more careful, both files can be corrected and the verification re-run to check that no discrepancies remain. A general command file (a short series of commands kept in a file for repeated use) to compare two databases of the same structure can be used

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[Byass 1989 B]


```
Structure for database: C:TRFOLL.DBF
Number of data records:     4783
Date of last update    : 05/12/88
Field  Field Name  Type       Width    Dec
    1  SERIAL      Character      4
    2  DATE        Date           8
    3  STUDYNO     Character      6
    4  TRDATE      Date           8
    5  AVAIL       Character      1
    6  FEVER       Character      1
    7  VOMIT       Character      1
    8  DIARR       Character      1
    9  TEMP        Numeric        4      1
   10  FW          Character      1
** Total **                      36
```

Figure 2. dBase III+ structure for treatment follow-up database.

(see Appendix A for an example in dBase III+), or it is possible to write simpler command files to do a similar comparison on a specific structure (Appendix B). The basic principle is to use one field, for example serial number of the form, as a key to match records between the two files and then to do a field-by-field comparison of the two records with the same key field value.

Rowan *et al.* (1987) detected and corrected keyboard errors at the rate of 0.61% (810/133, 420) of fields entered by this process of double entry and verification. Further investigation showed keyboard errors at a rate of 30 per million had survived the verification process.

Data validation

Once data have been entered and keyboard errors eliminated, it is relatively simple to check the validity of the data—in other words to query any values that are without a reasonable range or logically incompatible with other responses. Appropriate checks for a particular set of data depend largely on a common-sense analysis of the questions and possible responses. Some general examples of validation checks are:

yes/no answer: list any response other than Y or N

answer coded 1 to *n*: list any response <1 or >*n*

body temperature: list any responses <35°C or >42°C

identification code: check validity in register file

Consistency checks, for example establishing that there are no responses from unavailable subjects, and full details from available subjects, can also be used. Appropriate validation checks for the form shown in Figure 1, using the database structure shown in Figure 2, are listed in Table 1.

Maximum advantage is gained from this approach to data validation if the whole data collection process can be integrated and localized so that data entry and validation can be carried out on-site within a few days of collecting the data (Snow & Byass 1988). If this can be achieved, then queries arising from data validation checks can often be resolved by referring them back to the field within a sufficiently short time for correct responses to be recalled from memory. Rowan *et al.* (1987) detected erroneous fields at the rate of 0.29% (383/133, 420) by this technique and subsequently resolved 96.3% of the 383 queries thus generated.

Outputs to project staff

One of the major benefits in using on-site microcomputers in epidemiological projects lies in

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Table 1. Logical and range checks for treatment follow-up questionnaire (Figure 1)

Field name	Check
SERIAL	> "0000" and < "1200"
DATE	within the period of the study
STUDYNO	can be found in register database
TRDATE	within the period of the study and < DATE
AVAIL	"Y" or "N"
FEVER	"Y" or "N" if AVAIL = "Y", else " "
VOMIT	"Y" or "N" if AVAIL = "Y", else " "
DIARR	"Y" or "N" if AVAIL = "Y", else " "
TEMP	> 35.0 and < 42.0 if AVAIL = "Y", else 0
FW	one of codes assigned to field workers

the generation of computer output to assist project staff in the management of the study. As well as being a useful aid to field staff, the use of computer-generated call lists has been shown to increase compliance considerably (Byass *et al.* 1988). Again, it is necessary to have a relatively quick turn-round in data processing procedures so that lists and other material produced are genuinely current. These techniques are potentially most useful in longitudinal studies where repeated visits or interviews in a cohort are involved but, in cases where basic demographic details of the study population are available on computer, similar techniques also apply to cross-sectional work.

A further refinement of these techniques is to print personal details directly onto self-adhesive labels (continuously backed self-adhesive labels for feeding through ordinary printers are readily available). This has several advantages. Since the pre-printed labels are stuck directly onto a suitable space at the top of questionnaires, the possibility of errors in transcribing codes from lists to forms is removed. Experience suggests that up to 1% of transcribed 6-digit numbers can have transcription errors in one or more digits, so it is a useful source of error to eliminate. Secondly, since each field-worker has a label to peel off for each form that is supposed to be filled in, it is easy to check from the remaining labels which subjects have still to be dealt with.

In our example, weekly lists of children to be interviewed for morbidity surveillance would be produced from the continually updated register file. Processing the morbidity forms would give a list of children who had been found to have disease Y and treated, and this would then be the list for treatment follow-up. The morbidity forms would also reveal changes in vital registration which would be used to update the status of individuals in the register file in respect of children leaving the study area, etc. so that they would not appear on future lists. Validity errors in both morbidity forms and treatment follow-up forms would be listed and referred back as described above. Lists of exits from the trial would be based on treatment follow-up forms and those children reaching the age of 1 year in the register file, and in both cases the status field in the register file would be updated so that those children could be excluded from future weekly lists.

The main database

The primary object of all data handling procedures during a study is to accumulate a set of data for final analysis. Therefore each batch of data, after double entry, verification and validation as described above, has to be added to the master file for future use. This is normally a simple task since the working batch files will have the same structure as the master file and can thus be appended to it. It is very important however that the master files for a study are maintained very carefully, with regular

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[Byass 1989 B]

back-ups being made. If fixed storage media (e.g. a hard disc) are used it is most important to also keep a separate back-up of the main files on floppy discs or tapes, as well as printouts, and to store the copies in different places. If removable media (e.g. floppy disks) are used, several duplicates should be made. In addition, in the case of a major file that is regularly updated (e.g. the register file in our example) it is most important not to delete records when, for example, a child leaves the study. Instead, the status of that individual must be changed to indicate that (s)he has left the study. Data on all the subjects who have ever participated in the study will be needed in the final analysis.

Conclusion

If the data system for a study is well planned and implemented, then at the end of the data collection work, the result should be a database of high quality. The effort involved in following methods outlined above, while considerable, will be repaid at this stage in the project, since there will be available for analysis a database with minimal amounts of missing or incorrect data. Since much analytical effort is often otherwise devoted to cleaning data, excluding outliers, etc. analysis should be a much more straightforward task and hence results from the study should be available at the earliest opportunity.

Appendix A

```
* General dBaseIII+ verification program to compare two databases
* of the same structure
clear
clear all
set heading off
set safety off
set alternate to VERIFY.TXT
set talk off
? "VERIFICATION PROGRAM"
?
?
? "This program checks two databases of the same structure and"
? "notes details of discrepancies between records, or records"
? "missing in one or other database."
? "These details are stored in the file VERIFY.TXT which can"
? "subsequently be printed"
?
?
store '           ' to dbase1
store '           ' to dbase2
@ 15,10 say "Name of first file -  " get dbase1 picture "XXXXXXXX"
@ 17,10 say "Name of second file - " get dbase2 picture "XXXXXXXX"
read
use &dbase1
select B
use &dbase2
store '           ' to key
@ 19,10 say "Name of key field -   " get key picture "XXXXXXXXXX"
read
?
? "Indexing..."
index on &key to index2
clear
? "Analysing structure..."
copy structure extended to stru2
use stru2
count to nofields2
select A
copy structure extended to stru1
use stru1
```

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[Byass 1989 B]


```
count to nofields1
if nofields1 <> nofields2
 ?
 ? "Structures of the two databases not identical - terminating"
 return
else
 go top
 store 0 to fcount
 store str(fcount,1) to sfcount
 do while fcount <> nofields1
  store field_name to field&sfcount
  skip
  store fcount+1 to fcount
  if fcount > 9
  store str(fcount,2) to sfcount
  else
  store str(fcount,1) to sfcount
  endif
 enddo
endif

use &dbase1
select B
use &dbase2 index index2
select A
clear
?
set alternate on
? "COMPARISON BETWEEN "+dbase1+" AND "+dbase2
?
?
? "Records containing discrepancies"
?
?
do while .not. EOF()
 store A->&key to tkey
 select B
 find &tkey
 if .NOT. (EOF() .OR. BOF())
  store 0 to fcount
  store str(fcount,1) to sfcount
  do while fcount <> nofields1
   store field&sfcount to fname
   if A->&fname <> B->&fname
   ?  "Key ",tkey,", first file ",fname,A->&fname,",;
        second file ",fname,B->&fname
   endif
   store fcount+1 to fcount
   if fcount > 9
   store str(fcount,2) to sfcount
   else
   store str(fcount,1) to sfcount
   endif
  enddo
  delete
  select A
  delete
 endif
 select A
 skip
enddo
```

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[Byass 1989 B]


```
select A
set deleted on
?
?
? "Records in first file, but not in second: "
list
?
set deleted off
recall all
?
set deleted on
?
select B
? "Records in second file, but not in first: "
list
set deleted off
recall all
eject
set alternate off
set talk on
return
```

Appendix B

```
* dBaseIII+ verification program for TRFOLL.DBF

clear all
set safety off
set talk off
set print on
? "TRFOLL.DBF VERIFICATION PROGRAM"
? date(),time()
?
? "This program checks two TRFOLL.DBF files, called TRFOLL1.DBF"
? "and TRFOLL2.DBF, and notes details of discrepancies between"
? "records, or records missing in one or other database."
?
?
? "Records with differences:"
set print off
? "Sorting.."

use TRFOLL1 alias A
select 2
use TRFOLL2 alias B
index on serial to TEMP2
clear

select 1

do while .not. eof()
store serial to s
select 2
find &s
if found() .and. (A->date<>date .or. A->studyno<>studyno .or.;
 A->trdate<>trdate .or. A->avail<>avail .or. A->fever<>fever;
 .or. A->vomit<>vomit .or. A->diarr<>diarr .or. A->temp<>temp;
 .or. A->fw<>fw)
display to print
delete
```

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[Byass 1989 B]


```
select 1
display to print
delete
?
else
if found()
delete
select 1
delete
endif
endif

select 1
skip
enddo
select 1
set deleted on
?
?
set print on
? "Records in first file, but not in second: "
list
?
set deleted off
recall all
?
set deleted on
?
select 2
? "Records in second file, but not in first: "
list
set print off
?
set deleted off
recall all
eject
return
```

References

Byass P. (1986) The design of computer forms for tropical medical research. *Methods of Information in Medicine* 25, 229–232.

Byass P. (1989) Choosing and using a microcomputer for tropical epidemiology. Part I. *Journal of Tropical Medicine and Hygiene* 92, 282–287.

Byass P., Hanlon P. W., Hanlon L. C. S., Marsh V. M. & Greenwood B. M. (1988) Microcomputer management of a vaccine trial. *Computers in Biology and Medicine* 18, 179–193.

de Pace M. (1987) *dBase III Plus*. BSP Professional Books, Oxford.

Rowan K. M., Byass P. & Snow R. W. (1987) On-line tropical epidemiology: a case-study from the Gambia. *Methods of Information in Medicine* 26, 73–76.

Snow R. W. & Byass P. (1988) Computerised morbidity surveillance in the field. *Proceedings of African Population Conference, Dakar, Senegal* (IUSSP, Liege), pp. 1.2.31–1.2.38.

Stephens J., Alonso P. L., Byass P. & Snow R. W. (1989) Tropical epidemiology: a system for continuous demographic monitoring of a study population. *Methods of Information in Medicine* (in press).

Assessment of a Probabilistic Decision Support Methodology for Tropical Health Care

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As part of a project directed towards the development of a portable micro-computer decision support system for use in rural African health centres, data from 10,000 doctor/patient consultations have been incorporated into a system, using a previously described methodology. The performance of this system has been assessed against other documented consultations and achieved a good level of concordance.

1. INTRODUCTION

Although much research has been devoted to medical expert and decision support systems, very little of this effort has been directed towards health care problems in the tropics. Furthermore, in developing countries, particularly in Africa, there exists the greatest shortage of skilled medical manpower. The magnitude of these factors is clearly seen in Figure 1, which compares the origin of presentations at a recent international conference on medical expert and decision support systems with the ratio of doctors:population in different parts of the world.

In view of this situation, in The Gambia we are developing a decision support system which is designed to be used by paramedical staff in rural health centres, who otherwise have no direct access to higher expertise. The final system will be contained in a small portable microcomputer, powered with a solar cell. An appropriate probabilistic methodology has already been developed [1] which is computationally feasible for a small computer and which permits a flexible data-driven approach to decision support.

As a prelude to clinical trials of the system, we have built a database using documented details from 10,000 consultations between patients and experienced medical practitioners at the screening clinic stage of the Medical Research Council's (MRC) clinical services at Fajara, approximately 15 km from the capital of The Gambia, Banjul. The performance of the system using this database has been compared against a series of cases taken from those used in building the database, and a similar series that was not used in building the system.

2. CASES AND METHODS

2.1 Clinical Records

The MRC runs a general out-patient service from its base at Fajara on a daily basis Monday to Friday. Anyone in the locality seeking medical care at this facility is first seen at a preliminary screening clinic, unless they have already consulted, and been referred by, other medical practitioners. The majority of patients at the screening clinic are treated with one or more of a range

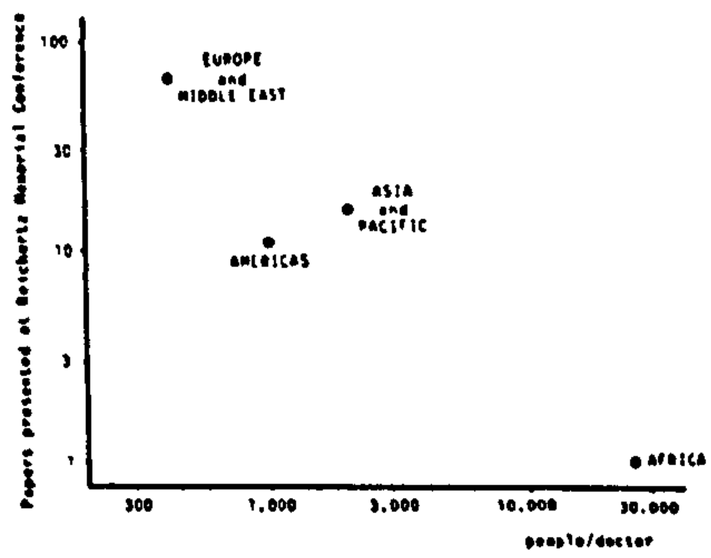

Fig. 1: Origin of papers at the Reichertz Memorial Conference compared with ratio of people:doctors.

Appendix VIII: Related publications

[Byass and Corrah 1989]

of common drugs, whilst a proportion are referred for a full consultation with a physician. During 1987, a total of 27,824 patients attended the screening clinic, and details were noted for a random sample of 13,212 consultations (47%) spread through the year.

For the recorded consultations, age group, sex and season were noted together with one or more of 40 specified signs and symptoms, and one or more of 27 treatments. Whilst neither of these lists were completely exhaustive, they covered a wide range of both common and rare medical conditions.

2.2 Computational Methodology

A Bayesian probabilistic methodology which calculates the advisabilities (A_i) of management strategies (S_i) given a set of patient indicators (I_j) has previously been described [1]. This method relies on a database containing the usages (U_i) of strategies at the patient population level and the occurrences (O_j) of characteristics (C_j) (which correspond to the indicators at the same level). Strategies and characteristics are related by relevances (R_{ij}) (the probabilities that the strategy is appropriate given the presence of a particular characteristic). The relationship between these terms is defined in the following Bayesian expression:

$$A_i(S_i|I_j) = \frac{R_{ij}(C_j|S_i).U_i}{(R_{ij}(C_j|S_i).U_i)+(O_j.(1-U_i))}$$

The method then involves repeatedly calculating $A_1..A_n$ for each applicable I_j. Strategies for which A_i exceeds a corresponding threshold T_i then form the recommended course of action.

2.3 Construction of the Database

From the 13,212 clinical records, a random selection of 10,000 was taken from which to build the model. The characteristics derived from these records, together with their occurrences, are shown in Table 1. Strategies and usages are shown in Table 2. Relevances relating characteristics to strategies were similarly calculated from the records (not shown).

In order to determine suitable thresholds for each strategy, 100 cases were taken at random from the 10,000 used to build the database. Advisabilities for each strategy for each of these 100 cases were then calculated using the cases' indicators. The distribution of advisabilities for each strategy were then considered, and a threshold value selected so that a proportion of cases corresponding to the usage of the strategy were above the threshold.

The relationship between thresholds and usages was then considered (Figure 2). On this basis, and for the purposes of this methodological evaluation, it was decided to set thresholds according to the relationship

$$\ln(T_i) = (0.5 \times \ln(U_i)) - 0.5$$

This includes all but 3/26 (11.5%) of the empirically determined threshold values and could be argued to be somewhat conservative, but since an important function of decision support as envisaged in the final system is to raise credible possibilities, this is arguably a reasonable course to take.

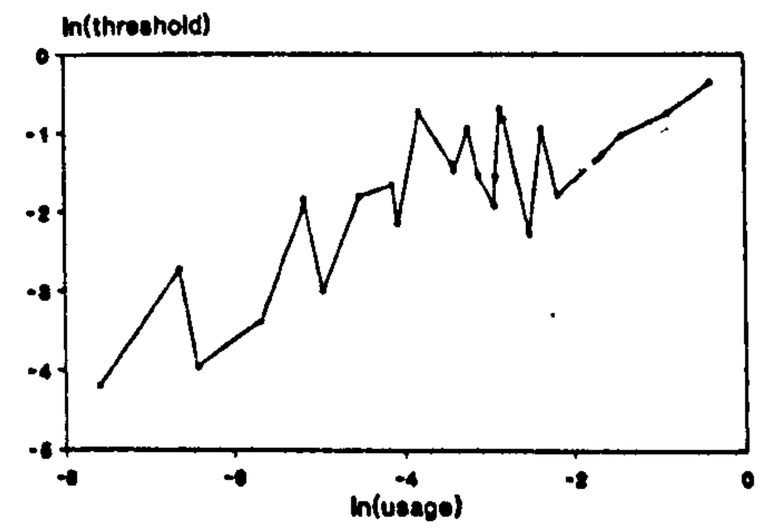

Fig. 2: Relationship between thresholds and usages. Dotted line shows curve for this assessment.

2.4 Test Cases

Initially a sample of 500 cases was selected randomly from the 10,000 cases used to build the system, in order to test its internal consistency. Subsequently a sample of 500 cases was drawn randomly from the 3,212 case records not used in the system.

In view of the considerable scope for different but equivalent management given the list of strategies used, for the purposes of evaluation the strategies have been functionally grouped as shown in Table 2, and the presence of one or more strategies from a group taken as "positive" for that group. This was necessary in part because of the inadequacy of the recorded symptoms and signs in differentiating between different treatments. For example, the pres-

Appendix VIII: Related publications

[Byass and Corrah 1989]

TABLE 1 Clinical details derived from 10,000 screening clinic consultations

	CHARACTERISTIC	OCCURRENCE
AGE	under 1 month	0.009
	0-5 months	0.046
	6-11 months	0.084
	1-4 years	0.219
	5-14 years	0.085
	15-40 years	0.445
	over 40 years	0.111
SEX	male	0.442
	female	0.558
SEASON	early rains	0.263
	late rains	0.227
	early dry	0.276
	late dry	0.234
SIGNS AND SYMPTOMS		
	fever	0.564
	general pain	0.177
	weakness	0.017
	dizziness	0.080
	weight loss	0.025
	joint pain	0.051
	fits	0.003
	shock	0.001
	trauma	0.007
	rash	0.105
	oedema	0.008
	local swelling	0.013
	loss of appetite	0.032
	anaemia	0.016
	jaundice	0.001
	mental confusion	0.001
	backache	0.058
	headache	0.114
	neck stiffness	0.002
	bulging fontanelle	0.001
	puffy face	0.002
	sore eye	0.037
	ear pain	0.016
	cough	0.242
	yellow sputum	0.013
	white sputum	0.043
	chest pain	0.154
	dyspnoea	0.017
	haemoptysis	0.006
	vomiting	0.113
	diarrhoea	0.099
	bloody diarrhoea	0.015
	upper abdominal pain	0.091
	lower abdominal pain	0.076
	dysuria	0.026
	haematuria	0.003
	genital discharge	0.024
	dysmenhorrea	0.003
	amenhorrea	0.004
	pregnant	0.003

TABLE 2 Patient managements derived from 10,000 screening clinic consultations

GROUP	STRATEGY	USAGE
REFERRAL		
	see doctor	0.113
	see surgeon	0.006
ANALGESIC/ANTIPYRETIC		
	aspirin	0.667
	paracetamol	0.060
VITAMINS ETC.		
	vitamins	0.410
	linctus	0.189
	magnesium trisil.	0.079
	iron tablets	0.059
	folic acid	0.022
	sytron	0.001
	laxatives	0.007
	kaolin	0.002
SKIN TREATMENTS		
	gentian violet	0.006
	hibitane	0.032
	benzyl benzoate	0.011
	benzoic acid	0.033
	tetracyline oint.	0.054
	calamine	0.016
	pot. permanganate	0.001
MALARIA TREATMENT		
	chloroquine	0.241
ANTHELMINTIC		
	piperazine	0.017
ANTIBIOTICS/AMOEBICIDE		
	septrin	0.053
	ampicillin	0.003
	chloramphenicol	0.039
	tetracycline	0.057
	flagyl	0.044
REHYDRATION		
	oral rehydration	0.092

ence of a rash is the only indicator for treatment with one or more of a total of 7 different strategies (gentian violet, hibitane, benzyl benzoate, benzoic acid, tetracycline ointment, calamine and potassium permanaganate). Although this would be unacceptable in a final system, for our present purposes we can consider "treatment of skin condition" as an endpoint in its own right.

In the clinical records, those patients referred to a doctor or surgeon had no further details of management noted. Thus, apart from the referral outcome, outcome comparisons exclude those cases which were referred in their original consultation.

Appendix VIII: Related publications

[Byass and Corrah 1989]

3. RESULTS

3.1 Sample of 500 cases from those in the database

Correspondence between the original clinical managements and the strategies proposed by the computer are shown in Table 3. Out of 443 cases not originally referred, 127 (29%) were given equivalent management in the clinic and by the computer for every functional group, and a further 200 (45%) were equivalent but included additional recommendations. Thus 74% corresponded closely. In the functional groups corresponding to potentially life-saving therapies (referral, malaria treatment, and antibiotics/amoebicide) only 61 cases (12%) who had received these therapies in the clinic were not recommended to do so by the computer. Thus it could be argued, if one accepts the validity of the original clinical managements as absolute, that the computer system performed tolerably well in 88% of cases.

3.2 Reassessment of discrepant cases

The 61 cases lacking important treatments on the computer's assessment were subsequently presented on paper to a senior physician for reassessment, without details of either their original management or of the computer's recommendations, nor with the knowledge that they were discrepant cases. In the reassessment, in 25/61 cases (41%) the expert opinion concurred with the computer recommendations, against the original management. In 20/61 cases (33%) the expert opinion concurred with the original clinical management, and in the remainder (26%) all three recommendations differed.

3.3 Sample of 500 other cases

Results for these are also shown in Table 3. Overall they are similar to the other group, with 145/451 (32%) exactly equivalent and 199/451 (44%) equivalent with additions, totalling 76% as being generally equivalent. Eighty-nine cases (18%) lacked referral, chloroquine or antibiotics in comparison with their original management.

4. DISCUSSION

The evaluation of the performance of medical expert and decision support systems is a notoriously difficult area because of the inherent variability of expert opinion in any moderately sub-

TABLE 3 Comparison of clinical management and computer recommendations for two groups of 500 patients. Sensitivities and specificities relate to computer recommendations compared with clinical management.

STRATEGY GROUP	500 CASES DRAWN FROM 10,000 IN THE MODEL				500 OTHER CASES			
	% PRESCRIBED CLIN	COMP	SENS	SPEC	% PRESCRIBED CLIN	COMP	SENS	SPEC
REFERRAL	11.4	11.6	54.4	93.9	9.8	11.8	40.8	91.4
ANALGESIC/ ANTIPYRETIC	81.5	95.9	98.6	15.9	82.5	98.7	99.2	3.8
VITAMINS ETC.	70.2	77.6	87.8	46.2	69.6	76.5	87.9	49.6
SKIN TREATMENTS	17.2	16.0	86.8	98.6	16.9	26.2	88.3	90.2
MALARIA TREATMENT	30.5	34.1	75.6	84.1	21.1	25.1	62.1	84.8
ANTHELMINTIC	1.8	2.7	*	97.7	0.2	1.6	*	98.7
ANTIBIOTICS/ AMOEBICIDE	17.2	29.1	68.4	79.0	12.6	20.2	57.9	85.2
REHYDRATION	10.6	23.9	85.1	83.3	1.3	8.4	*	91.7

Note: * insufficient cases

Appendix VIII: Related publications

[Byass and Corrah 1989]

jective field such as patient management. Rossi-Mori & Ricci [2] have identified four levels at which medical expert systems should be evaluated, taking the process right through to the impact of systems on the health problems for which they were designed. Our present evaluation is at their first level, namely the "raw efficiency of the system itself". It does not relate directly to the system's clinical effectiveness, its effect on the users' behaviour, or health in general.

In comparison with much expert systems research, the methods we have used are very simple. It is likely that more sophisticated AI methodologies could result in improved performance. However, this would increase the computational complexity so much that, at the present state of technology, there would be no possibility of getting rapid results on a small self-contained microcomputer. Since this is the only acceptable format for a system that could actually be useful in rural African health centres, we have deliberately excluded more complex methods from consideration.

Relatively few medical decision support systems have actually been implemented, much less evaluated, on microcomputers. de Dombal and colleagues [3] in their work on decision making as related to the acute abdomen have reported considerably higher initial accuracy by the computer system than by junior doctors (91% versus 42%), together with substantial improvements in human performance after using the computer system for some time. Uplekar et al. [4] have reported the use of a microcomputer system using flowchart logic (similar to that of Essex [5]) in which 78% equivalence between a physician and the system was obtained in a blind trial, excluding "non-essential" prescriptions for vitamins, etc., although their precise comparative criteria are unclear. Auvert et al. [6] have developed a hand-held system which was found to acceptable in Chad, although details of its performance are not available.

There is therefore relatively little with which to compare our results. Our evaluation also has the disadvantage that, rather than a live clinical trial, the computer case assessments were made retrospectively on the basis of the clinical records. It is likely that, at least in some cases, vague concepts such as "generally unwell" influenced the clinical decisions at the time of consultation but were not recorded and therefore unavailable to the computer. The relatively low sensitivities for referral, and to a lesser extent for antibiotics/amoebicide and malaria treatment, may well reflect the importance of disease severity, rather than the presence of particular signs and symptoms, as a determinant of clinical management. We are now investigating determinants of referral specifically in view of their importance in effective primary health care. However, in this assessment these effects are only likely to have caused underestimation of the inherent performance of the system, by increasing unknown inter-case variability. The results from the reassessment of the 61 discrepant cases suggest that many of them may represent unusual cases, or have other unknown peculiarities, such as mis-coding, which may account for the relatively poor correlation of both expert and computer with their original clinical managements. It should also be noted that there is little difference between the group of 500 cases from within the model and the other group in terms of either overall performance or sensitivities and specificities. This supports the view that a database compiled in this way can be used predictively on general cases.

The selection of appropriate thresholds above which strategies are recommended by the system is not trivial. The empirical basis which we have used for this assessment seems to have worked relatively well, but with some exceptions. Advisabilities for strategies with high usages (such as vitamins and aspirin) do not dichotomise well compared with those for rare strategies, and the ratio of their threshold:usage is not much greater than 1. In this assessment, the result has been that such strategies have been over-recommended, with consequent low specificity and high sensitivity. There is clearly scope for improving performance by adjusting thresholds for less essential strategies differentially from those involving crucial therapies.

Overall these results lead us to believe that our approach could form the basis of an effective system for use in health centres. Work is now underway to make the system more comprehensive and to develop an appropriate user interface, which will enable clinical trials to take place.

ACKNOWLEDGEMENTS

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Appendix VIII: Related publications [Byass and Corrah 1989]

REFERENCES

[1] Byass, P., A Probabilistic Approach to Health Care Delivery in Tropical Africa, in: Rienhoff, O., Piccolo, U. & Schneider, B. (eds.), Lecture Notes in Medical Informatics 36: Expert Systems and Decision Support in Medicine (Springer-Verlag, Berlin, 1988) pp. 136-141.

[2] Rossi-Mori, A. and Ricci, F.L., On the Assessment of Medical Expert Systems, in: Rienhoff, O., Piccolo, U. & Schneider, B. (eds.), Lecture Notes in Medical Informatics 36: Expert Systems and Decision Support in Medicine (Springer-Verlag, Berlin, 1988) pp. 292-297.

[3] de Dombal, F.T., Rev. Epidem. et Sante Pub., 32, (1984) 50-56.

[4] Uplekar, M.W., Antia, N.H. and Dhumale, P.S., Br. Med. J., 297, (1988) 841-843.

[5] Essex, B.J., Diagnostic Pathways in Clinical Medicine, (Churchill-Livingstone, New York, 1980)

[6] Auvert, B., Aegeter, Ph., van Look, F., et al., Comput. Biomed. Res., 19, (1986) 80-89.