FACULTY OF SOCIAL SCIENCES AND HUMANITIES

DEPARTMENT OF DESIGN AND TECHNOLOGY

SOME PROBLEMS OF DESIGNING FOR AUGMENTATIVE AND ALTERNATIVE COMMUNICATION USERS: AN ENQUIRY THROUGH PRACTICAL DESIGN ACTIVITY.

BY
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A Doctoral Thesis

Submitted in partial fulfilment of the requirements for the award of

Doctor of Philosophy of the Loughborough University

(28 January 2002)

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LOUGHBOROUGH UNIVERSITY

ABSTRACT

FACULTY OF SOCIAL SCIENCES AND HUMANITIES

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PhD

SOME PROBLEMS OF DESIGNING FOR AUGMENTATIVE AND ALTERNATIVE COMMUNICATION USERS: AN ENQUIRY THROUGH PRACTICAL DESIGN ACTIVITY

Jonathon Allen

The submission is concerned with, and addresses, problems of designing for people with disabilities, with specific reference to people who are illiterate and cannot speak. People with such disabilities often depend on electronic AAC (Augmentative and Alternative Communication) devices for interpersonal communication. A central theme of the thesis, however, is that such products, and products intended for people with disabilities more generally, have characteristics that inadequately attend to users' needs. Through a combination of practical product development and literature reviews, the thesis demonstrates how improvements to AAC devices can be made through user-participatory, user-centred and more sensitive and perceptive design. Literature reviews in the following subjects are reported: AAC; the operational knowledge base for design and disability; user participatory design; and wearable computing.

At the core of the thesis is the presentation and discussion of an empirical case study, carried out by the researcher, to design and develop the Portland Communication Aid (PCA). The PCA was conceived as an AAC product that would attempt to redress the inadequacies of predecessor devices. The design activity for the PCA is traced in the thesis, from initial concepts and development models through to a working prototype. Key ideas and essential principles of the design are illustrated. Throughout the work on the PCA, many problems associated with designing for people with severe communication disabilities were encountered. These problems, as with their resolutions, comprised matters of both designing (as an activity) and design (as product specification). The thesis contains comprehensive exposure and analysis of these problems and resolutions. In particular, the value of shaping meaning, metaphor, and other product semantics into devices intended for use by people with disabilities is explored.

The study provides two substantive conclusions. First, that both the activity and the outcomes of Industrial Design have a valuable role in the empowerment and rehabilitation of AAC users. And second, that key principles have been identified that will enable designers to better identify, articulate and respond to the needs of people with communication disabilities (and the needs of people with disabilities more generally).

ACKNOWLEDGEMENTS

Throughout this project many people generously contributed their time, thoughts, and advice. I would like to especially thank the following:

The Department of Design and Technology, Loughborough University, especially my supervisor, Paul Wormald; Director of Research, Professor Phil Roberts; and the workshop technicians.

The Staff and Students at Portland College, especially Sue Atkinson, Cheryl Davies, Charlotte Broughton, John Smallwood, Peter Davis, Mike Syms, Mathew Harrison, Peter Zein and Trung Quok Nguyen.

Dr. Colin Machin, Richard Mee, and Dr. Jon Knight from the Department of Computer Studies, Loughborough University.

Julian Page and British Telecom for the research license to use Laureate. Dr Bruce Baker and the Prentke Romich Company.

Colleagues at Massey University College of Design, Fine Arts and Music, Wellington, New Zealand.

Dr. Owain Pedgley for his continued support, encouragement and friendship.

My wife, Tracy, for too many things to mention.

This thesis is dedicated to those people who never got to see it – my late parents; Dr. Walton and Mike Hall.

INTRODUCTION

Introduction to the study

Designing, in its broadest sense, is about tackling problems. Designing involves *grasping* problems and *wrestling* with them in order to *overcome* them. 'Grasping' involves identification of the problems, and the situations which give rise to them, in order for the designer to gain sufficient understanding to proceed; 'wrestling' is the analysis of information, data, knowledge and understanding, whilst a resolution is synthesised to 'overcome' the identified problems. The success of a resolution is judged[1] by how well it overcomes the problem and, hence, may require fervent and rigorous wrestling. This analogy may appear to omit any evaluative stages in the design process – it does not. In order to overcome a problem, measures must be in place to establish whether or not the problem has been solved and, thus, this is an evaluative stage.

Problems are key starting points for design and also for research. The Cassell Concise English Dictionary states that a problem is, "a question proposed for solution; a matter, situation or person that is difficult to deal with or understand; a source of perplexity or distress; a proposition requiring something to be done; an investigation starting from certain conditions ...". This definition is a fitting description of what this research project has tackled, through both practical design activity and other research methods.

The aim of this thesis, put simply, is to communicate the tackling and outcomes of an inherently difficult design project, and thereby contribute to the body of design methods knowledge. This submission holds contributions to design research in three areas: research *into* designing, research *through* designing, and research *for*

1 Judgement can fall into two key areas: measured judgement and informed judgement (Abercrombie, 1960). This is particularly poignant for design research as much of designing relies on informed, or tacit, knowledge, in addition to measurable design data.

designing (Frayling, 1998)[2]. The essential focus of the thesis is how one designs for people with disabilities (or how, with current knowledge and understanding, one is susceptible to under-achievement in this task).

The starting point

Portland College, an independent college for people with disabilities at Mansfield, Nottinghamshire, in collaboration with the Department of Design and Technology, Loughborough University, presented a proposal for a jointly funded research project. The College had identified the need for a device to enhance verbal communication for people having severe speech difficulties and who are also illiterate.

Although considered to be state-of-the-art, the electronic communication aids used by Portland College's students (known as Augmentative and Alternative Communication (AAC) devices) presented a number of shortcomings.

> Often our non-speaking, ambulant students are unsteady on their feet yet they need to carry a large communication aid ...
>
> Smaller devices (which are easier to carry and less prominent) do not have the capacity to hold the range of vocabulary needed (in single words and short phrases) for conversation, requests, giving information, etc. Smaller devices are usually message-based which means students are restricted in their communicative ability.

(Atkinson, personal communication, 1994)

These shortcomings led to the initial problem statement: current AAC devices appear inadequate to their intended users. This problem statement provided the initial basis of the study – to investigate, through designing, the feasibility of producing an easier to carry and less prominent communication aid with vocabulary capacity equal to that of larger machines. A design project was accordingly initiated; the intended outcome and conclusion for the College would be a working prototype that fulfilled the needs of both the College and its students.

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2 Bruce Archer similarly refers to design research as falling into three areas – research *about*, *through*, and *for the purposes of* design(ing) (Archer 1995)

An exploration of the problems and contexts

Atkinson's personal communication also included an article written by a communication aid user entitled, 'Life Through the Eyes of a Non-Speaker'. This article confirms the need for a new device and, in addition, reveals more of the problematic nature of a communication disability.

> At the moment, I use a number of different ways to communicate. I do have a portable speaking machine, a 'Vois 135'. It can say words and short phrases. I got this when I was fifteen. It was a breakthrough but not good enough. The sound it produced was bad. At first it seemed good but then I felt disappointed in it ...
>
> Being a non-speaking person means that sometimes I feel sad. Because I have difficulty in communicating people tend not to speak to me. I think they are a bit afraid. They are afraid it will be too difficult to communicate with me. I don't think people mean to be bad. I try to put myself in their place. I can see how it would be difficult for me if I was in their position. I am always hoping that people will try to speak with me even though it's difficult. I am also nervous about speaking with people, but I do try. When I'm with other people and they are all speaking away to each other and I am left out of it, I sometimes feel as if I have two heads! It makes me feel quite lonely at times, even when I'm with other people.
>
> I get angry sometimes, and frustrated, when the word I want to say is not on my word board, especially if people ask me questions which are difficult to answer with the word board.
>
> ... In the future I know that things are going to get better. Technology is on my side.
>
> (McGregor, pp13-14)

So, can technology make things better? From the perspectives of the technologist, the engineer or the industrial designer, the answer (or rather, the assumption) is an overwhelming "yes, of course!" This, however, presupposes the articulation and understanding of an appropriate context.

On further analysis of McGregor's personal account, the problem would appear to be not just a technological one. He talks of his emotions – of feeling nervous, lonely, angry, sad, frustrated; of his difficulties and his disappointment. This indicates that sociological and psychological factors are a part of the problem space and points to underlying inadequacies in current AAC devices.

The relationship between the user and the product is of interest here. Products catering for people with disabilities have a crucial role in determining the quality of life for their users. These products must perform both functional and communicative goals[3] if they are to satisfy users' needs, wants, aspirations, abilities and capabilities. That is to say, the design of disability products must address not only technical functions but, as Buchanan describes, the "more thorough and diverse interpretation of the physical, psychological, social, and cultural relationships between products and human beings" (Buchanan, 1992 p9).

Regarding disability products in general, Paul Hogan, then Chairman of the European Institute of Design and Disability (EIDD), states:

> Most of the products on display are engineered and not designed. No thought appears to have been given to the psychological impact of the design on those who have to use them. The majority of products ... are ugly, shiny and say in the most emphatic way to the purchaser, "You are a cripple".
>
> (Hogan, 1994 p2)

This is a damning statement and highlights a profound problem. Technology is capable of granting people with disabilities greatly increased independence and quality of life, affording opportunities to perform tasks that would otherwise be impossible. A product's success is, however, often marred by a lack of consideration of how its technology is packaged. In many cases, the very devices intended to assist people with disabilities in fact do damage: they compound people's disabilities by drawing attention to impairments. (This is very apparent with AAC devices and will be discussed further in Chapter One.)

It is not just the experiences of AAC users that provide a complex and problematic context to this project. Problems face the designer too – related to how one goes about designing and specifying a device for people with severe disabilities. Through the process of investigation and designing described in this thesis, these problems were identified and tackled. These problems exist outside the range of issues that most designers are used to dealing with and will be identified and addressed in this thesis.

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3 Wolfgang Jonas refers to Functional goals and Communicative (semantic) goals in his paper 'Design as problem-solving? or: here is the solution – what was the problem?' (see Jonas, 1993 p 169)

Questions to be addressed

> Sometimes the problem is to discover what the problem is. ... You are unlikely to hit a target if you cannot see it, or are looking at a different one.
>
> (Glegg 1971, p5)

To achieve a good design outcome requires an accordingly good identification of the situation in which the design need is thought (or known) to lie. Within the field of AAC, gaining a comprehensive understanding of this situation is problematic. Blocking the designer's way to producing product proposals is the obstacle of how to assess what is required of a possible new device.

The most typical starting point in any design project is, 'what is the present situation and how can it be improved?'. The work in this thesis addressed several lines of enquiry, as described below.

- What is the present situation from the different perspectives of the interested parties, most especially AAC users, and the designer?
- What is the summation of the problems and issues facing each party (in other words, what constitutes the overall problematic state of affairs?)
- How does the problematic state of affairs affect the designer?
- How does the problematic state of affairs affect the AAC user?
- What are the shortcomings of current AAC devices?
- To what extent do AAC devices disable their users?
- What can industrial design contribute to the field of AAC?
- What is different, and perhaps more complex, about designing for AAC users than for other markets?

By exploring these constituent questions, and by distinguishing between symptoms and underlying problems, it is hypothesised that the seeds of a good solution will be sown.

The aim and breadth of the study

The following research objectives were set.

- To identify and explore the key problems and issues of designing for AAC users and the various parties involved.

- To then offer procedural and specification-based resolutions (in the form of design recommendations).

- To explore the efficacy of designed objects in raising the status, self esteem and pleasure of AAC users.

- To produce a prototype of a communication device that demonstrates its production feasibility, referred to as the Portland Communication Aid (PCA).

The design project

To fulfil Portland College's requirements of the study - a working device - it was a prerequisite to engage in a design project. A design project provides an ideal opportunity to empirically investigate and research the problems and issues of designing for the needs of AAC users. The project for Portland College provided penetrating insights into design and disability, since the field of AAC is multi-disciplinary, involves high-technology, and the range and types of disability encountered are varied.

A characteristic of design projects is that key areas for investigation become apparent once the project is initiated: designing and learning go hand in hand. In the process of designing, one learns more about the issues that are important to a project – this is echoed by many authors (Buchanan & Margolin, 1995; Cross & Cross, 1995; Lawson, 1990). Research enquiry through practical design activity (in this case research *through designing*) was used to meet the enquiry's objectives. From the designer's perspective, research undertaken in this manner is effective because it is a mode of work that makes good use of what designers are used to doing. Research through practical action places designing as a mode of investigation, which can then be used to complement more established research methods.

The research was undertaken substantially through the normal practices and activities of the author's design processes. In so doing, the investigative nature of the design process illuminated the complexities of designing for the needs of AAC users.

The industrial designer as researcher

An industrial designer is ideally suited to undertake a design-and-make project focused on disability products. The industrial designer, by necessity, is a generalist – able to interact with a variety of specialists involved with new product development (NPD). These specialists most typically include engineers, marketeers, ergonomists, manufacturers, and others. Trained in both technology-centred and human-centred subjects, the industrial designer can act as an interdisciplinary mediator between these parties, the intended users of the product, and the public. The ability to communicate with the various interested parties is important and involves listening, articulating and presenting on various levels and with various media. Interdisciplinary competence, the ability to analyse and synthesise information and knowledge, and the creative skills of problem solving, artistry and craft all combine to define the industrial designer's role.

With respect to research enquiry through practical activity then, the industrial designer has much to offer. In the case of designing the PCA, a wide range of subjects were anticipated to be covered – many of them within the remit of the industrial designer. Technical subjects such as meshing technology with user needs, design for manufacture, and scales of production were anticipated. Conceptual work (the creative exploration of design ideas) was expected to play an important role, as was grasping underlying problems and examining different parties' conception of the same situation.

Contribution to knowledge and understanding

The thesis spans several subject areas including design practice, design and disability, AAC, and design research. The submission, therefore, is intended to contribute to each of these:

- providing insight into how to cater for the needs of AAC users;
- identifying the complexities of designing for people who have severe communication disabilities;
- demonstrating the contribution that industrial design can make to AAC; and,
- presenting an empirical case study of designing for people who have severe communication disabilities.

The role of the designer in developing artefacts for people with special needs, the various design approaches applicable to this end, and the specific knowledge and skills industrial design can offer in this task are discussed within the thesis. The intention is to provide a clear and concise view of the difficulties that a designer venturing into the world of disability products will face. This thesis is to act not as a guide or a map (because the route and direction a designer takes is dependent upon the specifics of a situation) but rather as a torch to illuminate and shed light on potential difficulties.

The outcomes of the research enquiry are:

- An exploration and articulation of the problematic state of affairs surrounding the design of the PCA (and extrapolated to other such devices for people with disabilities).

- A contribution to the operational knowledge and understanding required to establish and satisfy AAC users' needs and desires (extrapolated to the needs and desires of people with disabilities more generally).

- An account and discussion of the approach and techniques used in the design of the PCA.

- A prototype of a new product that caters to the needs of Portland College and its students.

Structure of the thesis

The thesis is divided into three sections. Section One explores the nature and extent of the problem situation, assessing the present state of affairs. It explains the background, contexts, problems, research methodology and intended outcomes of this work. Section Two is a discussion on designing describing the design and development of the PCA. The final Section is an illuminative and critical commentary in the light of the discussion in Sections One and Two, leading to the chief conclusions of the research.

Section One contains four chapters. Chapter One serves as an introduction to Augmentative and Alternative Communication, providing an informative account and overview of the field including definitions and demographic information. It highlights the importance of communication and describes the methods and devices by which non-speakers communicate. A discussion of some of the shortcomings of current devices is discussed at the end of the chapter. The significance and gravity of the need for an improved device and, therefore for this study, is outlined here.

Chapter Two explores the problematic state of affairs. The Chapter is broken down into three focal areas. Problems and complexities facing the designer when designing in this field are first explored. Secondly situational issues particular to the disability sector, and to AAC more explicitly, are exposed. The discussion is centred upon what is different about the market for disability products compared to mainstream markets, and looks more closely at the provision of AAC devices. Finally, the sociological and psychological consequences of physical disabilities, and the issues these pose for people with disabilities are discussed. The chapter concludes that designing for people with severe communication disabilities is problematic, particularly as there is a general lack of information, data, knowledge and understanding to aid design work on AAC devices.

Chapter Three presents the state-of-the-art with regard to design and disability, and designing for AAC users. It explores what others have done in response to the problems discussed in Chapter Two and summarizes their design recommendations and proposals. Chapter Four poses the chief questions to be addressed in the study – that is, those areas worthy and appropriate for investigation that have not been addressed by other researchers.

Section Two discusses the design project and is divided into four chapters. The first of these chapters, Chapter Five, discusses both the methods and the outcomes of establishing user requirements. Chapter Six discusses the detailed design and development of the PCA, including time-scales and plans, the role of Portland College and other contributors to the design process, and describes the design development process itself. Key stages of the design and prototyping of the PCA are illustrated. The essential principles underlying the design of the PCA and those new ideas that are embodied within it are discussed in Chapter Seven. This chapter also serves as a comprehensive product description. An accompanying CD-ROM supplements Chapters Five, Six and Seven, cataloguing, in a visual format, more of the design process and design outcomes. The CD-ROM is navigable and includes a collection of animated and still images, sound samples, photographs, drawings, computer animations and models. Chapter Eight presents the results of evaluative work on the PCA.

The final Section, contained entirely within Chapter Nine, presents conclusions in the form of a reflective and critical commentary. The chapter identifies strengths and short-comings of the project, as well as pointing towards areas in need of further research.

Section One

CHAPTER ONE

Augmentative and Alternative Communication: background, definitions and devices

---

1.0 Introduction

This chapter provides a background to Augmentative and Alternative Communication (AAC). It serves as an introduction not only to AAC but to AAC devices that are used by people to communicate. Communication, language and speech are explored first and the significance and gravity of being able to communicate with people having disabilities is raised. Disability in general is discussed and definitions and terminology relating to AAC are clarified, along with a more detailed synopsis of communication disabilities. A review of the electronic communication aids used by Portland College's students appears at the end of the chapter to provide both an historical background to the AAC devices that they have been using and a platform on which the design of the PCA may be judged.

A prerequisite to designing a new product is the need to familiarise oneself with the product area involved. The acquistion of sufficient background knowledge of AAC and its associated subject matter (e.g. speech, speech synthesis, communication disabilities) was an important step in comprehending the world of AAC devices. As the subject matter was broad (and included specialist and disparate disciplines) a necessarily broad approach was taken to the gathering of information. Hence, material for this chapter has been garnered from four main sources: literature, products, users and specialists.

A literature search was conducted to provide some initial insights. To ensure thoroughness, key words of similar meaning were used in the search. Particular attention was paid to (a) discrepencies in UK and US English (e.g., 'aetiology' and 'etiology', 'modelling' and 'modeling') and (b) international terminology (e.g. 'ergonomics', 'human factors', 'human engineering').

Specialist and general terminology were used in certain instances to ensure as wide a coverage of literature as possible; an example being derivations of the terminology used to describe disorders of speech - 'aphasia', 'anarthria', 'aphonia', 'dysarthria', 'dysphasia', 'dysphonia', 'dyspraxia', 'speechless'. Boolean word searches permitted multiple derivations of search terms, accommodating differences of spelling and terminology used between countries, and so refined the literature exploration. Additionally, searches conducted upon word stems proved invaluable (eg 'therap*' found literature on 'therapy', 'therapeutic', 'therapist', as well as their associated plurals). Some of the key words became apparent from reading the literature, once the search was underway.

Starting with AAC, the literature search broadened to include such topics as:

- alternative interface systems;
- computer technology;
- design and disability;
- discourse analysis and pragmatics of speech;
- disability — the search for literature on disability was divided into two main areas: general literature on disability, handicap and impairment (including their respective definitions based on both the medical and social models of disability[4]); and literature specific to disabilities affecting communication (speech disorders and dysfunction);
- human computer interaction (HCI);
- illiteracy;
- rate of speech production; and
- speech synthesis and technology.

[4] A brief explanation of the differences between the medical and social models of disability is provided in Chapter Two.

The following data-bases were scanned:

- Applied Science and Technology Index;
- International ERIC;
- Global books in print;
- Science citation index;
- OCLC first search: Worldcat.

The Pilkington Library at Loughborough University and Portland College's Library were also searched extensively. The Micro-Centre at the University of Dundee, the AAC Research Unit at Stirling University, and Tony Jones from Liberator Ltd. kindly provided copies of their publications and, in the case of Tony Jones, an extensive bibliography of publications within the field of AAC was gratefully received. By far the most useful starting point for the search was Portland College's Further Education Unit. It possesses a wide selection of literature, primarily journals and articles geared towards the speech and language therapist (written predominantly by practitioners in the field), but also catalogues of existing equipment catering for people with special communication needs.

Publicity literature (catalogues, press releases and leaflets) from manufacturers and suppliers of AAC equipment was obtained, along with information gained from presentations given by various communication aids suppliers, interviews with AAC users and observation and analysis of current devices. All of this helped in constructing a review of commercially available communication aids. This review was carried out to help establish the state-of-the-art as well as to provide a basis for competitor analysis.

Consultation with a number of practitioners and experts in fields applicable to this study revealed further useful information. A lot of interesting and relevant literature emanated from The MicroCentre at the University of Dundee, and from the AAC Research Unit at Stirling University. Visits were arranged in early May 1995 to both these Universities to discuss their work further. A meeting with Dr. Alistair Edwards at the University of York to discuss speech synthesis and its application in devices for people with disabilities was also arranged to coincide with this Scottish trip.

Later a trip to the National Communication Matters[5] Symposium at Lancaster University in September 1995, funded by the Communication Aids Suppliers Committee (CASC), provided an excellent opportunity to find out more. This Symposium brought together many very influential and respected people within the field of AAC. The information and experience obtained from both the Scottish trip and the symposium proved very useful in refining the focus of this Ph.D. study, as well as getting to know those prominent in the field of Augmentative and Alternative Communication in the UK.

Trade fairs and seminars attended by organisations associated with, or catering for, the disability sector were also attended to gather further information about the fields of AAC and design and disability. Such organisations included: the European Institute for Design and Disability, the Computability Centre, NAIDEX (a UK exhibition of healthcare equipment and services for disabled and older people and their carers), the Tools for Living Foundation at Brunel Institute for Bioengineering, the European Minspeak Conference, and the Design for Ability research team at Central Saint Martins College of Art and Design.

The corpus of material has been gathered here to provide an introduction and background to AAC.

1.1 The importance of communication, language and speech

To communicate is to impart or reveal not only thoughts in a form that can be understood but also to enter into a social interaction that enhances, and can determine, the quality of life of an individual. Communication establishes the mechanisms for people to make needs and wants known. We communicate in a variety of ways (such as gestures and language) and through different mediums (such as writing, music, art, speech, drama and touch). By far the most common (and complex) way of communicating is language. The complexities of language can be broken down into semantics (the meaning), syntax (the word order), and pragmatics (the what and when of the use of language).

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5 'Communication Matters' is a national voluntary organisation concerned with the needs of people with severe communication difficulties. It produces publications and organises a two-day conference every year.

Speech is probably the most important form of human communication and is the most expressive medium. It is unique to human beings – language distinguishes humans from other species, whilst a voice distinguishes the individual. A useful definition of a voice is, "the expression of yourself to others or anything that gives another insight into your personal world" (Harvie, 1992 p137). The qualities of stress, rhythm, timing and intonation in speech (otherwise known as prosody) can determine how the spoken word is interpreted and, therefore, are important in the conveyance of meaning. Furthermore, verbal communication is reinforced by gesture, facial expression, body language, and structure of the sentence and, thus, additional meaning is given by these elements of communication (a wink, for instance, can indicate the opposite of what is being said).

Newell (1992b) reviews the use of speech within inter-personal communication. The section in his paper on 'The use of speech modality in Human-Human Communication' gives reference to the varied range of information that speech communication can convey.

> Effective speech communication between people requires familiarity with an enormously complex set of rules. These rules include:
>
> Phonetic;
> Phonemic;
> Syntactic;
> Semantic; and
> Pragmatic rules.
>
> Breaking any of these rules will reduce the effectiveness of communication, and even small errors can cause complete breakdown. This is particularly true at the pragmatic level, speech communication between people being relatively resilient to errors in the other characteristics.
>
> (*ibid*, p171)

He goes on to state that the speech waveform also contains information about various things, including:

- The sex and age of the speaker;
- The size of the speech organs;
- The primary accent as well as other geographical regions where he has spent significant periods of time;
- The socio-economic group to which the speaker belongs;
- The state of health of the speaker.

(*ibid*, p171)

A voice also conveys more than its owner deliberately intends. Paralinguistic qualities relate more about the speaker; such things as the quality of the voice (creaky, breathy, nasally), the emotional state of the speaker, the accent or regional dialect, the age and gender. Prosody and paralinguistic qualities are referred to as suprasegmental features of speech, and are as important as language in conversation. A speaker thus has the ability, whether consciously practiced or not, to add to the speech a wide variety of other important information by the variation and application of suprasegmental features in the spoken output.

Having a voice is more than just having the ability to say something: it provides the facility to speak and be heard, thus promoting autonomy, liberty, and expression of self. In turn this contributes to, and can determine, an individual's quality of life by providing the means to increase self esteem, motivation, confidence, and reduce frustration.

1.2 Background to AAC

Augmentative and Alternative Communication refers to all types of communication that supplement, increase or improve speech for people who have articulation, voice, and/or language impairments. Augmentative and Alternative Communication techniques have been practised for a long time, but the field of AAC has become established in only the last few decades. The field has developed as the paths of different specialists, professionals and practitioners have crossed. Contributors to AAC therefore include speech and language therapists, linguists, psychologists, medical practitioners, technologists, computer scientists, communication tutors, care assistants and, of course, those for whom AAC provides a facility to communicate. The subject is broad and multi-disciplinary.

1.2.1 Definitions

Before providing an explanation of the specific terminology within the AAC field it is first necessary to provide definitions of general terminology used when discussing disabilities and speech disorders. The World Health Organisation's (WHO) definitions of disability, handicap and impairment are as follows:

Disability -	Any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being
Handicap -	A disadvantage for a given individual, resulting from an impairment or disability, that limits or prevents the fulfillment of a role that is normal (depending on age, sex, and social and cultural factors) for that individual
Impairment -	A loss or abnormality of psychological, physiological, or anatomical structure or function.

(World Health Organisation, 1980)

The Disability Information Trust publishes books on equipment and services available for people with disabilities. Specifically related to communication disorders and Augmentative and Alternative Communication, Barrett (1995) explains the following terms which give an indication of the typical characteristics of specific disabilities and the nature of the physical problems faced by many non-speakers.

Disorders of articulation:

Anarthria	Total absence of articulation.
Dysarthria	Less severe disorders where articulation is distorted by slurred weak or explosive characteristics and the co-ordination of respiration and phonation may be affected. (Co-incidentally, there may be drooling and difficulties in feeding and swallowing).
Oral Dyspraxia	No muscle weakness but a partial inability to perform purposeful co-ordinated movements of the articulators caused by a parietal lobe disorder.

Voice disorders:

Aphonia	Total loss of voice.
Dysphonia	Partial loss of voice.

Language disorders.

Aphasia	Absence of recognition and loss of verbal expression.

Dysphasia — Impairment of recognition and use of verbal expression involving difficulty with reading, writing and numbers. Verbal symptoms of dysphasia may include perseveration (repetition of words and phrases), recurrent utterances, telegrammatic speech (omission of articles, prepositions, etc., and difficulty in word-finding).

(*ibid*, p1)

Further explanation of terminology can be found in Lloyd and Blischak (1992) who provide a list of key words, terminology and policy in a paper for the journal *AAC Augmentative and Alternative Communication.* Although specific to that journal, the paper is a useful introduction to key terms within the field of AAC Griffiths (1972) provides a useful introduction to aphasia. Some interesting definitions of language and speech from various authors are presented, as well as the social problems that arise through not having a voice (this matter is discussed further in Chapter Two).

1.2.2 Statistics and demographics on disability and AAC

Literature containing statistics for people with disabilities (and more specifically for people with a communication disability) has been used in this study to give a representation of the market size for a new communication aid.

Sandhu and Wood (1990) offer estimates of the number of people with disabilities. Although their report showed a great variation in statistics between countries (Spain has a disabled population of 25%, whilst that of Switzerland is only 1.6%), the overall estimates show that approximately 10% of the European population is disabled. Specifically related to verbal communication disabilities, a figure of 3.6 million people from thirteen European countries is reported, whilst within the UK, Collingsworth (1993) notes that 1,202,000 people, which is nearly 3% of the population, have a communication disability.

Ratcliff and Beukelman (1995) refer to various demographic surveys on users of AAC systems. The majority of these surveys cite statistics for specific regions in the United States, but one survey concludes that, "approximately 2 million Americans (0.8%) are unable to communicate using speech" (p61). The AAC research unit at the University of Stirling produced a demographic survey of AAC users in

Scotland (Murphy *et al*, 1995). This survey, carried out between 1991 and 1992, evaluated the needs of AAC users within Scotland, and cited statistics based on other studies within the UK, as below.

> The "Quirk Report Speech Therapy Services"... estimated that the speech-impaired population at that time [1972] was 324,180 (0.6% of the total population). ... However, more recently, Enderby and Philipp (1986) estimated that there are about 2.3 million people in the UK with various forms of speech and language disorders connected with medical and/or developmental conditions. Of these people, the authors estimated that 800,000 (approximately 1.4% of total population) have a severe communication disorder.
>
> (p26)

For the purposes of this study the figures stated by Murphy *et al* and Ratcliff and Beukelman will be adopted, as these figures have been established by AAC specialists. Thus, estimates of 800,000 people in the UK and 2 million people in the US will be used.

1.2.3 Common disabilities affecting speech

There are various disorders affecting speech. Damage to the vocal tract can result in a person not being able to speak effectively, as can damage to the region of the brain affecting muscle control. A severe speech disability is often the result of poor motor control affecting muscle co-ordination, so that the larynx cannot function effectively. The loss of motor control can occur from birth such as is the case with cerebral palsy, or can be acquired due to a degenerative disease, a cerebral vascular accident (a stroke), or a severe head injury.

The most prevalent AAC users are those people with cerebral palsy. Cerebral palsy (CP) is a form of brain damage that occurs either before or during birth and has one of three forms: athetoid, spastic, or ataxic. Although some features of the disability are common, there are significant differences between them that are of note. Athetoid cerebral palsy is characterised by constant wriggling and writhing movements, often violent in nature and consequently people with this form of CP are in danger of hurting themselves if unprotected. Spastic cerebral palsy has very different characteristics: the individual has abnormally increased muscle tension resulting in a rigid and clenched body causing slow, forced, but erratic movements. Ataxic cerebral palsy appears to have less marked impediments typified by difficulty in balancing. About 75% of people with cerebral palsy have some degree of speech defect; a quarter have poor vision; a quarter have hearing loss; and some also have epilepsy. Half of these people are deemed to be of 'normal' intelligence (based on Intelligence Quotient (IQ)).

The incidence of cerebral vascular accidents (strokes) is higher than those of cerebral palsy with about 100,000 cases reported each year in the UK (Collingsworth, *op cit*, p55), with the majority of patients being middle-aged or elderly. The effects of a stroke are varied dependent upon the severity and the location within the brain. Hemiplegia (paralysis of one side of the body) is common with stroke, and speech and/or vision may be impaired. Memory loss and incontinence are also common. If the right side of the brain is damaged, the left side of the body may become paralysed (left-hemiplegia), whereas if the left side of the brain is damaged, then the right side of the body is affected and speech problems may occur. The greater range of effects of strokes, the greater probability of them occurring in later life, and the fact that about half of all patients recover more or less completely, means that although there are more stroke victims than people with cerebral palsy, fewer stroke victims use AAC devices.

Degenerative diseases such as multiple sclerosis (MS), motor-neurone disease (MND), Huntington's chorea and Parkinson's disease also affect speech, but have different characteristics. MS often appears in a person's twenties or thirties and affects their central nervous system. It can cause locomotor paralysis, inco-ordination, incontinence, vertigo, slurring of speech, loss of sensation, deafness, blindness, impotence and an impairment of mental functions. MND is characteristically very similar to spastic cerebral palsy, but is acquired after birth and is progressive and degenerative. Huntington's chorea is a hereditary disease and is progressive, causing degenerative changes in the cortex (outer layer) of the brain. It can cause mental retardation, ataxia, involuntary movements and slow, slurred speech. It typically occurs between the ages of thirty and fifty. Parkinson's disease is a chronic disease of the brain causing tremors and muscle rigidity, impaired speech, inco-ordination, slow movements and shuffling gait. The facial muscles are affected making communication difficult and also results in dribbling.

Many deaf people have incomprehensible speech and so the deaf community could also benefit from AAC. At present, AAC devices do not cater for this group largely because the deaf community feels that such devices would handicap them more, due to the size, weight, cost and poor quality of voices of current devices, and the stigma associated with using such devices (Baker, personal communication, 1997). This group of people, however, are worthy of consideration as a potential market for AAC products if the products can be made suitable for them.

Of people with a speech impairment, 75% also have other impairments (Vanderheiden, 1990). Brain disorders that affect speech typically affect motor control as well, and result in poor muscle co-ordination characterised by drooling, uncoordinated movements, spasms, and breathing difficulties. These characteristics can hinder attempts to communicate.

People with physical impairments often face a lifetime of dependence on others; thus the ability to communicate allows them the means and opportunity to take control over their situation. However, for people who have a communication disability in addition, that control is often denied making their choices not only dependent on others, but also determined by others. For such people the power of communication has greater significance as it presents an opportunity to gain some degree of autonomy.

1.3 Communication aids

A person with a speech deficiency is typically referred to a speech and language therapist for assessment to establish whether he or she can be taught to talk effectively without an aid, or could benefit from a communication device. Communication aids vary from being as simple as card picture boards to advanced, fully talking, computer-based devices capable of storing thousands of words and phrases accessed through head movements. A variety of communication aids with speech output is currently available. These are often referred to as VOCAs (Voice Output Communication Aids), and typically take the form of an interface, microprocessor-based circuitry, and a voice output device enabling the user to select or generate words and phrases that are then spoken out by the machine. The speech and language therapist and the individual will assess which particular aid is most appropriate to the individual's needs.

The method of selecting or generating words and phrases (the interface or input device) and the speech output device are the most significant considerations for the user when selecting a communication aid (or at least they should be). There is a variety of input devices used in AAC, such as buttons, keyboards, touch screens, head pointers, switches and tongue palettes. The selection of a particular interface is largely dependent upon the physical ability of the user and, to some degree, his or her cognitive ability. The quality of speech synthesis produced by AAC devices is a very important (but often overlooked) matter for people who use them as it becomes *their* voice. Many things are conveyed by a voice and as a consequence the selection of a voice synthesiser for an AAC product is very important, perhaps critical to its success. Recent developments of natural-sounding voice synthesisers with English accents are an encouraging sign; with more work in this area, improvements in comprehensibility of artificial speech will ensue.

1.4 Language representation in AAC

There are two main approaches to language representation within AAC: iconographic based systems, and alpha-numeric (or text-based) systems. The use of a particular system over another is largely dependent upon the literacy levels of the AAC user. Text based systems tend to be favoured by literate users as this concept of language representation is familiar to them, whilst picture-based systems present an illiterate AAC user with a simpler and, therefore, quicker method to learn how to convey messages. (Picture-based systems are not commonly used by literate users, but can still allow them to communicate effectively and efficiently.)

Perhaps the best known example of someone who uses an AAC device is Stephen Hawking, the eminent physicist and author, who has Amyotrophic Lateral Sclerosis (ALS). The system he uses consists of a portable computer and a speech synthesiser fitted to his wheelchair. Words and letters are selected by controlling a cursor that moves across the screen which he can stop by pressing a switch in his hand. In this way sentences can be constructed, which are then spoken out by a voice synthesiser. Professor Hawking's device relies on his literacy skills. For people who cannot talk and are illiterate (those that this study concerns itself with), a different system of language representation is required.

1.4.1 Illiteracy, and iconographic based systems

Many AAC users are illiterate; this is an added complexity of some communication disabilities. Children learn to talk before they learn to read. The constructs of language are instilled early in a child's development and as a result he or she has the opportunity to become literate. Learning is accelerated through the acquisition of language. A person born with some form of aphasia is typically held back from learning due to the late acquisition of language, and may never become literate. People who lose their speech in later life may be literate or not. Those who become unable to talk owing to a developmental disease such as motor neurone disease are often literate, as they have had the opportunity to gain literacy skills in childhood. However, some people acquire aphasia due to a head injury and this, in many instances, necessitates learning again from scratch.

One alternative language representation is the iconographic or picture based interface. The use of pictures to communicate messages and words is a well established practice in teaching, and this is a popular way for children to be taught to read. A picture or an icon can convey much information. For this reason, picture, icon and symbol-based systems of language-representation and interfaces are used extensively by aphasic people, be they illiterate or not.

The first icon-based communication aids were simply a collection of pictures, usually in the form of a book or picture board, that permitted a user to convey a message by pointing at one of the pictures. The main problem with such a system is that an AAC user may wish to communicate more than is available on the particular picture board or book. The conversation partner thus has to interpret what the user is trying to say, for example, if the "apple" icon is pointed at, the user may be trying to say, "I'm hungry", or "I want an apple", or "green", or "Sir Isaac Newton". The ambiguity and possible consequential mis-interpretation is frustrating for both conversation partners.

The simplest of electronic aids provides a solution to this ambiguity, in that an icon represents only one entity (as only one word or phrase is stored in a particular location). The counter problem of this is that if single meaning icons are to be used, potentially several thousand are required (one for every word) to permit users to accurately make known what they mean. Communication aids that use single-meaning icons are limited to the number of keys they can provide within a given space. The number of keys dictates the number of utterances. There are two ways around this situation: make use of a dynamic interface or, if using a static interface, make use of sequencing the icons to convey messages. The latter approach presents a problem, however, in that using two icons or more to select a word or phrase may run the risk of losing the 'inherent' meaning of the icons themselves.

1.4.2 Multi-meaning icons: Minspeak

One resolution is to make use of multi-meaning icons, whereby words and phrases can be encoded by sequencing them in a way that is simple to remember. This can result in an increased vocabulary capacity from a limited number of core icons. This is the basis of Minspeak, an iconographic based system which uses semantic cues and multi-meaning icons in its approach to language and knowledge representation. Created in 1980, it "has developed from a concept in the mind of a particular graduate student to the most widely used technique in electronic communication aids" (Baker and Barry, 1990, p146). Many of Portland College's students make use of this system to communicate.

The system is a patented language representation technique that is based upon the inherent polysemy (multiple meaning) of icons and pictures. The icons are selected and sequenced in such a way that a small set can represent a large number of words. Thus, thousands of words can be accessed from relatively few icons. The icons make use of mnemonic cues and devices to reduce the cognitive load upon the user to remember all the sequences.

For example, to start a sentence the 'Judge' icon is selected (as judges give out sentences!). Icons are usually paired to form words. Figure 1 shows two examples of icon combinations that result in the following phrases:

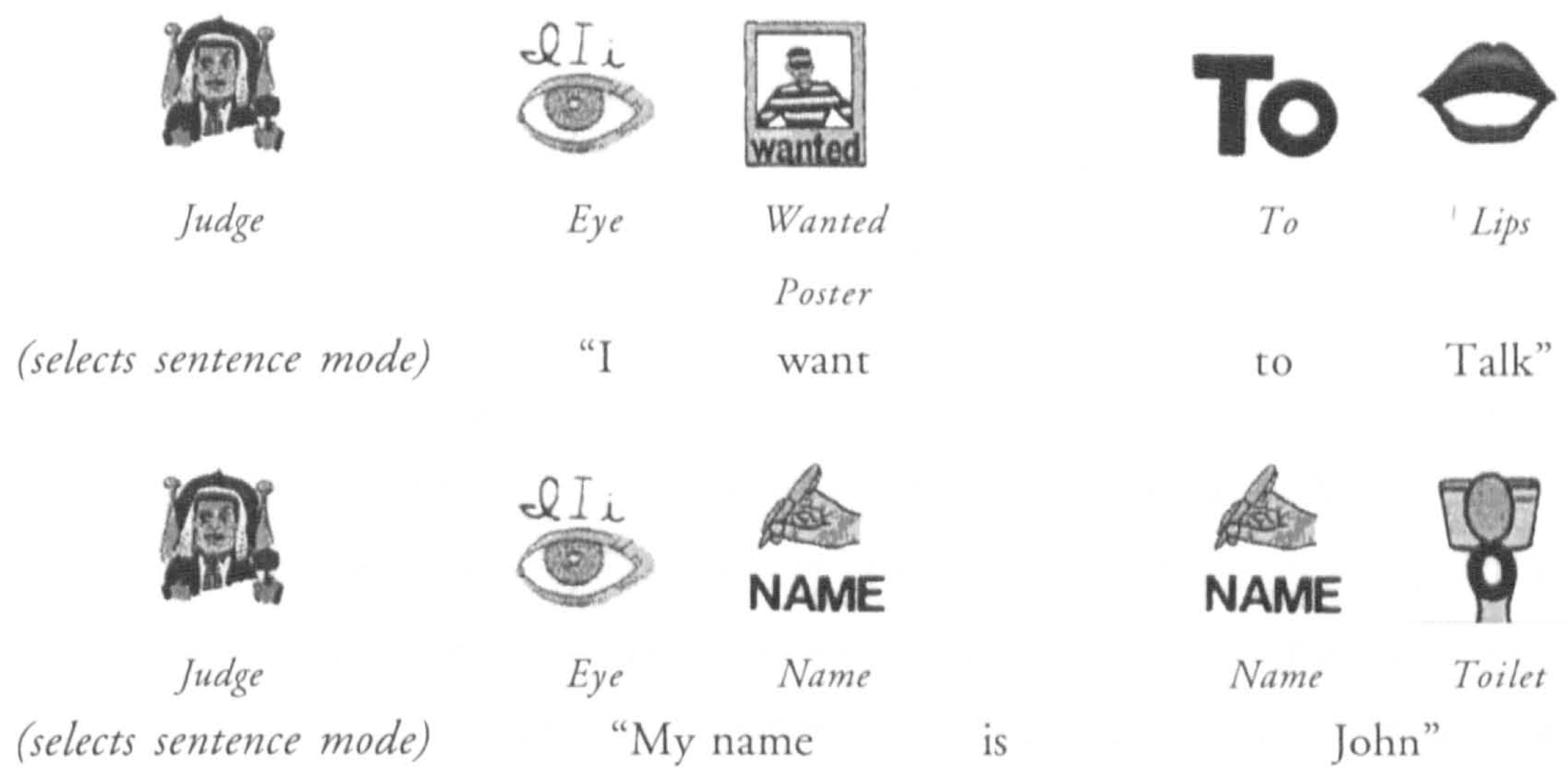

Figure 1: Examples of Minspeak icons used to generate simple sentences

The Minspeak system can be customised to meet the vocabulary requirements of a particular user. This requires each of the codes to be defined by the user, which can be very labour intensive, and so several pre-arranged vocabulary sets, known as *Minspeak Application Programs*, or MAPs have been composed. A MAP consists of core vocabulary, a particular icon set, and an overlay arrangement that is designed to meet the particular communication needs of its intended population.

1.4.3 Dynamic interfaces

Desktop computers have for a long time permitted users to jump from screen to screen. This principle is utilised for dynamic AAC devices. A series of screens is used to access conversation material relevant to the particular circumstances of the conversation. The advantage of these types of systems is that they are very flexible, permitting the device to be configured to meet the particular needs of the user (whether storing appropriate vocabulary or icons/pictures that have an inherent meaning for the particular user).

1.5 VOCAs used at Portland College

As has been discussed, the ability to communicate is of paramount importance in contributing to the quality of the lives of people with disabilities. Hence, for people with a communication disability, a communication aid presents an extremely important tool as an extension of themselves. A review of some of the electronic communication aids considered to be the state-of-the-art when Portland College initiated this project and that are used by the College's illiterate non-speakers appears in Appendix I. For a more comprehensive listing of AAC devices, Kraat & Sitver-Kogut (1991) have produced a very useful wall chart that provides detailed information about commercial AAC products. The chart acts as a synopsis of communication aids up until 1991. This goes some way in acting as an evaluation of existing devices; however, since Kraat's and Sitver-Kogut's study was undertaken, new devices have come on the market. The Disability Information Trust regularly publish listings of disability equipment manufacturers and suppliers, and *Communication and Access to Computer Technology* (Barrett, *op cit*) presents a listing and description of the state-of-the-art of AAC devices at the time this study commenced.

1.6 Shortcomings of current AAC devices

The AAC Research team at Stirling University (Murphy & Collins, 1994) identified various problems resulting from using current communication devices as well as problems with the devices themselves. Common complaints from users included sore fingers from accessing the keyboard, the effort required to access the device, the device blocking the user's vision, and difficulty in operating an AAC device in conjunction with an electric wheelchair. The majority of problems with AAC devices centred on the audio output. The poor voice quality and the lack of intelligibility (especially in noisy surroundings or outdoors) was a major concern with some devices whilst the lack of intonation and expression in synthesised speech was a general problem for all devices. In certain situations users could not use their devices; they had difficulty seeing the display in bright sunlight and were not able to use their machines in buses or cars. The slow speed of communication, the lack of privacy when speaking and machines running out of charge were also cited as additional problems.

In an article appraising a Light Talker, written by an AAC user, some common limitations of AAC devices are highlighted:

- it can't be used everywhere;
- it makes me harder to push around;
- the vocabulary is limited;
- tied to places where electricity is available;
- batteries don't last long enough and take too long to charge up;
- some functions aren't appropriate, e.g. songs;
- not enough memory;
- people can easily over hear things I say;
- monotonous voice.

(Robertson, *op cit*)

Over one hundred comments about the unreliability of high-tech systems were received by the AAC Research Unit. Mechanical malfunctions (machines and switches breaking) were prevalent and the durability of devices was poor. Twenty-one AAC users of the 100 people providing comments had more than one AAC system, "because they felt that their high-tech system was unreliable" (Murphy, Collins & Moodie, 1994 p9).

Many AAC devices are not used to their full potential due, in part, to some users not having access to their machines at all times. Indeed, of a large sample of Scottish AAC users, just over 46% could not use their systems when they went shopping; 38% said their machines were not available when they went on outings; and for 34% there was no provision of an AAC device in the place where they lived (Murphy *et al*, *op cit*).

There are, in addition, physical problems associated with the design of these devices, preventing accessibility. "Only 57.3% of AAC users were able to access their aids without assistance" (Murphy, Collins & Moodie, *op cit* p11). Not being able to switch a machine on is not just a matter of operation of the device, but one of censorship and oppression; switching a user's machine off is removing that person's right to speak and be heard. The very system that is supposed to grant independence often requires a helper to program what the user can say. This denies freedom of speech, and can result in much embarrassment for both user and helper. Hence, "There is an urgent need for design improvements which enable people to access their AAC systems independently" (*ibid*, p11).

All the so-called portable devices have a very limited vocabulary, permitting a user to communicate only the most basic of needs and wants. This often results in AAC users being forced to compromise their wants, through being denied a request for something other than is stored in the devices. Such devices as the Touch-talker and the Liberator have large vocabularies, yet are still not suitably portable for the ambulant user. These devices are frequently left behind when users go out because they are cumbersome and awkward to take around (Atkinson, *op cit*).

Electronic communication devices are now competent at handling language processing, but are poor at conveying more than just words. Many devices effectively handicap the user as the voice sounds monotonous and lacks any form of expression or emotion.

Some devices that incorporate a voice synthesiser, such as DECtalk™, allow the user to select one of ten different age- and gender-appropriate voices, but many users have expressed difficulty in finding an appropriate voice (Murphy & Collins, *op cit*). In addition, many AAC users have expressed a desire to sound different from their disabled peers, and more 'normal'. The majority of commercially-available voice synthesisers have an American accent. Taking Harvie's definition of a voice (*op cit*) it becomes clear that this can be grossly inappropriate to some people; an American accent may not be the best way to express yourself to others if you are not American. Stephen Hawking, talking of his voice synthesiser, states, "the only trouble is that it gives me an American accent" (Hawking, 1995). Many people who use AAC devices would like to have a different, more appropriate accent and would appreciate being able to use their own regional dialects.

Non-vocal people do not have an adequate facility to argue, as existing communication aids do not allow the user to respond quickly and with emotion (two things that can be used to good effect to emphasise a point of view). Further, when listening to someone using an AAC device, some people tend to feel very frustrated and impatient at the rate of conversation, and typically want to finish the person's sentences for them. This frustration is shared by the AAC user, leading to feelings of incompetence; the repercussions of which can result in the individual becoming withdrawn and the conversation aid not being used.

Carers and parents often remove communication aids from users because they are worried that the user may break the machine in some way. This issue is indicative that the system within day and residential placements is unsatisfactory to the needs of AAC users, and also highlights problems associated with the design of these machines. The sheer cost of these devices and their susceptibility to breakage instills little confidence in the carer or parent that the machines are capable of being used safely by their charges. This is, in part, a problem of how the product is perceived, and relates to product semantics. The result is that the potential of the machine is denied to many users.

1.6.1 Summary of shortcomings

The biggest failing of existing communication aids is that they do not adequately cater to their users' needs. All appear expensive and some, from a design perspective, are insensitively designed for the needs of their users. Too many of the current devices are simply bulky plastic boxes encasing yesterday's ideas built with yesterday's technology. Some AAC devices appear to be copies of other machines and are differentiated only on the basis of cost and build quality. Most of them are by today's manufacturing standards boxy and ugly, have limited functionality and have not kept pace with technological and consumer product development.

It is clear that there are many limitations with current communication aids and that there is a need for a better product. These shortcomings can be addressed by design.

1.7 Conclusions

The purpose of this Chapter has been to introduce AAC. In so doing the basis of communication - its facets and its importance - has been raised. The ability to communicate is vital to humans, and is a key component in establishing social interaction, status, and autonomy. The differentiation between communication, language and speech has been discussed and, whilst people communicate by a range of techniques, speech is perhaps the most important. Speech is complex and messages are conveyed not only through language structure, but also by additional elements such as suprasegmental features of speech. These features convey more about a person than the content of what is said.

In this Chapter, devices used in AAC have been introduced as an extremely important tool for conversation by people who would otherwise be left out of conversations. These aids are, in effect, electronic replacements for what able-bodied people so often take for granted. People with communication disabilities rely heavily on these devices to communicate. For those who have additional disabilities that seriously affect motor control, the dependence upon the aid is increased as they are limited in their ability to communicate by other means (such as using gesture). More than a tool, however, these devices are the voices of their users. An AAC device becomes a vital part of a user's identity, yet current devices appear to have neglected this important aspect, presenting only technological solutions to the problems of not having a voice and not solutions that take into account the users' identities.

Currently-available devices are, from the industrial designer's perspective, limited, and from the user's perspective, limiting. Worse still, they are insensitively designed, drawing attention to the user's disability. A great opportunity exists to improve the effectiveness of communication aids (and hence the quality of life for users), as well as providing benefits to potential manufacturers.

Standing in the way, however, are the practical problems of revealing and understanding precisely what users would want from a new device.

CHAPTER TWO

The wider contexts of the problem – or what constitutes the problematic state of affairs?

2.0 Introduction

The previous chapter provided an introduction to AAC and outlined some weaknesses of current AAC devices. It revealed that current communication aids appear inadequate to their intended users, and concluded that there is a need for an improved product. The pressing question, and a good starting point for designing is, 'what is the present situation, and how can it be improved?' To penetrate this question further, and in an attempt to answer it, perhaps one should also ask what has led to the current situation? This chapter explores these questions in order to articulate what constitutes the problematic state of affairs that the designer faces when designing for people with severe communication disabilities.

The information contained in this chapter is derived from a number of sources. In the early stages of the enquiry a design project was initiated. What soon became evident was that there were various problems associated with designing a product catering to the needs of AAC users and, through the process of designing, many of these problems were revealed. Primary and secondary sources, including literature, observation and discussion with AAC users, practitioners and specialists in the field were also useful in exposing issues facing AAC users, the designer, as well as others involved in the provision of AAC devices.

The chapter explores three key areas:

1. complexities faced in the process of designing;
2. complexities arising from circumstance and situational context;
3. complexities of physical disability (with special attention to human needs and interaction).

2.1 Complexities faced in the process of designing

Discussion on the nature of design problems is well documented, see for example Buchanan (1995); Cross (1998); Cross & Cross (*op cit*); Jonas (*op cit*); Lawson (*op cit*); and Margolin (1995). The nature of design problems is particularly intriguing and is consistently a subject for research. Design problems are: notably ill-defined (Cross & Cross, *op cit*), often not apparent but must be found (Lawson, *op cit*), complex, difficult to resolve (*ibid*, 1990), and intractable, nebulous and inter-linked (*ibid*, Buchanan *op cit*).

> The ill-defined nature of design problems means that *analysing and understanding the problem* is an influential part of the design process.
>
> (Cross & Cross *op cit*, p144)

Ill-defined problems, and 'wicked problems' (first coined by Karl Popper, later developed by Horst Rittel to describe the nature of design problems and more recently discussed by Richard Buchanan (1992 *op cit*)), are commonplace in design. The difficulty is in defining the problem. Various questions will play on a designer's mind, allowing meaningful exploration of the underlying problems behind a design brief or design need. Once that need is established, further questions are posed to generate an appropriate product design specification (PDS). This specification will give an indication of the persons who will use the product, the number of units to be produced and the environment in which the product will be used. Within AAC, finding answers to the most basic of these questions is problematic.

At the start of the design process, the designer is often found to 'work backwards' in order to gain sufficient footing to generate a PDS. To design without reference to a PDS is to risk the creation of misguided and misplaced product proposals. In order to establish the content of the PDS, the designer needs information. In order to obtain information, the designer needs to ask questions and initiate searches. In order to ask the questions and to search, the designer needs to know who to ask, what to ask and where to look. Thus it can be seen that the 'right' questions and the 'right' technique for asking those questions are chief concerns for the designer at the commencement of a project. These concerns are not always explicitly raised by the designer. Experience alone can count for much. In some cases a designer's experience can lead to a tacit knowing, which allows designing to progress with great fluency. In most cases information can be found, or else ways to obtain information are known or well documented.

Designers' knowledge of AAC, AAC users and their problems and needs tends to be limited. The conscientious designer will naturally realize that because the subject matter is unfamiliar it is necessary to take a step back to gain understanding of the design problem. In the case of designing for AAC users, however, there is insufficient information to help the designer proceed. Hence, "analysing and understanding the problem" is not only "an influential part of the design process" (Cross & Cross, *op cit*), but also a laborious one within AAC. More generally, Nicolle (1994) informs us that there is little in the literature that helps the designer properly cater for people with special needs, observing that design information is rarely reported in literature, or else reported in vague terms. The lack of appropriate design information and advice is an underlying, fundamental problem faced by designers working in the area of special needs. Much of the knowledge regarding design and disability is born of limited personal experience.

The manipulation, analysis and understanding of a design problem are not necessarily straightforward activities. Lawson (*op cit*) notes that:

> ... we learn design problems largely by trying to solve them. Thus it may take quite a lot of effort before a designer is really aware just how difficult a problem is.
>
> (p40)

Wicked problems and design problems tend not to have distinct starting and finishing points, and any design problem is prone to be perpetual as, through the course of designing, new problems emerge. In fact, since the design process can be said to be endless (*ibid*, p90), design problems are never truly solved, only suspended at a given point. The designer and other stake-holders in the design process are responsible for defining such limits. These limits are typically defined and dictated by constraints and provision of time, finance and knowledge.

A developed and considered solution is thus the goal of problem-solving in design. The designer considers and balances constraints and a solution is often reached by compromise. Indeed, Lawson states that "design almost invariably involves compromise" (*op cit*, p90). The artistry and skill of the designer is the ability to judge often conflicting requirements.

An issue of contention in design is the means of measuring and judging the efficacy of a solution. Many of the decisions made in the process of designing are subjective and, hence, comparing differing perspectives and priorities of those involved in the design process is difficult. Decision making is essentially based upon value judgements, but in turn these judgements are influenced by a number of factors (such as availability of information or prior experience) and will involve both analytical and creative thinking. Tools for measuring (and, hence, quantifying) the 'value' of value-judgements have been developed to aid decision making in complex situations (e.g. cost-benefit analysis, the House of Quality, Bruce Archer's model of the design process (1969)). However, the design of these tools is in turn a value-laden process, and so claims for their superior objectivity are a matter for debate.

When stake-holders in the design process have different perspectives and conceptions of the problem to start with (and this can often be the case when working in collaboration with others) measurement of the success of a design is further complicated.

> There are no established methods for deciding just how good or bad solutions are, and the best test of most design is still to wait and see how well it works in practice. Design solutions can never be perfect and are often more easily criticised than created, and designers must accept that they will almost invariably appear wrong in some ways to some people.
>
> (Lawson, *op cit*, p90)

In light of the above commentary of subjective judgement, designers face a problem of convincing an audience of the merits of their design. Whilst other professions have quantitative data that, although not always appropriate, can be difficult to dismiss or argue against unless one is extremely insightful, designers have to frequently rely on their persuasive skills to defend their design decisions.

The problem for the designer is to not only analyse quantitative and qualitative data but to synthesise such knowledge in a creative way. Many of the designer's judgements are tacit, and hence difficult to define and present in a convincing and concrete manner. The danger is that designers may use tools, methods and processes adopted from more scientific disciplines to help substantiate and defend their decisions, at the expense of demoting the emotive and creative aspects of their work.

> Perhaps it is because design problems are often so intractable and nebulous that the temptation is so great to seek out measurable criteria of satisfactory performance. The difficulty for the designer here is to place value on such criteria and thus balance them against each other and factors which cannot be quantitatively measured.
>
> ... Because in design there are often so many variables which cannot be measured on the same scale value judgements seem inescapable.

(*ibid*, pp58 -59)

The difficulty here is to ensure that the designer's value judgements correlate with those of the end-user. It is all too easy when designing for people with disabilities to assume that the same values and priorities are shared by designer and end-user. This can result in a design that is unusable by, or inappropriate for, its intended users. Conversely, designers may over compensate and produce designs based upon their own preconceptions of the needs and abilities of the people for whom their designs are intended. In both cases the designer is guilty of assumption, and unable to properly respond in the absence of information on the needs, abilities, values and lifestyles of people with disabilities. In addition the designer is unlikely to be familiar with people with particular disabilities prior to designing for them, as many people with disabilities are not fully integrated into society.

Many designers will perform some form of scenario modelling whilst designing products or systems for others and will enact assumed roles. Whilst this method can be a valid and effective approach in some circumstances, the same does not necessarily apply to the design of items intended for people with disabilities. Orpwood (1990) argues that many of the problems of aids faced by people with disabilities are hard to anticipate, drawing the conclusion that designers are not able to use their own experience effectively when designing for such people. Designers' experiences of disability are often very limited, and whilst there may be those who are knowledgeable, those with an empathic understanding of the disability experience are rare.

To help designers gain better understanding of the experience of disability, some researchers (e.g. Poulson, Ashby & Richardson, 1996) have proposed the use of disability simulation. This typically consists of the designer being handicapped by some form of prosthesis or experience (such as spending a period of time in a wheelchair) in order to replicate some of the difficulties faced by people with disabilities. Whilst there are some benefits of this approach (most notably the consideration of access requirements and spatial considerations in the case of using a wheelchair) it runs the risk of tokenism. If the method is used as a substitute for the involvement of people with disabilities in the design process rather than to supplement the designer's understanding, it can be extremely damaging. In such cases it removes the end-user one stage further from the design process.

In addition, disability simulation serves to demonstrate only the physical experience, not the psychological or sociological consequences of the disability experience. To model a more complete disability experience is extremely difficult, if not impossible, and certainly very time-consuming. The designer is therefore faced with a problem: how to uncover and thoroughly understand the perspectives of people with disabilities. By ignoring this problem, the designer is in danger of using assumption to compensate for a lack of understanding. Reich *et al* (1996) note that:

> In the case of sophisticated (i.e., complex) products and processes, user needs are either not known or are, at best, inchoate. In these cases, not only is user participation necessary, but also more sophisticated means may be needed to support this participation.
>
> (p168)

Participation in the design process by AAC users is complicated in that they cannot talk. The articulation of their needs and the transfer of related data from the user to the designer are thus problematic. Traditional techniques for assessing user needs and wants typically rely on the user providing some form of feedback. An added complexity within AAC is that users cannot talk but will rely on a communication aid to convey their thoughts. The very fact that an AAC aid is used in the communication process in assessing user needs can also detract from the quality and efficacy of the results.

The transfer of information between parties involved in the assessment, design and implementation of disability devices is of particular interest to the designer of a new device. The acquisition and generation of appropriate data and knowledge is critical if one is to successfully design for the user. Within the disability sector, however, the flow of information is either a mere trickle, or intermittent.

In AAC the end-user rarely has contact with the designer of the device. Companies producing communication aids tend to be in a situation where the designer relies on feedback from the company, and not from the end-users. The problem being that those people who could benefit from a communication aid cannot talk, and hence there is a great deal of difficulty for the designer to ascertain the needs of those users. As a substitute, the designer may rely on secondary and tertiary sources of information and knowledge of the end-users (Haaf, 1994).

An order exists resulting in knowledge not being transferred directly back to the designer. An end-user is assessed by a speech and language therapist who typically matches a person to a particular device (as opposed to matching the product to the user). The speech and language therapist is often placed in a position where a lack of funding will result in trying to 'make do' when allocating AAC devices. Over-stretched resources also result in limited time to evaluate the benefits and limitations of particular communication aids; hence the speech and language therapist often has to rely on the supplier to provide evaluation of these products. The supplier may well be a sales outlet for a particular or 'favoured' manufacturer, and so this information can be biased (Joyce 1996).

The speech and language therapist will liaise with the supplier, providing some evaluative feedback on devices. This is passed back up the ladder to the manufacturer, who may or may not integrate this feedback in the design of any new device (see Figure 2). This structure contributes to the problematic state of affairs resulting in many AAC products being inadequate for their intended users. The way in which information is transferred, with the designer and the end-user at different ends of the ladder can be like a game of Chinese Whispers. The designer may not be receiving a true and accurate translation of the users' needs and wants.

Designer

⇑⇓

Manufacturer

⇑⇓

Supplier

⇑⇓

Purchaser

⇑⇓

Speech and Language Therapist / Assessor

⇑⇓

User

Figure 2: The linear structure of communication between parties in AAC

The need for better communication and co-operation between the parties involved in the provision of AAC devices is raised by a number of authors (Quist and Blischak (1992); Light (1993); and Murphy, Collins and Moody (*op cit*) for instance). It is somewhat ironic that those people involved in helping others communicate do not communicate with one another as best they could. Such a situation does not stem from a lack of desire to communicate though, but rather from a lack of knowledge and understanding of how and why to do so.

A lack of knowledge is a common theme reported by those involved in the use and provision of AAC devices. When AAC users gain their first communication aid, they are often grateful as it may be the first time they can talk. Often these people have feelings of obligation and gratitude for receiving a device and do not want to appear ungrateful by showing dissatisfaction. Barber (1996) refers to this as "The Gratitude Effect" and notes that this often results in a lack of feedback and criticism from users of disability devices. This does not provide the best of circumstances to evaluate the effectiveness of that aid, or for end-users to communicate their needs and wants to those involved in assessment. Experienced AAC users may realise the limitations of their present communication aids, but be unaware of what they could and should expect from these devices. In short, AAC users tend to lack knowledge of what to expect from devices.

AAC is embracing new technology and has become a high-tech field. Advances in computing bring a wealth of potential to this field. Contemporary AAC now addresses additional specialisms such as natural language processing, semiotics, artificial intelligence, and neural networking. Keeping pace with technological change, however, presents difficulties for all those concerned in the provision and use of AAC devices. This is particularly so for the speech and language therapist – there is often insufficient time to keep informed of advancements, and consequently they may also lack knowledge of AAC devices and what to expect from them. There are few independent studies presenting the pros and cons of devices, and speech and language therapists often have to rely on communication aid suppliers and manufacturers to provide such information.

For the designer this is not really a problem, but rather a complexity. As discussed in Chapter One, AAC is a multi-disciplinary field, with each discipline being highly specialised. A designer entering into this field requires an awareness (and perhaps an understanding) of the disciplines likely to be encountered within it. Understanding the technology and the language specific to the professionals involved in AAC is a daunting task, but one in which the designer needs to be immersed in order to adequately cater for AAC users.

The transfer of knowledge about people with disabilities is made all the more difficult due to inconsistencies; this often renders data inaccurate. Erroneous data and knowledge can be more damaging than no data at all. Imprecision comes about largely due to contention with respect to definitions and terminology within the disability sector. There are two frameworks within which the context of these definitions should be considered. The medical model of disability proposes that a person with a disability is handicapped by his or her impairment (WHO); whilst the social model of disability is based upon the premise that it is the environment that handicaps. An alternative to WHO's definitions and one in sympathy with the social model of disability is promoted by the Disabled Peoples International (DPI):

> A disability is the functional limitation within the individual caused by physical, mental or sensory impairment.

> A handicap is the loss or limitation of opportunities to take part in the normal life of the community on an equal level with others due to physical and social barriers.
>
> (Finkelstein, 1995)

This is a somewhat controversial matter, and whilst it is important that terminology is used accurately so as to not entrench prejudice, the paradox is that often communication is stifled altogether by the discussion of semantics.

There are inconsistencies in the definitions and classification of disabilities between countries (*ibid*; Sandhu & Wood *op cit*; Carruthers, Humphreys & Sandhu 1993), and even within national confines: different terminology is used by health authorities, government departments and charities for instance. This presents confusion on a number of levels, but particularly for determining those persons responsible for the provision of disability devices and services.

2.2 Complexities arising from circumstance and situational context

2.2.1 Who buys equipment?

In the majority of cases, equipment for people with disabilities is bought by government agencies such as (in the UK) the NHS, Social Services or the Department of Employment. These agencies' criteria for selection of equipment are based on physiological factors, and not upon whether the intended user likes the product or not. Equipment tends to be bought on behalf of the user and, if funded, is largely done so by different government agencies. Education Authorities may provide equipment deemed necessary for the educational development of disabled students, whilst Area Health Authorities will only provide equipment if strict eligibility criteria are fulfilled and the equipment is used on health grounds.

The criteria for eligibility are based upon the remit of Authorities. Regrettably, funding for equipment to help facilitate communication is not always available for people with disabilities because they may not fulfil all of an Authority's criteria. As communication aids become more sophisticated and gain more functions, an added complication arises. Responsibility for funding a particular piece of equipment for an individual becomes less clear (Shipley, 1980). Individuals who could benefit from AAC equipment have to argue their case more vehemently or receive no Government funding at all.

> Sadly, many people still have to wait for many months, if not years, for the statutory services to provide funding for an AAC system – if they ever do – and many end up relying on friends, families, charitable donations and awards, or insurance or compensation payments to fund purchase of their communication systems.
>
> (Call Centre)

Bureaucracy and its entrenched rules give rise to a situation in which problems are exacerbated. An Authority may have preferred, or approved, suppliers of equipment. Once a supplier becomes established the market can become stagnant, as competitors are, in effect, neither entered nor disqualified from the race. These circumstances give rise to the problem where the end-user of the equipment is not actively involved in the purchasing decision. Hence, the end-user may not be happy with the choice that is made. In turn, the social constructs of disability are reinforced as autonomy is taken away. If others buy equipment on behalf of people with disabilities, the way in which the 'consumer' acquires equipment is not normal. The activist, Stephen Brisenden is quoted as saying, "Society disabled us by taking away our right to take decisions on our behalf" (quoted in Sandhu 1989).

Consider how most consumers choose products. Typically the user of the product is in a position to buy it and is provided with a choice of products. Criteria for selection can be based on price, aspirations, likes, dislikes and value judgements; yet seldom are people with disabilities presented with this option when purchasing an aid. End-users of disability products are rarely consulted about their aspirations of products, and so products within the disability sector do not cater for their wants (only, at best, their physical needs).

The bureaucracy of assessment, allocating of funds and buying from an approved supplier hinders addressing the communication needs of many people. Jonkers (1980), amongst others, argues that a step towards rectifying this situation is to provide people with disabilities money instead of aids. A free market would result, encouraging healthy competition amongst manufacturers and suppliers of communication aids. Sandhu (*op cit*) declares that the majority of products for people with special needs is poor and criticises the UK National Health Service for sustaining this problem by being "short-sighted" in relation to equipment purchases. He notes that disability groups are becoming increasingly demanding, and that it is in the interests of everyone to acknowledge this and produce accommodating designs.

In an emotive and critical commentary entitled 'Consumer Outcomes in AAC', Mick Joyce (*op cit*) writes as a representative AAC user, highlighting the inadequacies and hypocrisies of AAC device manufacturers and service providers.

> It would be especially worthwhileto [*sic*] think about the following: Suppliers that require devices to be sent in to replace "special" batteries; Company reps that evaluate and well as [*sic*] sell devices; System makers with old "lock boxes" that have to be moved from computer to computer; Device makers that up prices up to 8,000 percent over true cost; System providers that require many hours of training but don't have any free, accessible, on-line support; Training programs that are once a year and require "being there"; System evaluation clinics that mold people into their ways rather than listening first; Clinics that only provide token follow-up services; Payees that buy expensive devices, but say "no" to repairs; Expensive device makers that provide little warranty protection; and Professional Groups that provide little advocacy services and much lobbying.
>
> (p5)

2.2.2 Market issues

The market for disability products is perceived to be small by industry (Martin, 1991). Much of the market is fragmented with several manufacturers competing in very specialised markets, often with very similar products (Young & Sandhu, 1995). Consequently they share a dividend that is insufficient to sustain them all. Many companies produce only one product, competing for market dominance and in turn creating over-saturation in some markets whilst there is insufficient representation in others. Other companies produce bespoke products, often at great expense but with little profit.

In product design, the size of a potential market is of great importance in establishing the financial and production feasibility of a product proposal. The number of units to be produced, the investment required, the most appropriate production techniques, the expected sales and the marketing pitch can be determined by demographic analysis. Without this analysis, a manufacturer is somewhat in the dark as to the full potential of a market. The questionable validity of some data within the disability sector also poses a degree of uncertainty, against which many designers and financial backers are unprepared to invest in new product development. Many manufacturers seem resigned to the belief that the market for disability products is small, even though there is evidence that the market could in fact be substantial (Martin, *op cit*). Even though the need for a product may be great and the opportunity large, without research confirmation a company cannot be expected to remove scepticism.

The size of the market for products catering for people with disabilities could be perceived as a reason (or an excuse) for low quality products, and yet many companies can produce high quality products in small niche markets. Clearly, the problem is more complex than just the scale of the market. Consider mainstream commercial consumer products, or even products within small niche sporting markets, where people often aspire to acquire such products. A dichotomy exists between the disability product market and other product markets. The consequences of this dichotomy are severe for both the disabled population and for the companies attempting to cater for this market. In the UK there is a very high failure rate of small and medium sized enterprises (SMEs) within the rehabilitation sector (Young & Sandhu, *op cit*).

The preliminary findings of Young's and Sandhu's study indicate that the reasons for this are:

- insufficient financing
- lack of venture capital
- tax and administrative burdens
- poor management
- inadequate knowledge of the market
- lack of research and development
- inadequate knowledge of supply channels
- low quality products

(p187)

Designing in an environment where there is insufficient financing, a lack of venture capital, tax and administrative burdens, and poor management is difficult, and is sufficient reason to put off most designers from designing for the disability sector. It is not hard to conclude that this situation is, in part, responsible for discouraging designers from participating in this field. That, coupled to the high failure rate of

SMEs, presents a legacy of wariness, or hesitancy at best, amongst designers, manufacturers and financial backers. The lack of confidence in the market is another component of the problematic state of affairs responsible for products being inadequate. Designers do not readily get involved.

Berdel (1989), an industrial designer and Chairman of the Institute of Social Design in Vienna (ISD), declares his disappointment that social aspects and the needs of the user (the disabled, the old and sick and other disadvantaged groups) "were permanently neglected by designers" (*ibid*, p5). Sandhu (*op cit*) notes that:

> Clearly, a form of apartheid exists between designers of products for ordinary people and those designing for special needs ... One group has the eyes and ears of the market place, designs from the top downwards, *a priori* knows what is good for consumers and often looks for market openings for new designs which have little to do with actual needs. The other much smaller group is seen as a mirror image with reverse attributes.
>
> (p3)

It is often the case that designing for the disability sector is seen as a moral commitment as opposed to a business venture. The two are, of course, not mutually exclusive yet changing designers' perceptions of this field and demonstrating the business opportunity is an important step in procuring design talent to this field.

Many products within the disability sector are rejected by their users (Ring 1980; Jonkers *op cit*; Murphy *et al*, *op cit*) due to their unreliability (Murphy & Collins *op cit*), their appearance (Hogan *op cit*, Collingsworth *op cit*) and the handicapping aspects of the product (Ring *op cit*, Hogan *op cit*, Murphy & Collins *op cit*).

Jonkers (*op cit*) points out that although large amounts of money are spent each year on technical aids, these aids seldom meet the expectations of the disabled users. He presents some reasoning of how such a situation comes about:

> To justify the provision of an aid, the acceptability of the level of mental load needed for its use should be carefully evaluated, taking account of the subject's character, intelligence, motivation, physical and psychological condition.
>
> ...all effects causing shame, irritation, repulsion, impatience, or fear, should be considered as contributing to the user's total emotional

> stress. Although the emotional stress may chiefly depend on the user's situation, sensitivity, and social environment, this factor pre-eminently affects the user's acceptance of an aid. Correct judgement of this factor, which is of paramount importance to the successful introduction of aids, demands close co-operation between designers, manufacturers, retailers, therapists, and users.
>
> (p172)

Given that various aids are rejected by their users, three abstractions can be drawn from Jonkers' statement. Firstly, not all things are considered in the design process (especially the user's emotional stress). Secondly, the user's acceptance of an aid is based upon psychological, sociological and physical attributes of that aid; and finally it would appear that the parties involved in the process of product introduction are not co-operating. Jonkers concludes that,

> ... the field of technical aids for the physically disabled appears to be somewhat chaotic and uncontrolled. The lack of co-ordination and management in the field of adaptation technology is evident, not only nation-wide [the Netherlands] but world-wide. This field is in need of, and offers great opportunities for better management.
>
> (*ibid*, p177)

A number of initiatives have been established within Europe to address this situation. Such initiatives include the COST (Cooperation in the field of Scientific and Technical Research) 219 project '*Future Telecommunications and Teleinformatics Facilities for Disabled People*' (von Tetzchner, 1991) set up in 1986 for a five year period, and then continued for a further five years; and TIDE (*Technology Initiative for Disabled and Elderly People*) (Porrero & de la Bellacasa, 1995). Many of the research outcomes of the contributors to these initiatives are useful[6], but too few of the outcomes make their way into products that are readily available to people with disabilities, and these initiatives are somewhat technocratic.

2.2.3 Summary of situational issues

Designing within AAC, and indeed the wider area of disability, is problematic due to a lack of coherent, public knowledge of the area. Market size, demographic information and anthropometric data of user population are scarce (or worse, inaccurate). Inconsistencies of definitions, political correctness and the

6 Some of these will be discussed further in Chapter Three

complexities of terminology provide a difficult start for a designer entering into the area of design and disability. The designer working within mainstream markets has the advantage of having such data available. Or, if not, techniques to obtain such data are well documented.

2.3 Complexities of physical disabilities

AAC could benefit many people, but the needs, wants, and physical and mental abilities of the different people involved are varied. The complex range and nature of the disabilities of those people who could benefit from AAC devices presents perhaps one of the most complicated set of individuals in any market. Designing for this group's physical ability is very challenging for the designer. It is, however, not just the physiological and anatomical aspects of disability that challenge the designer and the person with the disability. Beyond physical and biological issues, there are additional consequences and problems faced by AAC users (and by people with disabilities more generally) brought about by their impairments. This section of Chapter Two examines both the sociological and psychological consequences of a physical disability, and highlights how these affect not only people with severe communication disabilities but also the designer attempting to design for them.

2.3.1 Sociological considerations

> Society establishes the means of categorizing persons and the complement of attributes felt to be ordinary and natural for members of each of these categories. Social settings establish the categories of persons likely to be encountered there. The routines of social intercourse in established settings allow us to deal with anticipated others without special attention or thought. When a stranger comes into our presence, then, first appearances are likely to enable us to anticipate his category and attributes, his 'social identity'.
>
> (Goffman, pp11-12)

When it comes to an encounter with someone with a disability what is clear is that first impressions are made "based on the most obvious and superficial data" (Thomas, 1982, p70). Thomas goes on to state that "the most obvious datum they [people with disabilities] communicate is their disability" (*ibid* p70). Based upon observations of how people with impairments are received by society he identifies four categories of disability.

1 Highly visible disabilities – a signal, such as a wheelchair or a white cane, provides a visible cue to the public to anticipate an 'atypical' person;

2 Interpersonal communication difficulties – no visual cues, but problems of reception or expression will occur early in the encounter (such as is the case with deafness or a speech impediment);

3 Social stigma – stigma by connotation (for instance nervous breakdowns, epilepsy or schizophrenia, whilst often invisible, are socially stigmatizing);

4 Combination of the above (this is often the case with cerebral palsy).

As many of us do not regularly come into contact, or do not have the opportunity to get involved with, people with disabilities, we may find it difficult to interact with such people. Such a lack of awareness is not surprising, as traditionally many people with disabilities have been separated from mainstream society. This is particularly so in relation to education. Children with disabilities often attend 'special schools' – their needs are perhaps better anticipated and catered for in such specialised environments – but as a result many feel outcast and rejected from society, whilst the wider public do not get the opportunity to integrate, socialise and grow and learn together.

It is this unfamiliarity of the situation and of people with disabilities that contributes towards a very problematic and complex state of affairs. Stigmas are established by society and are based on a lack of understanding; they serve to compound and fuel problems for people with disabilities.

When faced with someone with the symptoms of communication impairment, wrong impressions may be formulated, adopting a correlation between intelligence and appearance. As Professor Stephen Hawking points out, "If you have a slurred voice, people are likely to treat you as mentally deficient: Does he take sugar?"

(Hawking, *op cit*). The inability to read or write only serves to compound this view. People born with cerebral palsy often never develop literary skills, and because they may be held back from learning, are often judged by people as being 'stupid' or 'slow'. This prejudice is based on ignorance as opposed to being a form of deliberate discrimination; nonetheless, the consequences for people with disabilities are severe, as such prejudice handicaps people.

In one keynote address, Hawking is reputed as saying,

> I am dumb in the literal sense in not being able to speak; maybe I'm dumb in the figurative sense as well, but we won't go in to that here.

Professor Hawking is clearly not 'dumb in the figurative sense', but his light-hearted statement is rather poignant, and highlights many people's preconceptions. In contemporary society language and terminology used to describe people with disabilities is also a cause of handicap. Most words used to describe people with impairments are negative – there are few words in our vocabulary that describe such people in a positive light. Much of the reasoning for this may lie in the fact that key disability terminology originated from medical practitioners whose role was (and is) to make people *better* and to diagnose and put right what is *wrong*. Such prefixes as:

an – without	-	e.g. anarthria (total loss of articulation);
dis – the reverse of	-	e.g. disability (the lack of ability);
dys – bad	-	e.g. dysarthria (bad articulation);

are examples of this. In addition, people often impose additional negative connotations upon the terms 'disability' and 'disabled', to the extent that they imply distinction between two kinds of people, 'the disabled', and 'the normal'. Syntax of language can reinforce such tacit prejudice. For instance, referring to someone as a 'disabled person' implies that the disability is the most noteworthy thing – he or she is disabled first, a person second (hence, syntactically placing people first in sentences is preferable – ergo, 'people with disabilities'). Misuse of words is another example of how prejudice in language is manifest. For example, the word 'spastic' is often used as an insult synonymous with stupidity, rather than to describe spasms or muscular contractions. It is this common abuse and misuse of language that labels people and can be so damaging.

Beyond names and terminology, society's perceptions of people with disabilities can compound handicaps. Goldsmith notes that:

> In the action of life the person with a disability is doubly handicapped. First, he is handicapped simply because he does not physically have the capabilities that others have. This can have a variety of effects, causing social, financial and emotional depravations. Second, he is handicapped because he is perceived by others as handicapped, because there is a social doctrine which says that to have a disability is to be blighted and impoverished.
>
> (Goldsmith, 1976, p13)

Social doctrine and stigmas associated with disability have a long history. Michael Oliver in 'The Politics of Disablement' (1990) points out three implicit and historical theories of disability. The first identifies religion or magic as being the cause of disability; that is, disability was a punishment from God or the manifestation of evil magic. The second theory proposed that to be disabled was to not be fully human, whilst the third is based on the notion that the weak, impaired or elderly threaten the survival of society, that is, they are a burden to society.

Whilst a hermeneutic perspective of past theories of disablement and stereotypes of people with disabilities can conclude such views to be misinformed and politically incorrect, unfortunately the same stereotypes are still prevalent today. The media are largely responsible for perpetuating this in contemporary society and compound problems for people with disabilities by entrenching negative stereotypes so that the prevalent image of such people is not positive (Hevey 1992, Barber *op cit*).

There are two categories of stereotypes of people with disabilities commonly portrayed by the media. Historically, but also still commonly, the 'bad-guy' in the story often had some form of deformity or physical impairment – scars, hunchbacks, gnarled and twisted bodies (Byrd & Elliot, 1988), or as David Hevey (*op cit*) explains in *The creatures that time forgot: photography and disability imagery*:

> Within general disability representation, it is clear that it is the impaired body of the disabled person on to which is projected the negative manifestations of that impairment in society: that is, the disability. In this way, characters like Richard III, Frankenstein,

Graham Greene's Raven, most villains in the James Bond films and so on, have their evilness signified by their impairment.

(p12)

There has been much discussion of how stories, the media, and other forms of cultural communication contain inherent racism, sexism, anti-semitism or other forms of social prejudice. The discussion is set to continue and the portrayal of people with disabilities in a negative light by the media has more recently become a focal point of anti-discriminatory action[7]. Whilst politically correct and anti-discriminatory censorship can go too far (to the point of being counter-productive) such discussion and lobbying are important as they draw attention to society's often entrenched and tacit prejudice.

Secondly the media often collectively group people with disabilities – *the disabled* – and present them as impoverished, pitiful, weak, poor, sad, and generally in need of help. Whilst some of these personal attributes may be true, the association and collectivisation is not appreciated by many.

2.3.2 Psychological considerations

People need to feel that they are accepted by society – that is, that they are a part of society, not apart from it. The majority of people (to a greater or lesser extent), compare themselves to others, as a form of self-questioning and appraisal, looking for clues to establish whether they fit into what is deemed socially acceptable and normal. For people with disabilities, many of the clues indicate that they do not conform to what is deemed 'normal', and so many feel apart from society. Society reinforces these clues, as Thomas (*op cit*) points out:

> To be perceived as a handicapped person is to experience a distinct social status. These perceptions and the values associated with them give meaning to being handicapped, and such meaning appears to involve feelings and styles of behaviour which provide the handicapped person with clues to his social and personal worth.

(pp16-17)

7 See Driedger D, *The last civil rights movement*, London: Hurst & Company, 1989, or Shapiro J, *No pity: people with disabilities forging a new civil rights movement*, New York: Times Books, 1994

Society's perceptions and labeling of people with disabilities can have a profound effect upon their personal worth – their personal image of themselves. If people are told something often enough they start to believe, or at least question, it. Such questioning can be emotionally and psychologically damaging. Many people with disabilities experience feelings of rejection, inferiority, loneliness, depression and frustration. Many have low self-esteem and lack confidence, often withdrawing from others. Some, as a result of their impairment, their self-image, or the way they are perceived or treated by others, experience such emotions as anger, sadness, disgust, fear, grief, bitterness, jealousy, or shame. For some these feelings are heightened because such emotions cannot always be released due to their physical impairments.

Many people with disabilities are reliant on others for assistance. Although this is much appreciated by those being helped, some experience frustration at the resultant lack of control, autonomy and independence. Being helped can be viewed as synonymous with being helpless. The use of disability aids, to a certain degree, offers some form of independence for their users through opportunity to become more socially integrated. They are able to look after themselves, and so can live in the community instead of in government, charitable or private institutions.

It is important to consider, however, the effects of the use of such disability devices by people with disabilities. Often disability devices are seen as extensions of their users. Self-image is very important, and often the very devices designed to help people in fact compound their problems by drawing unwanted attention to their impairments. "The main disadvantage mentioned by users of high-tech [AAC devices] was that their devices drew attention to them that they did not want" (Murphy, *op cit* p59); indeed, one user said, "people focus their attention on the machine, not me" (*ibid,* p59). This gives rise to a situation where many people are reluctant to use aids as the devices may contribute to their problems compounding a psychological stigma of inferiority.

When examining the wider consequences of disability, it is important to consider both society's views and the views of people with disabilities themselves. Csikszentmihalyi & Rochberg-Halton (1981) discuss a very insightful sociological study presenting a compelling examination of mankind's relationship with material objects. They argue that material culture is not just a passive reflection of society, but has an active role helping to create its identity. This happens at the level of society, but also at the level of the individual. The psychological issues they raise, particularly the connection between man-made items and the constructs of selfhood, however, are of particular interest here.

> ... men and women make order in their selves (i.e., "retrieve their identity") by first creating and then interacting with the material world. The nature of that transaction will determine, to a great extent, the kind of person that emerges. Thus the things that surround us are inseparable from who we are. The material objects we use are not just tools we can pick up and discard at our convenience; they constitute the framework of experience that gives order to our otherwise shapeless selves.

(*ibid*, p16)

This statement mirrors similar discussion by Dewey who argues that we live in a series of situations and transactions between people and the environment which shape and influence us (Dewey, 1938). The term transaction is particularly poignant – the relationship between object and individual is interactive in that objects are not only a reflection of who a person is, but are in themselves a part of an individual's identity. People form relationships with products, and in time people superimpose the relationship with the product upon the product in its own right. This superimposition affects a person's judgement and the product's perceived value and importance to that person.

Material artefacts not only convey aspects of ourselves, but they create them. A beautiful piece of clothing may make people look beautiful when they wear it, but it also has a significant role in making people feel beautiful, and can affect how they act. Moreover, like actors, we often will dress or use material artefacts as props to communicate a different persona. People will often dress-up, or put on 'airs and graces', to change their perceived social status. Material possessions, therefore, have an important role in establishing social identity as well as in the construction of selfhood. Whether it is the clothes we wear, the car we drive, the brand of fragrance we use, or the material possessions we deem precious or significant to us – all communicate to others aspects of our identities.

There are many benefits to be drawn from the psyche of material objects, but the counter-side is also true: products can detract from the self. This is a trend of disability products. In the case of a communication aid that provides an audible voice for its user, the expectations and aspirations for that product are especially important since the device becomes an extension of its user (Light *et al, op cit*). If a voice communicates to the outside world everything that a person is, it should represent him/her accordingly.

> Things contribute to the cultivation of the self when they help create order in consciousness at the levels of the person, community, and patterns of natural order. An object that, when attended to, inhibits the pursuit of goals at any of these levels is a hindrance to the development of the self.
>
> (Csikszentmihalyi & Rochberg-Halton, *op cit* p16)

In light of the above, the shortcomings of AAC devices discussed in Chapter One can be seen to stem from complex underlying problems. In fact it would appear that those shortcomings may inhibit the pursuit of goals on more than one level and so be a significant hindrance to the development of the self. A paradox: disability products often disable their users, not necessarily in a physical sense, but on a psychological and sociological level.

2.4 Summary

Whilst Chapter One revealed that there were problems of Current AAC devices, this Chapter has shown that designing for the needs of AAC users is complex and problematic. The disability market is fragmented, there is insufficient financing for projects, there are problems associated with the implementation of new technologies, and there is a lack of coherent and accurate information available to the designer. Market size, demographic information and anthropometric data of user population are scarce or worse, inaccurate. Inconsistencies of definitions, political correctness and the complexities of terminology provide a difficult start for a designer entering into the area of design and disability. There is ineffective communication between parties concerned in the assessment, design, development, manufacture, use and evaluation of AAC devices.

The complex nature of the disabilities concerned, the varied and specialist disciplines involved and the way in which AAC devices are provided also presents added complexity to the design problem.

Society's perspectives of disability are varied, but underlying public attitudes towards people with disabilities often set them apart from the rest of society. People's social programming can lead to prejudice. Physical, social and psychological barriers are put up between different groups. The 'disabled' are placed in different schools, or streamed into sets catering for 'special needs': our language and definitions segregate. This results in insufficient social intercourse with people with disabilities to the extent that they are perceived, by and large, to be greatly different. The majority of the public does not know how to comfortably interact with people with disabilities, all too often focusing on the disability and not the person. Louis Batty puts it well:

> The cripple is an object of Christian charity, a socio-medical problem, a stumbling nuisance, and an embarrassment to the girls he falls in love with. He is a vocation for saints, a livelihood for the manufacturers of wheelchairs, a target for busy-bodies, and a means by which prosperous citizens assuage their consciences ... He is pitied and ignored, helped and patronized, understood and stared at. But he is hardly ever taken seriously as a *man*.

(quoted in McConkey & McCormack, 1983 p34)

Ignorance often handicaps people with disabilities. Stereotypes, attitudes, entrenched prejudice in society and even the language we use to describe people with disabilities reinforces the notion that people with disabilities are social outcasts – they do not fit society's perception of 'normal' and/or desirable.

The next chapter presents findings of a literature review establishing the routes predecessor researchers have adopted to address the problematic state of affairs discussed in this chapter.

Prior art linking design activity, disability and AAC

3.0 Introduction

This Chapter presents the results of a literature search to establish the state-of-the-field and the state-of-the-art with respect to designing for the needs of AAC users. The review was guided by the simple question, 'how does one go about designing for the needs of AAC users?'. The aim was to explore the approaches people have taken to designing for AAC users (and people with disabilities more generally), and to extract from the findings successful techniques and pertinent advice.

3.1 Designing for people with disabilities

The architectural profession has published material relating to how to design for people with disabilities. The majority of texts concentrate predominantly on the consideration of physical parameters of people in wheelchairs with respect to the built environment. Two works are of wider interest. One of the better works in this area is by Lifchez and Winslow (1979), who advocate a user-centred design approach and discuss techniques that permit a designer to "enter the lives of physically disabled people and design environments for them" (*ibid*, p129). The key to this, they state, is empathy and this comes from the designer's involvement and interaction with the people he or she is designing for. They stress that involvement of the end-user in design is extremely important, and present a set of techniques useful in both the assessment of user needs and other stages of designing to accommodate user participation. Such techniques include: the use of existing information (such as literature); interviewing people with disabilities; using performance interviews; looking at specific tasks; ethnographic studies (a day in the life of a person with a disability); visual documentation including film, photographs, and time-lapse photography; discussion; and scenario modelling. The second book, Goldsmith's *Designing for the Disabled* (*op cit*), is an often-cited work, respected as being one of the first authoritative texts. The sections entitled "Preamble" and "The behaviour of disabled people" are of particular interest and relevance to fields beyond architecture.

One of the reasons the architecture profession led in the publication of guidelines and recommendations for designing for disability (and other design professions followed) is probably due to early pressure from the Disability Rights Movement[8] to make buildings more accessible. The Disability Rights Movement came about in the wake of the Civil Rights Movement of the 1960s. Whilst the initial focus of the Movement was access to buildings, concerns soon broadened to include granting access to the workplace, to education, to computers and to telecommunications. Over the last few decades in the United States, a number of the Movement's policies have developed into legislation. A useful summary and history of these policy Acts are provided by Story, Mueller & Mace (1998, pp8-10) and are summarised below:

- The Architectural Barriers Act of 1968 (requiring all buildings designed, constructed, altered, or leased with federal funds to be made accessible).

- The Rehabilitation Act of 1973 (Section 504) made it illegal for any institution that received federal funding (including agencies, universities, and contractors) to discriminate on the basis of disability.

- The Education for Handicapped Children Act of 1975, later known as the Individuals with Disabilities Education Act (IDEA), ensured free education for all children with disabilities.

- The Americans with Disabilities Act (ADA) of 1990 covers a greater range of issues and states that physical barriers impeding access (to employment, places of public accommodation, services, programs, public transportation, and telecommunications) must be removed.

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8 See Driedger D, *The last civil rights movement*, London: Hurst & Company, 1989, or Shapiro J, *No pity: people with disabilities forging a new civil rights movement*, New York: Times Books, 1994 for a history and discussion of the Disability Rights Movement

- The Telecommunications Act of 1996 mandates that telecommunications services and equipment (including telephones, television programming and computers) be "designed, developed, and fabricated to be accessible to and usable by individuals with disabilities, if readily achievable."

Whilst the earlier Acts predominantly refer to the built environment (and therefore are applicable to individual buildings and building schemes), the ADA relates to mass-manufactured items (in particular computer products, telecommunications and public transportation). This Act has particular significance for Industrial Design; indeed, the ADA went some way towards bringing the needs of people with disabilities to the attention of many manufacturers. In the United Kingdom, the Disability Discrimination Act (which became law on 8 November 1995) has also raised some awareness of disability issues, particularly for employers. Although this UK Act has no stipulation that products must cater for people with disabilities, by necessity equipment in the work place must be accessible. The implications of such increased legislation are that companies (and hence designers) need to give proper consideration to designing mainstream products that are useable by people with disabilities.

Legislation provides the impetus for industry and designers to cater for people with disabilities, but does not necessarily provide guidance as to how to go about doing so. Working parties were established to help write and implement guidance notes. For instance, the Prince of Wales' Advisory Group on Disability / King's Fund project, *Living Options in Practice*, has outlined the following principles that service providers, designers, and manufacturers producing products for people with disabilities should employ:

People with disabilities should have the right:

- of Choice [alternative options and services should be made available to people with disabilities wherever possible];
- of Consultation [people with disabilities should be kept adequately informed of policy or decisions that may directly affect them];

- to Information [appropriate (independent and accurate) information should be made available to people with disabilities and those responsible for their care];
- to Participation [users of equipment and services should be involved in decision making wherever possible or else be adequately informed of decisions made on their behalf];
- to Recognition [the opinion of people with disabilities should be sought and acknowledged];
- to Autonomy [wherever possible, people with disabilities should be given the opportunity to make decisions that affect their lives independently]. [9]

(Department of Health 1992, p3)

On the whole, the body of literature covering designing for people with disabilities comes from independent researchers and organizations.

Collingsworth (*op cit*), in *Design for Disability: A Handbook for Students and Teachers* offers a broad introduction to issues relating to designing for people with special needs. The article is fairly general, and is more concerned with setting the scene and presenting the opportunities of working in this field than design praxiology but, nonetheless, is a very good initial source of information. She advocates that all designers should consider the needs of people with disabilities, and commends Scandinavian design training for embodying this awareness in its design philosophy. (Ehn (1992) also reiterates this point in his chapter 'Scandinavian Design: On Participation and Skill', in *Usability: Turning technologies into tools*.)

Collingsworth comments that:

> ... goods on the market seem to fall broadly into two separate groups. The products designed for the 'average and healthy person' ... [and] ... products and services designed specifically for people with disabilities.

(*op cit*, p54)

The handbook notes a dichotomy in the market place where products for the 'average and healthy person' do not adequately cater for people with special needs,

9 Author's own explanation in square brackets

whilst those that have been specifically designed for this particular group may be effectual, but are aesthetically inferior. By pointing out problems, presenting some relevant statistics and offering some general advice on how to design for people with disabilities she encourages designers to redress this phenomenon.

Martin (*op cit*) argues that the special needs market is traditionally seen as small and unprofitable and, hence, the prospects for the design, manufacture and marketing of specialist products, if viewed in this way, are often poor. However, he asserts that there is a large market for products catering to people with disabilities if the market is viewed beyond national confines (in this case on a European or international basis). Carruthers, Humphreys and Sandhu (*op cit*), however, point out that a lack of standardization in classification of disability is a large obstacle to developing a single market in rehabilitation technology within Europe.

Martin observes that failure rates of disability devices are high, often as a result of poor quality and a very specialised marketplace. Many devices intended for people with disabilities could be of use to a wider proportion of the population if they were better designed, accommodated larger audiences, and were marketed accordingly.

> This approach should be much more on the lines of selling domestic products, rather than 'prosthesis for disabled people.'
>
> (*op cit*, p57)

It is noted that unless large companies adopt this approach, the market will not open up and will remain fragmented. Martin's paper also includes a useful marketing checklist that can help NPD and marketing in the disability sector.

The Design for Ability Research group at Saint Martin's College of Art and Design, London, conducted a study into the interests of people with disabilities which Johnston and Barber (1996) declare, "could radically affect the way that products for disabled people are conceived and made" (p11). The group's aim has been,

> ...to improve the design of products used by people who are physically disabled. We help designers working in the field, by providing them with the insights generated by real-life qualitative information.
>
> (*ibid*, p12)

The Group's study of six hundred adults with physical disabilities reveal that there are five distinct and different consumer groups within the disability sector, thus challenging the traditional stereotype of 'a disabled consumer'[10]. It is noted that the range of backgrounds, interests and tastes of the 6.2 million people who are registered as disabled in Great Britain are as diverse as those of the rest of the population, and yet the products that cater for them tend not to make allowances for this. It is argued that producing a range of products targeted at these five groups need not cost a great deal more than providing just one product, and could actually increase profitability. The research found that many people with disabilities were prepared to pay up to seventy five per cent more for 'better design'.

The Design for Ability Research group has incorporated its information and findings into an interactive CD ROM called *Design Aid*. The intention is that with this extra source of information, products for people with special needs can be designed and developed to cater for the needs and tastes of each specific consumer.

> We hope it's the start of a shift in thinking which might question the fundamental mindset that underpins disability products, creating new visual solutions that break away from established stereotypes.
>
> (*ibid*, p14)

A number of authors have identified problems of, and offer suggestions and explanations for, why products in the disability sector are inferior to mainstream consumer products. Several of these authors present proposals to redress the balance and suggest approaches to designing for people with disabilities.

In particular, Hogan (*op cit*), then Chairman of the European Institute for Design and Disability (EIDD), has stated that products catering for people with disabilities and for the elderly are poor, and discusses his standpoint against the objectives of the EIDD. The EIDD was formed to:

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10 See Byrd & Elliot (*op cit*); Oliver (*op cit*); Hevey (*op cit*); and Barber (*op cit*) for further discussion of stereotypes of 'disabled people'.

- promote interest in design as a response to disability;
- undertake studies and provide information on the relationships between design and disability; and
- initiate design solutions to meet identified needs.

Seven principles and approaches underlying an inclusive design philosophy that the EIDD promote are mentioned by Hogan; namely:

> 1 That the critical role of design and of the designer in meeting the needs of elderly people and elderly people with disabilities be recognised.
>
> 2 That design be viewed as an essential bridge between technology and the consumer with the designer as a mediator and interpreter.
>
> 3 That national and international programmes in favour of old people explicitly recognise the design dimension and include designers in their project teams as a matter of course.
>
> 4 That designers adopt an inclusive approach to design, replacing the tendency to target specific groups with a 'design for all' concept.
>
> 5 That in the formation of architects and designers, a study of the needs of elderly people and people with disabilities and the problems of wider society be mandatory.
>
> 6 That technological and gerentological studies include elements of design appreciation in their syllabus.
>
> 7 That the elderly consumers who are the object of the design work should be involved at all stages of the process rather than merely at the testing or evaluation stage.
>
> (*ibid*, p3)

Heinz Wolff (1980) and his *Tools For Living* team are of the opinion that people with disabilities and the elderly require tools that help them in their everyday lives. He argues that rather than seeing these devices as aids which can place negative connotations upon the product, they should be considered as tools to facilitate the user. The paper forecasts that a greater percentage of the population is going to need, or could benefit from, these tools, in which case talented and imaginative people are needed to design products for our future selves. According to Wolff, this will require knowledge elicitation, the exchange of information, greater cultural expectations of users, better education of people to accept technological help, and methods of distributing technological aids.

Torrens (1994) discusses research and development methods drawn from experience of taking design concepts through to a commercial conclusion whilst working for the Tools for Living Team, Brunel Institute for Bioengineering. He stresses the importance of working closely with users, and considers working prototypes rather than concept drawings are the best way of assessing and evaluating product ideas. He notes that products in this field are rarely designed by product or industrial designers, and welcomes designers to contribute to what he deems a challenging area of design. An additional point made is that financial constraints necessitate broadening the market within the disability field and to look at mainstream markets to promote products as convenience items. He notes that innovative products and ideas from the disability sector can often be transferred to the mainstream market to improve performance and/or provide useful consumer products. (This latter point is also qualified by Newell, Arnott and Cairns (1991/92) who claim the cassette tape recorder, the ball-point pen, early remote control systems and the machine shorthand transcription system used in law courts are products that have successfully transferred from the disability sector to more mainstream markets.)

3.2 Universal Design

Universal Design is essentially a philosophy of attempting to cater for as many people in design as possible. More specifically, within industrial design, it attempts to ensure that people with disabilities and the elderly are catered for in the design of consumer goods. Universal design is also reported in literature as Barrier-free Design, Design for All, Trans-generational Design, and Usability.

Universal Design is discussed by Harkins (1995) who identifies two paradigms characterizing the development of aids for people with disabilities. The first is the assistive technology paradigm in which devices are developed as specialist pieces of equipment for people with disabilities and are used uniquely by them. She states that:

> ... our field [RT/AT] has tended to invest its efforts on the assistive technology paradigm in which specialized equipment and related services are developed, marketed, and used uniquely by people who have disabilities. ... These products are generally characterized by small markets, high prices, and information barriers – meaning

> difficulty of getting enough information about these products to their intended customers. ... The second and newer paradigm of universal design (also called accessible design) aims at broadening the usability of mass-market products to people with a much larger spectrum of functional abilities, and therefore to larger markets.
>
> (p24)

Harkins notes that funding for research into Universal Design has been minimal but points out that a "research agenda on Universal Design" will involve "extensive work on human factors research to define the product characteristics that improve accessibility, and to suggest design solutions." (*ibid* p24)

The Center for Universal Design proposes seven key principles of Universal Design intended to help guide the design process, and these are discussed by Story, Mueller & Mace (*op cit*). The seven principles are:

> 1 Equitable use (the design should be useful and marketable to people with diverse abilities).
>
> 2 Flexibility in use (the design should accommodate a wide range of individual preferences and abilities).
>
> 3 Simple and intuitive (the design should be easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level).
>
> 4 Perceptible information (the design should communicate necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities).
>
> 5 Tolerance for error (the design should minimize hazards and the adverse consequences of accidental or unintentional actions).
>
> 6 Low physical effort (the design should be used efficiently and comfortably and with a minimum of fatigue).
>
> 7 Size and space for approach and use (appropriate size and space should be provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility).
>
> (pp34-35)

The Telecommunications Industry Association in conjunction with the Electronic Industries Foundation (1996) has produced a publication entitled *a Resource Guide for Accessible Design of Consumer Electronics: Linking Product Design to the Needs of People with Functional Limitations.* The guide is based upon literature on human factors and disability in addition to the practices of designers. The document covers general disability issues and contains a detailed and useful design checklist and evaluation tool. The guide is intended for both electronic industry executives and product designers and its purpose is to encourage both parties to design products that are accessible and usable for people with disabilities. Eight general design principles are prescribed for designers:

1 Know the user (understand functional limitations of users).

2 Make it adjustable (to cater to individual preferences).

3 Provide alternatives/redundancies (ensure that functions can be performed in more than one way or, through redundancy, present multiple formats (such as auditory and visual feedback) so that a greater number of users are catered for).

4 Make functions conspicuous (all features, functions, actions, and controls should be immediately apparent to the user, preferably through more than one sense).

5 Provide adequate feedback (immediate and meaningful feedback of operational use).

6 Make the design forgiving (reduce the possibility of a user making an error, but if an error is made ensure that it is simple for the user to recover. The provision of warnings, confirmation messages and cancel options, and the use of default settings are desirable).

7 Strive first for accessibility, then for compatibility (accessibility in this case refers to designs that incorporate inherent features that permit both people with disabilities and those without to use a product. Providing adaptations to products falls into the category of making a design compatible for use by people with disabilities).

8 Evaluate your design (for ease of use and for accessibility).

(pp14-17)

With specific reference to design evaluation, the guide states that "the best design evaluations for accessible products will be conducted by asking potential users (including those with functional limitations) to perform various tasks with a prototype" (*ibid* p17). Although the guide briefly discusses speech and language limitations, issues specific to the design of AAC devices are not covered in any depth by this document.

Other proponents of Universal Design include Penton (1989), an architect who argues for "designing for a broader average". His practice makes use of a sample group of people with varying degrees of disability to test, evaluate and participate in the design of their buildings. A process of de-specialization is described which is presented as an effective design approach towards catering for people with special needs whilst also resulting in practicable and attractive design solutions for all. He notes that the principles of Universal Design are a compromise and quotes Alvar Aalto in support: "It is always a compromise, but it is a compromise which is best reached by the study of Man at his weakest" (i.e. people with severe disabilities) (*ibid*, p7). Penton has found that better solutions for all often result from applying Aalto's philosophy and that "designing to meet the needs of disabled people doesn't mean more expenditure, it means thinking the problem through" (*ibid*, p7).

Vanderheiden (*op cit*), an adherent and one of the prime advocates of the Universal Design philosophy, challenges the 'traditional' human factors approach of catering for between the 5^{th} and 95^{th} percentile population (two standard deviations from the mean) by, in fact, questioning the 'mean'. He argues that accommodating the majority of users by this method is a myth as only single attributes are examined. He calls for human factors researchers to look more closely at the disability sector as it is a large market and more work is needed to refine the practice, principles and methodologies of design to make products more accessible by people with special needs. A suggestion made is that disability issues should have a greater importance in ergonomic training to provide designers who are more aware of the needs of people with disabilities. He also claims, like Penton (*op cit*), that the cost of catering for people with disabilities in mainstream products can be minimal and, in some cases, can result in a cheaper product option than if they were excluded.

There have been critics of the concepts of Universal Design and its Utopian ideals. Ward (1989), for instance, argues (somewhat with a truism) that Universal Design is unobtainable as it is not possible to accommodate everyone. Rather, and more realistically, it is proposed that designers should try to exclude the fewest potential users as possible. Certainly some of the early proponents of Universal Design were somewhat charismatic and zealous in their depiction of the virtues of this approach to which Ward's comment was in response. In consideration of this, the Universal

Design Guide proposes that it is more appropriate to consider Universal Design as a process rather than an achievement (Story *et al, op cit* p2). Importantly the Guide acknowledges that the practice of design involves considerably more than the principles of making design universally accessible (including such considerations as economic, engineering, cultural, gender and environmental concerns).

3.3 Who are the users in AAC?

Whether the intention is to design according to the Universal Design Philosophy or else design for a specific group (or even a particular person), it is imperative to establish exactly who falls into the category of 'user'. Within the design of disability products, a user can be defined as anyone who interacts with the device in an intentional way. According to Fuller, Lysley and Colven (1995), there are "four distinct, although overlapping, categories" of users in the disability sector, "End-users, Facilitators, Integrators, Developers." (*ibid,* p4) An end-user, in the case of AAC, is the person who uses the communication aid as their voice. A Facilitator is "the person or persons most closely involved in adjusting the end-user's interface with technology" (*ibid,* p9); in this instance a carer, a friend or relative, or a therapist. "Integrators create, configure and maintain at a technical level the systems which end-users acquire and which facilitators adjust" (*ibid,* p11); in this instance a therapist, technician, teacher. "So how are developers users? Developers themselves use and modify the more fundamental engineering tools." (*ibid,* p13)

In the particular instance of AAC, a fifth category of user is of importance: the public, or any conversation partner. A conversation requires participants, thus those who converse with AAC users should be considered in the design process too. Voice quality is not only of importance to the AAC user, but also to the person hearing that voice. A voice's quality will determine its comprehension and will also be a factor in whether people listen to it.

3.4 User-participation in the design process

A number of authors have written on the subject of user participatory design, and it is particularly well attended to in HCI (human computer interface) and computer systems design literature. The *Computer Professionals for Social Responsibility* for instance has sponsored the biennial Participatory Design conference since 1990 and contributors have written about a wide variety of projects. Major texts on user participatory design include Greenbaum & Kyng (1991), Muller & Kuhn (1993), and Schuler & Namioka (1993).

Common to many projects that incorporate user participation, researchers report that through the process of participation, users typically develop a greater acceptance of the artefact or system being designed. The literature identifies that user-participation is incorporated at different stages of the design process, but is typically used in the generative stages of projects where the goal of the designer or design team is to establish user-requirements. Clement & Besselaar (1993) take *A Retrospective Look at PD* [Participatory Design] *Projects*, and note that, "Central to the whole notion of "user participation" is the right of people to have a direct influence on matters that concern them in their work" (*ibid*, p36). Whilst Clement & Besselaar's study concentrated on user participation as applied to the work environment, employment related issues and systems design, the same principles apply to user concerns beyond the work environment.

Kyng (1994) notes that user involvement in product development "seems to be marginal" (*ibid*, p3) and that most participatory design projects have "been research projects or of the type in-house or contract development, and that the claim is often made that this way of involving users is not suited for product development" (*ibid*, p3). He goes on to describe a commercial-based computing systems design and development project in which user participation and cooperative work were important aspects of the design approach.

User participation in the design and development of mass consumer projects is mentioned by Welker, Sanders & Couch (1997) who introduce their work at the design studio, Fitch. They discuss the role of design scenarios as a tool for developing understanding of user needs. These scenarios are co-developed with potential users in "participatory work sessions" and through "observations of users in context" (*ibid*, p26). Sanders has written some significant work on the subject of user participation in the design process. She believes that user experience has an extremely valuable role in the process of designing but also, and rather significantly, in providing a source of inspiration and ideation in designing. It is noted that the traditional research processes of observation and listening to what users do and say are insufficient at providing essential details of design needs and wants, and can even be contradictory (Sanders 1999). Additional and alternative tools, often based on non-verbal modes of expression, have been applied by Sanders in her work at both Fitch and SonicRim (where she is president) to help capture user requirements in user-participatory design (*ibid*; Sanders 2000). These tools are used to "access experience" of users, and are based on three key activities: "what people do, say and make" (Sanders 1999, p4). Sanders notes that:

> when all three perspectives (what people do, what people say, and what people make) are explored simultaneously, one can more readily understand and establish empathy with the people who use products and information systems.
>
> (*ibid*, p4)

Sanders, and the team at SonicRim have coined the phrase Postdesign – a philosophy of "making user experience (as opposed to artefacts, interfaces, systems or spaces) the focus for design inspiration and ideation" (Postdesign). SonicRim's approach to participation is further described in Dandavate *et al* (2000) where the authors describe a case study of participatory design in action.

> Drawing from the domains of marketing, anthropology, psychology and design, SonicRim has developed different types of tools that allow participants to articulate their experiences. Rather than taking a functional/behavioural view of people's work practices, the focus is broadened to include emotional and cognitive experiences ... Besides seeking an understanding of the more explicit facets of people's experiences, which they could articulate through conversations and journals, we needed them to reveal what they knew, how they felt and what they aspired to – things they could not easily articulate, nor reveal in their observable behaviours.
>
> (p104)

The tools described fall into two categories: *Emotional Make Toolkits*, and *Cognitive Make Toolkits*. The *Emotional Make Tools* are used to help reveal emotional and attitudinal perspectives of participants. The participant is asked to make something, such as a diary or a collage, and to then explain the story of its conception. Both the artefact and the participant's explanation of it can shed light on the participant's latent feelings. The *Cognitive Make Toolkits* are somewhat more pragmatic and are used to reveal participants' understanding and interpretation of the particular situation or artefact being examined. Participants are asked to make such things as cognitive maps, 3-D models of functionality, diagrams of relationships and flowcharts of processes using the *Toolkits*.

> A toolkit usually contains a background on which to work, together with a large number of simple and ambiguous components that can be arranged and juxtaposed in a variety of ways. The components cover a range of representational types: from literal to abstract.
>
> (Sanders 2000, p6)

Sanoff (1985) discusses *The application of participatory methods in design and evaluation*, and in particular identifies some common arguments for and against group participation in design projects. The principle arguments against are centred on "the proposition that teams cannot design" (*ibid* p179), and upon time constraints. Problems occur when the group lacks discipline: responsibility for decision making can be unclear, and so the team often "degenerates towards the level of the safest or most obvious solution." (*ibid* p179) Communication between those involved in the process of designing is critical and can be hindered by a number of factors including the clash of egos and personalities of those involved in the design process, and the duration of projects (participants in the process may change – particularly in long-term projects).

This last point is discussed with regard to user-participation in the development of new buildings:

> Since the time span from the renovation or construction of a new building to occupancy may take several years, opponents of participation have argued that the original participants may have or will soon leave, thus invalidating their involvement in the design process.
>
> (*ibid*, p180)

This argument could also be applied to many industrial design projects: users' tastes change over time as new fashions emerge. User-Centred Design has value in assessing initial user needs and wants, but by the time of design implementation (tooling up, or construction for instance), those needs and wants may have changed. Sanoff states that this is a,

> recurring myth [that] ... has plagued designers for many years ... This argument suggests that since there are individual differences among people, the best way to cope with this situation is to ignore individual differences and design for no one in particular.
>
> (*ibid* p180)

Sanoff defends user participation, noting that it can improve the quality of designers' efforts, and more imaginative outcomes can result. Most significantly he identifies that:

> Participatory design is advantageous in that it increases people's awareness of the consequences of the decisions that are taken. ... the major source of satisfaction [of users] is not so much the degree to which the individual needs have been met but the feeling of having influenced the decisions.
>
> (*ibid* p178)

Victor Papanek devotes a chapter in *Design for Human Scale*, to 'Design Participation' (Papanek 1983, pp30-43).

> Because design must be both responsible and responsive, it must be performed by a team. But any team made up only of designers would be an ineffectual debating team. What is needed are nondesigners.
>
> (*ibid*, p31)

Non-designers' knowledge of designers and of how design affects their lives is often limited (*ibid* p30) and so it is argued that designers should help facilitate users to make their design needs explicit, and to educate them about design and designing. In a later article, and with specific reference to designing for people with disabilities, Papanek (1989) highlights some problems of user participation in the design stages, but comments that user involvement is the only way to produce appropriate design. The place of the designer in the roles of facilitator, researcher and entrepreneur with respect to producing innovative products is also discussed in the paper.

Berdel (*op cit*), an industrial designer and Chairman of the Institute of Social Design in Vienna (ISD), declares his disappointment that social aspects and the needs of the user (the disabled, the old and sick and other disadvantaged groups) "were permanently neglected by designers." (*ibid*, p5) He advocates the need for user participation in the design process; the ISD involving "intensive use of ergonomic and anthropometric data coupled with close liaison with the user group".

Reich et al (*op cit*) scrutinise the participation of users in the design process. They note that although, "the still prevalent view of design is that active involvement of users is not useful and in most cases it is avoided" (*ibid*, p165), "there is considerable evidence that user participation leads to more general acceptance of both the process itself and its consequences." (*ibid*, p169). Communication between designers and users is essential for participatory design, but the communication process is evolutionary;

> Communication is thus seen as a continuous process of perspective, conceptual and information exchange, always requiring interpretation and translation by the designers and users who are learning, building and evolving shared meanings of the design situation. The designers need to learn about the users' needs, about the context in which the problem is posed and about what may be a solution that will suit users' needs and 'personality'; while the users need to learn about what is possible to achieve thereby potentially modifying their needs as initially perceived. In this ideal, each participant traces, follows, influences, and is influenced by the evolution of views of others, while all influence the progress and direction of the design process.
>
> (*ibid*, p170)

Whilst there is evidence that user participation in the design process has virtues, and indeed Reich *et al* argue that it is necessary (*op cit* p168), there are particular difficulties with involving users when communication is impaired. Sanoff (*op cit*) states that "Participation in design involves open dialogue, communication and trust" (p178). When communication is impaired, as in the case of an AAC user, 'open dialogue' is difficult. Whilst the communicative abilities of some AAC users is very good, often people with severe communication disabilities will communicate using a number of techniques and strategies – some of which assume prior knowledge and interpretation by the communication partner. In such instances, the designer must be very perceptive in order to interpret and translate users' ideas with neutrality. Hence, trust is critical.

Methods to facilitate communication between designers and people with disabilities, in particular AAC users, are needed. In the case of AAC users, such methods are practiced by Speech and Language Therapists (discussed further in

Section Two of this thesis) and require familiarity of the disability encountered and of the individual person. Hetzroni & Harris (1996) note, in addition, that "Knowledge and judgement regarding the cultural elements of linguistic, operational, social, and strategic competence may assist the professional in identifying the strengths and needs of the AAC user." (*ibid*, p58)

3.5 User-centred design

The majority of texts dealing with approaches to designing for people with special needs advocate (whether explicitly or implicitly) a user-centred design approach. Put in very simple terms, this means concentrating on the experiences of the end-user of a product rather than focusing on a product as an isolated object. All going well, the result, according to advocates of user-centred design, is a product that meets the needs of the user. Literature relating to user-centred design lies predominantly within two areas: design for disability and RT/AT, and Human Computer Interface (HCI).

Norman (1986) offers some design guidance for structuring how the design activity might proceed with regard to interface and systems design. These 'prescriptions for design' are to:

- Create a science of user-centred design.
- Take interface design seriously as an independent and important problem.
- Separate the design of the interface from the design of the system.
- Do user-centred systems design.

(*ibid*, pp59-61)

This, he argues, necessitates the development of sufficient design principles and simulation tools to permit effective prototypes early in the design activity. He maintains that to obtain a 'truly user-centred design' necessitates collaboration with people trained in all areas of a particular field, and thus advocates teams of designers and other specialists working together. For this to be effective, he states that everyone must start with the needs of the user. The nature of the interaction and the needs of the user should dominate the design of the interface, whilst the requirements of the interface should dominate the design of the rest of the system.

Norman also presents the subject of cognitive engineering, and demonstrates the importance of applying cognitive psychology when designing for the user. Two models are referred to. The first, the Design Model, is the designer's conceptual understanding of the system or product to be constructed. The second is the User's Model, and this is based on how the user interprets the design (or the "system image'). His argument goes on to state that, "the primary task of the designer is to construct an appropriate System Image, realizing that everything the user interacts with helps to form that image." (*ibid*, p47)

A useful summary and diagram of task analysis relating to performing and evaluating an action are also presented. The seven stages of user activity are:

- Establishing the goal
- Forming the intention
- Specifying the action sequence
- Executing the action
- Perceiving the system state
- Interpreting the state
- Evaluating the system state with respect to the goals and intentions

(*ibid*, p41)

Norman's recognition of the different perceptions and perspectives of the same system by designers (and other specialists) and the user is significant. The important issue in the system design is to ensure that the Design Model and the User's Model are not dissimilar. This is also true beyond interface and system design, where matching the designer's perception and understanding of the design problem to those of the user is critical to ensure the design meets the needs of the user. Lewis (1986) in arguing for the virtues of design that is centred on the user maintains that design and its associated methodology have to be empirical. "Empirical design needs methods: ways to learn about users, ways to detect, measure, and diagnose the problems in a design" (*ibid*, p6).

3.6 Summary of designing for people with disabilities

A number of sources offer guidance, proposals and principles for designing for people with disabilities. However, whilst advice is offered, there is little in the literature on its application in practical situations. Perhaps this is indicative of the nature of giving advice – it is easier to give than to act upon. Likewise, it is perhaps easier to identify problems at hand rather than devise actions to resolve them (something experienced in NPD, where a cascade of sub-problems arises through the process of designing).

A thread that runs throughout the findings of this literature review is that whilst a range of tools and techniques is available to the designer, these are useful only when bounded by a context. That is to say, they should be applied with care and not considered as hard-and-fast rules. As Holt (1989) warns, the danger of becoming too tool oriented (or relying heavily on one particular tool) can lead to blinkered designing: "if your only tool happens to be a hammer, you may begin to see every thing as a nail to be driven in by it" (p166). Like craft tools, the key is to select the most appropriate procedural tool(s) for the given conditions. The selection is based not only upon the materials and the design task, but also the knowledge and skill of the craftsperson who uses the tool(s). Thus, for designers, the selection of particular tools to facilitate User-Centred Design will be based upon their familiarity, knowledge and skill of using those tools.

3.7 Development work within, and applicable to, AAC

A number of research projects relating to NPD in AAC were under development (or were reported) at the commencement of this study. The following section reports on those projects (thus presenting the state-of-the-field at the time of the study). The material cited here was reviewed and considered in response to the shortcomings of current AAC devices (as discussed in Chapter One), and the problematic state of affairs faced in designing for AAC users (discussed in Chapter Two). In addition, approaches to the design of AAC equipment were sought. More recent projects, including some carried out in 2001, are also discussed to help frame the study and to explain the state-of-the-art in AAC.

Gemmell (1980), from the standpoint of a company producing assistive devices for people with disabilities, states that products must be designed on modular lines and must also be designed for maximum reliability and ease of servicing. This, he notes, should go hand in hand with providing a complete package, comprising of assessment, installation and follow-up service.

Desch (1986) identifies three approaches to providing high technology devices for people with disabilities. The approaches are to:

- use commercially available aids;
- custom-build aids; or
- modify commercially available 'standard' systems.

He goes on to discuss the advantages and disadvantages of each approach. Techniques and devices for augmenting communication are mentioned, and some of the problems as well as the advantages of communication aids are discussed more specifically. An evaluation process that prescribes electronic devices for physically and/or communicatively disabled children is presented. Although this evaluation process is geared towards paediatricians and rehabilitation therapists, it is of use to the designer in establishing a product design specification based on user needs. Beyond design, Desch points out that training in the use of a particular product is a fundamental factor in its success.

With specific reference to NPD, two case studies of adapting current consumer devices to cater for people with disabilities are of interest to this study. Jönsson and Svensk (1995) discuss the development of a personal digital assistant (PDA) for people with cognitive disabilities. The device, *Isaac*, demonstrates a particular design approach to providing high technology aids to people with special needs. *Isaac* is based upon a palmtop computer by Sharp, and the "emphasis on multimedia and communication puts Isaac in the forefront of PDA technology as an example of future personal computing" (*ibid*, p358). *Isaac* incorporates features such as a digital camera and GPS satellite navigation to permit a support centre to know exactly where a user of the system is. As the developers note, these features could be of use to the general public too, and so the potential market for *Isaac* is thus greater.

A similar approach – that of developing a system based on an existing PDA – has been adopted by Walsh, Tippell, Mowse, Colven, Mortley & Brough (1995) in the production of a communication aid for AAC users. Their device, *TouchSpeak*, based on Apple's *Newton*, permits messages in the form of digitized sound samples to be output when icons or words on the touch screen are pressed. Whilst presenting the product at the Communication Matters Symposium (September

1995), various problems were highlighted, the most significant being the dependence upon the *Newton* as the foundation for the product, resulting in the following consequences.

- The developers do not have autonomy. If the commercial product were to be withdrawn from the market, or upgraded, this could render the modified device obsolete.

- Inappropriate design. Consumer products may cater for the majority of their users, but be unsuitable for use by those for whom the product is altered (for instance, control buttons may be hard to modify to accommodate particular users with disabilities).

- Inherent problems with existing systems, that the able-bodied can tolerate, but which prove too awkward for people with disabilities. (The Newton has no back lighting on its touch screen. Thus, the product can be used only in bright conditions. This means that people using TouchSpeak can speak only when there is sufficient light to see the screen.)

TouchSpeak has been further developed and is described in Whitehouse *et al* (1999), Hardy & Davies (1999)); Tippell (2000); and ACE Centre (2001). The project, now known as PCAD (Portable Communication Assistant for People with Dysphasia), consists of a Hewlett Packard 'Journada' palmtop instead of the Newton which posed earlier problems. Tippell (2000) outlines the research team's approach to user requirements capture and the development of PCAD. Their approach to establishing users' requirements consisted of:

1 a review of the literature on communication aids in general and with people with dysphasia;

2 interviews with Speech and Language Therapists, communication partners and individuals with dysphasia, to determine the needs of the target population;

3 observations of individuals with dysphasia communicating in a range of environments (one to one and groups) in order to define the target population and their needs;

4 a review of existing hardware and software communication aids.

(*ibid*, p7)

It is noted in the development process of PCAD, "that products should be developed with users in an iterative manner" (*ibid*, p8). Whilst "There have been some serious delays in making the successful transition to the commercial phase" (ACE Centre, 2001), a commercial version of PCAD is intended.

Gardeazabal *et al* (1995a and 1995b) refer to work carried out at the Laboratory of Human Computer Interaction for Special Needs, Donostia, Spain. The Laboratory has worked in the field of rehabilitation engineering, with a particular focus on people with severe motor and speech dysfunction for several years. In Gardeazabal *et al* (1995b) the development of a communication device, CAAP, is discussed, with reference to the methodology employed in its evolution. CAAP is a redesign of an earlier communicator, the JAL-2, and incorporates speech synthesis with some degree of control over the characteristics of the voice, a LCD display and a small internal printer. The device is between the size of a notebook and a palm-top computer. Gardeazabal *et al* (1995a) discuss the development of AAC interfaces operating upon a personal computer under a Windows® environment to allow people with disabilities to access standard computers and software. This paper offers a brief discussion of issues relating to the development of interface equipment for AAC users.

Flachberger, Panek and Zagler (1995) introduce 'AUTONOMY', a modular system that allows control of various systems within the home for motor- and multiple impaired people. The system supports AAC (as well as environmental control, personal safety devices and access to computer networks), and uses multi-modal icons, pictures, letters, words or phrases, combined with speech synthesis and a built in editor to facilitate communication. A separate mobile user-interface is connected to the main system via a wireless communication link. AUTONOMY's modularity results in a highly flexible user-interface. The principles of supporting other systems by the use of standard computer input and output hardware to facilitate modularity and access to other AAC devices and peripherals is particularly commendable.

The research group responsible for AUTONOMY has since worked on a project called RESORT (Remote Service Provision for RT-Systems), whose aim is to develop a system providing online support for users of RT systems (Panek & Zagler, 2000). The project emerged from the realisation that whilst RT has the potential to help people with disabilities live more independently, often the RT systems are not used to their full potential as configuring the systems for individual users often requires expert involvement. Carers are often not sufficiently skilled in the use of the particular RT system, and professional support is often expensive. Importantly, Panek & Zagler (*ibid*) identify that the successful introduction of a RT product or system is often dependent upon the service provision.

Haaf (1994) reports upon the Ontario Research Technology Consortium who have a team focusing on the design of "a comprehensive, computer-based portable communication system incorporating modules to support face-to-face and written communication" (*ibid*, p9). The article proposes that this system will include such features as the ability to express emotion through synthesised speech and the ability to recall stories. The team is dedicating the system to meet the needs of its users and this article discusses the Consortium's approach towards designing a new AAC product. Information and technical requirements are elicited from various sources, and the relevance of these sources to the development process is discussed.

The article notes that a clinician's report is a very useful source of information regarding the needs of AAC users. The Consortium defends this source, stating that because clinicians are involved in device assessment, the training of AAC users, and the customization of devices they are likely, therefore, to have a broader view of the strengths and weaknesses of various devices than AAC users. Haaf reports that whilst individual AAC users may have a good knowledge of a particular product, they tend to have limited experience of a range of device-characteristics and problems. The device distributors (such as Prentke Romich Company, Liberator, Toby Churchill Limited) are also deemed a valuable 'front-line' resource because they are reputed to gather information from professionals and users by means of interviews and questionnaires.

Haaf quotes Fraser Shein, the coordinator of the Consortium's Communication Team, stating that there "needs to be a clear understanding of the process of developing and marketing technology ... if AAC users and other consumers are to be partners with developers" (*ibid*, p10). Indeed, partnership and co-operation are noted as being important in the development of new technologies, but the Consortium have identified that there are problems of incorporating user involvement in the development of AAC equipment. Most notably these problems include the expense of doing so (transport of AAC users, personnel time) and the time constraints of arranging and carrying out interviews. Haaf highlights the need of, and calls for, an effective medium that would facilitate AAC users and others to present their ideas through less time-dependent channels.

The Department of Applied Computing, University of Dundee, has been prolific in publishing articles relating to its work within the field of AAC. The Centre's Director, Professor Alan Newell, introduces two projects, PAL and CHAT (Newell 1989a). PAL, or Predictive and Adaptive Lexicon, is cited in various articles by the Department of Applied Computing [see Alm *et al* (1992b, 1994), Newell (1990a) and Newell *et al* (1990b)], and was originally designed as a writing aid for people with physical handicaps. It is a form of word prediction system that adapts to suit the user. Word prompts appear in a menu bar with the most frequently used words appearing at the top of the list, so as to allow for faster selection of words from a menu.

CHAT – Conversation Helped by Automatic Talk – is a system that stores conversational material in a database and randomly outputs a phrase from a given menu based on the circumstances in which the conversation is taking place. This system allows the user to maintain control over a conversation, as it takes only a couple of keystrokes to output a phrase, and thus permits quicker generation and output of communication material. This system, however, is of use only in the opening and closing stages of a conversation and for passing general comments during social intercourse.

An integrated system is discussed in Newell, Arnott and Alm (*op cit*, and 1990a), where PAL and CHAT, along with two other developments, TOPIC and TalksBack, are incorporated into a prosthesis for people who cannot talk. TOPIC is similar to CHAT, and stores reusable conversational material. The phrases stored are to be entered by the user, using the PAL system as an editor, and then re-used when appropriate. It is envisaged that these phrases will be pre-stored prior to a conversation, and are likely to be of key events or things that the user would like to bring into a conversation at some stage. TalksBack is presented in greater depth in Broumley *et al* (1990) and, in addition, this paper discusses the contribution that artificial intelligence (AI) can make to a communication prosthesis. Communication is augmented by the prosthesis being a bridge between the user and the environment, "with AI helping to (a) facilitate the communication between the user and the prosthesis and (b) improve the effectiveness of the prosthesis' performance in the environment." (*ibid*, p17)

Four requirements of a communication prosthesis are identified:

> To prove a more usable [*sic*] the next generation of communication prosthesis need to:
>
> a) represent relevant linguistic and social knowledge used in communication;
>
> b) involve potential users at all stages of the design and evaluation of the system;
>
> c) allow the user or a helper to personalize the system to the requirements of the user;
>
> d) allow the user to communicate at rates approaching normal speech rates without excessive cognition load.
>
> (*ibid*, p17)

These projects were further developed with assistance from the European Union's Telematics Application Programme, initially as the ALADIN project, and later the REACT project (Alm *et al*, 2000). One key output of this work was the development of a communication system called ScripTalker, a system that aids non-speaking people carry out transactional conversations based on conversational scripts. ScripTalker uses a series of cartoon-style pictures of scenes presenting conversational scenarios (such as at the shops, at the doctors, and so on). Each scene contains objects that represent conversational tasks, and hence the user "receives a pictorial overview of the script, what happens in it, and what options are available" (*ibid*, p3). By selecting scenes and objects, pre-stored scripts can be recalled and used to produce conversational material. ScripTalker is now being marketed as a commercial system.

Alm *et al* note that:

> A number of techniques have been developed to try to improve the efficiency of use of AAC devices, in order that users might be able to interact more effectively with their communication partners. Despite these advances, there remains a need for improved AAC techniques to enable users to participate in lively, fast moving dialogues with a wide range of conversation partners, including people whom they have never met before. One of the goals of AAC research is to improve the design of AAC devices in order to allow their users to communicate more effectively. An ideal AAC device would have the following characteristics: production of speech acts quickly with the minimum of physical effort, low cognitive load during use, and a minimal requirement for training.
>
> (*ibid*, p1)

Conversational modelling to produce near real-time conversations with non-AAC users has been put into effect in a project called UNICORN, run jointly by the Department of Applied Computing, Dundee, and Kagawa University in Japan. Iwabuchi *et al* (2000) describe the prototype of the UNICORN system which, in a similar vein to ScripTalker, uses pre-stored conversational material that can be spoken out by a speech synthesiser. Iwabuchi's paper identifies that since AAC users may be using a computer to generate conversational material, it may be possible to output the conversational material in another language. Additionally, non-disabled people who wish to converse in other languages could use such a system.

A further application of AAC systems for people who do not usually use AAC devices is currently under development by the Department of Applied Computing, Dundee. ICU-Talk is a project for which the chief aim is to develop an AAC system "which meets the needs of patients who find themselves in an Intensive Care Unit (ICU) and who because of their condition or treatment are temporarily unable to speak" (Judson, 2001, p1). ICU-Talk will build upon the TalksBack project (Broumley *et al*, *op cit*).

The Department of Applied Computing has also conducted research into speech synthesis that is applicable to the field of AAC. Murray *et al* have worked upon developing a system that incorporates emotional characteristics within a communication prosthesis (reported, 1989, 1990, 1991a, 1991b). The system, called 'HAMLET' (Helpful Automatic Machine for Language and Emotional

Talk), takes the speech waveform produced by a voice synthesiser, and applies rules that change the pitch and timing of the utterance dependent upon what emotional quality has been selected. Three factors that portray emotion in speech were identified:

1. Voice quality
2. Pitch contour of the utterance
3. Timing of the utterance

(Murray *et al* 1991a, p1)

HAMLET adjusts these factors based on simple rules and produces appropriate effects "to suggest emotion in the voice" (*ibid* p1). Six emotions were selected, namely: anger, sadness, disgust, fear, grief and happiness[11]. A later version allows for 'three-dimensional control' over the degree to which the particular emotion will sound, and allows for the selection of two emotions at once (e.g., by selecting both happiness and disgust, a form of sarcasm can be emulated). HAMLET was developed as a software program as part of Murray's Ph.D. and was based upon the output of the DECTalk voice synthesiser. It is, however, equally applicable to other voice synthesisers.

The VAESS (Voices, Attitudes and Emotions in Speech Synthesis) project is described in Cudd *et al* (1995). A multicultural team is working on this TIDE-funded project whose purpose is to provide new voices within speech synthesis that sound more human, as well as to develop a new communication aid that has significant ergonomic improvements upon predecessor devices. An initial specification for the hardware platform for the device is included in Cudd's paper.

The Speech Research Lab at the University of Delaware is developing a voice synthesiser specifically for use by AAC users. The voice synthesiser, ModelTalk (Yarrington *et al*, 2000), uses a personalised voice obtained by recording someone's voice using a software program. This feature permits AAC users to sound more like a person of their choice (such as a friend or relative). Whilst the resulting voice sounds synthetic, the virtue is that the voice is more individual.

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[11] Incidentally, the letters beginning each word appear in order upon the second row of the 'qwerty' keyboard; this could be a useful design feature.

Kathleen McCoy's work at the University of Delaware centres on the application of Natural Language Processing techniques to AAC, "in order to develop intelligent communication aids that attempt to provide linguistically "correct" output while increasing communication rate" (McCoy, Pennington & Badman, 1998, p73). The project, called Compansion, automatically generates phrases by expanding the keywords input by a user to form complete sentences. The paper points out some difficulties of incorporating the Compansion technique into AAC devices, and proposes the research team's efforts to overcome these difficulties. The Compansion system has been developed upon powerful Unix workstations, and the University of Delaware has now linked up with the Prentke Romich Company (one of the leading manufacturers of AAC devices) to attempt to incorporate the Compansion technique within PRC's Liberator AAC device. The research has concentrated on demonstrating the feasibility of incorporating Natural Language Processing techniques in AAC but has not dealt the design of an AAC product *per se*.

> ... research efforts have dealt with the front-end component as a separate "black box" that provides the system with words. We have not tackled the many issues involved with developing a front-end appropriate for a specific population of users.
>
> (*ibid*, p84)

The paper also identifies that making a formal evaluation of a research prototype of an AAC device or system is problematic, "as an interface and full vocabulary coverage are crucial components for real world evaluations" (*ibid*, p84). The paper also notes that covering a full vocabulary set in a prototype system can be very time consuming to produce. The selection of interfaces and vocabulary coverage for communication aids is the focus of an additional paper by McCoy & Hershberger (1999), who discuss the inherent difficulties of evaluating a single aspect of an overall system (such as the word selection method) compared to a complete system for use by AAC users.

3.7.1 Summary of developmental work in AAC

It is encouraging to see work upon new AAC devices carried out at a variety of academic institutions. Some very interesting and exciting developments are underway in selective areas – most notably in voice and language processing and user-interface design. Nearly all work upon the development of new communication devices reported in the literature appear based within a computing discipline and, as such, there is a bias towards software design. No literature that discusses the design of new AAC devices, however, mentions the importance of the appearance of the device, or of social or psychological considerations within the product design, yet clearly these are of great importance. Furthermore, where the literature discusses the design of AAC devices, only the design of the software is described. No literature addresses the product design, development and manufacturing issues of AAC devices.

3.7.2 Wearable computing

The field of wearable computing is of particular interest and presents tremendous opportunities for applications within AAC, and disability more generally. The following review of wearable computing literature identifies research pertinent to AAC.

Steve Mann, one of the pioneers in this field, defines wearable computing thus.

> Wearable computing facilitates a new form of human-computer interaction comprising a small body-worn computer system that is always on and always ready and accessible. In this regard, the new computational framework differs from that of hand held devices, laptop computers and personal digital assistants (PDAs). The "always ready" capability leads to a new form of synergy between human and computer, characterized by long-term adaptation through constancy of user-interface.
>
> (Mann 1998, p1)

Mann identifies six key attributes, or "information flow paths", of wearable computers that distinguish them from other so-called portable computers (*ibid*, p2).

1 Unrestrictive to the user.
2 Unmonopolizing of the user's attention. One can attend to other matters whilst using the apparatus.
3 Observable by the user. The output medium is constantly perceptible by the wearer.
4 Controllable by the user. Responsive.
5 Attentive to the environment, ultimately providing the user with increased situational awareness.
6 Communicative to others.

Two additional attributes emerging from the above are noted by Mann. These are *constancy* – that is, the wearable computer is "always ready ... always on and always running"; and *personal* – which is elaborated as follows (*ibid*, p2).

- Prosthetic: one can adapt it so that it acts as a true extension of mind and body. After time one forgets that it is being worn or used.
- Assertive: the computer provides a physical barrier to requests to remove belongings and prevents forceful and unwilling removal. This is in contrast to a laptop computer in a briefcase or bag that could be separated from you by a "please leave all bags and briefcases at the counter" policy of a department store, library, or similar establishment.
- Private: others can't observe or control it unless you let them. Others can't determine the system's status unless you agree to provide that information.

In the light of the shortcomings of AAC devices discussed in Chapter One, the above definition of wearable computers provides an important and apposite area for investigation and application in AAC. The latter attributes of wearable computers described by Mann (constancy and personal) are particularly pertinent to AAC. Indeed, Mann identifies "the most fundamental issue in wearable computing is no doubt that of personal empowerment, through its ability to equip the individual with a personalized, customizable information space, owned, operated, and controlled by the wearer" (*ibid*, p5).

Bass *et al* (1997) identify and discuss four distinct types of wearable computer users:

- expert users ('a computer sophisticate' – a programmer or hardware hacker)
- mass horizontal market users ('analogous to home computer user')
- dedicated vertical application users ('analogous to typical office worker')
- physically challenged users (assistive technology)

(*ibid*, pp3 - 4)

Currently, it is the first of these types that has received the most attention and coverage in the literature. This is largely because the field is emerging and was pioneered by individuals and small research groups working on areas that interested and motivated them. Much of the literature discusses or is based upon individual's own wearable computers. Steve Mann, for instance, has made a considerable contribution to the field of wearable computing through experimentation and development of his own wearable computers. Mann has configured his own wearable computers since the 1970s and a brief history of the evolution of his wearable computer can be found in *Smart Clothing: The "Wearable Computer" and WearCam...* (Mann, 1997). Miniaturisation of computer parts over this period has reduced the size of his wearable computer from a backpack-mounted version 20 years ago to his current (2001) almost-inconspicuous device incorporated into ordinary clothing and glasses.

Starner, *et al* (1999) provide a brief background to wearable computing and discuss some of the pioneering work conducted at Massachusetts Institute of Technology (MIT). The MIT Wearable Computing Project, set up in the mid 1990s at MIT's Media Lab, had an emphasis on "augmenting the mind and senses of the user" (*ibid*, p1). Further, Starner (2001), who was largely responsible for initiating the MIT Wearable Computing Project, presents a range of possibilities and future applications of wearable computer technology, including augmented reality.

DeVaul, Schwartz & Pentland (2001) explain current research carried out at MIT's Media Lab into what they describe as "the next generation wearables research platform". The project, called *MIThril*, is described as a research architecture rather than a product, whose goal is the design of a system consisting of small components which connect together to make a highly configurable wearable computer. These components are networked and powered via the *MIThril* vest, which can be worn under a jacket to conceal the system.

> The MIThril project is driven by the need for a truly functional, wearable, and flexible research platform for context-aware wearable computing research ... Wearable computing is technology you live with; it must be synergistic, flexible, and adaptable to a wide range of circumstances. Our goal is to learn how to support people in their daily lives, which means building technology that is reliable, comfortable, useful, and makes maximal use of the time and attention of the person wearing it.
>
> (DeVaul, Schwartz & Pentland, 2000)

A key area of their investigation and research is context awareness, that is the wearable system senses and interprets the user's state and the environment in which the user is located, in order to "proactively support, anticipate, and facilitate the person's task" (*ibid*). Thus, the system can extend the capabilities of the wearer providing a myriad of attributes, such as mnemonic assistance, immediate access to information anywhere and heightened awareness of situations.

In a similar vein to *MIThril*, Georgia Tech have developed a 'Smart Shirt' or Wearable Motherboard™ into which sensors and devices can be plugged to permit the computer to monitor its wearer. The shirt was primarily developed for combat soldiers but a number of other applications are stated, such as monitoring patients, astronauts and athletes, or preventing Sudden Infant Death Syndrome (SIDS).

Military application of wearable computing is a significant market, and a growing area for research. The Defense Advanced Research Projects Agency (DARPA) has funded a number of projects related to wearable computing for the battlefield at a number of research centres.

Some of the key research centres investigating wearable computing include:

- Massachusetts Institute of Technology (MIT) Media Lab;
- Carnegie Mellon (CMU) School of Computer Science;
- University of Washington Human Interface Technology Laboratory (HITL);
- Georgia Tech Contextual Computing Group;
- Steve Mann at the University of Toronto;
- University of Oregon Computer & Information Science;
- Columbia University Computer Graphics and User Interfaces Lab.

The Human Interface Technology Lab at the University of Washington undertakes research on wearable computing in two main areas: intuitive interfaces, and the use of wearable computers to enhance collaborative work. The HITL website hosts a useful bibliography of wearable computing literature (Billinghurst *et al*, 1998) and is a good source for more in-depth discussions.

Collaborative work is also discussed by Smailagic & Siewiorek (1999b) who describe interdisciplinary work carried out at Carnegie Mellon University (CMU) on wearable computers. Students from mechanical engineering, electrical and computer engineering, computer science, and industrial design have worked to produce several wearable computers. The paper presents the wearable computers developed by CMU, a description of their design approach, and some particularly useful information on energy usage in wearable computing.

Additional information about the wearable computers developed by CMU is presented in another paper by Smailagic & Siewiorek (1999a). The paper also includes the results of user evaluation studies carried out on three wearable computers, VuMan 3, MoCCA and C-130. Whilst the description of the evaluation is brief, field tests with five participants were carried out on the MoCCA, a mobile computer used by field service engineers, yielding improved performance results than had been the case prior to the MoCCA's conception. The paper provides a list of the roles and activities of the participant designers in the product development phases.

Strano (1999) provides a useful summary of the field of wearable computing, tracing its evolution from early pioneering work to current research and provides a prediction of future trends and opportunities for the field. She comments that some of the areas to gain significantly from wearable computing are:

- medicine;
- assisstive technology; and
- "affective" computing (that is "computing which involves detecting a user's moods and emotions by the computer, which then makes appropriate changes" (*ibid*, p3)).

Affective computing is described further by Picard & Healey (1997) who note that "there is a movement in computer science toward developing systems that *learn* what their users want" (*ibid*, p231). Monitoring people's biorhythms via discrete sensors provides the computer with key information to help interpret and learn from its users. A possible application of this could be in AAC. If key emotions can be detected and interpreted correctly by affective computing, the computer could be used to control the intonation of a TTS synthesised voice (for instance, by methods described in Murray *et al*, *op cit*).

Echt (1998) discusses *Wearable Computer Interfaces for People with Disabilities*, providing a somewhat ironic note on the advancement of computer technology.

> The ability of people with disabilities to function independently and with a reasonable quality of life is ... being reduced as each new electronic interface is introduced. Unless a means of easily interacting with such interfaces is made available soon, this trend will continue, and affect even greater numbers of people.
>
> (*ibid*, p1)

She goes on to propose a solution to this based upon Infra-Red Digital Association (IRDA) wireless communication protocols that would permit universal access to a number of electronic devices (provided an IRDA link was in place). It is proposed that people with disabilities could have their own interface that would communicate with electronic devices through Infra-Red communication links. Efforts to include IRDA links in Automatic Teller Machines (ATMs) in the UK and US are cited as an example of the viability of such a system. Starner (2001) proposes something similar, but does not allude to the actual communication protocol[12] (see note on the footnote).

> Imagine a more general-purpose wearable computer that, through software, adapts to provide a consistent interface to any electronics or computer systems in the environment. ... The infrastructure needed for such interface adaptability will be a boon to the handicapped. An individual can carry an interface appropriate for his abilities that automatically adapts to the services provided by the electronics in the environment.
>
> (*ibid*, p47)

Ross & Sanford (1997) also identify the use of wearable computers by people with disabilities to act as a remote interface and environmental controller. Whilst the literature identifies the potential use of wearable computers by people with disabilities, few projects based on practical application were identified in the literature. Discussion of the use of wearable computing for the blind and the deaf were identified within the literature, but the application of wearable computing to AAC has not been attended to.

Whilst the virtues of wearable computers are discussed extensively in the literature (and even somewhat zealously in the early work) inhibiting factors are also well

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12 In other articles Starner has stated his preference for Bluetooth technology as a protocol for wireless communication between devices; for instance, see Rosenberg (1999)

covered. Strano (*op cit*), for instance, identifies some of the general technological limitations of wearable computers, identifying screen resolution and control mechanisms as culprits. She also notes that, "there are limitations with the power supplies, heat dissipation, and bulkiness" (*ibid*, p2). Bass *et al* (*op cit*) also identify a number of inhibitors to the general acceptance of wearable computers by individual wearers, and society more widely. The inhibiting factors are linked to the observation that the market for wearable computers falls into 'general use' and 'specific use' applications. The inhibiting factors are summarised as:

- ease of use of the user interface;
- ergonomics and obtrusiveness of the device;
- loss of dignity or self-determination;
- necessity for new applications;
- social acceptability.

(*ibid*, p5)

The social acceptance of wearable computers is discussed further by Maney (2001), who notes that when Sony's Walkman first came out there was initial concern that the public would feel "like absolute imbeciles walking around in public wearing, of all things, headphones" (*ibid*, pl). He goes on to draw the same analogy with wearable computers and head-up displays, noting that perhaps the public may accept them if the benefits of the technology are immediately apparent, or that wearing one may be seen as a fashion statement. Mann (1999) writes from personal experience about people's perception of him wearing his computer and of the social acceptance of wearable computer users (or "Cyborgs" as they are commonly referred to by Mann), noting that "people find me peculiar" (*ibid*, pl). Starner *et al*, (*op cit*) also discuss the public's perception of wearable computers based upon personal experience. A salient point they state is that public perceptions and associations of wearable computers have changed as the public gain familiarity of consumer electronics. They observe that the first wearable computers were often mistaken for disability aids, then as camcorders, and later, when mobile phones, personal digital assistants and portable video games became more commonplace, people interpreted them as one of these items. They note that fashion and design are key factors in the public's acceptance of wearable computers and that how the product looks determines the interaction, or lack thereof, between wearable computer users and others.

Martin (2001) discusses parallels between the development of the watch and the future development of wearable computers. He identifies major lessons from the history of watch development that can be applied to wearable computers, particularly with regard to wearability, user interfaces and the cultural impact of these technologies. The first of these lessons is that "Wearability will be a function of fashion as well as a function of anatomy" (*ibid,* p3). He notes that from technological and economical perspectives the watch could have been worn on the wrist long before it became socially acceptable to do so. The constraining factor was that wearing a watch on the wrist was seen as effeminate, and it was only after soldiers in World War I began wearing them on their wrists (in this case for functional reasons) that it became fashionable for men to do so.

Gemperle *et al* (1998), discuss the *Design for Wearability* project carried out at CMU into dynamic wearability of computers. Their research is concerned with defining locations on the body "where solid and flexible forms can rest – without interfering with fluid human movement" (*ibid,* p1). A number of wearable form mock-ups have been made to test appropriate locations on the body and to help generate a set of design guidelines. The guidelines for wearability are really a set of design considerations, and are listed below:

1 Placement (where on the body it should go)
2 Form Language (defining the shape)
3 Human Movement (consider the dynamic structure)
4 Proxemics (human perception of space)
5 Sizing (for body size diversity)
6 Attachment (fixing forms to the body)
7 Containment (considering what's inside the form)
8 Weight (as its [*sic*] spread across the human body)
9 Accessibility (physical access to the forms)
10 Sensory Interaction (for passive or active input)
11 Thermal (issues of heat next to the body)
12 Aesthetics (perceptual appropriateness)
13 Long-term Use (effects on the body and mind)

(*ibid,* p2)

The first six considerations are discussed further in the paper. Gemperle is an industrial designer working within a multidisciplinary team at CMU's Institute for Complex Engineered Systems

This section has identified some key work in the area of wearable computing that is applicable to NPD in AAC. Interesting parallels may be drawn between AAC and wearable computing. Both involve high technology, utilise alternative interfaces, are exposed to similar environmental extremes, and the public, as a whole, are uncertain how to relate with users of these technologies. Chapter Six revisits the theme of wearable computing and explores further the technological aspects of wearable computing applicable to the design and development of the Portland Communication Aid.

3.8 Research priorities as defined by AAC professionals

Before drawing conclusion to this chapter, it is appropriate to state the research priorities within AAC, as defined by AAC professionals. These research priorities not only reveal areas in need of research, but also offer guidance on reaching them, and so it is important to mention them here. By doing so the following section, in part, reveals the perspectives and perceptions of those in the field of AAC. There is, of course, a difference between what AAC professionals identify as the research priorities, and those that the designer would identify. By revealing these research priorities the intention is to help frame the research enquiry, but to also identify how and where industrial design can be seen to contribute to the field of AAC.

Murphy's, Collins' and Moody (*op cit*) discuss the limited use of AAC systems based on a study carried out between 1991 and 1992 on behalf of the AAC Research Unit at Stirling University. This study concluded that the use of AAC equipment was poor, and to improve this situation there needs to be:

> a) greater co-operation and contact between SLT[13]s and AAC system suppliers
> b) greater co-operation between SLTs and others involved with the AAC user
> c) more time allotted for training AAC users
> d) more time allotted for training people who work with AAC users
> e) greater involvement by the AAC user in the whole process.
>
> (*ibid*, p12)

[13] Speech and Language Therapist

Another paper by the AAC Research Unit identified the *Advantages and Disadvantages of AAC Systems* (Murphy and Collins 1994). These two papers, in addition to other work carried out at the unit [see Collins (1994), Collins and Murphy (1994), Marková (1994), Murphy, Ellis and Davidson (1993), Murphy *et al* (1994), Murphy *et al* (*op cit*), Scott and Murphy (1994), Walker (1994)], provide a useful source of information to establish a product design specification based upon the needs and wants of AAC users.

Light (*op cit*) in *A vision of Simplicity for Augmentative Communication Systems* identifies four areas that must be reconsidered in the design of AAC systems and challenges those involved in AAC:

> a) to reconceptualise the problem of providing access to communication in order to discover simple solutions;
>
> b) to ensure that designs are responsive to the conceptual models of task requirements that clients have already developed;
>
> c) to provide distinct clues within the systems that clearly designate operational requirements to users; and
>
> d) to build in sufficient flexibility so that systems are able to evolve and accommodate changing cognitive models of consumers.
>
> (*ibid*, p9)

A research agenda is proposed to realise the above:

> 1) research to explore the cognitive development of children and adults who use augmentative communication systems, including their memory processes, their prior knowledge and expertise, and their mental models of the world;
>
> 2) longitudinal research to study the development of cognition in consumers and to identify the changing system needs of clients;
>
> 3) research to investigate the operational demands of augmentative communication systems in order to better understand the factors that facilitate and those that impede learning;
>
> 4) research to delineate the process of learning to operate systems and to investigate strategies to facilitate the learning process; and

5) research to identify design features that clearly specify functional requirements for users (e.g., logical mappings for controls, constraints, feedback mechanisms, and design visibility).

(*ibid*, p11)

She acknowledges that to meet this agenda "will require the active participation and commitment of a wide range of persons" (*ibid*, p11), and will need:

- consumers, families, clinicians, and educators to identify their needs and to define the problems to be addressed;
- researchers to develop appropriate methodologies to investigate the problems identified and to interpret and disseminate results;
- professionals in other fields (e.g. cognitive science, human factors) to share their expertise and resources with professionals in the field of augmentative communication;
- system designers and engineers to translate specifications of client needs and requirements into systems that are simple, but eloquent in their design;
- funding agencies to provide the financial support to allow clinical and technical research incentives in the field to become a reality, and
- most importantly, dreamers to dare to reconceptualise the problems posed and experiment with new and innovative ways to achieve the end goal of full participation.

(*ibid*, p11)

Further research agendas are identified by Beukelman and Ansel (1995) who report upon a workshop held in 1994 to review the research needs of the AAC field and to recommend research priorities for the future. Various research groups in the USA working in this field are mentioned, and six research priorities are proposed.

1 To study the impact of AAC technologies on the development of communication, language, natural speech, and discourse skills of persons with severe communication disorders.

2 To study the influence of user variables (for example, knowledge, skill, and learning style) on AAC system use.

3 To investigate the impact of AAC system features on communicative competence and interactional skills users.

4 To develop tools and strategies to validly and reliably measure communicative, operational, linguistic, strategic, and social competence of children and adults who use AAC systems.

5 To investigate the effectiveness of AAC interventions by studying users of a variety of age, etiologies, and social contexts and to determine those factors that are related to success and failure of AAC use.

6 To encourage the academic development of researchers with a focus in AAC by establishing predoctoral and postdoctoral research and training opportunities.

(*ibid*, pp132-134)

The National Institute on Disability and Rehabilitation Research (NIDRR) is a US-based organization that sponsors research to improve options available to people with disabilities. NIDRR funds a number of Rehabilitation Engineering Research Centers (RERC), of which AAC-RERC is one.

> The NIDRR objective for the RERC on Communication Enhancement is to improve Augmentative & Alternative Communication (AAC) technologies that further the development of communication, language, natural speech, discourse skills, and literacy of persons with significant communication disorders.

(AAC-RERC, p1)

AAC-RERC has developed a research agenda based upon the following assumptions.

1 There is a healthy computer technology industry active worldwide that is developing technical capability important to the AAC field: speech synthesis, inexpensive memory, high quality dynamic screens, small electronic components, efficient batteries, inexpensive storage, touch screen technology, and so on.

2 There is a healthy AAC commercial community.

3 That RERCs should focus on those activities that are important to persons with significant communication disorders that probably will not be developed or researched by the computer technology community and may be difficult for commercial manufacturers.

(*ibid*, p1)

With this in mind AAC-RERC identifies two major research priorities:

> The primary emphasis of the research and development aspects of the AAC-RERC is to focus on understanding of the cognitive-linguistic issues between an individual with a severe communication disorder and AAC technology, as well as between AAC technology and communication partners (listeners). The second emphasis is to focus on the use patterns of individuals with severe communication disorders of AAC technology in employment, by the elderly, in school, and in literacy activities.
>
> (*ibid*, p1)

Much of the work proposed by these AAC professionals is certainly outside the scope of this project. There are, however, significant areas that the industrial designer can tackle. Although many of the research agendas and priorities proposed in the literature have a bias towards the scientific and clinical disciplines, such proposals have significant bearing on the design and the development of AAC devices. All appear to acknowledge that communication between parties is a problem needing to be addressed and that a number of different disciplines are required to cooperate in order to address these research needs. With regard to this study, Beukelman's and Ansel's fifth proposal is of interest but, to an extent, has been addressed in the study carried out by the AAC research unit at Stirling University. The 'vision' proposed by Light presents particular challenges to the industrial designer. Whilst Light states that "a wide range of persons" is sought, the industrial designer-researcher can certainly address several of these. Chapter Four will identify more explicitly the research objectives appropriate for this study.

3.9 Conclusions

This chapter has discussed designing for people with disabilities, and in particular has presented advice, approaches, legislation, methods and recommendations proposed by other authors. There are problems of current disability products, qualified by Collingsworth, Hogan, Nicolle and Sandhu to name a few, and products within the disability sector need to be better designed and marketed. Proposals to address this have been suggested within literature, and these are summarized below.

Team work:

- Design must be performed by a team, and should incorporate non-designers and users (Papanek).
- Make use of multi-disciplinary teams (Norman).
- Collaboration and communication between the parties involved in the design process is vital (Norman, Reich, Sanoff).
- The team should focus on the users' needs (Hogan).
- Scenario modelling can help a team focus on the user (Moggeridge (1993), Poulson *et al*).

The role of the designer:

- The designer has a critical role in meeting the needs of people with disabilities (Hogan).
- Designers should be involved at all stages of the product development process (Hogan, Jonkers).
- The designer should be seen as a mediator and interpreter (Hogan), and as a facilitator, researcher and entrepreneur (Papanek).
- Designers should educate users about design (Papanek).

The design process:

- Design for a broader average (Hogan, Papanek, Penton, Story *et al*, Torrens, Vanderheiden), an example of which is presented by Jönsson & Svensk.
- Designers should see the devices they design for people with disabilities not as aids, but as tools (Wolff), or consumer products (Martin), or alternatively promote such product as convenience items in mainstream markets (Torrens) (of which examples are provided by Newell *et al* (1991/92)).
- Universal Design, if seen as a process rather than an achievement (Story *et al*), presents opportunities for products in mainstream markets to cater for people with disabilities. However, there will still be the need for products catering specifically for people with disabilities. Johnston and Barber proposed that, rather than adopt a

design for all approach, a range of products catering for the five different consumer groups they have identified in the disability sector should be produced.

- Start with users' needs (Norman).
- Take a user-centred approach to designing (Norman).
- Work closely with users (Torrens).
- Get users involved at all stages of the design process (Berdel, Hogan, Papanek, Penton, Torrens, Sanders).
- User experience has a valuable role in the process of designing, and in providing a source of inspiration and ideation in designing (Sanders).

Design recommendations applicable to NPD in AAC:

- Design for reliability and ease of servicing (Axup (1999), Gemmell).
- Design with modularity in mind (Gemmell, Torrens).
- Separate the design of the system from the design of the interface (Norman).
- Working prototypes are useful in the design process (Torrens), especially early in the process (Norman).
- Think the problem through (Penton).

The literature review has also exposed areas in need of investigation and further and continued work. Some of the suggestions for continued work include the need for the following.

- Improved training and education of designers about the needs of people with disabilities (Collingsworth, Desch, Ehn, Hogan, Papanek, Torrens), ergonomists (Vanderheiden), other professionals (Hogan) and the public (Wolff).
- Greater exchange of information between parties involved in NPD, assessment and distribution in the disability sector (Wolff).
- Greater elicitation of knowledge of and about people with special needs (Wolff).
- Greater cultural expectations of users (Wolff).

- The promotion of the interest in design as a response to disability (Hogan).
- The creation of a science of user-centred design (Norman).
- The development of sufficient design principles and simulation tools (Norman).
- The production of better design solutions within the disability market (Hogan).

Many authors advocate User-Centred Design, but pay little attention to design and development, or production and manufacturing requirements. These are critical issues to consider if a product concept is to succeed as a commercial artefact. Industrial designers do not presently appear to have an integral role in the multi-disciplinary research and development teams working on AAC devices. It is as if the connection between industrial design (as the synthesis of users needs and wants with appropriate design, technology and manufacturing methods) has yet to be cemented with the efforts of specialist researchers working in the field of AAC.

There is therefore a connection to be made and investigated: to examine the potential impact of industrial design expertise in the development of AAC devices. Section Two of the thesis is focused on just this matter: the industrial design of the Portland Communication Aid.

Chief questions to be addressed – the case for a design project

4.0 Introduction

Chapter One introduced AAC and presented some shortcomings of AAC devices. Chapter Two widened the topic by discussing the problematic state of affairs of designing for people with disabilities, and in particular of designing for AAC users. Chapter Three reviewed literature relating design and disability and reported on approaches that have been taken to design for people with disabilities. This Chapter brings together the main threads presented so far, in order to determine the chief questions to be addressed by the remainder of this thesis.

4.1 The problem structure

The shortcomings of present AAC devices (as discussed in Chapter One) led to the initial problem statement, that 'AAC products appear inadequate to their intended users'. Further examination and questioning revealed that this problem statement was in fact a symptom of more underlying problems. These underlying problems fall broadly into three key areas, as described in Chapter Two:

1 complexities faced in the process of designing;
2 complexities arising from circumstance and situational contexts;
3 complexities of physical disability.

It is the first of these underlying problems that is the focus of this thesis. The complexities faced in the process of designing can be attended to on two levels. The first is concerned with the *what* of design, and is based upon the shortcomings of current AAC devices. This level relates to *matters of design*. *Matters of design* simply refer to product specifications that a designer considers when designing a product (e.g. the consideration of function, materials, ergonomics, colour, finishes, shape, semantics, and users' tastes, needs and wants). The second level is concerned with *how* to design – *matters of designing* an AAC device. In other words, the processes a designer goes through to reach a product proposal.

Matters of designing link directly to *matters of design.* For example, product specifications can be considered as sub-problems for which a period of investigation and interrogation is necessary: design activity *(matters of designing)* will typically be required to generate relevant evidence and develop appropriate proposals *(matters of design).* Within AAC, the question 'what features should be incorporated in an AAC device?' (a *matter of design*) raises another question concerned with *matters of designing*: 'How does one assess what users need and want from an AAC device?'. Figure 3 illustrates how matters of design and designing are separated for the purpose of this thesis.

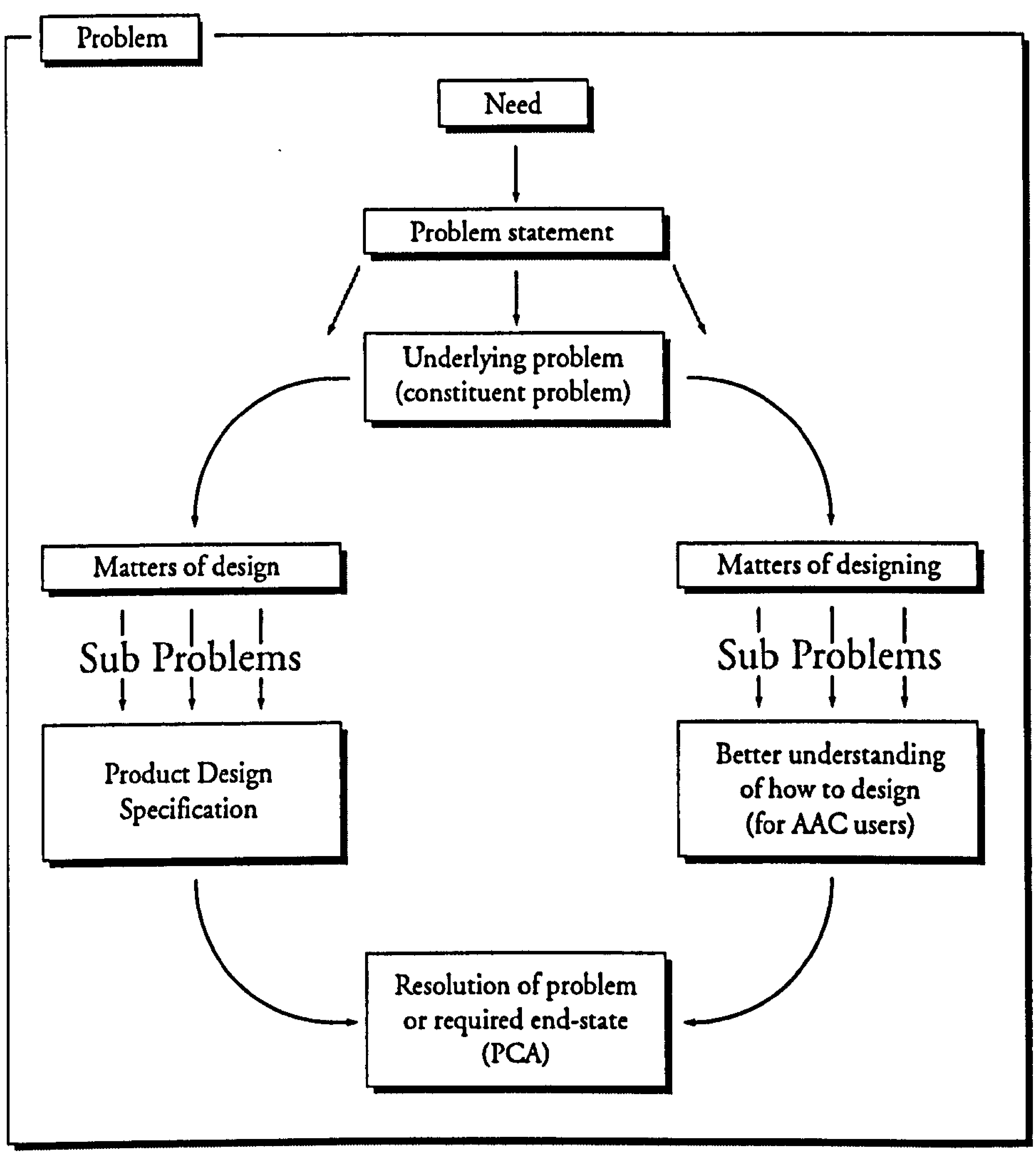

Figure 3: Matters of design and designing

Consideration of *matters of design* typically leads to the generation of a product design specification (PDS). Consideration of *matters of designing* typically leads to the implementation or development of special design methods. The combination of the two, it is postulated, provides sufficient knowledge to produce a product catering for the needs of AAC users. This is put to the test through the development and analysis of a case-based project: the Portland Communication Aid (PCA).

4.2 Chief research questions

Contributors to the field of AAC come from a variety of professions. It is a multi-disciplinary field, yet one in which the industrial designer has made little contribution. Many SLTs and AAC users have outlined problems with equipment, yet not realised that these could be remedied with Industrial Design input. In Chapter Three, Light (*op cit*) stated that "a wide range of persons" is needed to address the pressing research issues in AAC. The skills of the industrial designer appear to be well suited to addressing several of the research issues that Light lists (as well as other issues raised in the previous chapters). All of these issues are brought together below in the chief research questions that the remainder of this thesis will seek to answer.

Important questions relating to *matters of design* are addressed in the thesis.

- What features would improve AAC devices?
- What features will satisfy users' needs, wants, aspirations, purposes, abilities and capabilities?
- How can the features be successfully meshed with technology to produce a product that is functional, desirable, economically feasible, manufacturable, and marketable?

Also addressed in the thesis are important questions relating to *matters of designing.*

- How does one assess users' needs and wants for an AAC device?
- What assessment methods are available to the designer?

- How can one help users to identify their needs?
- What methods can be used to increase AAC users' involvement in the process of NPD?
- Ultimately, how should one go about designing for the needs and wants of AAC users?

4.3 The practical case-based project

The Introduction to this thesis posed that designing is its broadest sense is about tackling problems, by which the activities of identification, analysis and synthesis are undertaken. Designing necessarily involves comprehensive exploration of problems in order to solve them. Allinson *et al* (1996), state that "research is concerned with seeking solutions to problems or answers to questions" (p4). The links between design and research are therefore strong, and by definition the activities of *researching* and *designing* may be seen to be closely related. Archer discusses the links between research and design, and elegantly states,

> Design, in a certain sense, is research done backwards. Research starts with the particular, and moves towards the general. Design starts with the general and works towards the particular.
>
> (Archer, 1992)

One of the most impressive powers of design activity is its focus on synthesis; on creation rather than deconstruction. With this comes a sometimes uncanny (sometimes just dogged) ability to beat often short odds and arrive at a functional and beautiful object. It is this author's opinion that design activity, as a mode of research enquiry, has particular application in research projects where the aim is to construct or produce objects and systems. Specialist design activity allows for rational information searches and wild imaginative thinking to co-exist and, importantly, requires these two elements to be fused together. As a mode of research enquiry, designing is, if you like, a way of undertaking both basic and applied research together, and can be considered vital if one is to produce a groundbreaking new artefact or system.

> Research is systematic enquiry which is reported in a form which allows the research methods and the outcomes to be accessible to others.
>
> (Allinson *et al, op cit* p4)

This statement demands the question of 'how best to make the outcomes accessible to others?' Of course, to whom the research is intended to communicate has an important bearing upon how the outcome is presented. In the particular instance of designing for illiterate AAC users, a thesis in a written format presents little benefit for these people. For practising designers, an academic thesis would not be the most appropriate or obvious media to present the findings of research, as they are unlikely to have access to, and familiarity of, academic libraries. This is to not undermine the value of the academic thesis, but rather promote the validity of other media to present findings of research and embody knowledge ***in addition to*** the thesis.

The intention of research is to communicate the new knowledge generated. How that knowledge is communicated though, is the source of some conjecture within design research. Work by Dewey (*op cit*) and Csikszentmihalyi & Rochberg-Halton (*op cit*) would indicate that value and meaning reside in products, and Morrison & Twyford state that:

> Design ... is a product of imaginative thinking and problem-solving, and is often the means by which new information or understanding can be discovered and used
>
> (Morrison & Twyford, 1994 p65)

The development of the Portland Communication Aid formed the case-based project through which matters of design and designing in the field of AAC were exposed and attended to. The project is described in Section Two of the thesis and is presented in the form of an extended project report. An interactive CD-ROM (Annex A) provides important audio-visual data to accompany the text of Section Two.

Section Two

CHAPTER FIVE

Establishing user and product requirements

5.0 Introduction

This chapter, the first of Section Two, describes the design methods and techniques that were used in the conception and development of the Portland Communication Aid (PCA), the case study at the heart of this thesis. Throughout the designing the aim was to address the chief questions posed in Chapter Four: to reveal and attend to the problems of designing for AAC users. Engagement in practical activity (i.e. the activities of industrial design), along with the meta-activities of recording, reflecting upon and reporting outcomes, were central to this aim. With this perspective in mind, designing was adopted as the mode of enquiry, forming a class of Action Research (as Archer defines the term).

> Systematic investigation through practical action calculated to generate or test new information, ideas, forms or procedures and to produce communicable knowledge.
>
> (Archer 1995, p2)

The 'practical action' in this case was to design the PCA. Through designing, the proposals so far given in this thesis to redress inadequacies surrounding AAC products are explored at a practical level. They are implemented, analysed and where appropriate rejected or commended. The intention was to expose not only the users' requirements of a new AAC device, but to explore whether the needs and wants of the various users could be effectively and realistically synthesised into a design proposal. An evaluation of the resulting product – the PCA – is presented in Chapter Eight, from which conclusions are drawn on the success of the adopted design methods.

5.0.1 Establishing user requirements – an introduction

Often, one of the first steps in a design project is to capture, analyse and appraise requirements and user needs in order to define the problem. This in turn typically leads a designer to formulate a PDS (product design specification). Gaining an understanding of the problem necessitated, in this particular instance, gathering as much information as possible about the requirements of the end users. This chapter discusses the conduct and results of a quest to find out what people with communication disabilities need and want from an AAC device. The literature on methods to assess user requirements is first reviewed, and is followed by an explanation of the design methods selected for the project. A more detailed discussion of the conduct of establishing user requirements then follows. The chapter concludes by summarising the results of the activities to establish user requirements. The resulting product design specification is to be found in Appendix VII.

To supplement Section Two of this thesis, and to help explain key events and aspects of establishing user requirements, a CD ROM (Annex A) has been created. The audio-visual data contained on the CD ROM is intended to provide readers with essential audio-visual data. The CD ROM not only illustrates points raised in the text of Section Two but provides an immediate, revealing, accessible and contextual view of the activities involved in designing the PCA. (The sub-section 'Getting to know the users' under the section 'Conduct of project' is particularly relevant to this chapter.)

5.1 Review of methods of assessing user requirements

Literature on methods of assessing user requirements was reviewed in order to identify appropriate investigative techniques to adopt in the design of the PCA. Different methods of learning about users are reported by a number of authors. The following are identified in literature as techniques for assessing user needs and requirements.

Holt, Geschka and Peterlongo (1984) in *Need Assessment – A Key to User-oriented Product Innovation* identify 27 methods for assessing user needs. They state that these methods fall broadly into three categories, namely: *existing information*, *generation of new information* and *other methods*.

Existing information

- Customer information
- Staff information
- Government information
- Competitor information
- Trade fairs
- Literature
- Experts

Generation of new information

- User questioning
- User employment
- User projects
- Multivariate methods
- Dealer questioning
- User observation
- Active need experience
- Simulation
- Brainstorming
- Confrontation
- Morphological analysis
- Progressive abstraction
- Value analysis
- Delphi method
- Scenario writing
- System analysis

Other methods

- Informal contacts
- Product safety analysis
- Ecological analysis
- Resource analysis

Galer (1983) describes test procedures for the evaluation of products with particular reference to aids intended for people with disabilities. The report presents some useful information on task analysis techniques, the use of field surveys, user trials, expert appraisals, evaluation criteria and ergonomic tests. Beyond evaluation, the material contained in the report provides a good basis for assessing user requirements of devices.

Literature from the fields of Rehabilitation Technology and Assistive Technology (RT/AT), as well as from social science disciplines, also indicate various techniques for carrying out individual assessment of people with disabilities. These techniques include the following.

- Activities of daily living indices
- Activity diaries
- Capacity demand analysis (analysing video of users performing set tasks)
- Dynamic anthropometry
- Elemental resource model
- F-JAS (Fleishman Job Analysis Survey)
- Functional assessment tools
- GOMS analysis (Goals, Operators, Methods and Selection rules)
- Health assessment tools
- Home interviews
- Instrumental activities of daily living
- Interviewing techniques
- MPT (Matching Person and Technology)
- MTM (motion analysis of people as they perform everyday tasks)
- MUSIC (methodology of physical work load assessment)
- Personal interface design method
- Quality of life indices
- Residential performance checklist
- User panels

The HUSAT Research Institute (Poulson *et al*, *op cit*) has developed a handbook embodying principles and methodologies for conducting user-centred design. The *USERfit* handbook discusses many of the above techniques and provides the reader with practical advice on implementation. *USERfit* is intended for the RT/AT sector as well as for 'mainstream design activity' and its purpose is to help designers "collate, analyse, evaluate and develop information to build ... [a] product specification" (Poulson 1998, p2). At its core, the *USERfit* methodology consists of seven principle tools. These tools are:

- User Analysis;
- Activity Analysis;
- Product Analysis;
- Environmental Context;
- Product Environment;
- Functional Specification; and
- Usability Evaluation.

(*ibid*, p2)

Poulson states that:

> The use of USERfit will enable you to identify and describe your intended user population; describe in detail what it is they need from your product; convert these tools into a product specification; and finally create usability goals against which your product may be evaluated.

(*ibid*, p2)

The term Usability is an indication of how effectively a product may be used by its intended users. Usability is defined by ISO 9241 as "a concept comprising the effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in a particular environment" (ISO 9241, 1992). Usability can be judged according to a set of measurable performance tests intended to gain an objective appraisal of a product. A number of objective-test elements for measuring Usability relevant to HCI design are described by Axup (1999) and include the following.

1 Learnability
2 Efficiency
3 Memorability
4 Errors
5 Satisfaction
6 Productivity
7 Training time
8 Data input speed and interpretation of data
9 Technical support needed
10 Maintenance costs

(*ibid*, p1)

In order to define usability problems, a number of methods are also proposed by Axup. Some of these techniques overlap with techniques that have already been mentioned. The additions, mentioned in the context of HCI design but equally applicable to NPD and industrial design, include:

> - Validation test: ... This is done late in the design cycle and extensively uses usability requirements. It confirms that the software is performing as expected by gathering simple statistics of usage. The results are compared against the requirements and changes made to areas that need improvement.
>
> - Comparison test: ... Sometimes it is important to compare your product to a competing product or a previous design with a new design. ...
>
> - Heuristic analysis: A style of expert review which uses a set of "rules of thumb" or short guidelines for design.
>
> - Cognitive walkthrough: A style of expert review which heavily utilizes "user-scenarios" and attempts to view navigation through the eyes of the user.
>
> - Participatory design: A style of development that advocates having a user on the design team to provide domain-specific knowledge necessary for development.
>
> - Follow-up study: Determine how the product is being used, how it has affected the work environment and how it can be improved.
>
> (*ibid*, p2)

A collection of papers on 'usability evaluation in industry' can be found in a book of the same name (Jordan *et al*, 1996). The book presents both formal and informal methods by a variety of authors, and a number of quick and cost-effective methods are described. The book is easy to read and the majority of techniques are simple to apply. A paper in the book by Stanton & Baber (1996) notes that usability evaluations have traditionally been conducted upon finished products, but there are benefits of involving usability earlier in the design process (it is cheaper to make changes prior to production). They note that observations and interviews are "the most obvious manner to collect information about how people perform a task ..." (*ibid* p41). Stanton & Baber (*ibid*) also present in their paper a chart covering usability evaluation techniques and methods intended to assist the designer select appropriate evaluation methods.

5.1.1 Models of Users

Interestingly, not all techniques to gain understanding of users require the active participation of users. Designers often generate their own models of users. Moggeridge (1993), for instance, discusses the use of scenario modelling at IDEO design consultancy. He identifies the importance of story-telling to initiate design teams into designing in an effective manner for particular groups of people (whose needs and wants may be unfamiliar to the individuals of the team). Four steps of scenario modelling are identified in his paper, namely: understanding, observing, visualising, and evaluating.

Scenario modelling can help design teams because the participant designers jointly focus upon the scenario described or generated, and not upon their individual interpretation or understanding of the problems involved. In essence a collective stereotype of user or users is generated, and so it is of great importance to ensure the stereotype relates accurately to actual groups of people. As Robin Jacques (1982) notes:

> The level at which people may be stereotyped for design purposes is a design decision of significance affecting the appropriateness of solutions and the quality of life for their users.
>
> ... The designer's personal view of what the critical or sensitive issues are in a project will be only one of many, and is likely to be based on illegitimate transfer of experience, unjustified assumptions, and partial information, all of which must be modified through the interactive process of design.
>
> (*ibid*, p50)

As discussed in Chapter Two, designers' experiences of people with disabilities is often limited, and so without such experience 'unjustified assumptions' can be expected to result. The validity of story-telling, therefore, is when the story is based upon fact and is told by an informed story-teller.

To help designers gain an understanding of the needs of people with disabilities, empathic modelling, or disability simulation, is suggested as a useful technique in the *USERfit Handbook* (Poulson *et al*, *op cit*, pp91-96). Such an approach can vary in levels of sophistication. It may consist in simply spending a day in a wheelchair; in wearing a blind-fold (or else wearing spectacles that simulate the effects of a particular visual impairment); or in wearing gloves that constrain finger movement and thus mimicking impairment from arthritis. Importantly it is noted that such a technique should not be a replacement for user involvement, but rather should be used to help a designer learn more about the effects associated with a particular physical impairment.

> There is a big difference between the situation an investigator puts himself in, and the situation of an actual disabled person ... a disability "simulated" in this way will have a lot of differences from a real disability.
>
> (*ibid*, pp91-93)

Penny Munn (1996) in arguing against such an approach states more explicitly what these differences are:

> I would have thought that this approach is slightly worse than useless because it cannot reproduce the experience of disability for the following reasons:
>
> (1) Disability usually has secondary effects on developmental processes that are impossible to recreate on a simple physical level. One very striking example of this is the impact of blindness on emotional expression and language use, but there are many others.
>
> (2) The rippling (or cascading) effects of disability are usually unique to a particular individual's characteristics and social context and cannot be predicted in any simple way. Coping mechanisms and dispositional responses to disability may have quite marked effects on the course of the disability, yet be related to an individual's family or history in quite perplexing ways.
>
> Students need to understand and respect such individual variability. Simple physical approaches to the experience of disability would communicate a lack of interest in the psychological dimension.
>
> (*ibid* p1)

The role of user-models is discussed in detail by Hasdogan (1993 and 1996), who conducted a survey of design practitioners' use of user-models as part of her Ph.D. study. Three groups of user-models were identified: empirical models which include published material, tools and software available to the designer (e.g. anthropometric data, mannequins); experimental models (live users of the product or prototype); and scenario-based models (formal or informal story lines relating to the user). Of these, it was found that scenario-based models were employed the most frequently, and practitioners' attitudes towards this approach were very positive. Experimental and empirical models were used to a lesser extent. The high cost of performing user-tests was offered as an explanation for the low usage of experimental models. Hasdogan found few physical empirical models describing approaches that can be taken to designing for people with disabilities.

5.2 Discussion and selection of methods

As mentioned in Chapter Three (section 3.6) it is important to consider design methods in context. The selection of particular methods to assess user requirements depends upon a number of factors, including:

- who the users are;
- the available funding;
- the nature of the artefact being designed;
- the time available;
- the type of information required;
- the particular stage in the design process;
- the availability of equipment; and,
- the assessors' familiarity of the method.

Some authors present guides to the selection of particular methods (Stanton & Baber (*op cit*), Poulson *et al* (*op cit*)), and some note the problems and issues specific to selecting methods of assessment for people with disabilities (*ibid*, Galer (*op cit*), Nicolle, Poulson & Richardson (1995)). However, little is discussed with regard to communication disabilities[14]. Of the techniques mentioned in the list above, some are inappropriate for the particular context of the PCA. Techniques that were deemed invasive or techniques that are dependent upon AAC users' ability to communicate in written form were ruled out. Likewise, whilst the tools described in Sanders (1999; 2000) hold much potential for the discovery of latent needs in requirements capture, these tools are somewhat reliant upon participants' physical and communicative abilities and so in this instance had limited application.

Of the three perspectives – "what people do, what people say, and what people make" – described in Sanders (*op cit* 1999), the latter two presented particular

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14 There is an exception – Poulson *et al* (*op cit*) present a worked example of the application of the *USERfit* methodology. The example discusses the design of a communication aid for children with cerebral palsy (*ibid* pp65-82). Whilst this article contains some pertinent material, its publication was after the author began this study, and so was not available at the time when investigative methods were being selected.

difficulties in the case of establishing requirements of AAC users. They also presented an interesting and provocative challenge for the research study.

Observations and interviews seemed apt starting points, whilst usability evaluation techniques were deemed more appropriate for the idea generation stages of the PCA development. The following section of this chapter discusses the application of observation and interview methods in the context of the PCA.

Figure 4 presents a guide to the methods used to establish user requirements. The design activities of idea generation, sketching and modelling were used to help users articulate their requirements and were central to the study (hence these activities appear in the central column of the diagram). The diagram shows early work feeding into idea generation and identifies the development work that followed, culminating in a concept presentation. The tasks of (i) learning about aspects of AAC, speech and language, (ii) idea generation, and (iii) observation were concurrent activities.

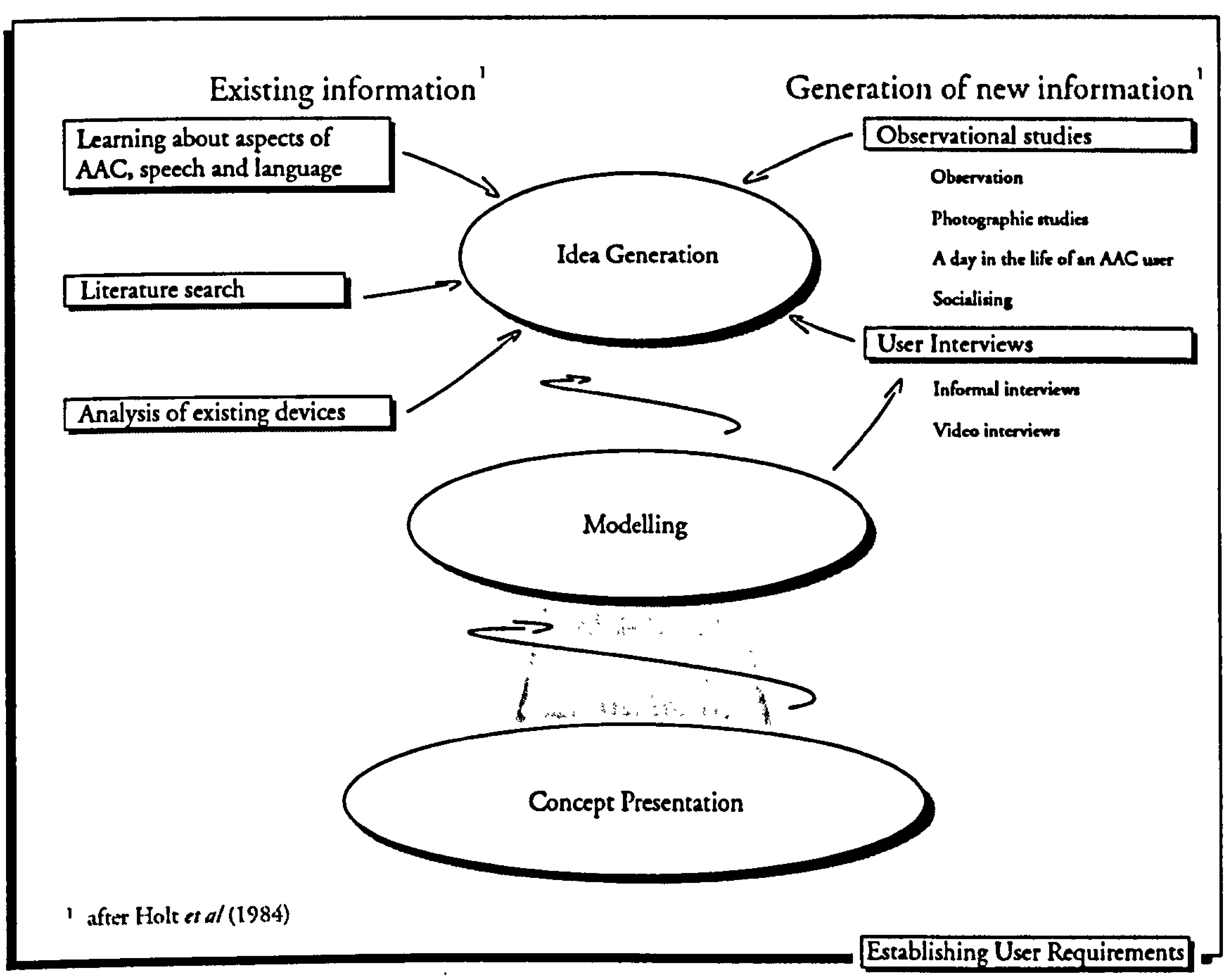

Figure 4: A diagrammatic guide to the methods used to establish user requirements for the PCA

5.3 Gaining familiarity of AAC

After being shown Portland College and being introduced to some staff and students, a period of 'acclimatising' to the subject of AAC was undertaken. The intention was to gain sufficient understanding of AAC to feel prepared, confident, and at ease in the College environment and with communicating with AAC users. Gaining awareness of the field of AAC and its subject matter by searching and reading related literature was one activity entered into. Another was a review and analysis of existing AAC devices (see Chapter One). In essence the methods falling into the category of 'existing information' (Holt *et al, op cit*) were conducted early in the programme. Theory had to go hand in hand with practical experience however. It was decided that the strongest accompaniment to theory was to spend time with AAC users and get to experience AAC first hand.

5.3.1 Observational studies

In the initial stages of the designing, much time was spent at Portland College observing students, without influencing their actions, as they conducted their everyday activities. It was important for the students, staff, and this researcher to become comfortable in each other's company. A journal was kept during this time in which observational comments were reported. These comments were based on questions formulated through the process of observation and included such things as:

- how the students communicated (the strategies adopted, how particular people would get the attention of a conversation partner, whether students initiated conversations);
- how AAC users interacted with others (both AAC users and non-AAC users);
- how AAC devices were used;
- particular difficulties, problems and frustrations AAC users experienced (particularly with their AAC devices) and what seemed to be the cause of them;
- typical activities, routines and habits; and,
- what the AAC students appeared to like (what they liked to talk about, what they liked doing, who they liked, what interests they had).

A typical day's work at the College consisted of attending classes in the morning (usually 'Communication' class, 'Life-Skills' class, or 'Computing' class), having lunch in the dining room (typically with the staff, but often with the students too), and then attending afternoon classes or sessions (Sports, 'Communication Club'). Attendance at these classes and events provided the opportunity to observe the students in different situations, at different times, and doing different activities. Whilst the classes were generally structured (so that students were engaged in tasks set by the tutor), the sessions between classes (e.g. breaks and lunchtime) provided the opportunity to observe the students in more informal settings. Figure 5 shows a Communication class in progress at the College.

Figure 5: A Communication class in progress at the College.

The observational sessions were conducted such that after being introduced to the students and after the pretext of being there was explained, the author would either sit in on sessions between the tutor and the student(s), or else spend time reading, sketching, or note-taking whilst 'eaves dropping' on what was going on in the class. With the author being deliberately visible and engaged in designing, the sessions provided the students with opportunities to become accustomed to the author's presence. The sessions also afforded the students some insight into the processes of designing a new product. For the author, the observational work was vital in gaining familiarity with AAC users and for revealing problems students experienced in day-to-day life (especially with their communication aids). In addition, and importantly, the sessions provided the opportunity to learn about communication strategies adopted by AAC users and the staff, and to judge appropriate communication strategies for different situations. Overall this helped in the construction of the interview protocol (discussed later). The following details were noted.

- Making sure not to finish AAC users' sentences off for them, but to wait patiently until they finished inputting into their devices what they wanted to say.
- Making sure not to read the screen of the AAC device over the shoulder of its user.
- Ensuring use of open and closed question formats.
- Allowing a proper place for humour, determining what was acceptable and what was not (there was very little that was not acceptable since the students and staff had wicked senses of humour).

After gaining familiarity with AAC users and how they communicated, more interactive activities were engaged in. In addition to classes, the 'Communication Club' (a voluntary discussion group consisting of AAC users and either a communication tutor or a SLT) provided an ideal opportunity to chat and discuss things with AAC users. The informality of these sessions meant that students did not feel under pressure to communicate (they were not assessed or taught during these sessions and so felt more comfortable if, and typically when, they made mistakes). Students could set the agenda of the conversation, which invariably tended towards joke telling and gossip. Evening sessions in the social club where there was a bar also allowed for more liberated conversations.

5.3.2 Photographic studies

Photography was used to help build a visual record of the target audience of the PCA, revealing within each photograph some details of the students' lives – their clothing, character, habits, expressions. The majority[15] of students did not mind

[15] The exception was one young woman who acquired a head injury after a road accident when she was twelve years old leaving her with brain damage and limited motor control. She is conscious of the difference between how she is now and how she was then. Consequently she has not fully come to terms with her present state, is rather self-conscious, and hence was reluctant to be captured on camera.

having their photographs taken – some were even quite flattered that someone wanted to take their photo. The photos provided a useful resource for designing, as they helped to keep the AAC users in mind whilst working on design ideas. Moreover, showing the students the photographs once they were developed proved quite popular and helped in developing amity between the author and some of the students.

5.3.3 A day in the life of an AAC user

After getting to know one particular student, he was happy to be followed around and photographed as he went about a typical day at the College. The day provided an opportunity to observe the minutiae of events that were not always apparent in situations previously encountered. The day helped to reveal not only the physical and utilitarian requirements he has of a communication aid, but also of his affective, psychological and socio-cultural requirements of a device. Seeing posters in his flat revealed something about his music preferences, his wardrobe revealed his fashion tastes. The TV programmes he chose to watch and the things that made him laugh or react in particular ways also revealed aspects of him and his requirements. Collages of the photographs were then generated and used to provide the author with visual stimuli whilst designing away from the College environment. Figure 6 presents a sample of one of the collages.

Figure 6: Excerpt from a photographic collage of a day in the life of an AAC user

5.3.4 Socialising

People act differently in different situations and circumstances. Not only do people act differently, they often communicate differently and say different things when in formal situations (e.g. a classroom) compared to informal situations (e.g. a chance meeting). The environment and social context often dictate how people communicate (e.g. raising one's voice or using gesture to get attention in a noisy club, or whispering in a library). For this reason, some of the most useful and insightful observational sessions were at social events. Throughout the study, various social events were attended by the author, including a barn dance, a disco, and a pub-lunch. These events provided the opportunity to observe different aspects of AAC users' behaviour and experiences. The role and limitations of communication aids in such circumstances revealed areas in need of clear design improvement.

5.3.5 Building a rapport with students

A particular rapport developed between the author and two students. Building a rapport with these students over a year provided the opportunity to experience in an intimate way their frustration, hopes and everyday interactions. Being accepted into their social activities gave an opportunity to see, at close hand, different sides to these students when compared to their behaviour in a classroom setting. In addition, over the year key events took place in their lives: birthdays, parties, achievements, relationships, illnesses and injuries, and so on.

To develop the rapport it was important to establish a trust between the students and the author. An obvious way to achieve this was to act upon what the AAC users discussed or stated during the observational and interview sessions. Design work that incorporated the AAC users' comments was often shown and discussed in follow-up sessions and interviews. This was intended to foster user participatory design, build rapport, and to remind each other of what had previously been discussed. The intention in establishing trust and rapport was to ensure that the AAC users explained what they needed and wanted from an AAC device, and not what they thought the author wanted to hear[16].

5.4 Interviews

5.4.1 Informal interviews

Informal but semi-structured, one-to-one interviews were carried out with AAC users at Portland College. The interviews were conducted under the guise of chats so as not to intimidate the interviewees, and to allow the interview to be participant-led. An interview protocol was followed when conducting the interviews (see Appendix II). The interviews were usually conducted during class times. Open-ended questions were first offered in order to encourage the AAC users to respond as freely as possible. As the AAC users' communicative abilities varied, the same basis of the questions was usually posed in a closed format to prompt and encourage responses. Often the ordering of questions would change to ensure the interview sounded more

16 Barber (*op cit*) notes that this is a common problem when first encountering people with disabilities, referring to it as 'the gratitude effect'.

conversational than set. Where possible the questions were adapted to focus upon issues raised by the interviewees. A set of questions was posed to determine:

- users' needs of a communication device;
- users' wants and desires for a communication device; and,
- users' perceptions of their machines, the relationship between themselves and their machines, and their perceptions of how others saw them and their machines based on their own experiences.

The interviews were structured to first find out about the interviewees, and then find out what the interviewees thought about their communication aids. Once this was established, the questioning was then focused upon what the interviewees would want from a new communication device. When the interviewees suggested ideas it was typical for the author to take the initiative and respond with questions to draw out more specific details. After the interviewees finished discussing their hopes for a new communication aid, the questioning then moved to a process of obtaining feedback on the author's own design suggestions.

Sketches of concepts were shown in the interviews to solicit interviewees' thoughts and preferences. The author's ideas were deliberately left until last to ensure that the interviewees' perspectives and ideas were not shaped or manipulated by poor interview technique. In addition, it was important to reassure the interviewees that they were involved in the design of the device, and that their comments were valued.

Initially interviews with fifteen of Portland College's students were conducted. Because some of the students lacked the communicative skills necessary to obtain clear results that could assist in establishing their requirements, more frequent interviews were conducted with those students who had better communication skills. Two students were particularly communicative, and were motivated to talk and be participants in the study. Further interviews were conducted with these AAC users.

Informal discussions with AAC professionals (communication tutors, speech and language therapist, and carers) at Portland College prior to and after interviews provided further support to the AAC users' statements and, in addition, these discussions provided the author with key circumstantial and contextual information to help interpret and comprehend some of the AAC users' statements. (For instance, the AAC user might have mentioned names of people in the interview without explaining the relationship of that person to the AAC user – in this instance the carer or tutor could fill the author in on what the relationship was.) For some of the interviews carers would help interpret during the interview, whilst occasionally, tutors would interject in an interview to help the AAC user articulate or construct an answer by providing prompts as to where conversation material was located on their communication aids. Often, after the interviews the author would elaborate on points raised by the AAC user with the AAC professionals working at the College ("*So and so* mentioned that he had a problem with *such and such*. Is this a common problem?"). Thus, although two participants provided the primary focus, others contributed informally to the process of requirements capture.

There were both positive and negative aspects of focussing on two AAC users. Naturally, with only two primary participants the validity of the findings could be questioned, and the breadth of issues raised in the interviews was thus narrower than if a greater number of participants were interviewed.

Focussing on two participants was certainly more time-efficient and expedient for the author, particularly as it can be time-consuming gaining familiarity with an AAC user's communicative ability and style in order to accurately comprehend the participant's intention. Fewer participants provided the opportunity for the time to be better invested in gaining familiarity with the participants' communication styles. There were obvious logistical advantages too, as the availability of participants who had sufficient communicative ability and were motivated to talk was limited.

Conducting more frequent interviews, but with fewer participants was beneficial for both the author and the participants – and ultimately for the study – for a number of reasons. A strong rapport developed between the author and the two participants, permitting more open communication. This allowed, when necessary, sensitive and difficult questions to be asked with comfort, compassion and consideration, as mutual trust and respect were established. Thus, issues raised by the participants could be penetrated at depth (something more difficult to establish with a greater number of participants). The interviews also provided the participants the opportunity to spend time talking with someone who was genuinely interested in what they had to say, and hence they felt flattered. The interviews also provided the participants with a form of symposium by which issues central to their everyday lives could be expressed and explained.

For the study, a key advantage of conducting several interviews over a period of time was that new and important areas for investigation emerged through such discussions. The time between interviews permitted the filtering of information and the author became more focussed and aware of the salient issues and problems in need of investigation. In time the author gained greater insight as to what constituted the problematic situation facing AAC users and permitted more appropriate and timely lines of questioning. What at first appears an important line of questioning can later appear unimportant, as new knowledge and awareness are revealed.

It was felt that although only two participants were interviewed at length, the results would be indicative of the needs and wants of young adult AAC users. In defence of this proposition, Virzi (1992) notes that, "the first few subjects run in an evaluation are likely to let the experimenter uncover the majority of the usability problems" (p459). The results of the interviews were used in conjunction with the findings from literature (Murphy, 1993; Murphy & Collins, 1994; Murphy, Collins & Moodie, 1994; Murphy *et al*, 1993, 1994, 1995; McGregor, 1994; Robertson, 1992, 1993; Joyce, 1994) and from observations in order to triangulate the findings.

Several interviews and discussions with the two participants were conducted over the College's academic year, providing the opportunity to review findings in relation to the participants' circumstances and experiences at the time. Seasonal changes revealed different physical requirements of both the user and the AAC device (for example, in summer fingers may slip on keyboards due to sweating, whilst in winter hands operating a keyboard get cold and numb). Such findings may not have been apparent if only one 'snap shot' interview had been conducted. In essence, interviewing the same candidates periodically provided a more comprehensive account of their needs at different times. In all, over fifty interviews and discussions were conducted at the College over the period of the study.

After trying to transcribe the first interviews it became clear that a transcription did not provide a true record of the interview. If the interviews were transcribed verbatim they were difficult to understand. Many AAC users communicate by means other than verbal language and, in addition, much of the interviewees' spoken output was syntactically and linguistically incorrect. As a result the author often had to interpret or re-word the interviewees' responses and utterances in order to divulge intended meanings. This necessitated gaining not only familiarity with the communication strategies of AAC, but of individual students. An example of an interview transcription, including a commentary to help explain and interpret the transcription, may be found in Appendix III. As rapport developed between the students and the author, comprehension and understanding of the AAC users at Portland College became easier.

5.4.2 Informal video interviews

In an attempt to more accurately record interviews, some latter sessions were video recorded. Videoing the interviews provided a permanent record of AAC students using their devices, and could be used for purposes beyond recording the contextual details of the interview (including as it does the interviewees' gestures, expressions, and actions). The audio visual data contained on the video recordings made it convenient to measure the time taken to compose and utter sentences. Additionally, the video recordings helped reveal how AAC users communicate to others who may be unfamiliar with people with severe communication disabilities. (Appendix V contains a transcript of three such interviews with one participant. In addition, a brief excerpt from one interview appears on the CD-ROM).

5.4.3 Structured scripted video interviews

Structured scripted video interviews were conducted with several of the College's students. In conjunction with the communication tutor and the speech and language therapist it was realised that a video record of students could be of use in assessing progress and achievement of individual students at the College. With regard to this study, the purpose of conducting the interviews was simpler: the intention was to note and record students using their AAC devices. The interview team (consisting of a speech and language therapist, a communication tutor and the video operator (the author)) introduced themselves to the AAC user explaining what was being done and why. The AAC user was then asked whether he/she had any objections to the interview taking place. (The interview script, a description of the interview protocol, and an explanation of the key events in the interview can be found in Appendix VI)

5.5 The use of design work in establishing user requirements

The design activities of ideation, sketching and modelling had a significant role in establishing user requirements, and are discussed briefly below. (Two-dimensional and three-dimensional based design activities are discussed further in Chapter Six.)

5.5.1 Sketch work

The researcher generated ideas early in the study – the observational sessions in the classes at the College were often productive and creative. Sketching the students and placing design ideas upon the same drawing helped to put the concepts in context. Figure 7 shows an example of one such drawing (additional sketch work may be found on the CD ROM under the sub-section 'Idea Generation' in the section headed 'Conduct of The Project'). The sketches were then used, in part, to help focus the participants upon particular points being discussed in the interviews. Moreover, the sketch work was used to help the participants think about alternative possibilities to their own preconceived ideas (there were often differences between participants' initial statements of what they wanted and those posed by the participants after exploring other options and design proposals).

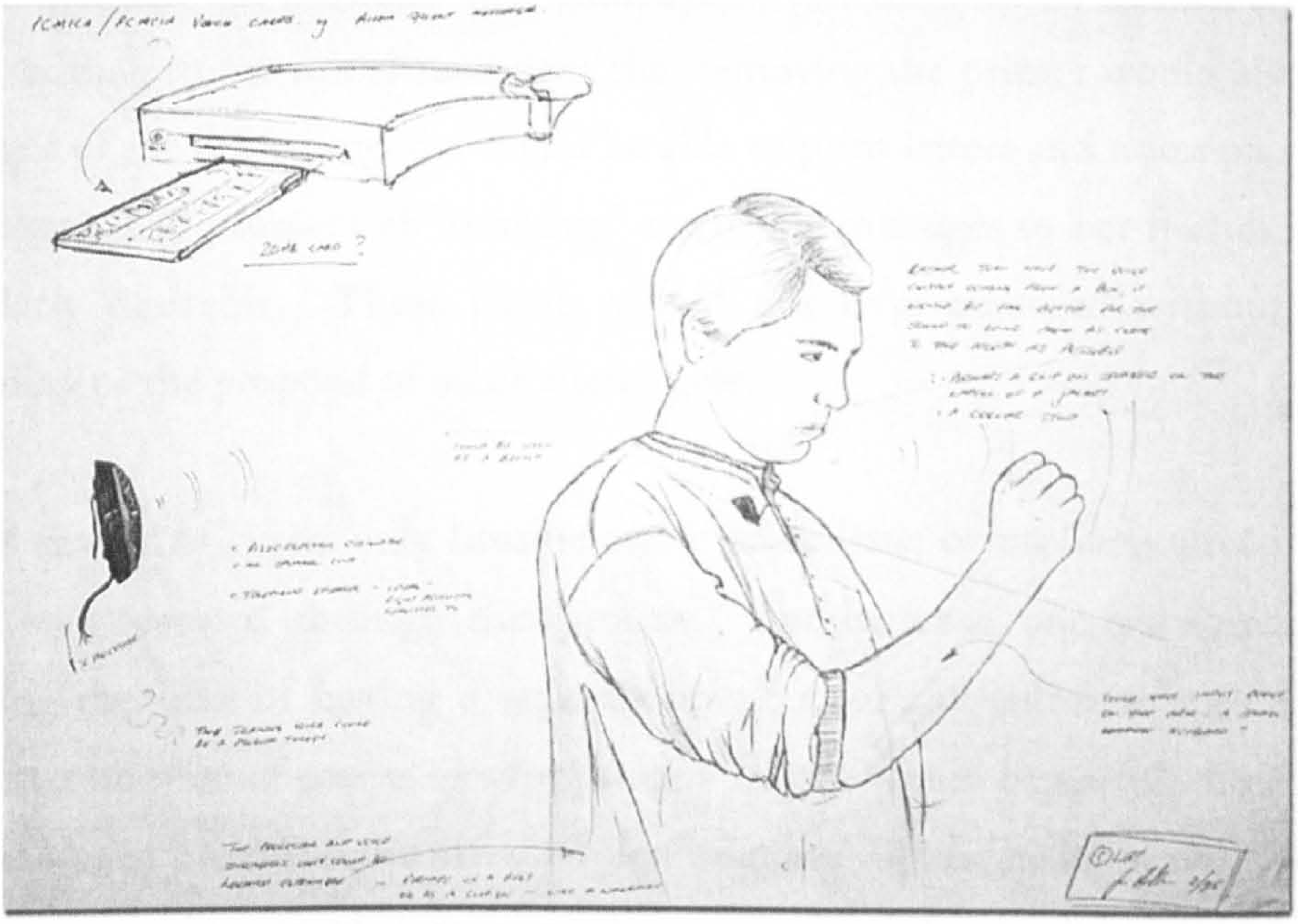

Figure 7: An example of sketch work

Often the AAC users' statements of their needs and wants changed when presented with alternative ideas. It could be argued that these changes were the result of an imposition by the author. Rather than supplant the AAC users' ideas with those of the author, however, the author's ideas, typically presented though discussion or in the form of sketch work, provided an opportunity to further explore ideas coming directly from AAC users. Whilst there can be dangers of this approach, most notably that the designer is at risk of usurping the role of the participants, in this case there were distinct advantages. The ideas of the participants were often bound by their knowledge of what they believed to be possible or, counter to this, participants would propose possibilities outside the practical constraints of the project.

For instance, whilst one AAC user was discussing the virtues of her AAC device, she stated that the till receipt-like printer available on her device was an attractive feature. Further questioning revealed that she did not often use the printer and, in fact, her main reason for wanting a printer was to be able to share written material with others. The author showed sketch ideas of alternative possibilities, and proposed that the text-based material she generated on her AAC device could be shared in other ways, such as sending e-mail, or by sending it to a standard desktop printer, by making use of either a cable or a wireless link. Whilst this may be common knowledge to anyone who has owned or used a computer, the participant was unaware that this was possible. She immediately saw the benefits of such a proposal though, adding to her initial statement that removing the printer would also reduce the weight of the device and she would be able to print letters and notes on standard sized paper. The prospect of "beaming" electronic messages to her friends was also particularly desirable. These points would not have emerged without further questioning or the proposal of other alternatives.

In some cases AAC users only became aware of an issue or problem affecting them once it was revealed through this process. For instance one participant, after discussing the idea of having a separate speaker for the communication device, identified a number of scenarios where such a feature would be useful. One of these scenarios was to provide some privacy when toileting. Whilst he knew that he needed assistance from his carer when toileting, he now realised that he did not need help for the entire duration of toileting – he could leave the speaker unit with his carer so that when he had finished he could inform the carer to come and get him (rather than have the carer wait with him). This would thus grant him some privacy whilst toileting. This particular benefit of having a remote speaker would have been difficult to predict if it were not for the author intervening and exploring scenarios with the participant.

Often the AAC users' statements of their needs and wants became more comprehensive after consultation with the author. Intervention and co-operation led to a comprehensive Product Design Specification – without it, the specification would have been patchy. The designer has the ability to articulate and "specify", in functional terms, what is required. In this sense, the designer, knowledgeable in many areas, has a vital part in articulating user needs. Further, the designer can facilitate participants in the design process by helping to:

- generate and develop more creative ideas
    - by prompting questioning
    - by visualising the participant's ideas

- broaden options
    - an idea can be extrapolated to cover other, unthought of, areas
    - the designer's knowledge of contemporary and emerging technology can expand options and possibilities

- rationalise ideas
    - the designer's technical acumen (manufacturability, availability of technology, predicted costs, and so on) can help focus a participant's ideas into practicable concepts

- articulate and define user needs

After each interview further sketching and ideation were conducted, with many of the ideas that participants suggested being incorporated into product proposals. The drawings would then be shown to the participants on later occasions for further evaluation. In turn, drawings would help in the articulation of user requirements by transforming users' own mental models into recognisable and feasible sketched design ideas.

5.5.2 Physical models

It was found from the interviews that drawings could hold inherent bias – one drawing might be drawn or rendered better than another, thus influencing the situation. A solution was to do black and white line drawings, but these were open to interpretation. Isometric drawings often needed explaining to those unfamiliar with this drawing convention. Three-quarter views and perspective drawings were again open to interpretation. AAC users tend not to draw, as most do not have the dexterity or muscle control to produce drawings. Lacking such experience of the activity of drawing may perhaps hinder the understanding and interpretation of drawings. Whether this is the case or not, it was found that physical (3D) models allowed the AAC users to more fluently comprehend design ideas.

Three-dimensional models were produced early in the project. Some of these models encompassed ideas that arose from the initial interviews with AAC users and from discussions with non-AAC users in the field. The models proved much more powerful tools for evaluating and discerning user requirements than verbal presentations and sketches. Models helped to focus the interviewees upon the issues at hand and, as something physical, could be compared with other AAC devices and could be manipulated to show what interviewees wanted from a new device. Figure 8 shows a photograph of an interview between one participant and the author, where sketch work, presentation panels and models were used to help establish user requirements.

Models were more time consuming to produce than drawings but, for the reasons mentioned above, their high value outweighed concerns for elapsed time. Card and foam models, although quicker to produce than those constructed from more resistant materials (e.g. MDF, acrylic, HIPS, ABS), unfortunately lacked the durability to be handled by some AAC users. Hence, solid painted MDF models were typically constructed to demonstrate key ideas and forms. The additional advantage of the MDF models was that they more accurately approximated the weight and feel of the intended designs. There is a great difference in how someone with cerebral palsy interacts with a hard or a soft material – typically the harder material can be used to help support the hand when performing a task. Hence, the MDF models were more useful in establishing whether certain tasks (such as reaching for a button) could be performed by AAC users.

Figure 8: The use of physical evidence of designing in an interview with one participant

In addition to physical models, other representations of design ideas included the use of:

- sound samples (representing different voices available at the time);
- tactile materials;
- colour swatches;
- examples of features taken from other products; and,
- metaphors and analogies.

Tact and discretion were essential in proposing new ideas to the students. Although it was important to let the generation and discussion of ideas flow between the author and the AAC users, the reality was that many of the features suggested by the users could not be incorporated into the design of the PCA owing to constraints on time and finances. It would have been unfair to suggest that 'anything was possible' as this may have increased AAC users' expectations.

5.6 Summary and discussion of findings

The results of observational studies and interviews for the PCA project tallied with many of the findings of the Stirling University study (Murphy *et al, op cit*) and also supported the comments made by McGregor (*op cit*), Robertson (*op cit*), and Joyce (*op cit*). In addition, the observational studies and interviews revealed a number of key findings. The investigative activities helped provide an insight into aspects of AAC users' lives, allowing the author to gain sufficient understanding to design for AAC users' needs and wants. Significantly, the study revealed some of the difficulties and problems experienced by AAC users in their day-to-day lives and in particular the inadequacies of current devices. The inadequacies of current devices, the statements of users' needs and wants, and the generation of ideas (and evaluative feedback of those ideas from the participants) led to the generation of a PDS (Appendix VII).

The following section of this chapter focuses on the mismatch between the attributes of devices that AAC users need and want and the attributes of currently-available AAC devices.

5.6.1 Physical shortcomings of AAC devices revealed through the study

The communication aids appeared too heavy and cumbersome for many of the students, particularly for those who were ambulant (able to walk) and carried their devices around with them. One student would leave his communication aid behind, seeing it as a choice to either be able to walk or talk (he preferred the freedom of being able to walk unaided). The machines had handles and were typically carried on one side of the body, invariably setting the student off-balance. Consequently the aid (or else the student) was prone to being knocked into walls and objects in the path of its carrier. The communication aids were occasionally subjected to rough treatment (not deliberately but as a consequence of their users' uncoordinated movements). Some of the devices – especially the older ones – had evidence of wear and damage (scratches, dents, cracks, abrasion marks), whilst others had protective material adhered to them in an attempt to prevent damage.

The students experienced a number of problems with the physical attributes of their AAC devices including:

- Fingers slipping on keys in summer – this was most evident from an informal video interview with one participant who struggled for several minutes to inform staff that his fingers were slipping on his keyboard. (Please refer to Appendix V, *Third informal video interview* for the complete transcript.)

- Activating the wrong keys by accident. This was a frequent occurrence in classes, as witnessed by the observational studies and also the interviews (refer to Appendix V, *Second* and *Third informal video interviews*). One participant would verbalise, "oh bugger", each time a mistake was made – at times this was a frequent statement! The reasons for accidental key activations varied, but included: fingers slipping on keys, poor motor control of the AAC users, and mistakes based on users trying to remember or find the location of a word or phrase on the AAC device.

- The icons on the keys getting worn off. The author observed certain icons were more worn on the AAC devices (such as the on/off button, which was often used to clear the screen to make corrections). The wearing was largely due to the frequency of use, but the selection of material used for the keyboard array was a significant contributor to keys wearing prematurely.

- Limited tactile feedback from the keys (this was discussed with a group of users in the 'Communication Club', and was also stated by one participant in an in-depth interview).

- The device blocking the user's vision when attached to wheel chairs. One AAC user stated in an in-depth interview that this was a particular problem he experienced when shopping and in conversations with people. The AAC user had devised a way around this that involved repositioning his wheelchair so that a conversation partner was perpendicular to the chair (rather than face-to-face).

- Getting glare from the shiny plastic casings in certain lighting conditions. It was noted through observation that this was a particular problem when the light source was perpendicular to the screen. The orientation of the AAC device was thus a contributing factor (ambulant users typically rested the AAC device on their laps in a near-horizontal position, and so fluorescent lighting would occasionally cause glare, whilst non-ambulant users would typically have the AAC device mounted at an oblique angle, and so point-source lighting (incandescent bulbs) and morning and afternoon sun caused glare).

- Not being able to see the screen or keyboard in the dark or in poor lighting (such as at a disco or social occasion) – again, this was discussed with a group of users in the 'Communication Club', and at a social event attended by the author, where the problem was also witnessed first hand by the author.

5.6.2 Shortcomings of voices on AAC devices

One of the most obvious mismatches and problematic areas apparent from the observational studies (and frequently stated in the interviews) was with the speech output of the communication aids. Some participants expressed dissatisfaction with their voices. As a limited number of voices was available on the AAC devices used by the students, some duplication of voices occasionally occurred. This meant that some students had to change their voice preferences in order to be distinguishable from their peers in certain classes or situations. Often this was confusing for all concerned, as associating the voice with the person was not possible. Some students, however, would use this as a source of amusement, and change their voices to imitate someone else.

At one point, just before a Christmas break, the class broke out into song (their communication aids had been programmed to sing carols). As amusing as the situation was, there was only so much that the staff at the College could take of hearing 'Jingle Bells' sung by voice synthesisers, before they lost their patience. Knowing this, the students proceeded to tease staff by disruptively playing carols over and over again. The problem being staff could not tell who was responsible because all of the voices sounded the same, and it was difficult to trace the voices back to particular machines. Whilst this presented a source of amusement for the students in this instance, transferring this to other situations and circumstances could be a source of concern.

One participant recorded sound samples (usually famous lines from films) and then played them back in conversations. The communication aid he used had such a facility, and he was most keen that any new design would also incorporate a digital recorder. When asked why he wanted this feature, his first response was because he thought it was quite fun to do so. He paused for a while and then said that it was also because it was a way for him to enact a different role – to be someone else for a moment. In part this was a reflection of his frustration of being disabled; another aspect of this statement was the sentiment of wanting to be perceived differently. A common frustration amongst the participants was being associated with an electronic sounding voice. One participant commented that some electronic toys now have similar sounding voices and he didn't want to sound like a toy or have others think that he was using a toy. Other participants stated that the voices made them sound like robots (one participant said this was amusing when he was younger, but now that he was a young adult it was no longer appropriate – he should sound "like other people"). The majority of students wanted to sound like one of their family members, largely because this would indicate to others where they were from (ie they wanted a regional dialect), but would also distinguish them from their disabled peers.

The volume and tone of the voices presented some problems. In the classroom situation it was often difficult to distinguish who was talking and if several communication aids were speaking at the same time the voices merged into a loud cacophony. Hearing the voices and distinguishing what was spoken in a crowded environment was particularly difficult. The low tones of some of the voices did not carry well, and people with hearing impairments had difficulty distinguishing the synthetic voice (hearing aids also had difficulty picking out particular tones). The facility to hold private conversations was often difficult as the volume settings and orientation of the speaker meant that the voice dispersed around the room. The students appeared to have little facility to initiate private conversations, having to rely upon a staff member to close the door or to go somewhere more private (or in one instance hold the conversation in the cupboard). Hence, and ironically, it was obvious to others when a student wanted to discuss something in confidence or secrecy.

A common desire of the AAC users at the College was to have greater control over the voice output than their current devices permitted. Students wanted the facility to raise and lower the volume of the voices simply, and the possibility of incorporating intonation within the voice was thought of as highly desirable. The participants pointed out that speed of communication was probably more important than expressing emotion and so, whilst the facility to control the voice output was highly desirable, it should not be at the expense of slowing communication further. An interview with one participant discussed this point further and in particular the discussion centred on how best to incorporate and control intonation in an AAC device (see Appendix IV for the transcript). One proposal was to use artificial intelligence to predict, on the basis of the conversational material generated, the likely emotional output. A further idea was to use bio-feedback (in the form of discreet sensors) to detect the user's emotional state based upon such variants as pulse rate, sweat production, temperature of the skin, and muscle tension. One participant, quite rightly, pointed out that there are often times when one may be angry with someone, but not want to show or sound like it. Rather, the user should have control wherever possible.

5.6.3 AAC users' perceptions of their communication aids

The initial comments the participants made about their communication aids were generally positive. Participants were grateful that they had the facility to talk – in interviews, most would make some reference to how they couldn't communicate that well before getting their communication aid, and that their lives had improved since having an aid. Typically it was only when the participants were challenged or alternatives posed that negative comments about their communication aids were made. (The interviews would always seek to be balanced, and so questions such as "what do you dislike about your communication aid" were preceded by "what do you like about your communication aid".) For the purposes of this study, the negative comments were of greater value in establishing a PDS.

The AAC devices were precious to their users as, after all, they were essential for communicating with others. Such preciousness often dictated how the aids were used and treated however, even to the extent that the devices were not used in certain circumstances just in case they got damaged or went missing. Some students did not have their communication aids with them at all times. Whilst the students did not appear to forget to take their communication aids with them, the devices were often left behind because of inclement weather, or because of the perceived risk of being damaged.

Some AAC users (and for that matter their carers, and some staff at the College) had little confidence in the performance of their communication aids. The majority of participants asked had experience of their AAC devices breaking down. The devices typically took several days to get repaired or replaced as they had to be sent off to a specialist repairer. Much pressure was placed on the students when separated from their communication aids for this length of time. The repairs were typically expensive, and so the majority of the students paid an annual fee to extend the warranties upon the machines. Carers or technicians on hand at the College were not permitted to repair the devices, even if it was only a simple task, as doing so would infringe the supplier's warranties upon the machines.

The machines' batteries were also cited as being a source of irritation. The rechargeable batteries would periodically run out of charge (usually at inconvenient times). The batteries needed to be re-charged several times a week, and so spare batteries were deemed necessary. The batteries were very expensive, were unique to the devices, and could be bought through only one supplier. Students found it necessary to carry spare batteries with them or else they were tied to a place where mains electricity was available (for which, incidentally, someone would typically be required to plug in the device). The limited availability of batteries presented particular problems when travelling (there was no way of going to a shop and picking up a spare if batteries were forgotten or went flat). Additionally, the majority of AAC users had difficulty replacing batteries, and had to rely on someone else to do this for them.

AAC users' dependence upon others was apparent from observation and from some comments in interviews. The participants all sought greater independence. Whilst the communication aids they used had granted them some autonomy, the participants agreed that there were certain attributes that could be addressed to achieve greater independence. Desired features included making AAC devices:

- easier to carry;
- easier to manoeuvre (move out of the way whilst eating for instance);
- easier to replace batteries; and,
- easier to program by AAC users.

5.6.4 AAC users' perceptions and experiences of how others saw them and their devices

AAC users' perceptions and experiences of how others saw them were particularly noteworthy. Most students had experienced some form of unwanted attention: usually stares or else avoidance and patronising comments or actions. Most of the participants noted that the public typically did not know how to react towards people with disabilities. Although the public tended to be polite, the participants noted that few people wanted to enter into, or else maintain, a conversation.

When asked about how other people tended to react towards the communication aids, the comments varied. Most of the participants acknowledged that people seemed curious of the AAC devices. Some people wanted to know what the AAC devices were and how they worked. One participant had been requested to give a demonstration of his *TouchTalker*, another participant had been asked by a member of the public whether he would let her child have a go with the AAC user's communication aid. This latter statement was echoed by another participant, noting that people thought his communication aid was a toy. When asked why they may have thought this he replied, because "it looks like a toy". He went on to discuss his experience of people interfering with his communication aid. On one occasion someone erased the memory of his machine by pushing the buttons on it; "I couldn't stop them", he said.

The participant said that the public most commonly referred to the communication aids as "machines". The participants noted that the public tended to not acknowledge that the communication aids were a vital part of the AAC users – that is, *their* voices.

An interview with one participant raised some interesting issues (see Appendix IV for the transcript). The initial intention of the interview was to discuss some of the concepts that had been generated and to get the participant's feedback on what approaches should be taken with regards to the development of the PCA. Three options had been identified to either design from scratch, adapt a current product, or to collaborate with a manufacturer of electronic goods (this is discussed further in Chapter Six). The conversation that followed was far more significant than the selection of a particular approach. The participant was very much in favour of the idea of adapting mainstream consumer products because he felt that if the public used the same product as people with disabilities, then people would not be frightened off by the sight of him using a machine to talk. The participant felt strongly that if the public were more familiar with AAC users and their devices, then both parties would benefit. If the public used the same device as he did, he would feel more equal, and then possibly fewer people would look at him and his AAC device with curiosity. Whilst adapting current devices was seen positively by the participant, the reasons for doing so were less to do with the manufacturing virtues of this approach but, more saliently, with a product's role in integrating people with disabilities into society. Another way of attempting to achieve such integration is to design an AAC device that people without disabilities would want to use.

5.7 Table summarising identified needs

A brief summary of some of the problems AAC users experienced with their devices and of their needs as identified in the study is tabulated below. The problems or identified needs are categorised into seven principal areas for clarity. The methods by which the problems or needs were established is listed in the second column.

Problem or identified need (•)	How found out
Physical	
Current AAC devices are hard to carry and can put ambulant users off-balance	• Observation
• AAC devices need to be more resilient to knocks and breakage	• Literature • Observation • Product analysis • Interview
AAC devices often breakdown	• Literature • Observation • Interview
AAC devices run out of charge	

Perception of device	
AAC devices are perceived as unreliable	• Literature • Interview
AAC devices are perceived as toys / machines	• Interview
Interface	
Fingers slip on keys	• Literature • Observation • Interview
Keys are wrongly activated	• Observation • Interview
Icons wear off keys	• Product analysis • Interview
Fingers get sore from accessing keyboard	• Literature • Interview
* Tactile feedback on buttons needed	• Interview
System	
* Ability to be programmed by AAC users	• Literature • Interview
* Other software features/programs should be able to be added	• Interview
* Easy to learn how to use	• Literature • Interview
* Security of AAC user's information	• Observation • Interview
* Increased memory / storage	• Literature • Product analysis • Interview
Situation	
Can't be used everywhere (particularly outdoors)	• Literature • Product analysis • Observation • Interview
AAC devices block users' vision	• Observation • Interview
Glare from AAC devices make seeing icons and screen difficult	

* Need to be able to use in dark	• Observation • Interview
* Need to be able to manoeuvre AAC device (e.g. move device out of the way whilst eating) – particularly if AAC user is in a wheelchair	• Literature • Observation • Interview
Unwanted attention drawn to users by AAC devices	
Voice quality	
Lack of intelligibility	• Literature • Observation • Interview
Lack of intonation	
Lack of expression	
Voice doesn't carry well	
The voice is associated with the machine, not the person	• Observation • Interview
* Want to sound like family / friends	• Interview
Other	
Reduce cost	• Literature • Product analysis • Interview

Table 1: Summary of problems and identified needs

5.8 Conclusions

A number of techniques were used in the designing to establish user requirements. Through reading, observation, social intercourse, discussion and interviews, a comprehensive understanding of the needs, wants, abilities, capabilities and experiences of AAC users was established. Over time, a rapport was established with the students of Portland College. The nature of this informal and unobtrusive approach to requirements capture provided a much needed sympathetic comprehension of the nature of the problems faced by AAC users. The observational studies helped to foster an understanding and appreciation of the lives of the participant AAC users, and of how to conduct interviews with people with severe communication disabilities. The processes of designing and the 2-D and 3-D models thereby produced were important in the exploration and articulation of user requirements. Through consolidation of these user requirements, a PDS could be drawn-up which would form a reference for the concept development phase of the PCA project. Chapter Six discusses this next phase of the PCA project, leading to a working prototype.

CHAPTER SIX

Design and development of the PCA

6.0 Introduction

The first year of the study was primarily concerned with gaining familiarity with the subject matter, and with the problems facing AAC users. Some design work was carried out during this time, but the majority of the design and development of the PCA was undertaken in the second and third years of the study. This chapter discuss the design and development work conducted during the latter period. The CD ROM (Annex A) contains pertinent audio-visual data to supplement this chapter (the section 'Conduct of project' is particularly relevant). Figure 9 presents a guide to the concept development processes used in the study. Key areas depicted in the diagram will be discussed in this chapter in turn.

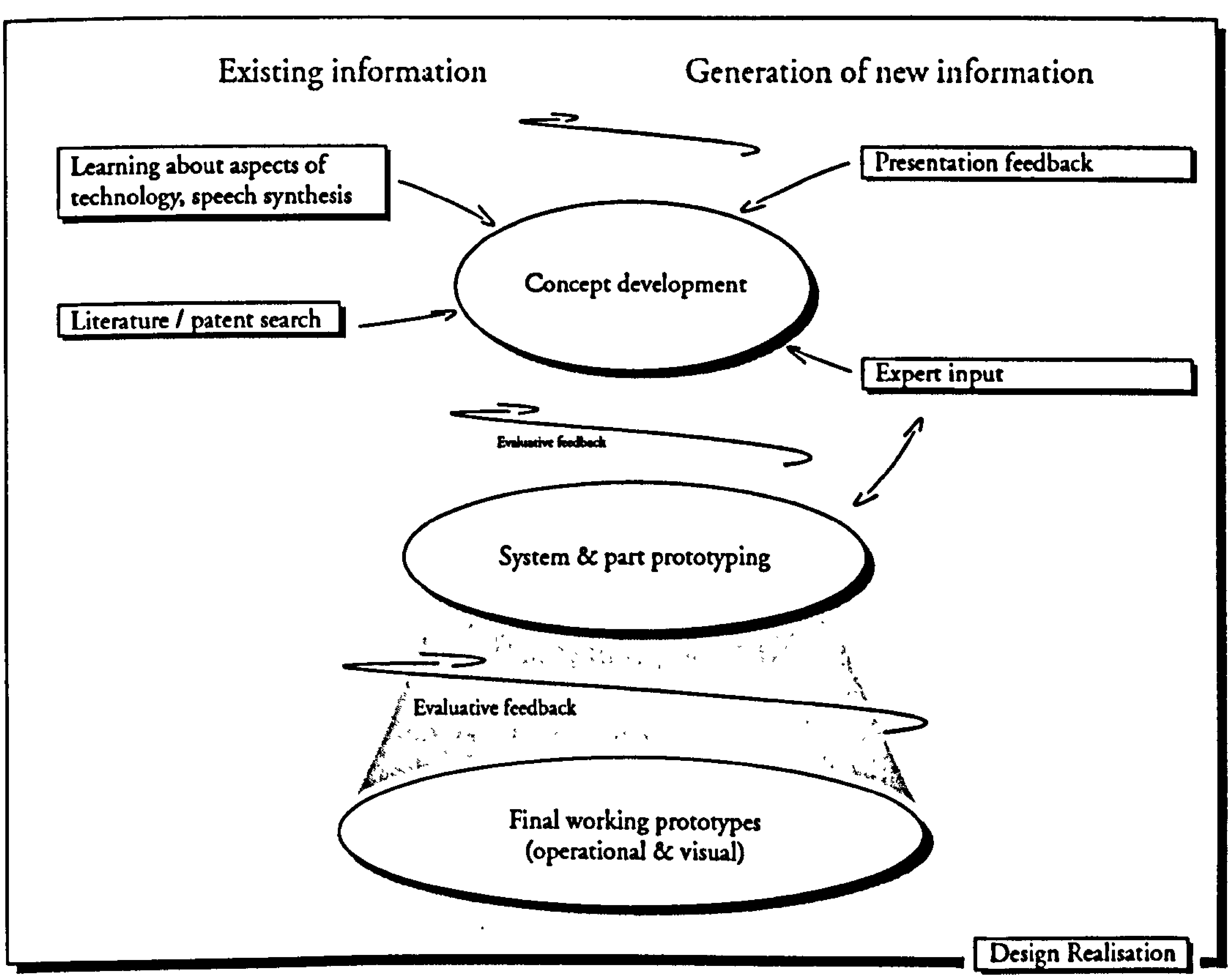

Figure 9: A diagrammatic guide to the concept development processes used

6.1 Background to the design and development of the PCA

6.1.1 Project management

A Project Steering Committee was established prior to the commencement of the study. The committee comprised representatives from Portland College and Loughborough University's Department of Design and Technology, and had the following members:

From Portland College:

Peter Davis	–	Director of the College (and later, Mike Syms)
John Smallwood	–	Senior Education Officer
Charlotte Broughton	–	Senior Tutor, Further Education Unit
Nick Corbin	–	Director of Appeals (and later, Lois Edmonds)

From Loughborough University:

Professor Phil Roberts	–	Director of Research
Paul Wormald	–	Academic and Project Supervisor

It was agreed that meetings would take place at least twice every year within the three year timeframe of the research project (13 meetings over the three years in fact took place). A Progress Review Group consisting of the Loughborough members monitored and managed the day-to-day progress of the project and meetings were conducted every three months or so. Periodic presentations of the design and development of the PCA were given to the Project Steering Committee by the author, and the Committee was kept informed of key decisions. The members of the Committee were consulted from time to time to seek their advice and guidance, as well as their assistance and support in conducting and coordinating activities at the College.

Dr. Colin Machin, from Loughborough University's Department of Computer Studies, became a member of the Project Steering Committee at a later stage of the project, when his technical expertise was sought to help develop parts of the PCA prototype. Dr. Machin visited Portland College with the author a number of times to gain familiarity of the College and its students. In addition, the results of the video work described in the previous chapter were shown to Dr. Machin to introduce and explain the design need of the PCA as well as to brief him of the project requirements.

6.1.2 Intellectual Property Rights

Both Loughborough University and Portland College had stakes in the Intellectual (and possible future commercial) Property associated with the design of the PCA. All discussion with external parties concerning the design of the PCA were conducted in confidence and were subject to the signing of an Intellectual Property Rights (IPR) agreement produced by the University. As a matter of course, all drawings were stamped with 'Commercial and in Confidence', and were dated and signed by the author. The students at the College were unable to sign confidentiality agreements (as they could not write).

6.1.3 Project presentation to the Steering Committee

A concept presentation of the PCA was given to the Project Steering Committee in the first year of the study. A number of presentation drawings and models were shown of the various concepts that had been developed separately and in conjunction with the students at the College. The idea of dividing the PCA into three main components, in preference to designing a single all encompassing unit, was well received by both the students at the College and the Committee. The three components of the PCA proposal consisted of:

- the processor and hardware section;
- the input and output interfaces; and,
- the speaking unit.

Design ideas for the first component of the PCA included a design similar in size and form to a personal stereo, a unit housed in a bum-bag, and a hip-mounted wearable computer. A greater range of ideas for the second component of the PCA were presented, and included a tongue-palette, a hand-held touch-screen, a discrete motion sensor switch, a pair of glasses incorporating a screen and eye motion detector, a book, and a palm-top computer. Ideas for the speaking unit included a loud speaker incorporated into a broach, a badge, and a mobile phone. It was decided that an essential principle of the PCA design should be to create a hardware platform upon which software could be easily upgraded and adapted for versatility. Figure 10 shows a sketch sheet of early design ideas for the first and second components of the PCA. In all, over two hundred A3 sketch sheets and developmental drawings were produced.

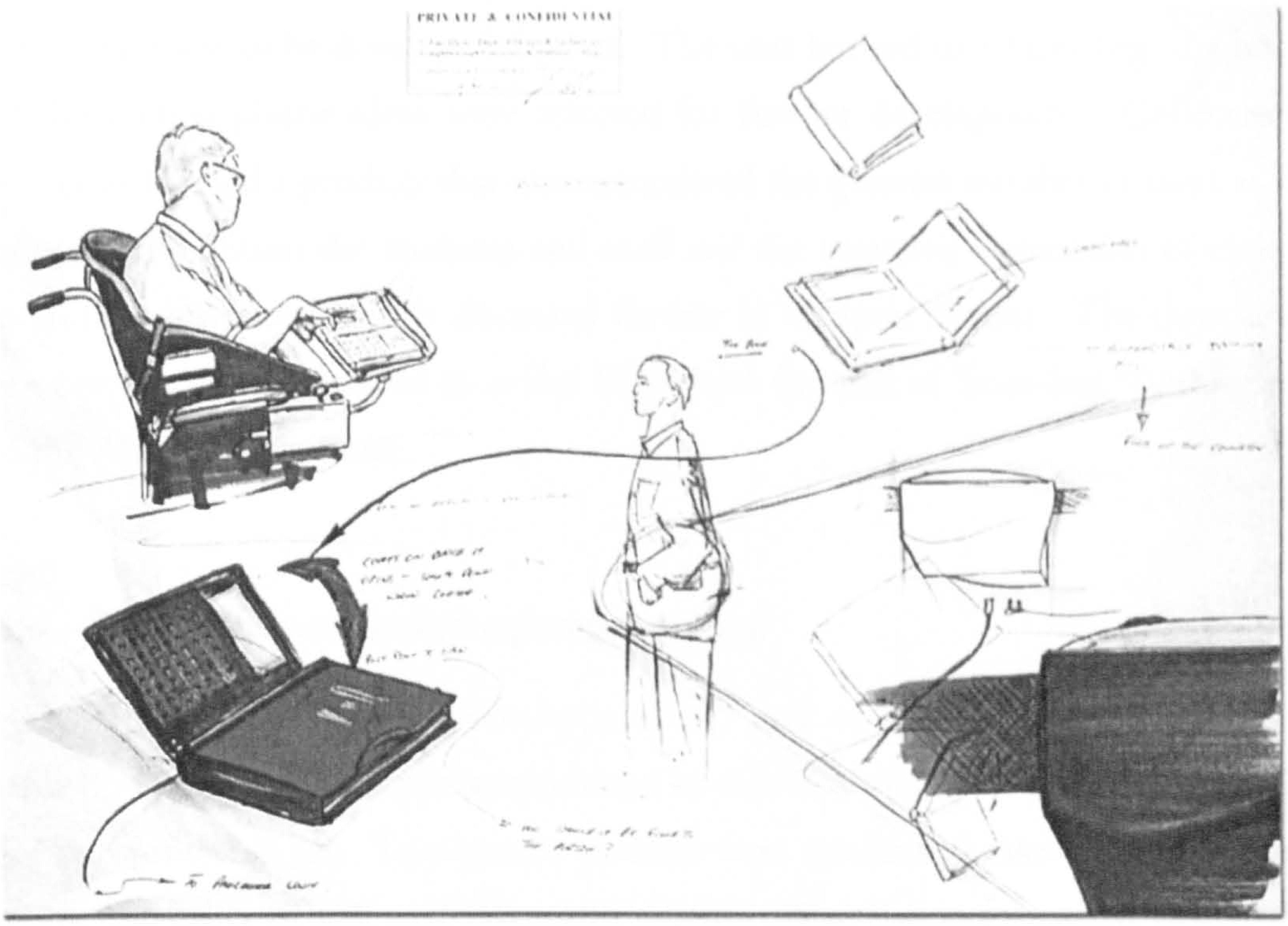

Figure 10: Early design ideas for the PCA

A number of factors influenced or dictated the selection of the final ideas to be developed into the working prototype, including:

- time constraints;
- financial constraints;
- availability of technology;
- access to technology and expertise; and,
- preferences of the Committee, AAC users, and the author.

Further, three options concerning the production of the PCA were presented to the Project Steering Committee.

1 To design from scratch
2 To adapt an existing product to meet the needs of AAC users
3 To collaborate with a manufacturer of electronic products

After considered discussion, the former option was chosen, as it was deemed to allow greater control over the design of the device, and was more likely to ensure the needs of AAC users were considered explicitly in the design (the other options were seen by the Committee to lack autonomy). This choice was also influential in the selection of the final ideas to be developed further. The unit housed in a bum-bag, the book, and the mobile phone ideas were selected for further development. Collectively, these units formed a product that accommodated the greatest number of users at the College. In addition the students and staff saw the semantic association of each of the units as beneficial (this is discussed further in Chapter Seven). The three units from here on will be referred to as the *Waist pack* (instead of 'bum-bag'[17]), the *Book*, and the *Mobile* speaker unit.

6.1.4 Searches of patents and registered designs

Reviews of current products (see Appendix I) and of patents were conducted to establish whether the concepts incorporated in the PCA's design were in conflict with prior and protected art. Two patent searches were conducted: one of United States patents, the other of UK and European patents. The European patent search also covered some World patents.

An initial patent search was undertaken in March 1996, using the US Boolean Search Page on the World Wide Web of US patents (US Patent & Trademark Office, 1996). The following search terms were used for all years between 1976 and 1996 (patents are valid for twenty years only):

Open search terms:

- communication *and* disability;
- augmentative and alternative communication *or* AAC;
- augmentative communication *or* AAC.

17 This descriptive name was chosen to avoid Anglo-American confusion. The term 'bum bag' can be construed negatively by Americans whilst the American term, 'fanny pack', can be construed negatively by the British.

Known companies and/or inventors:

- Prentke Romich;
- Baker *and* Bruce R;
- Romich *and* Barry;
- Zygo.

Patent Numbers obtained through other literature and products:

- 4,661,916;
- 5,097,425;
- 5,210,689;
- 4,558,315.

A European patent search was carried out using the Espace CD-ROM, ACCESS - European Patent Application Bibliography. The search covered the period from October 1978 to February 1995.

In addition to the open search terms mentioned above, additional terms were used in both the abstract and title classes. These terms were:

- impairment;
- disability;
- disab*;
- VOCA;
- communication *and* aid (*and* electronic);
- speech *and* aid;

Known companies and/or inventors:

- Toby Churchill Limited;
- Churchill, *and* Toby;
- Mardis;
- Liberator;
- Alm, *and* Norman;
- Newell, *and* Alan.

The patent searches revealed little – which for the development of the PCA was good news. The only patents that had bearing on the development of the PCA were those that protected software. Patents that were considered to be applicable, or that the PCA's design may infringe are listed in the Product Design Specification (Appendix VII).

6.2 Learning about aspects of technology

In order to proceed in developing the concept of the PCA it was imperative to gain familiarity and understanding of the technology anticipated to be involved in the end prototype. Searches of literature and trade documentation on speech synthesis, computer technology, and manufacturing technologies were conducted to establish sufficient technical and practical acumen. Design ideas were developed through sketch work concurrent to the search activities.

The knowledge gained from these searches helped in defining the operational parameters of the PCA, as well as influencing the system design. The searches also revealed material that was applicable to the design of the PCA that met, in part, some of the user requirements discussed in Chapter Five. Reviewing technology applicable to the design of the PCA also helped to set limits and priorities for the design project. The material discussed in sections 6.3 and 6.4 had particular bearing on the system design of the PCA.

6.3 Speech Synthesis

Edwards, in *Speech Synthesis: Technology for Disabled People* (1991) provides a good introduction to the ramifications of speech synthesis and its importance for people with special needs. He explains various methods of producing synthetic speech and relates the needs of people with various types of disability to the technology involved. The important factors to consider in the design of a speech synthesiser are presented. These are:

- the vocabulary requirement;
- the monetary cost;
- the speed of communication; and,
- the intelligibility and naturalness of the speech output.

There are two forms of electronic artificial speech: digitised speech, and text-to-speech synthesis.

6.3.1 Digitised speech

Digitised speech, or copy synthesis, involves recording someone's voice and storing it digitally. This has the advantage of being a very accurate representation of a human voice but, for an AAC user, limits what can be said, since everything to be stored must be recorded. The disadvantages of this method is that it requires considerable RAM (random access memory) to store a large vocabulary and takes a relatively long time to process and, hence, output as speech. However, there are methods for reducing this large memory requirement, namely the following.

- Pulse Coded Modulation, which is the direct digitisation of sounds, and will take 80 000 bits, or 10 000 bytes to store one second of speech.
- Adaptive Pulse Coded Modulation: the memory requirements are reduced to 32 000 bits per second.
- Linear Predictive Coding: this method requires only 10 000 bits per second.

AAC users have a great desire to sound more 'normal' (Robertson 1992, Murphy *et al op cit*), and digitised speech has some potential for achieving this as the sound is a direct recording of a human speaking (including suprasegmental features of speech). Faster processors and cheaper memory can solve many of the problems associated with copy synthesis; however, the method necessitates that somebody makes recordings of speech. Aside from the time taken to do so, this poses two key problems for the AAC user: increased dependence upon others and a lack of privacy (as any sensitive or private conversation material has to be pre-recorded by a third party). The way in which phrases are accessed is also problematic. Allocating a phrase or word to an individual key limits the number of possible phrases that can be stored, whilst a hierarchical structure (where one set of words is linked to another) greatly increases the time taken to access stored phrases. In addition, the links between words will not sound natural, as individual words within a phrase tend to have particular intonation dependent on where the word fits into the sentence.

6.3.2 Text-to-Speech Synthesis

Text-to-speech (TTS) synthesisers typically break up written text into individual segments of words (diphones, allophones), and then link these segments together and output them as speech. Rules are applied that indicate how the words are to be broken up, how they are to be rejoined, and how the word or phrase should be uttered. This is a complex task to perfect, as language is made up of many complex rules and, especially within English, the pronunciation of similarly spelt words changes considerably (an obvious example is the complication with the pronunciation of '*ough*'; 'rough', 'Slough', 'through', 'thorough' and 'thought' are pronounced very differently). For this reason, a dictionary of exceptions is included in most TTS synthesisers' software to limit mis-pronunciations.

Many speech synthesisers sound very poor, but the quality of electronically produced speech is improving as computer technology advances. One of the most widely used synthesisers in VOCAs is DECtalk[18], produce by Digital Equipment Corporation. This synthesiser allows the user to select a variety of voices (male, female and child); however, many people have difficulty understanding some words on it (Murphy 1993) and the voice has an American accent.

6.3.3 Laureate

A number of English-sounding voice synthesisers were under development at the time of this study. Breen and Page (1995) discuss British Telecom Laboratories' development of a text-to-speech synthesiser, Laureate. This synthesiser has been designed to "accommodate multiple speakers, accents and dialects", and is respected as being one of the best of the state-of-the-art English-sounding voice synthesisers. The Laureate system differs from many other TTS synthesisers by making use of several different linguistic models and theories to produce speech from text. Laureate supports different languages and has a variety of voices. Importantly, additional voices can be added and even customized (at a cost of approximately £5000) – a relative of an AAC user may have his or her voice recorded, modelled and

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18 DECtalk™ is a text-to-speech synthesiser developed by Digital's Assistive Technology Group (ATG) as an alternative to a character-cell terminal and for telephony applications, and has been used commercially for approximately fifteen years. DECtalk uses a digital formant synthesizer to simulate the human vocal tract.

incorporated into the Laureate system so that the AAC user can 'sound' like his or her relative. Laureate is a software-based synthesiser and so, unlike DECtalk, does not dictate the physical dimensions of the hardware to be used. Laureate does, however, require a minimum specification of the hardware upon which it runs, and works under a Unix environment.

Sound samples of several of the synthesisers were available via the World Wide Web, and the author down-loaded these, along with samples of Laureate, and played them back to students and staff at Portland College to seek their opinion. Laureate was very popular, as it sounded "normal", and "not like the BBC", and included both male and female voices. (The CD ROM (Annex A) contains samples of three Laureate voices and one DECtalk voice.)

British Telecom Laboratories were contacted by the author, and a meeting with Julian Page, one of the system developers, took place at Loughborough University in May 1996. A license to use the Laureate voice synthesiser was successfully negotiated and granted there and then, on the basis that it would be used solely for research purposes, and if the PCA were to be produced commercially, royalties and rights would need to be re-negotiated.

6.4 The selection of a language representation system

Early in the project the author and the Project Steering Committee realised that to develop a language system for the PCA would not only be time-consuming, but also unnecessary. The College had been instrumental in developing a Minspeak application program, 'Language, Learning and Living' or 'LLL', and had been teaching this language system to its students. LLL operates on the Prentke Romich Company's range of products (see Appendix I), and the College, whilst open to the use of other language systems, were keen to continue its use.

A number of systems to generate conversational material other than Minspeak were investigated (see section 1.4 in Chapter One, and section 3.7 in Chapter Three). Whilst some of these may have been appropriate for inclusion on the PCA, they were either developmental systems or had not undergone sufficient trials with illiterate AAC users. The efficacy of using these systems with illiterate people would have taken a long time to evaluate, as the language would have to be taught to the AAC user. Minspeak, for example, takes in the region of two years to learn. Many of the students at Portland College were already familiar with the Minspeak system, and due to the limited time scale of this project, it was decided that this proven language system should be incorporated into the PCA. This was also in line with the first of "The Three Golden Rules" of AAC system implementation, namely, "Try to integrate. Do not make the user learn more skills than necessary" (Hawes, 1994).

Since the majority of the alternative language systems were software-based, a view was taken that a suitably adaptable and generic hardware platform should be used in the PCA. The PCA would then have the potential for more widespread use, catering for the needs of AAC users, whether illiterate or not.

6.4.1 Attempts to procure Minspeak

The process of attempting to procure the rights to use Minspeak was decidedly more difficult than had been the case with Laureate and was ultimately unsuccessful. Dr. Bruce Baker, President of Semantic Compaction Systems and the developer and licence holder of the Minspeak system, was first contacted by the author at the Communication Matters National Symposium where he was a keynote speaker in September 1995. Dr. Baker appeared interested in the PCA project, and wanted to help.

In April of 1996 a meeting with Dr. Baker concerning the possible use of Minspeak took place at Portland College. Dr. Baker agreed that Minspeak could be used, but explained that there were several technical and legal issues to attend to. A meeting six weeks later with Dr. Baker, his lawyer and Loughborough University's Intellectual Property Rights Officer was organised at which a presentation of the PCA concept was given by the author. Dr. Baker was impressed with the proposal, stated that he wanted to offer as much assistance as he could, and agreed to grant a non-exclusive research license to use Minspeak on the PCA.

A meeting in January the following year with Bruce Baker finally saw a draft agreement to use Minspeak for research purposes produced by Semantic Compaction Systems. An unanticipated signing fee of $1000 was also levied. The Project Steering Committee were disappointed by this, but agreed to pay the 'signing fee'. Further correspondence continued through the University's and Bruce Baker's respective lawyers, but by September 1997 no progress was made, and the Project Steering Committee agreed to no longer pursue attempts to get a research version of Minspeak.

6.4.2 Rationalisation of the language system on the PCA

During the eighteen months or so following Dr. Baker's verbal permission to use Minspeak and his offer of assistance, the design and development of the PCA continued in the vain expectation that Minspeak would be incorporated. Over this period, and supported by the affirmations that permission to use Minspeak was granted, as well as the positive feedback from Dr. Baker, a reliance and dependency upon the use of the Minspeak system ensued. Whilst this was ultimately a disappointment, in the process the PCA design was not undermined, particularly given that the working prototype needed only to prove the efficacy of the design (and this could be done by other means).

To prove in principle that the Minspeak language system could operate on the PCA, the PCA was programmed to mimic Minspeak. A key sequence to generate a particular phrase on an AAC user's machine was observed and the PCA was then programmed accordingly so that when the same key sequence was keyed into the *Book* on the PCA the same phrase would be spoken out. The LLL icon set was chosen (as this was the most popular of the Minspeak Application Programs used at Portland College), and the keyboard of the *Book* had the icon set incorporated into it. Although this could be construed as reverse-engineering, the intention was solely to test the efficacy of the PCA and not to copy the entire language system or a substantial part of it, as this would infringe the intellectual property of Semantic Compaction Systems (the developers of Minspeak). The Project Steering Committee were content in the knowledge that Minspeak could in theory, if not in practice, be incorporated on the PCA.

6.5 Project planning

Designing from scratch presented a number of difficulties. The work involved in developing a working prototype of the PCA was substantial and necessitated careful planning and coordination. The dependencies of the tasks involved in the development of the PCA were analysed by listing the anticipated tasks, and mapping out which of those tasks were dependent upon others. The process was similar to the Design Structure Matrix described by Ulrich and Eppinger (1995, p262). Sequential, parallel, and coupled activities were determined, and a provisional Gantt chart was drawn up (Figure 11), depicting the key activities in the design, development and prototyping of the PCA.

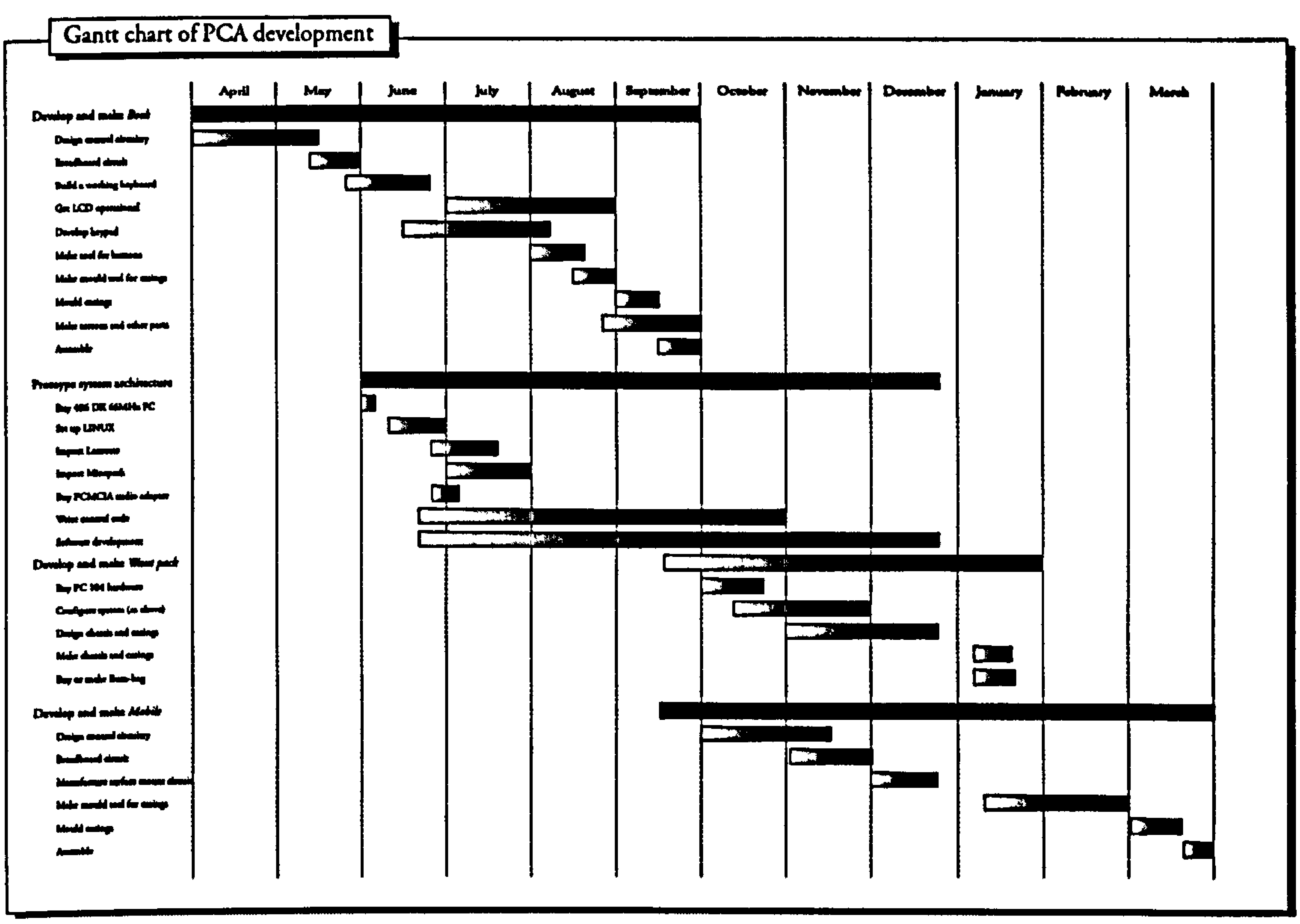

Figure 11: Provisional Gantt chart of the design and development of the PCA

A provisional time-plan allowed for the design, development and prototyping work to be conducted over a year. The work in fact took closer to twice as long than anticipated, by and large due to the complexity and involvement of the task. The project development process started out as sequential, but the decision to divide the PCA into three key parts meant that the activities happened concurrently. The *Waist pack*, *Book* and *Mobile* units were developed in parallel (i.e. independent of each other) but each was dependent upon the initial design ideas. The activities and tasks involved in the design and development of each unit were coupled (i.e. mutually dependent) and involved simultaneous, iterative developments and fluent exchange of information. The development of each unit is described in greater detail in the remainder of this chapter.

6.6 Development of the *Book*

6.6.1 Models

A number of models were created in the development of the *Book*, each with iterative changes made on the basis of evaluative feedback from students at the College. The first two models incorporated removable speaker units, so that if users desired the speaker could be detached and worn. After discussion with one participant and getting him to remove the speaker from the model, it was decided that it was best to not incorporate the speaker in the *Book*. (Whilst the participant could perform the removal and replace task adequately, it nonetheless appeared clumsy, and drew unwanted attention to his actions and to himself.) Figure 12 shows the first and second of the *Book* models.

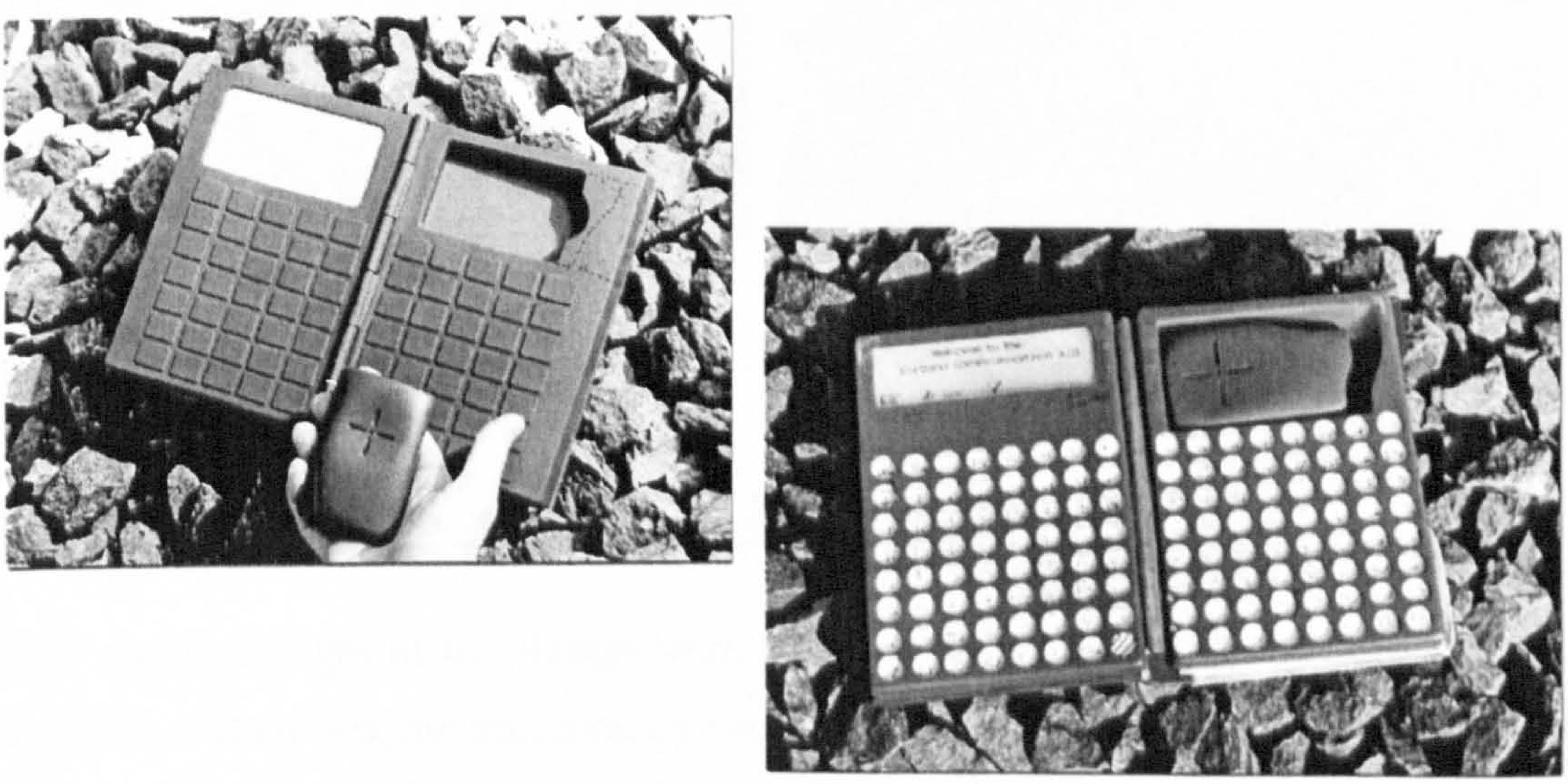

Figure 12: The first and second models of the *Book*

The second model incorporated a 128-key keyboard (to facilitate the use of Minspeak), and a larger *Mobile* unit (the participants requested a larger unit because it would be easier to hold).

6.6.2 The first *Book* prototype

Feedback from participants about the *Book* models was generally positive, and particular features were adapted according to the participants' comments. A third model was developed, but with a difference in that it incorporated some working features. Additional expertise within the field of electronics and computer engineering was sought in order to take the *Book* forward to a working prototype. Dr. Colin Machin provided this expertise and designed and developed the computational hardware and firmware of the *Book*. Dr. Machin created a controller circuit board, an off-the-shelf Liquid Crystal Display (LCD) unit was bought and two keyboard arrays, each consisting of 64 discrete key switches were designed and constructed by the author. Two identical Light Emitting Diode (LED) arrays were also constructed and housed in vacuum-formed high impact polystyrene (HIPS) casings. Figure 13 shows the construction of the first *Book* prototype.

Figure 13: Construction of the first *Book* prototype

Two major changes in the design were incorporated into the first *Book* prototype. The first of these was the inclusion of a solar panel where the *Mobile* speaker unit was housed. The inclusion of the solar panel was initially to conserve power and thereby achieve a longer operating time, but it also had the additional virtue of sensing ambient lighting conditions to control back-lighting on the keyboard and LCD. Whilst the power generated by the solar cell was minimal, and could be considered a token effort at energy conservation, its inclusion was received favourably by the students at the College. (Even after explaining the limited power the cell would generate, the participants thought the solar cell should remain, noting that it conveyed an important message that they wanted to be associated with). The second major design change to the *Book* was to rationalise the design to minimise the costs of anticipated tooling. The intention was to minimise the number of separate parts to be made, and so the two halves of the *Book* were made from the same vacuum-forming tool, and the screens were identical. To make the 128 keys, a simple injection mould tool was made by the author, and a clear elastomeric polymer was used to form the keys. The control circuitry did not fit into this prototype, but instead the keyboards, LCD, and LED arrays were connected to the control circuit with a serial cable.

The first working prototype was demonstrated to the Project Steering Committee and the students at the College, and their critical comments were welcomed. The prototype of the *Book* was well received, and it allowed students to more critically comment about precise details. For instance, through pressing different button types and by experiencing the kind of feedback produced, the participants stated their preferences for the PCA's buttons. Two different types of button were used on the prototype: one that 'clicked' when depressed, and a silent one. The first prototype also revealed areas in need of further development.

Some participants lacked control when opening and closing the *Book*, and the covers and screens on the prototype soon became damaged from the two halves 'crashing' into one another when being closed. Opening the *Book* was also awkward for one participant who could not prise the two halves apart. It was realised that some assistance was needed and so the idea of using a torsion spring in the hinge to help 'spring' the *Book* open and to cushion it as it was opened out flat or closed was incorporated into the final prototype. The HIPS casings lacked rigidity and soon became scratched from simple use. Other plastics were considered, as were the inclusion of strengthening ribs. These options were ruled out as plastic casings did not comply with electromagnetic compatibility (EMC) regulations, and would also necessitate more expensive manufacture (injection moulding). Some of the buttons became stuck in the holes in the casings, as their flexibility was insufficient to consistently return the buttons to their upright position. A new material for the buttons was needed.

6.6.3 The final prototypes of the *Book*

Two final prototypes of the *Book* were produced – a larger operational version incorporating the control circuitry, and a visual model that was an accurate representation of the intended manufactured version.

The casings for the final prototypes of the *Book* were vacuum-formed in a material called Super Plastic Zinc (SPZ), providing rigidity, strength, and EMC compliance. The mould tool to produce the metal casings of the *Book* was machined from aluminium with the assistance of the technicians in the Department of Design and Technology at Loughborough University. Computer Numerical Control (CNC) code was written by the author to create the holes in the mould tool that would form the cavities to house the buttons in the *Book's* casings. The aluminium mould tool was sent to Custom Metal Forms who kindly produced four metal casings without charge.

New buttons were also produced, this time in translucent silicone rubber, as this material provided the desired flexibility and chemical and water resistance. The silicone had to be cast, and took a day to cure. The injection mould tool that created the first set of buttons was therefore insufficient (it would have taken nearly five months to create the 128 buttons using this tool with this material. A new tool that produced 64 buttons upon a single sheet was created using the same CNC data that created the holes in the aluminium tool. CNC machining the holes in both mould tools using the same data ensured accuracy and compatibility. The tool for the buttons required 128 inserts, which were CNC lathed. Once the control code had been generated, producing the components was relatively simple and far less time-consuming (and arguably more accurate) than doing so by hand. The hinge components were machined by hand as it was quicker to do so, but CNC lathing these components for the production version of the PCA would be the most appropriate technique. Figure 14 shows the components of one side of the operational prototype prior to assembly.

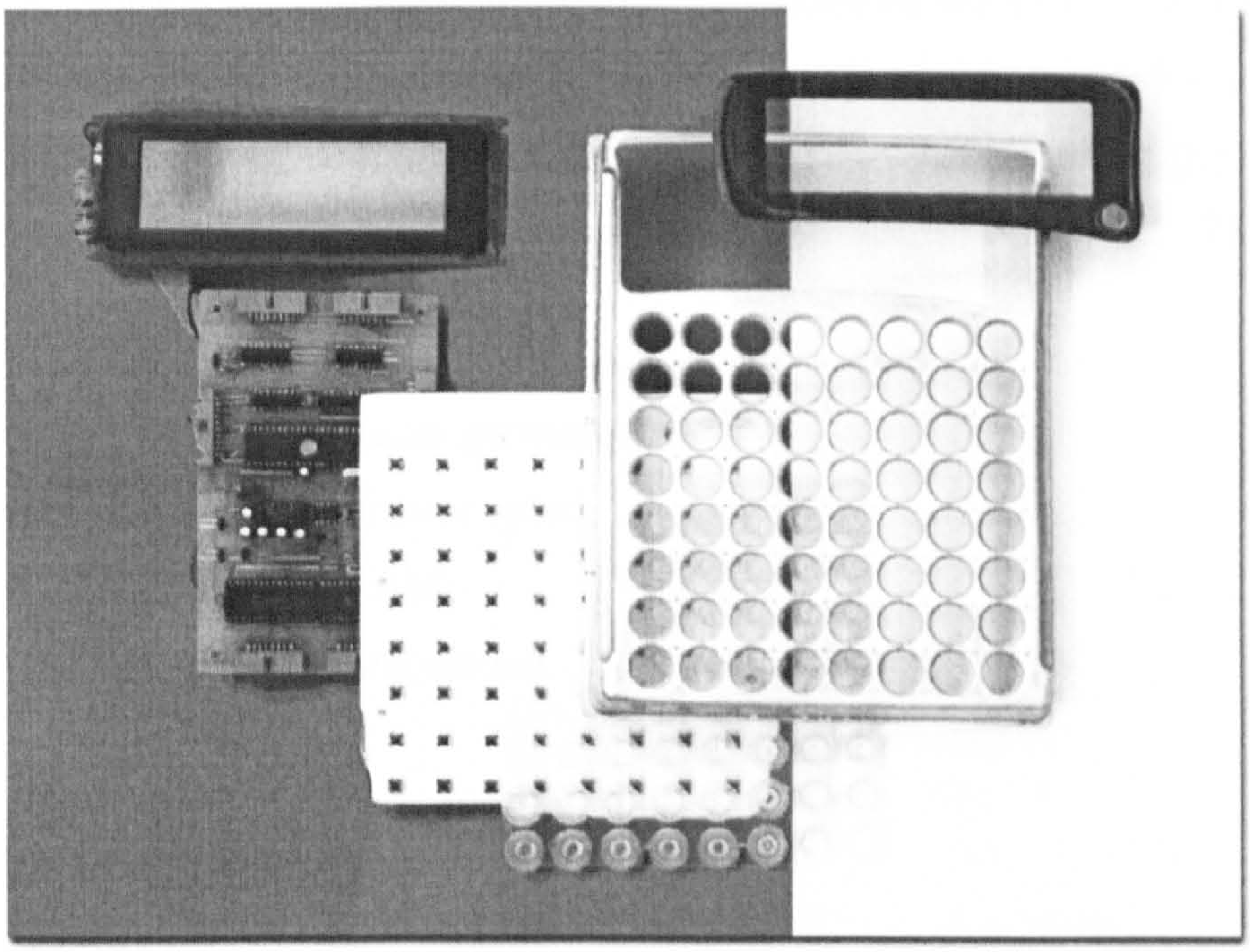

Figure 14: The components of the operational prototype of the *Book*

Figure 15 shows the operational working prototype of the *Book*. Chapter Seven discuss the key features of the PCA in detail, and also includes images of the visual model.

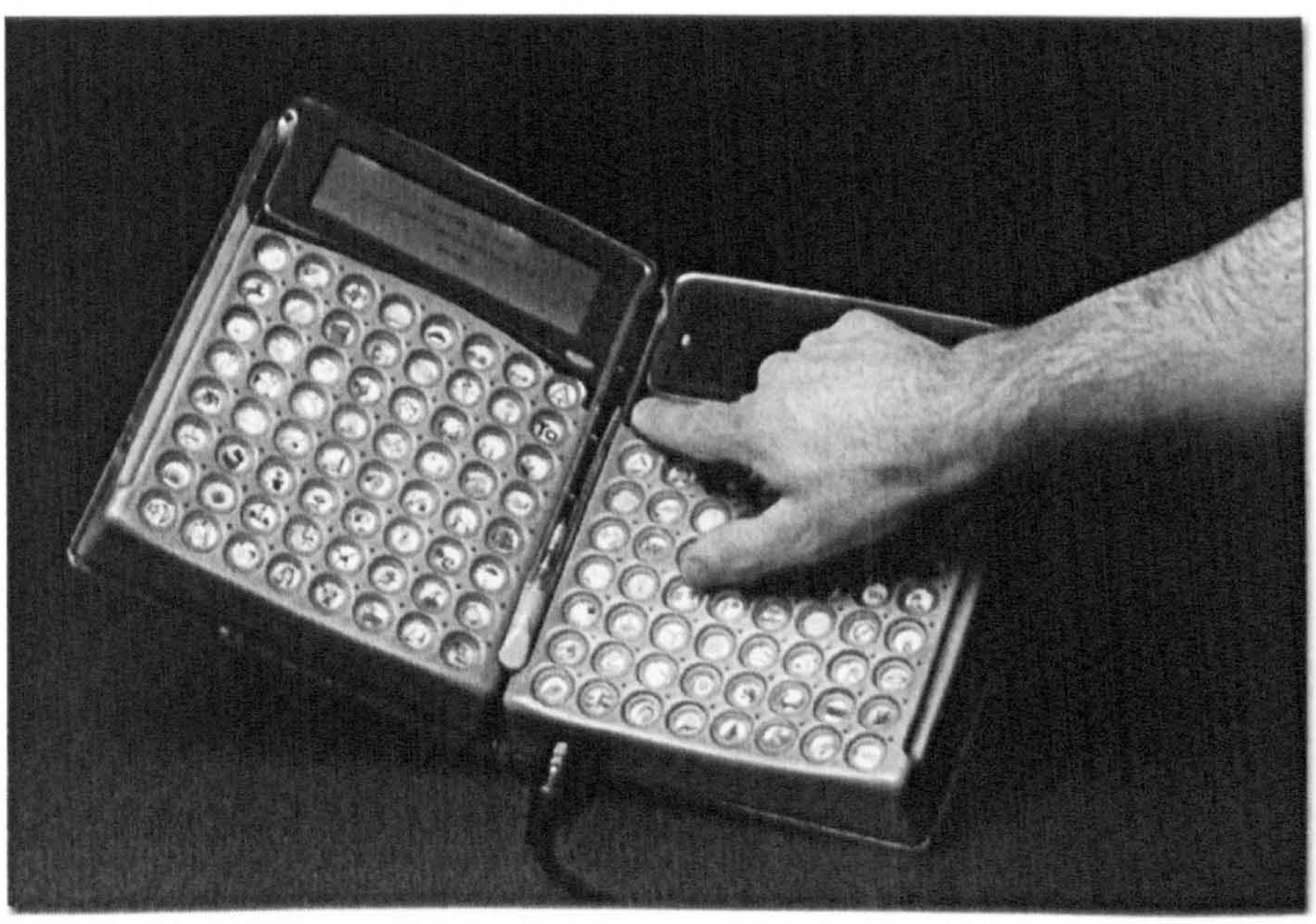

Figure 15: The operational prototype of the *Book*

6.7 Development of the *Waist pack*

In order to develop the processor and hardware section of the PCA, it was necessary to establish the system and software requirements. Laureate required a minimum hardware specification, and to a large extent this governed the configuration and system requirements of the PCA main processor and hardware section. These were the minimum requirements:

- 80486 DX micro processor;
- 66 MHz processor speed;
- 16 Mbytes RAM;
- Unix operating system.

6.7.1 System configuration and operating system

Configuring the system under a Unix environment (in this case using Linux) allowed for multi-tasking (several software applications could run in parallel). The feature of protected memory in Unix resulted in a reliable system (a crashed application could not cause problems to correctly-running applications). Unix also allows symmetric multi-processing, meaning that dedicated processors can be used to perform set functions, thus resulting in an efficient system – particularly for processing speech in real-time.

The software base for the desktop personal computer (PC) market is very large, and a large proportion of this software is written for a DOS environment. To gain access to this software base, a DOS emulator was incorporated into the PCA's system configuration. This meant that additional software, such as a word processor, games, drawing and multi-media packages, could be included into the PCA. Figure 16 shows the configuration and hierarchy of the PCA system architecture.

The choice of Linux as a base operating system has proved to be a good decision as that platform has gone from strength to strength and now has a large number of applications available for it. It has also had considerable work done on it to make it suitable for access by people with disabilities (for example there is a distribution of Linux specifically designed for blind users).

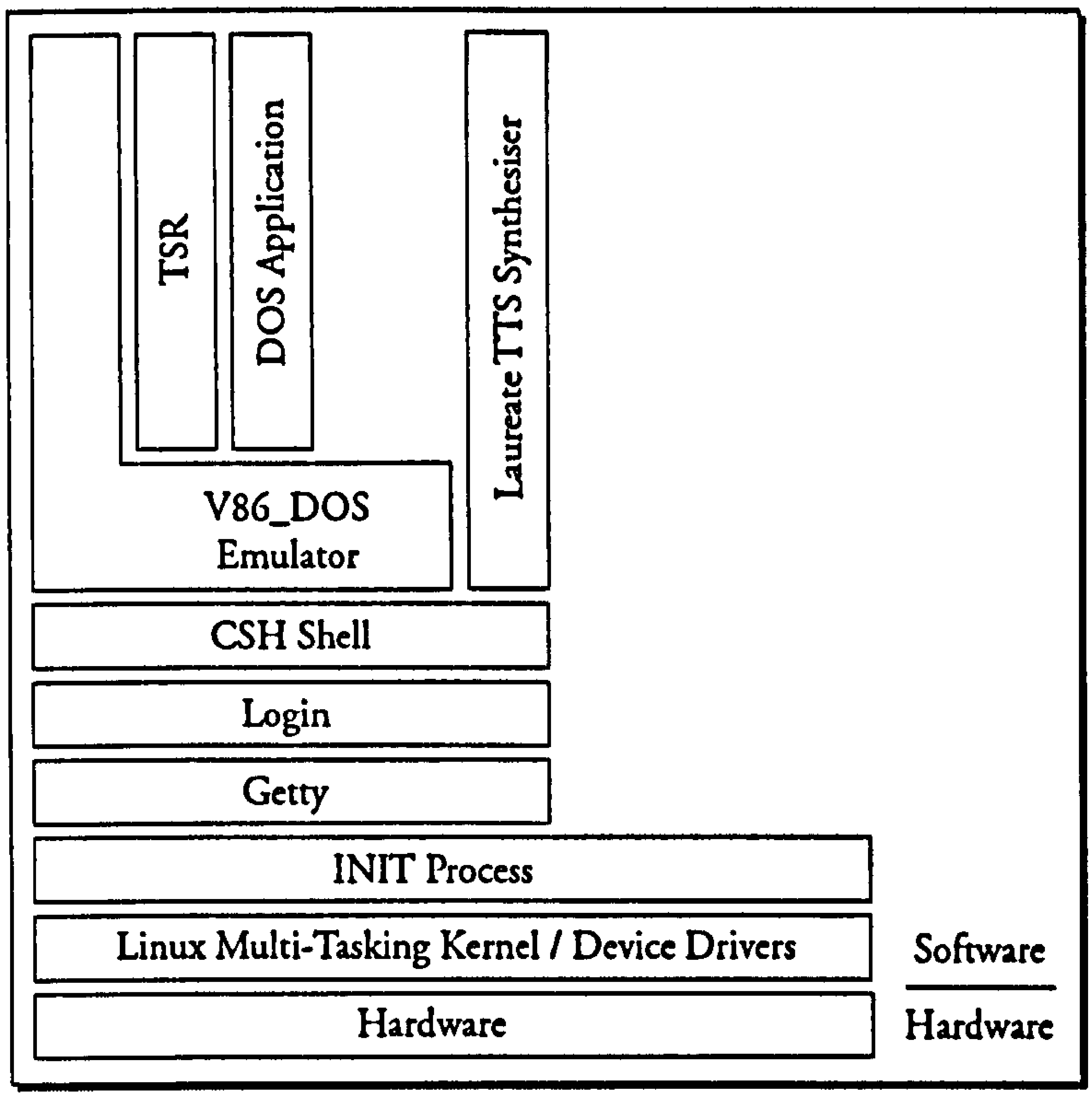

Figure 16: Configuration and hierarchy of the PCA system architecture

The system architecture was configured on a desktop PC before committing to the detailed design of the *Waist pack*. A desktop PC was a cheap alternative to buying separate PC boards or developing from scratch, and permitted quick and effective development of the system. A Sound Blaster card included in the PC was used to output the speech generated by Laureate. Once the system was operational on the desktop PC, a miniature version was developed. Doing initial development on a standard desktop PC and only purchasing the miniature version later, meant that the advantage could be taken of the constantly improving price-performance ratio. Figure 17 shows an overview of the development of the *Waist pack* and the parallel development of the *Book*.

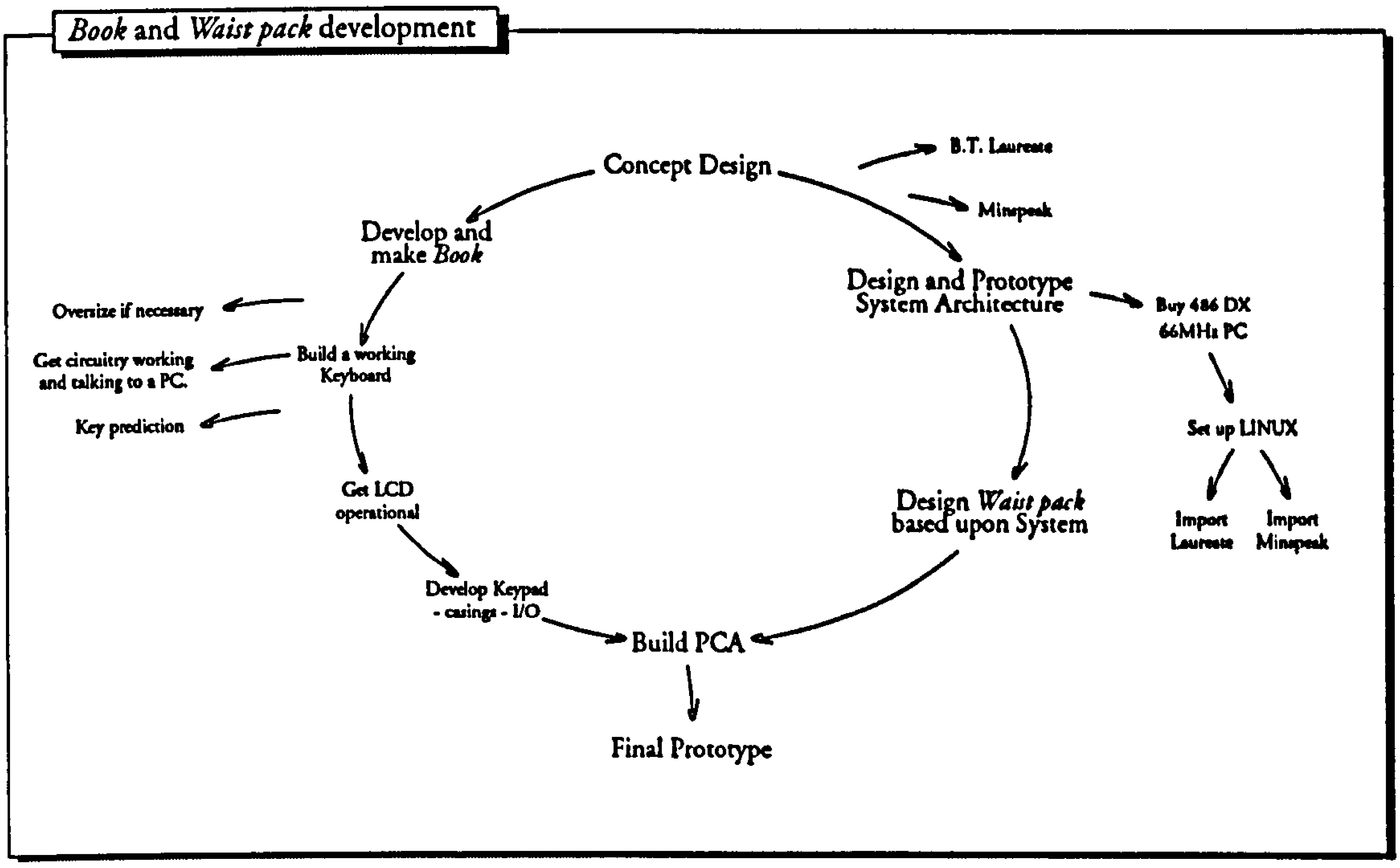

Figure 17: Overview of the development of the *Waist pack* in relation to the development of the *Book*

6.7.2 Wearable computing technology

This section presents some of the challenges facing the author in the prototyping of the hardware of the *Waist pack.* It draws on the wearable computing literature as it offers pertinent advice on hardware development applicable to this area.

There are some interesting challenges posed in the design and development of wearable computers. These challenges include power sources, consumption and management of power, heat generation and designing packaging to contain all the components. These challenges are the topic of much of the conversations on the Wear-Hard mailing list[19] and are archived at Wearables Central[20].

The wearable computing field is still small, and as such does not typically have the money to produce dedicated original hardware, instead relying on 'hacking' commercially available devices. Much of the hardware described in the literature on

19 wear-hard@haven.org

20 Wearables Central, set up in July 1998, is a useful website providing advice and links to hardware and software sites (see <http://wearables.blu.org>).

wearable computers is based upon embedded computer boards (such as PC/104 boards), or laptop and palmtop computers, with the additions of custom made components and peripherals.

Starner, Rhodes, Weaver & Pentland (1999) describe the basis of many wearable computers:

> In general, users wear some variant of a head-up display, type using a Twiddler one-handed keyboard, and carry a PC/104-based computer in a shoulder satchel, back-pack, waist-pack, or vest.
>
> (*ibid*, p1)

Some developers have also embedded displays in clothing (such as jacket sleeves) or small pads that can be kept in a pocket. Part of the reason for doing this has been the high cost and lack of availability of high resolution Head Mounted Displays (HMDs) but also because it is easier to 'camouflage' body worn displays compared to HMDs. Some work has been made on 'covert' HMDs but these are not widely available even now. Other researchers at MIT have used Palm Pilots as the user interface to a wearable computer. A brief technical report at MIT's website compares the use of the Palm Pilot to a HMD. The report notes that the "primary benefit of the PalmPilot is that it increases the social comfort of the wearer." (Healey, 1999) It is interesting to note that wearable computer developers are keen on hiding their technology and using socially acceptable devices: it is not just AAC users that do not wish to draw attention to the technology that they carry around with them.

Starner developed one of the earliest wearable computers in this format, called "Lizzy", the details of which were made public in 1997[21]. The design is based around PC/104 computer boards – a series of small, industry standard embedded computer boards (measuring approximately 100mm by 100mm). The Lizzy design was based around the Intel 80x86 microprocessor family. It evolved through several generations of Central Processing Unit (CPU) including the 80286, 80386 and later 80486 processors.

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21 The author's own design had a similar basis, but was developed independently and in isolation of Starner's and MIT's work. The similarity is testament to the logical basis for this configuration given the availability of miniature computer hardware available at that time.

At the time the author was developing the PCA, little information was publicly available on the design of wearable computers. However the population of wearable computer users and designers is constantly growing, and further descriptions and even detailed instructions on how to build wearable computers can be found at numerous websites. Many of these designs make use of PC/104 or PC/104+ embedded board products in much the same way as the PCA design documented here did. This tends to indicate that the choice of using off-the-shelf PC/104 boards for the PCA product was a reasonably good choice.

Smailagic, Siewiorek, Martin & Stivoric (1998) discusses the virtues of custom-designing wearable computers versus developing them utilising off-the-shelf components. Their study found in favour of the design from scratch approach, noting that:

> The off-the-shelf approach required ten times the overhead, 30% more cost, fifty times the storage resources, 20% more effort, five times more power, but 30% less effort to port software than the embedded approach.
>
> (*ibid*, p217)

The PC/104 boards used in embedded computers can form a useful basis for wearable computers. They are relatively small, implement most, if not all, of the main features of larger desktop machines and are relatively cheap compared to the custom design motherboards used in commercial laptops. However, the technology implemented in even the most up to date PC/104 boards lags some way behind the cutting edge desktop processors and chipsets of the day.

Even so, there are good reasons not to use the top of the range PC/104 boards. Firstly these often have power hungry CPUs as will be discussed below and so older boards with slower CPUs or boards with special low power processors may be better for mobile applications. Secondly cost is of course a factor: a premium is paid to have the latest and greatest processor possible in a PC/104 board as in any other field in computing. If a slower, cheaper processor board will satisfy the requirements of a product, a designer would have to think very carefully about what benefits, if any, a faster, more expensive processor would give to the product.

PC/104 boards are stackable and there are more than just processor boards available. PC/104 video cards, sound boards, frame grabbers, PCMCIA interfaces and many more options are available. These must also be carefully selected when designing a PC/104 based system to ensure that the required interfaces and additional devices are supported using the minimum PC/104 board count. High integration boards may reduce peak power consumption compared to several separate boards for example, but that advantage can be lost if they implement unnecessary interfaces and/or do not implement effective power management. It is also worth checking that PC/104 support boards have drivers supported by the manufacturer of the board or the operating system vendor. Some boards may claim to be PC/104 versions of normal desktop ISA cards but low-level chipset changes can make drivers for some operating systems useless.

As a CPU performs functions heat is generated. The greater the number of functions, the greater the heat produced, hence faster processors tend to generate greater heat. The efficiency of the chipset is also a significant factor in heat generation. More efficient chipsets are now available such as Transmeta's Crusoe™ chip[22], released in January 2000, which offer substantial reduction in heat generation, but these were not available at the time of the study. Heat dissipation is an important issue and a considerable challenge for wearable applications. A careful balance between computational functionality and heat generation must be made. To minimise heat production processor speeds are often reduced and heat-sinks and fans are generally used to cool processors down.

Whilst computational hardware has made radical advancements in recent years, battery technology has not. Indeed, batteries are typically the most significant contributor to the weight and bulk of most portable electronic devices. Whilst lithium batteries currently provide the best power-to-weight-to-price ratio they must be recharged carefully otherwise they may explode. This presents problems if the intention is to recharge batteries whilst in use (as is the intention of the PCA). Some of the wearable computer hackers have attempted to use Li-Ion batteries and chargers from laptop computers but the shape and size of laptop batteries are not always ideal for wearable use. Others have used camcorder batteries as these are sometimes cheaper and more readily available. Despite having a lower charge density, some people have opted for Nickel Cadmium (NiCad) or Nickel Metal Hydride (NiMH) cells as the charging technology is easier for individuals to fabricate and use.

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22 <http://www.transmeta.com/why/index.html>

So power sources are still an area holding back the development of wearable computers. Some interesting work into this area is on-going. The commercial release of Li-Ion polymer batteries and fuel cells will be significant advancements in permitting wearable computers to be more of a commercial reality. Additional options for powering wearable computers have been proposed by Thad Starner (1996), who produced a notable report on the options for using human powering of wearable hardware, including the use of generators in shoes, and even nasal turbines. Micro Power Generation and Micro-combustion (such as the MEM Rotary Engine Power System under development at the University of California at Berkeley) present exciting opportunities for power generation.

Power management is often critical to many of the applications of embedded devices, particularly for devices reliant upon non-mains power. Whilst the desktop market is striving to have the fastest and most powerful CPUs within machines, this typically results in computers that consume lots of power. Reducing power consumption is an important driver in the development of the laptop market, as the ability to work without charging for long periods is highly desirable. Hence, lower power chipsets and boards, more efficient power sources, and overall better power management have been developed in this market. Some early wearable computers were based upon laptop components for this reason.

Power management is implemented both in hardware and software. Hardware devices may need to provide the ability to be switched into power saving modes when not in use. There can also be lower power alternatives to existing devices that can be utilised (such as flash memory instead of hard disc drives for example). Software on the machine is needed to allow the operating system and/or user to make appropriate use of these power saving modes. The longest serving standard for power management is the Advanced Power Management (APM) system. This is implemented in many laptop computers and some desktop machines and provides a mechanism for controlling power consumption of components such as hard disc drives and screens, as well as often being involved in putting the whole machine into suspend or sleep modes. Unfortunately some embedded single board computers either do not support APM at all or only a limited subset as their major target markets (which still do not always include the wearable computer or battery operated markets) do not necessarily view power management as a vital feature. One common problem is the lack of information about remaining battery charge, something that can result in data loss when the battery runs out without warning.

Smailagic & Siewiorek (1999b) note that:

> from 1990 to 1995, the power / performance ratio dropped by a factor of ten every 2.5 years, and from 1996 is expected to continue to drop by a factor of four and a half in the next five years.
>
> (*ibid*, p253)

This prediction proved to be roughly correct for individual components. Unfortunately it does not take into account that users demand increased functionality from their computers. This means that extra devices are often included in subsequent generations of portable computing equipment, so battery life does not necessarily improve at a similar rate. For example, whilst a new model of a hard disc might use 50% less power than the previous version, some of that gain might be offset by the inclusion of a higher performance display or a GPS unit. This is especially true of wireless equipment, where the current popularity of cellular telephone modules and wireless networking gear can rapidly consume available battery charge.

"Packaging is an extremely important contributor to overall wearability, flexibility, and reconfigurability" (DeVaul, Schwartz & Pentland 2001, p4). The product case of a wearable computer serves many functions simultaneously. Firstly it must be physically robust enough to protect the delicate electronics of the wearable computer from the day to day bumps and knocks resulting from being carried around whilst the user goes about his or her daily life. It may also have to resist moisture, both from external water sources (rain, showers) but also sweat from the user and, often in the case of AAC, saliva. The packaging of a wearable computer is also one of the interfaces between the user and the machine. It must be made so that the wearable computer is easy to put on and take off and must be comfortable to wear for prolonged periods. It is worth noting that different parts of the human body can carry the same load with varying degrees of ease – hanging a couple of pounds of electronics off a belt around the waist will be less tiring than having them attached to the forearm for instance. The electronics in a wearable computer will dissipate heat and the packaging design must take into account the need for removing this heat away from the computer and the human wearer. Lastly the packaging must present the correct 'image' for the user, which might range from being completely hidden by the user's normal clothes to being a piece of hi-tech fashion wear designed to make a statement about the user and his or her lifestyle.

Packaging design also needs to consider the connectors used to join the various components in a wearable system together. These need to be mechanically strong, as small as possible and yet easy to insert and extract when required without becoming disconnected accidentally. A surprising number of the standard connectors used in the PC world fail to meet one or more of those criteria. Even laptop computers fail to have suitable connectors as those machines tend to be stationary on a desk or lap whilst devices are connected to them. A wearable computer on the other hand will need to be connected to battery packs, external modules, displays, and so on whilst the user is moving about without restricting his or her movements or accidentally coming undone.

6.7.3 The *Waist pack* prototype

The final prototype of the hardware was based upon PC/104 technology. A self-contained PC/104 computer board was used for the final prototype of the *Waist pack* and a PCMCIA version of the Sound Blaster card was used to output the speech. The decision to develop the system upon a PC prior to developing the final prototype had an additional virtue in that postponing buying the PC/104 boards meant there was a wider choice of PC/104 boards available. Advances in technology over the six months or so that the PCA system was being developed meant that when the PC/104 boards were purchased, prices had come down and higher specifications were available. There was, however, an important balance to be made in the selection of the PC/104 boards to ensure that sufficient processing capability was attained whilst minimising the power consumption of the processor. Lower power consumption chipsets were not commonly available at the time, and so an Intel 80486 based board was used as the power requirements and heat dissipation needs of this processor were much lower than the faster (and more expensive) Pentium based PC/104 boards.

A camcorder battery was used to supply power to the *Waist pack* hardware for the prototype, as it was a cheap and readily available power source. For the same reasons the intention was to use the same source of power for the production version of the

PCA. Figure 18 shows the presentation sketch of the *Waist pack* including the basis for its construction, drawn in early May 1996.

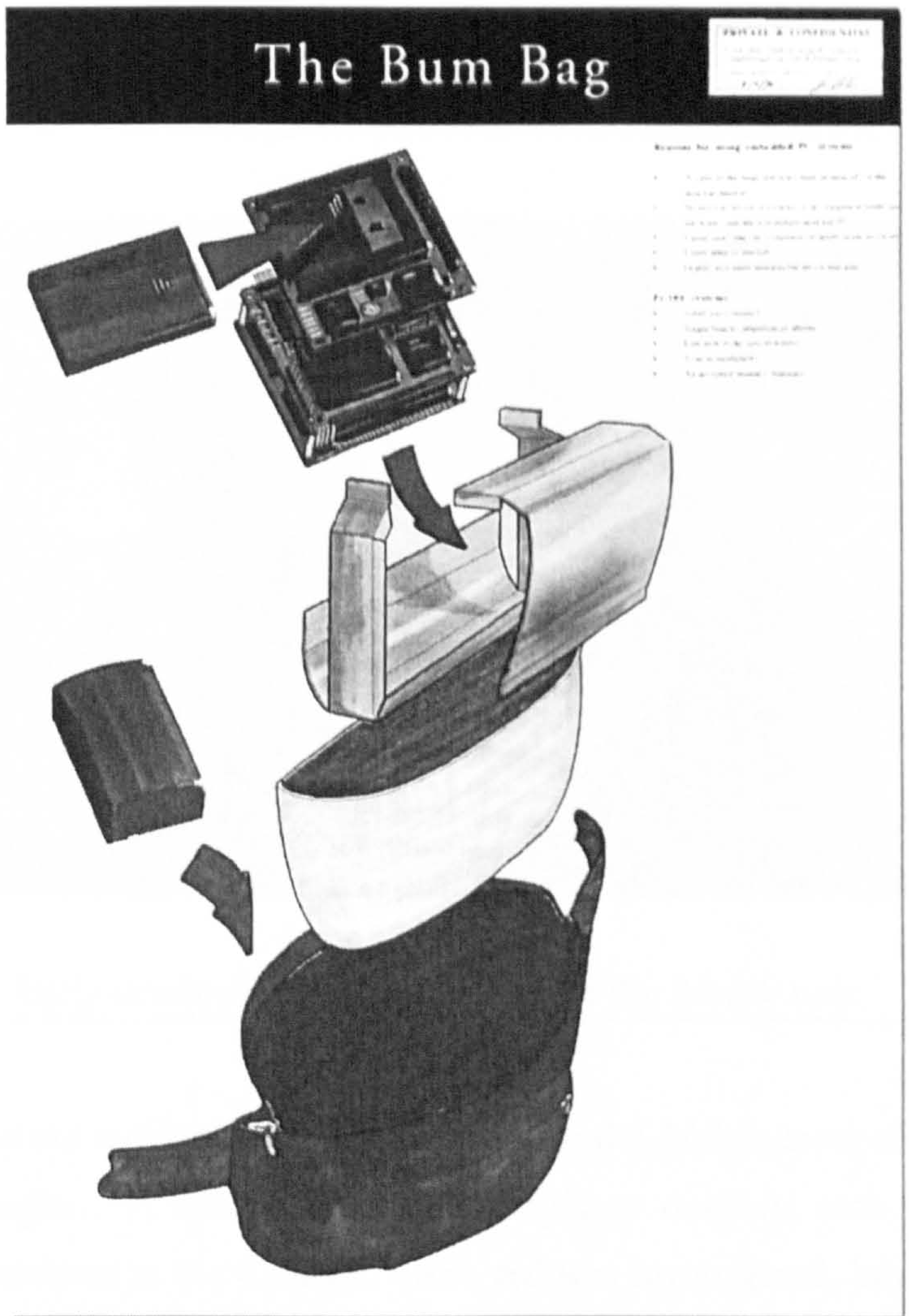

Figure 18: Presentation sketch of the *Waist pack* concept

The chassis for the *Waist pack* was first modelled in card to develop a net of the shell structure. The net was then used to produce an aluminium shell which had the advantages of being lightweight, provided EMC shielding, and was ductile. A number of nets and shells were made, the latter versions were drilled along curved paths and then folded to provide more sculpted forms that fitted the body better than the first linearly folded shells had. The curved forms also provided better torsional rigidity and resistance to deformation on the surfaces. An off-the-shelf bum bag was purchased for housing the chassis and PC/104 hardware. Chapter Seven discusses the final working prototype of the *Waist pack* in more detail, and includes an image of the final prototype.

6.8 Development of the *Mobile* unit

Like the development of the *Book*, a number of solid visual models of the *Mobile* unit were made, each with iterative changes based upon user feedback and technological rationalisation. Figure 19 shows three such models of the *Mobile*.

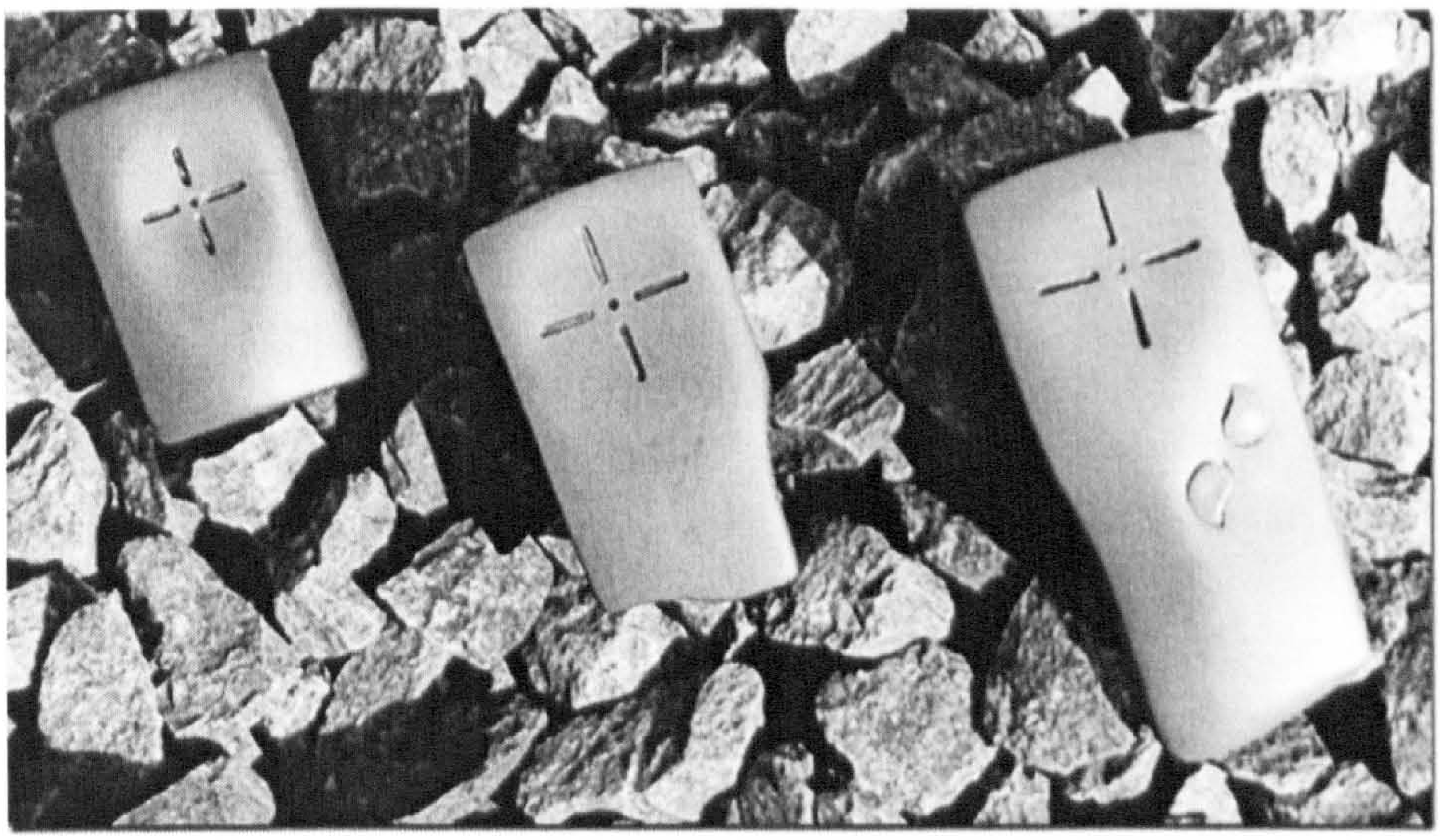

Figure 19: Early development block models of the *Mobile* unit

The decision to use radio to transmit the signal to the *Mobile* came after investigating other technologies. A wire link, whilst simple to develop, was very unpopular amongst the students at the College. Infra red was investigated, but was dependent upon line-of-sight transmission, and therefore if clothing or other objects got in the way the signal would not be successfully received. Radio provided an ideal transmission medium, and could be two-way (or more), thus presenting additional uses than simply speaking out messages (some of these are discussed further in Chapter Seven). A licence-free low power radio band was selected (MPT 1340, operating at 418MHz), and a paired receiver and transmitter were bought.

The author initially attempted designing and bread-boarding the transceiver circuitry, but with little success. The transceiver circuit worked, but also picked up spurious noise. A filter was added and the transmitted signal was modulated, but again, with little success. A colleague of Dr. Machin's, Richard Mee, had particular interest and experience of radio transceiver design and offered his help. Mr. Mee designed and produced a working bread-boarded circuit before producing a surface-mounted version of the digital transceiver circuitry housed in the *Mobile* unit. The final version incorporated squelch and encoding so that a carrier signal was required to ensure only the intended radio receiver picks up and broadcasts the message. A digital volume control was also incorporated.

Again, an off-the-shelf battery (a mobile phone battery) was used to provide power for the *Mobile* prototype. The use of an existing battery had considerable bearing upon the aesthetic of the *Mobile*, and it was important to ensure the battery and the *Mobile* visually matched each other. The key components (speaker, battery, and radio transceiver) were bought and a spatial layout was drawn up that accommodated them. The form of the *Mobile* was developed through sketching and foam modelling. More resistant models, along with sketches, were taken to the College for student feedback, before the final design was established. The final design dictated the space and layout of the transceiver circuit housed in the *Mobile*. The surface-mounted circuit board that Mr. Mee designed accommodated these space limitations successfully. The transceiver circuitry was embedded in silicone rubber to prevent the circuit being damaged by the ingress of liquid, and the loud speaker was splash-proof.

Before the production of the *Mobile* unit's final prototype casings, thin-walled section models incorporating internal features of the three principal components (back casing, front casing, and battery holder) were produced. Two-part silicone mould tools were then created from each of these models. The silicone mould tools were then used to cast a number of parts, in both rigid and flexible urethanes, and in several different colours. Rigid versions of the *Mobile* unit's components were used to create a visual model. Flexible back and front casings with a rigid battery casing were combined with the electronic components to form the working prototype of the *Mobile* (Figure 20).

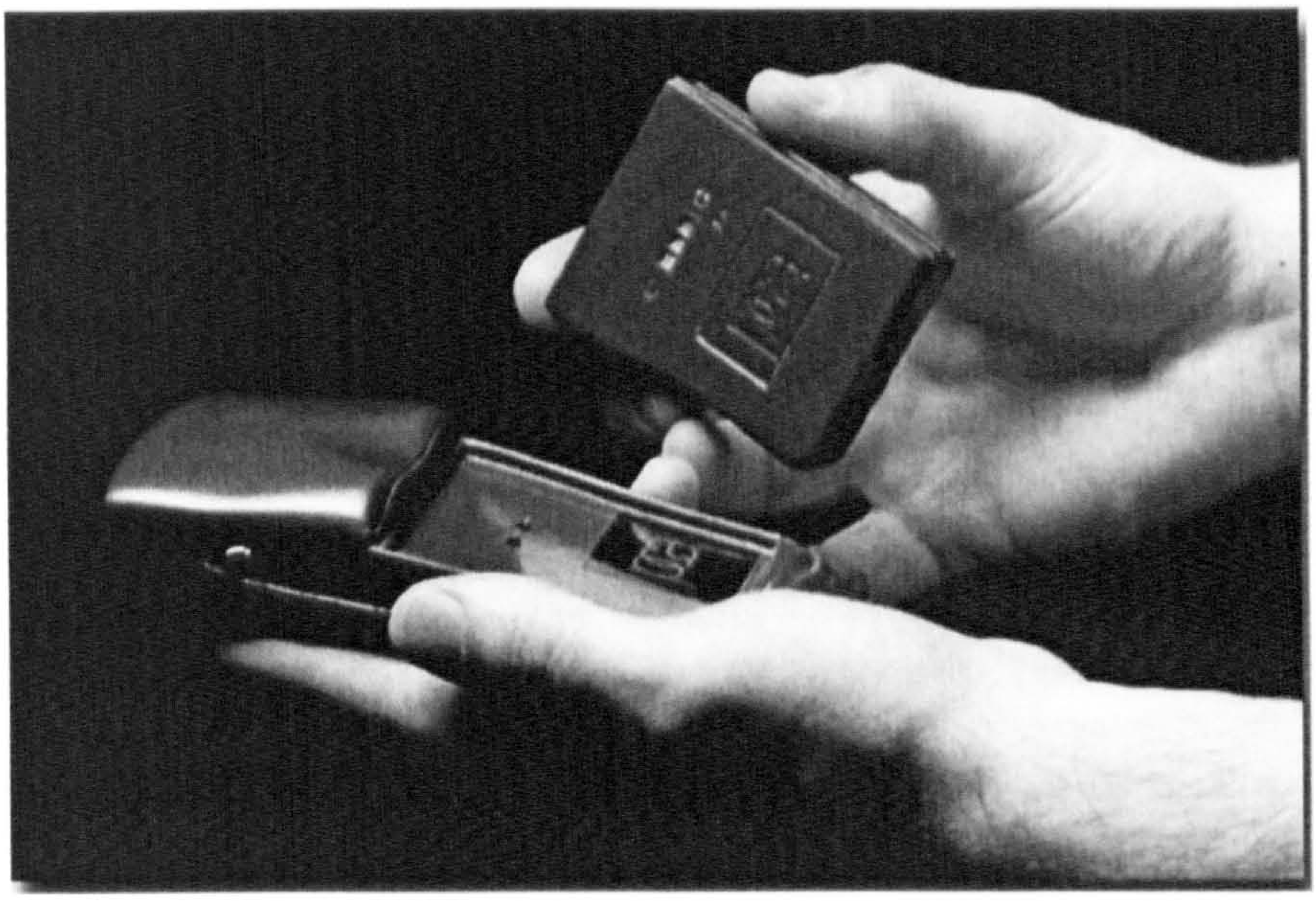

Figure 20: The final working prototype of the *Mobile* unit

6.9 Conclusions

Chapter Five discussed how physical models allowed AAC users to more fluently comprehend design ideas when compared to drawing and discussion alone. Developing those ideas through working prototypes added an important sense of realness to these design concepts. Owing to their interactive properties, the prototypes discussed in this chapter proved important tools for eliciting user feedback. The prototypes provided important feedback: an action on the user's part resulted in a reaction from the product (the keys clicked on depression, LED's lit up and words appeared on the screen of the *Book*, and a voice was sounded from the *Mobile*). Visual models rely on interpretation and imagination to comprehend the final item, whilst working prototypes are easier to perceive and relate to as final production items. Presenting prototyped parts of the PCA to AAC users at the College, and getting them to try them out and comment resulted in more critical, rational, and precise feedback on design details than either drawings or solid models had done.

The prototyping of the PCA involved the author in many different tasks and required the acquisition of new knowledge, awareness and competence. Complex decisions were made. The management of the project, was particularly difficult given the multiple and complex parts of the PCA, all of which required development and prototype manufacture to a standard suitable for testing.

Time constraints and costs limited the outcomes that could be achieved from the prototyping programme. Such limitations were necessary to ensure an achievable and realistic outcome. As a workable version of Minspeak was not available, it was necessary to prove the efficacy of the system design in another way. It was decided to represent just one language system and develop the PCA as a case study (i.e. designed for a particular user), yet have it manifest features, ideas and qualities that were applicable to a wider population.

Chapter Seven provides a complete overview and description of the PCA product.

CHAPTER SEVEN

Essential principles and description of the PCA

7.0 Introduction

The previous two chapters have discussed the establishment of user requirements and the determination of functions and features to be embodied within the PCA. This chapter presents the synthesis and final outcome of these activities, revealing the essential principles and a detailed description of the final PCA design. The work described here is a resolution to the shortcomings and problems of AAC devices highlighted in previous chapters.[23] The section 'Essential Principles' on the CD ROM (Annex A) should be viewed in conjunction with this chapter.

The PCA consists in three key parts:

- the *Book*;
- the *Waist pack* (Bum-bag); and,
- the *Mobile* speaker.

These are discussed in turn.

7.1 The *Book*

Early in the design of the PCA, a proposal for what was dubbed the *Book* by one of Portland College's students proved popular. The idea was to camouflage the technology and to attach to the product an association of intelligence, whereby those using it would be perceived to be literate and, hopefully, intelligent. A book carries more than just the association of intelligence, however. The information or stories contained within books, rather than the physicality of them, stimulates emotive or reactionary responses. In this way, the intention of the *Book* was to draw the public's attention away from the 'machine' and to focus upon the content of what was

23 Some of the material in this chapter appears in an unpublished paper co-written by the author and Dr. Colin Machin. (Allen & Machin, 1997)

generated upon it and spoken by the PCA (in other words, what the user was saying). The association of books with story telling was also apt for the PCA, in that a story-teller can captivate an audience by reading from a book. The correlation between learning and books was also intended to be explicit, as the PCA was intended to be used as an aid for learning. (Figure 21 shows the *Book* in its closed state.)

Figure 21: The closed *Book*

The *Book's* resemblance to a personal organiser or a diary was by no means coincidental. Both objects are used to store personal information, and have significant value to their owners. Likewise, the *Book* sought to foster such an association. (Figure 22 shows the *Book* in its open state.)

Figure 22: The *Book* in its open state

Beyond the semantic association, the *Book* has additional virtues, such as:

- a full-sized keyboard that can be housed in half the area required conventionally (the *Book* can fold up);
- avoidance of unwanted attention drawn to the user (to all intents and purposes the user is reading);
- a means of keeping private material private (the *Book* can be closed by users);
- the act of closing the *Book* allows a very demonstrative statement to be made: "I don't want to talk to you" (this was discovered when demonstrating the PCA to one participant).

The *Book*, leather bound or clad in whatever finish grabs the owner's imagination, accommodates the keyboard and graphics-capable liquid crystal display. A single-chip micro-controller integrates the input and output functions of the *Book* to an external, serial link.

The keyboard and display are both back-lit and additionally each key has a light emitting diode (LED) associated with it. These low power, super bright LEDs are used to guide the user to keystrokes that naturally follow, within the adopted AAC language, the one just made. This key prediction feature provides the PCA with the potential to become a device from which its user learns new words and phrases. The *Book* also contains a solar panel both to assist in maintaining battery charge levels and to provide the system with information regarding the ambient light conditions in order that back-lighting may be controlled in the most-energy efficient manner. The solar panel trickle-charges the battery in daylight and detects when ambient light levels drop, automatically switching on back-lighting of the screen and keyboard. Back-lighting permits the AAC user to operate the PCA in the dark or in poor lighting.

Figure 23 shows an exploded view of the *Book* and identifies key components.

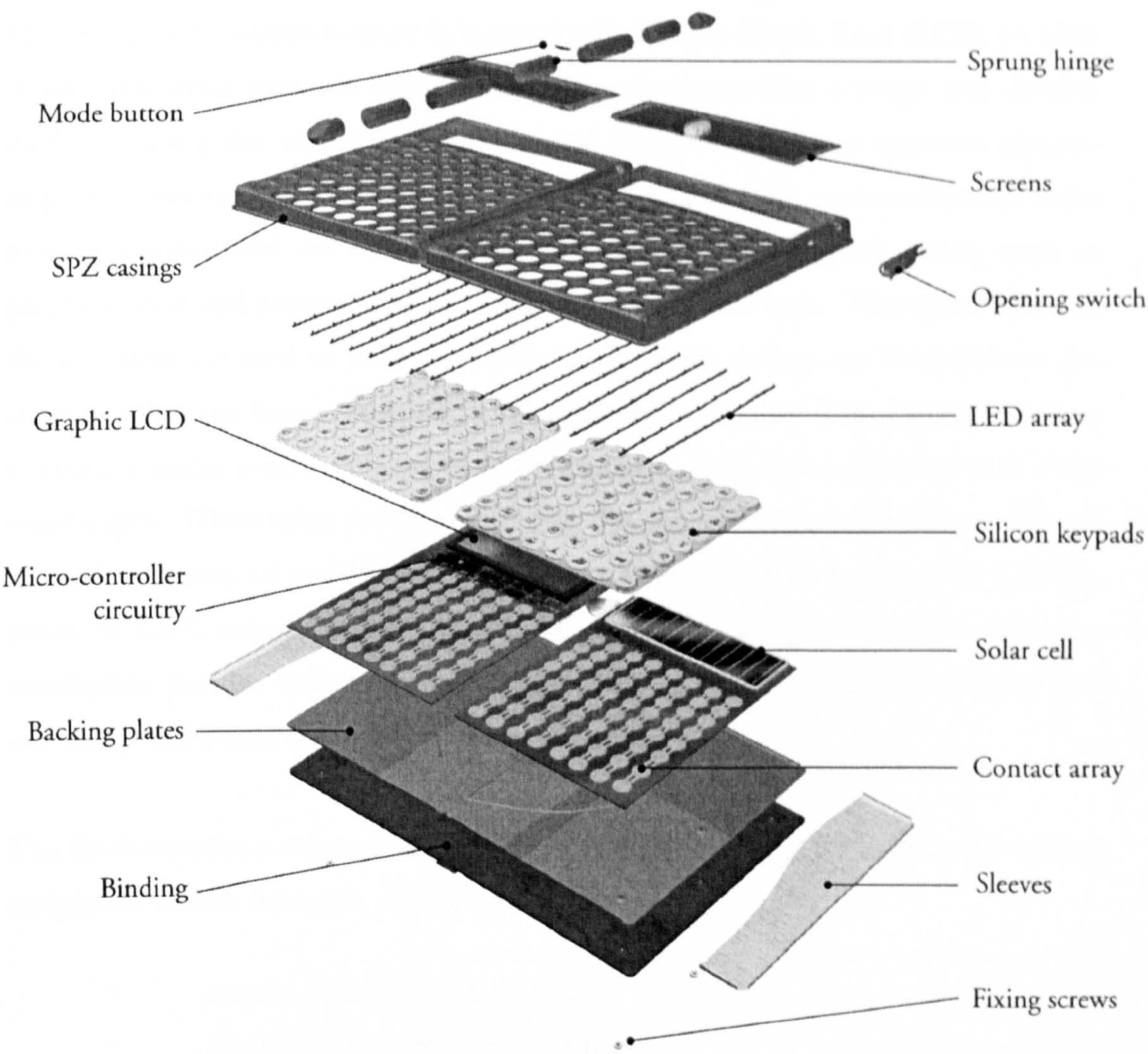

Figure 23: Exploded view of the *Book*

A sliding switch latches the two halves of the *Book* closed. Pulling on the switch will open the *Book* and initiate power to the PCA. The switch is designed to permit threading a cord or tag through to allow for easier opening. The switch is sprung to return it to the closed position. The latch is made from a CNC machined aluminium billet that is rumble polished (and can be powder coated if desired).

The hinge incorporates a torsion spring that assists the opening of the *Book* and acts as a dampening cushion, preventing damage to the casings when closing the *Book*. The hinge is pre-tensioned so that when in a relaxed position, the casings are at an angle of approximately 30° (the weight of the top casing counteracts the spring forces). The hinge is CNC turned from aluminium rod and tube.

The casings are vacuum-formed in a metal called Super Plastic Zinc (SPZ), an alloy of predominantly zinc and aluminium. The metal provides a tough and durable shell, shielding the circuitry from physical knocks and from spurious electro-magnetic emissions or radiation (EMC compliancy). The vacuum-formed holes provide rigidity and act as an integral key-guard, thus helping guide users to particular keys and preventing unintentional depression of keys. The spaces between the key holes are used to hold the LED arrays. Both casings are formed from the same tool, but the boss is attached in two different orientations during manufacture to create a wedge profile (the depth of the casing at the hinge is less than it is at the outer edge). When open the *Book* rests flat, but the two opposing wedge profiles of the casings create an arced keyboard. Waste material can be removed by LASER, water, or CNC cutting. The SPZ can be polished to a high sheen and a clear or translucent powder coat applied for protection, or else a variety of coloured and textured powder coat or paint finishes can be applied.

The *Book* contains a micro-controller based concentrator that looks after the various peripherals within the book. These are:

- a main keyboard with 128-keys;
- an auxiliary keyboard with 8-keys;
- a matrix of 128 LEDs;
- a graphics-capable Liquid Crystal Display; and,
- a sounder.

The concentrator is connected to a host PC (an embedded format PC/104 housed in the *Waist pack*) using a standard serial line running at 19200 Baud. The PC sends requests for patterns to be displayed on the LEDs and for text and graphics to be displayed on the LCD. Furthermore it can make requests for updates regarding the status of the keyboard. The micro-controller runs in low-power mode as much as possible, waking every 10mS to check the keyboard status and detect for a serial line communication.

Metal contacts on the printed circuit boards provide light-weight and thin contact arrays upon which silicone rubber keypads rest. The control circuitry, contact arrays, and keypads constitute the keyboard. The silicone rubber keypads give tactile and responsive feedback, whilst also providing a splash proof membrane to ensure the control circuitry is protected from the ingress of liquid (e.g. saliva, drinks, rain). Icons (or text) are printed and encapsulated within the rubber so that they do not wear off. The rubber is translucent, allowing the keyboard to glow when the back-lighting is activated. The back-lighting for the keyboard consists of eight white LEDs mounted on the perimeter of each circuit board.

The liquid crystal display (LCD) supports text and graphics. Once words are generated on the PCA, they appear upon the display. Such direct feedback can help in the construction and sequencing of words, but also may encourage the development of literacy for some users. Polycarbonate screens protect the LCD and the solar panel. The screens are cut from sheet, polished and screen printed on the underside in colours to suit.

A small mode button is located on the screen covering the LCD. This button is intended to allow cycling between various functional modes of the PCA. No special modes are incorporated on the PCA as yet, but the facility has been made available. The button is located next to the graphic display so that a digital icon or word can be output to the display to indicate the current functional mode of the PCA.

The leather covering on the book provides a resilient surface that wears and ages well. The covering is available in a variety of colours and can even have lettering or logos embossed upon it (the name of the owner perhaps). The covering material is adhered to thin pressed aluminium backing plates, which provide both a rigid backing for the *Book*, EMC protection and physical shielding for the electronic circuitry. The assembly of the backing plates and leather cover slide onto the lips of the SPZ casings and are crimped in place. Six fixing screws hold the components of the *Book* in place. Brushed stainless steel sleeves then slide over the book backing, hiding the screws and providing a hard-wearing surface to protect the edges of the *Book*. The profile of the sleeves are LASER cut with minimum waste (since the forms tessellate), are folded, and then crimped in place on the *Book*.

The Book has been designed for economy of production. The two sides of the Book, from a manufacturing perspective, are the same. The left and right casings are made from the same mould tool, the screen and the solar cell cover are duplicate parts (but are printed differently), and the keyboard parts and the LED arrays are identical. Removing the Book's sleeves and undoing the location screws allows the back plates to slide off the lips of the vacuum-formed metal casings, exposing the contents of the Book. The contents of the Book simply stack in place inside the casings allowing ease of assembly.

7.2 The *Waist pack*

The *Waist pack* (or 'Bum-bag' as it is more commonly known in the UK) was devised as a convenient housing for the main PCA computer hardware. The unit provides a secure repository for the more expensive parts of the system, as well as being a conveniently worn or carried item. A 'chassis' containing the computer hardware can simply be fitted into an off-the-shelf bum-bag. This allows users to select bum-bags according to their fashion tastes (and, in time, changes in fashion tastes), and each PCA can be easily and inexpensively customised. Figure 24 shows the *Waist pack* and the computer it houses.

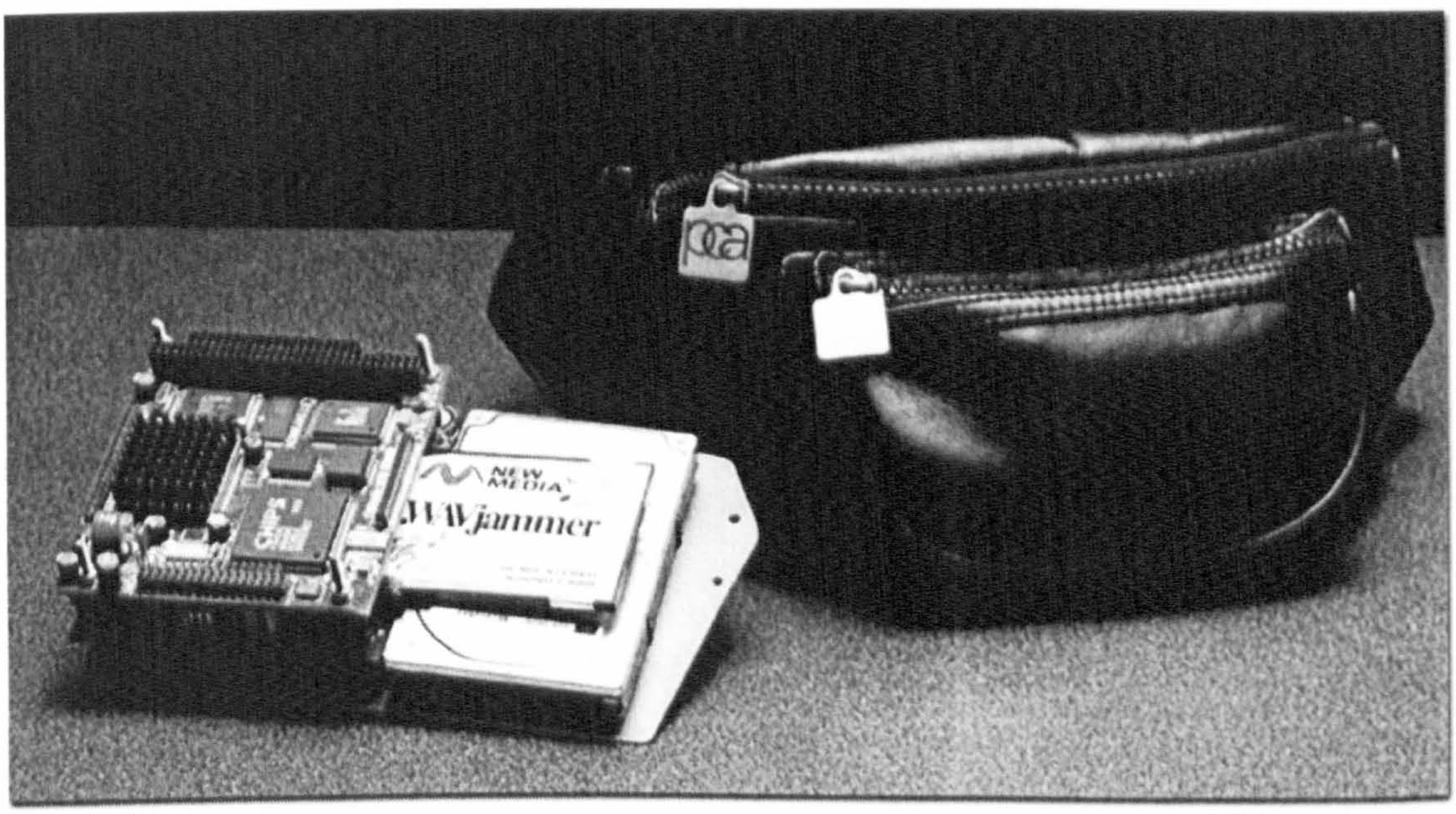

Figure 24: The *Waist pack*

The *Waist pack* contains the main power source by way of a cam-corder battery, an embedded PC-compatible computer system, a speech output device controlled by sophisticated speech synthesiser software and a radio transceiver. The main computing element, the embedded PC, links to the *Book's* micro-controller and commands it to perform various operations on the display and LED array to convey the keyboard's status. The radio transceiver in the *Waist pack* provides a link to the *Remote* speaker unit. In order to constrain development time and costs, standard units were utilised wherever possible. It was decided to make use of commercially available batteries so that additional batteries could be quickly and relatively inexpensively sourced from high-street shops. The main processing power in the PCA is derived from PC technology. The selection of a PC-compatible computer afforded access to the huge software base produced for the desktop market, easier and faster development of application software and hence faster time to market. The implementation is based on standard, off-the-shelf PC/104 technology offering substantial computing power in a very small package. The PC/104 format is an accepted industry standard and echoes and enhances the system modularity that is part of the design basis of the PCA. The speech synthesiser, offering programmable changes in mood and inflection, runs on the embedded PC and outputs via a PCMCIA version of the standard SoundBlaster product.

With present battery technology the major contribution to the weight of the PCA comes from the power source. The decision to place the battery in the *Waist pack* results in this concentration of weight being in an area that does not upset the balance of a semi-ambulant user. Indeed, the wearing of a strap around the waist may increase the user's stability. Further, placing the more delicate and expensive parts of the PCA in the *Waist pack* affords them greater security and protection from damage. Figure 25 shows the assembly of the *Waist pack.*

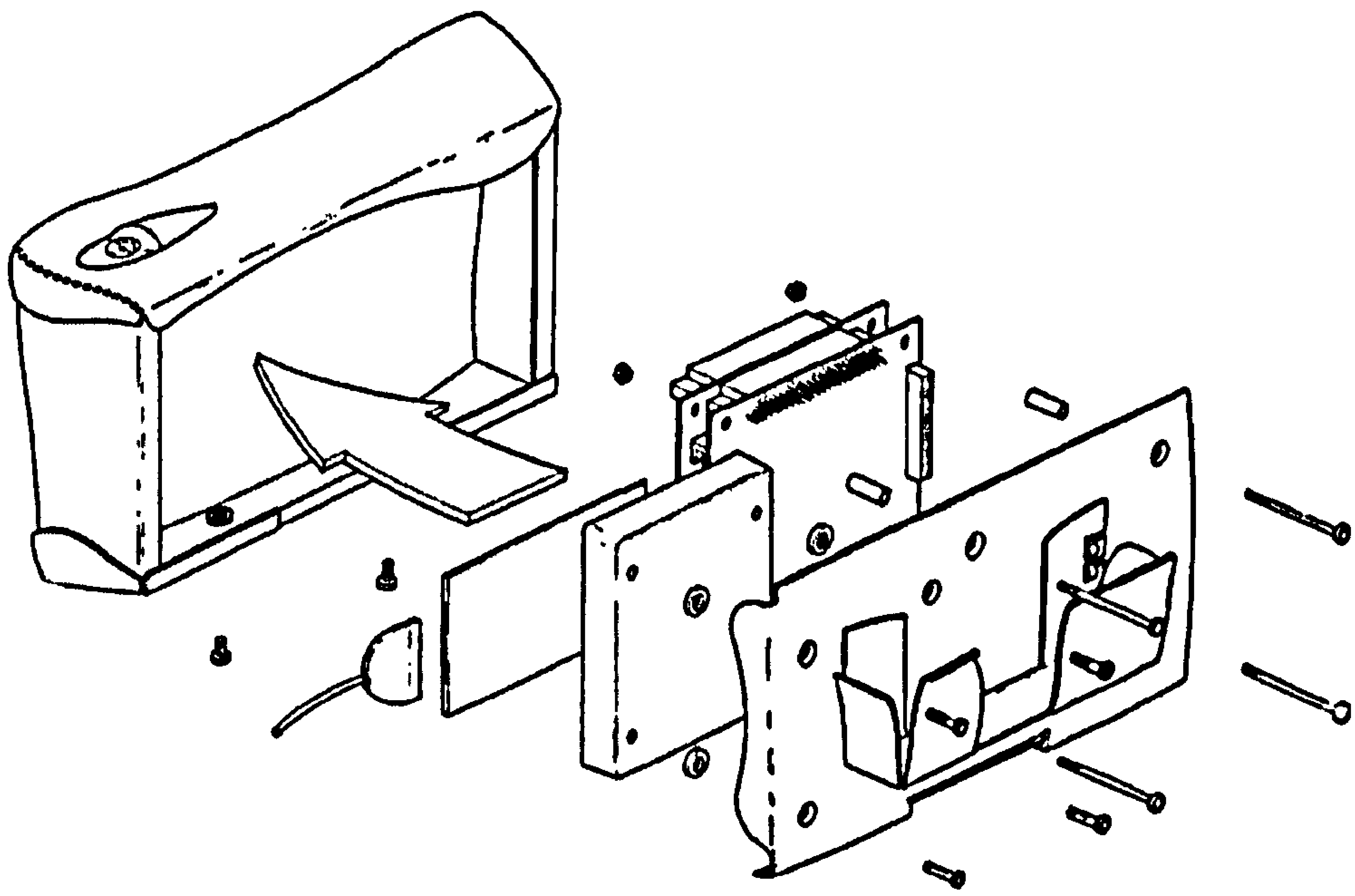

Figure 25: The *Waist pack* parts

A radio link is used to transmit the audio signal to the listener's hand-held unit. There is a transceiver unit in both the *Waist pack* and the *Remote* unit, with the latter additionally carrying a small RISC-based micro-controller. In order that a number of PCAs may be used in the same area, the radio link operates on a principle not unlike a token ring. Each remote receiver is assigned a 16-bit address and that address is known to the PCA. When the PCA wishes to transmit audio it first turns on its own receiver and listens for a carrier. If a carrier is present it assumes that another PCA is transmitting in the immediate vicinity and waits for a short time before trying again. If no carrier is present, it opens its own transmitter channel and after a short delay sends a stream of data at 9600 Baud that alerts remote units in the vicinity that an address is coming after which it immediately sends its own remote unit's address.

The housing around the PC/104 unit is LASER cut and perforated from sheet aluminium, then folded along the perforations. Folding along the perforations allows a more sculpted form to be achieved when compared to conventional linear sheet bending. Perforation folding is also cheaper than using pressing tools to deform the material, and changes to the form can be made quickly and cheaply. The curvature of the housing provides rigidity and fits comfortably in the cavity of the bum-bag. This process provides a cheap shell that is lightweight, provides good torsional rigidity, resilience to knocks and dents, and protection of the electronics housed inside. The PC/104 boards are secured to a flat front faceplate using machine screws and the PC/104 stack is mounted on rubber O-rings to provide some resistance to shock and vibration.

7.3 The *Mobile* unit

The *Mobile* speaker facilitates the speech output for the PCA. This self-powered unit contains a transceiver matching the one in the *Waist pack*. Having a separate unit producing the final audio output offers a number of alternative ways of using that output. The user may wear the unit in such a position that the voice sounds as though it is coming from the user, or the user may pass the unit to the conversation partner so that a more intimate conversation may ensue. In either event the integral digital volume control is close at hand allowing the unit to produce anything from a respectable shout to a whisper. The *Mobile* speaker unit is shown in Figure 26.

Figure 26: The *Mobile* speaker

The *Mobile* speaker concept was very popular amongst staff and students at Portland College for a number of reasons. The facility to talk privately was a major virtue of this proposal, as was the option of wearing the unit (say, in a shirt pocket) so that the voice sounds as if it emanates from the wearer (as opposed to the machine). The proposal to make the audio output device resemble a mobile phone was favoured by the students, as mobile phones were perceived to be desirable items by the students and, from a practical perspective, the size also provided sufficient space to house the components. The association with mobile phones had an additional advantage in that if a conversation partner held the *Mobile* to his/her ear, people assumed that the conversation partner was on the phone. Hence, conversation partners drew little attention when conducting conversations with AAC users, even though they were holding something to their ears.

In order that a number of units may be used on the same frequency within their respective radio transmission ranges, each main and remote unit is coded. In normal use, only the identically encoded receiver will receive the speech intended for it. However, the same provision of a global receiver in a classroom or seminar or emergency situation would allow individuals to have their views heard by many. All of the remote units default to what might be termed their 'address capture mode' (in which they are listening out for an address stream). The remote unit identifying the address as its own switches to audio relay mode, decodes the incoming signal and sounds the loudspeaker. Once the PCA has finished transmitting, it closes its transmitter channel (which in turn causes the selected remote unit to return to address capture mode).

The *Remote* incorporates a splash-proof 2-Watt mylar speaker / circuitry unit. The casing is made from Reaction Injection Moulded (RIM) flexible and rigid urethanes (a process also known as PU moulding). RIM moulding allows for considerably cheaper tooling than conventional injection moulding. The flexible urethane provides impact resistance and has notable tactile qualities. Figure 27 shows a user changing the digital volume on the *Mobile*.

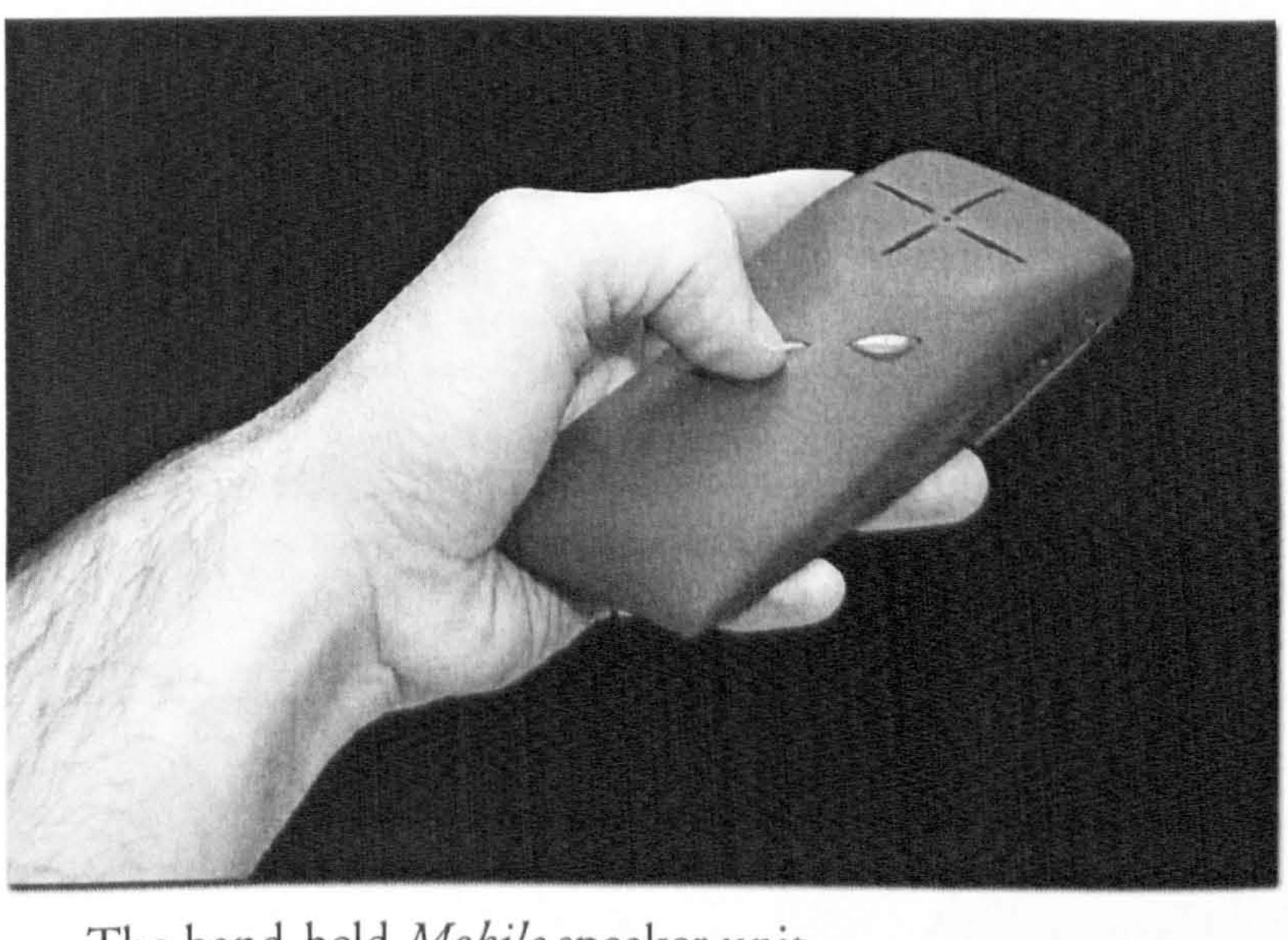

Figure 27: The hand-held *Mobile* speaker unit.

7.4 Summary of PCA features in response to identified needs

A summary of the features incorporated into the PCA as a response to the needs and problems identified in previous chapters is tabulated below.

Problem or identified need	How synthesised in PCA (product features)
Physical	
Current AAC devices are hard to carry and can put ambulant users off-balance	• PCA weighs less than predecessor devices • Items broken up into separate components that are worn or carried (weight is distributed) • The majority of weight is worn centrally about the waist in the *Waist pack*
* AAC devices need to be more resilient to knocks and breakage	• Rugged metal casings used on *Book* which is bound in leather (providing good grip and abrasion resistance) • Padded bum-bag and resilient aluminium chassis protects electronics in *Waist pack* • *Mobile* made of rubber to resist impact and provide non-slip tactile properties
AAC devices often breakdown	• (as above) • Parts can be replaced with relative ease - standard parts such as batteries are used - designed for ease of assembly - modular parts used - computer hardware is easily upgraded
AAC devices run out of charge	• Solar cell incorporated • Low power PC/104 boards used • Power management incorporated • Standard rechargeable batteries used (spare batteries can be purchased relatively cheaply and are readily available)
Perception of device	
AAC devices are perceived as unreliable	• More rugged materials and construction used than predecessor AAC devices, eg: - aluminium chassis containing electronic components in *Waist pack* - leather/fabric bumbag provides padding for electronic components in *Waist pack* - SPZ metal casings on *Book* - rubber casings for *Mobile* • *Book* and *Mobile* are splash proof
AAC devices are perceived as toys / machines	• Materials and manufacturing processes that provide high quality finishes without expensive production costs have been used • Noble materials used (leather and metal) to provide level of exclusivity • Product design takes cues from consumer electronic products

<table>
<tr><th colspan="2">Interface</th></tr>
<tr><td>Fingers slip on keys</td><td rowspan="2">• Integral keyguard on Book helps locate fingers
• Tactile silicone buttons
• Buttons are recessed
• Resistant material of Book allows users to rest or place hands on Book without activating keys
• LEDs provide icon prediction thus reducing the cognitive load of trying to remember locations</td></tr>
<tr><td>Keys are wrongly activated</td></tr>
<tr><td>Icons wear off keys</td><td>• Icons embedded in silicone rubber</td></tr>
<tr><td>Fingers get sore from accessing keyboard</td><td>• Soft tactile silicone rubber used for keys
• Increased travel of buttons than predecessor devices
• Adopted recommendation from BS EN ISO 9241-4:1998</td></tr>
<tr><td>* Tactile feedback on buttons needed</td><td>• Tactile feedback from silicone rubber buttons</td></tr>
<tr><th colspan="2">System</th></tr>
<tr><td>* Ability to be programmed by AAC users</td><td rowspan="2">Not dealt with directly, but this feature could be incorporated at a later stage. The use of Linux provides access to a wealth of free software that can be downloaded. The remote networking facility of the PCA (in this case via radio, but a technology such as Bluetooth could alternatively be used) allows information to be shared between users, and networks.</td></tr>
<tr><td>* Other software features / programs should be able to be added</td></tr>
<tr><td>* Easy to learn how to use</td><td>Minspeak language system was incorporated as the students at the College were familiar with this language representation technique. Other software based systems of language representation could be incorporated at later stages, and alternative interfaces can be plugged into the PCA's Waist pack</td></tr>
<tr><td>* Security of AAC users' information</td><td>• PCA components are camouflaged as everyday items
• Book can be closed to keep material private
• Contents and operation of PCA can be password protected</td></tr>
<tr><td>* Increased memory / storage</td><td>• 1 Gbyte hard disc incorporated
• More RAM can easily be added to PC/104 stack, and hard disc can be upgraded if desired</td></tr>
<tr><th colspan="2">Situation</th></tr>
<tr><td>Can't be used everywhere (particularly outdoors)</td><td>• PCA components are protected from the ingress of liquids (therefore can be used in the rain)</td></tr>
<tr><td>AAC devices block user's vision</td><td>• Book is slimmer and smaller than current devices and can be carried on lap
• The Book can be moved out of the way if necessary</td></tr>
<tr><td>Glare from AAC devices make seeing icons and screen difficult</td><td>• Book can be moved more easily than current devices, as smaller, slimmer and lighter
• Matt finish used on Book</td></tr>
</table>

* Need to be able to use in dark	• Back lighting on keyboard • Back lighting on LCD screen • LED array for icon prediction
* Need to be able to manoeuvre AAC device (e.g. move device out of the way whilst eating) – particularly if AAC user is in a wheelchair	• *Book* can be closed and stowed away easily • *Book* takes up half the area of predecessor AAC devices when folded • *Book* is lighter, slimmer and smaller than predecessor devices • *Waist pack* does not get in the way when user is sitting
Unwanted attention drawn to users by AAC devices	PCA broken up into discrete camouflaged components
Voice quality	
Lack of intelligibility	Laureate voice synthesiser provides English sounding voice and greater intonation than the AAC users' current devices. The voice sounds less artificial that the AAC users' devices
Lack of intonation	
Lack of expression	
Voice doesn't carry well	If worn the *Mobile* allows the voice to be projected and directed by the movements of the wearer
The voice is associated with the machine, not the person	The *Mobile* can be worn so that the voice emanates from the AAC user
* Want to sound like family / friends	Laureate voice synthesiser provides English sounding voice and greater intonation than the AAC users' current devices. The voice sounds less artificial that the AAC users' devices
Other	
Reduce cost	• System modularity • Minimal parts • Use of standard parts where possible for internal components (batteries and hardware) • Designed for variable scale of production, with minimal set-up costs (cheap hard tooling and the use of computer numerically controlled processes (eg LASER cutting, CNC machining) provides manufacturing flexibility)

Table 2: Summary of PCA features in response to identified needs

7.5 Conclusions

This chapter has discussed key features and specifications of the PCA (the culmination of the design activity discussed in the two preceding chapters). The particular functions and features of the PCA have been generated in response to user and technological requirements. These, in turn, have been meshed together within a framework of limited finances and affordable componentry.

Although the PCA is intended for use by people with severe communication disabilities, its use is not limited to that population. Many of the attributes of the final design have equal application in mainstream products. There is no reason why the PCA should not cater for a wider audience, as the same device could potentially cater for anyone having a form of communication disability. Taking this one stage further, there is the possibility for the PCA to also be useful to those without recognised disabilities. Considering that a powerful and up-gradable computer is housed in the PCA *Waist pack*, the system could be used in a number of situations to perform the personal computing of, for instance, business people, students and travellers. There are situations when the 'able-bodied' become disabled by their physical environment. For example, using a lap-top computer when travelling in an aircraft can be precarious. The limited space, vibration and turbulence, people getting in and out of neighbouring seats, and being served drinks and foodstuffs present hazards that lap-tops are not always capable of surviving. Such a situation is not dissimilar to someone with cerebral palsy trying to use a communication aid. The cultural environment can also disable people: not being able to speak the language of the country one is travelling in can be a handicap. As the PCA has the facility to output speech, by the inclusion of appropriate software, one could write or use icons to generate words in English, and the PCA could translate and speak out in another language. One view to take, then, is that the needs of AAC users are not dissimilar to those of able-bodied peers, but tend to be extreme. This idea will be revisited in the main discussion chapter, Chapter Nine.

CHAPTER EIGHT

Evaluation of the PCA

8.0 Introduction

This chapter revisits the user requirements discussed in Chapter Five and the resultant PDS (Appendix VII), and discusses how well the PCA has addressed those requirements.

8.1 Selection of evaluation methods

Chapter Five described a number of test elements, procedures and methods used to assess user requirements, some of which are applicable to the final evaluation of a product. Ten objective test elements of Usability were listed in Chapter Five with respect to HCI (Axup, *op cit*). The use of these elements in the evaluation of the PCA was considered, but decided against, as the PCA prototype was not at a level of completion suitable for such detailed testing (and hence the validity of the results would have been questionable). Additionally, these test elements are really intended to measure the Usability of software rather than hardware. (Their value in this current project would reside in an evaluation of the Minspeak application program specified for use in the PCA.) The fifth of the Usability test elements, 'satisfaction', whilst very relevant to the PCA evaluation, was difficult to measure without conducting longitudinal trials of the PCA in use.

Since the PCA prototype was developed with the inclusion of only a limited range of its potential functions, a full user trial could not take place. Instead, a trial was planned in which the functional aspects of the Minspeak application program were to be simulated in much the same way as described in Chapter Six (section 6.4.2). The basis of the trial was to be similar to the structured video interviews, except that the video camera was to focus upon the user's key-strokes, and only closed questions were to be asked (and hence the answers would be predictable and consistent in time). The AAC user was to be interviewed first using his/her communication aid and then a week later the same interview was to be conducted using the PCA. The period of a week between the interviews was to provide sufficient time to analyse the videotape, record the key-strokes and the respective words or phrases generated, and then re-program the PCA to mimic the AAC user's current AAC device. In this way, the intention was to glean quantitative performance data (comparison of key-stroke time between the current device and the PCA for instance) from the task analysis trial.

As the primary participants had left the College by the time the PCA was ready to be trialed, another student who fulfilled the criteria of the target group (namely illiterate, ambulant, and familiar with Minspeak) was sought for the trial. The student agreed to participate in the trial, but at the last moment withdrew. Unfortunately other students at the College did not fulfil the criteria of the target group. In order to trial the PCA with another student, significant changes to the PCA would have been required (including dismantling the ***Book***, changing the icons, and re-programming it), and hence, such a trial did not take place. This was unfortunate, but in a very explicit way highlighted a key problem of the evaluation of AAC products, and so for the study was a useful finding. The functional testing of the PCA was therefore not conducted as had been originally planned. Instead, the product features were appraised by the author against the requirements set out in the PDS.

It was important to ascertain users' perceptions of the PCA. The way a product is perceived by people is dependent upon the relationship they have with it. Kemp and Van Gelderen (1996) state that the way a product is perceived, "can be divided into three phases: the first impressions, initial use, and habitual use phases." (p140) The selection of methods to evaluate a product is dependent upon the phase of use in which the user is engaged, and the stage of development of the object under evaluation. The majority of the evaluation of the PCA was therefore based upon the first impressions phase, and did not include the habitual use phase because of time and financial constraints.

The following methods were used to evaluate the PCA, and are discussed in turn:

- concurrent evaluation;
- a heuristic evaluation;
- a questionnaire;
- an evaluation interview with one of the primary participants.

8.2 Concurrent evaluation

A number of authors report difficulties of conducting formal evaluations of AAC devices with AAC users (Haaf (1994); Higgenbotham & Bedrosian (1995); McCoy *et al* (1998); and McCoy & Hershberger (1999) for instance). They identify difficulties for both the researcher and the AAC user. Difficulties for the researcher centre on the time and effort required to conduct formal evaluations with AAC users, and the availability of suitable candidates to conduct user tests. Trialing AAC devices with AAC users requires substantial effort on behalf of the AAC users. The physical and cognitive effort of participating in user trials is typically far greater for people with severe communication disabilities than for others, and often additional effort and time are required for the participants to familiarise themselves with the AAC device or systems (in some cases this may require extensive time to brief, train and assess the participants). Higgenbotham & Bedrosian (*op cit*) for instance note that,

> the extraordinary demands placed on many AAC users in terms of their time spent accomplishing daily living activities can seriously conflict with their ability to participate in many research projects. We suggest that in those cases where it is inopportune to directly involve these persons as subjects, they could serve as project consultants, providing feedback about subject-selection procedures and research design issues.
>
> (p12)

For this reason, and given the enormity of the design and development task, concurrent evaluation, consisting of informal evaluative discussions, interviews and practical tests with students and staff at Portland College throughout the design and development of the PCA was the primary evaluative method. The AAC participants at Portland College were consulted regularly and provided the primary focus for these evaluations. Such evaluations included:

- comparing models and drawings (often as paired comparisons) to establish user preferences for such things as design features, tactile qualities, materials and aesthetics;
- asking participants to perform quick tests (such as opening and closing the *Book*, locating and pushing buttons, and so on);
- wearing the *Waist pack* for the duration of an interview and discussing pros and cons of the design;
- using role play to see how an AAC user would attempt to use the PCA in a variety of scenarios.

As the design and development of the PCA was complex, these informal evaluations provided a quick and helpful method to further the development and to ensure AAC users needs were accommodated in the design. Setting up more rigorous testing would have been too time consuming, and would have exposed AAC users to unnecessary pressure.

8.3 Heuristic evaluation

Some of the utilitarian features of the PCA were tested by the author and Dr. Machin by using a heuristic checklist based on the performance requirements listed in the PDS (Appendix VII). A heuristic evaluation involves the expert appraisal of the outcome of the designing, comparing the designed item to the initial specification of requirements.

Some areas listed in the PDS were inappropriate for the author to judge, as they related to user perception (these areas were evaluated by the questionnaire and the interview, and are discussed later). Additionally, not all aspects were tested since only one prototype was made, and testing may have resulted in damage to the PCA. Hence it is inconclusive whether or not the PCA can successfully function in the range of climates specified under 'Environment' in the PDS. Likewise, the splash-proofing of the components were not tested, and the conformance to the standards mentioned in the section 'Standards and specifications' are unsubstantiated. Further testing upon sacrificial versions of the PCA would be required to establish whether the PCA has, or has not, achieved these performance specifications.

The costs of commercial licenses to use Minspeak and Laureate were not discussed with their respective developers, and so the predicted retail costs of the PCA are hard to determine. Based on the costs incurred in producing the prototype, the indication is that the PCA could retail substantially below the £6000 upper limit. The combined hardware costs incurred in the final PCA prototype were in the region of £1500 - £2000.

The main computer board housed in the *Waist pack* incorporated standard ports, and so standard computer peripherals (e.g. a printer) could be used. A major concern was for battery life. Whilst low-power computer boards were used (drawing only 5 Watts), the cam-corder battery in the *Waist pack* was rated at only 1.8 Amp-hours, and as the operating voltage was 5 Volts, the battery would therefore last just under two hours. Developments in battery technology, lower-power processors and better power management will, in time, extend the life in service of the PCA. Additionally, the solar panel was not operational and so the power saving from this would also extend the operating time. The combined weight of the PCA was less than half the upper limit of 60Newtons (6 kg). The *Book* had a mass of 1.2kg, the *Waist pack* was 800grammes and the *Mobile* was 300grammes.

8.4 Questionnaire

A questionnaire was used to garner initial responses by AAC users to the design of the PCA (see Appendix VIII[24]). The questionnaires were answered by a group of Portland College's new intake of students, who were unfamiliar with the research project and the author. The care-givers and helpers of the AAC users in the group were first briefed by the author about how to complete the questionnaire (as the AAC users could not fill out the questionnaires themselves, the questions had to be posed as if in an interview). A short presentation explaining the key features of the PCA was then given to the group by the author. The presentation made no reference to the fact that the design of the PCA was the work of the author (in an attempt to avoid prejudicing the results). The questionnaires were then distributed to the AAC users' care-givers and helpers, who went through the questionnaires with the AAC users. Before the questionnaires were filled in, agreements were signed on behalf of

24 The filled in copies of the questionnaire do not appear in the Appendix for reasons of respondent privacy. However, copies are available from the author by request.

the respondents by their respective care staff. The agreement stated that the reasons for conducting the interview were explained, and that the results would be used for the purposes of research or to compile a report. The models of the PCA were passed around the group whilst the questionnaires were filled out.

The majority of the questions used five-point rating scales to help discriminate between users' perceptions of the PCA. The five-point scale provided a simple guide to help stimulate responses. The first question simply asked what the AAC user thought of the PCA, and was intended to seek immediate thoughts and responses. The second section consisted of questions focusing on the three parts of the PCA in turn, and sought responses on AAC users' likes and dislikes of key features of the PCA. The last section queried how the PCA would affect how users felt about using a communication aid and whether, given the choice, the users would prefer to use the PCA over their present communication aid. Any comments made by the users in relation to a specific question were noted down in a space on the questionnaire.

8.5 Results of the questionnaire

Seven participants completed the questionnaire; the results are tabulated below. Table 3 combines the responses of the first and last two questions on the questionnaire and presents the AAC users' perceptions of the PCA concept. Tables 4, 5 and 6 present the participants' subjective judgements of the *Waist pack*, the *Book*, and the *Mobile* speaker unit respectively. Not all questions were answered by all participants (on some occasions for the reason that participants thought questions did not apply to them, on other occasions for reasons unknown to the author). The tables below present the findings in two formats: frequency count (number of people responding) and percentage response (of the total sample). For clarity the percentages have been rounded to the nearest integer value. The comments of the individual respondents follow the tabulated results.

8.5.1 AAC users' general perceptions of the PCA

What do you think of the PCA?

	Really like it	Like it	Neither	Don't like it	Really dislike
Number	4	2	1	0	0
Percentage	57%	29%	14%	0	0

Given the choice, would you use the PCA over your present device?

	Yes	Maybe	No
Number	5	1	1
Percentage	72%	14%	14%

How would the PCA make you feel about using a communication aid?

	Very happy	Happy	Neither	Un-happy	Very un-happy
Number	4	1	0	1	0
Percentage	66%	17%	0	17%	0

Table 3: General responses of seven AAC users about the PCA

The PCA was well received, with 57% of the AAC users stating that they really liked it, and 29% saying they liked it (14% neither liked nor disliked it). Responses to the last question, 'How would the PCA make you feel about using a communication aid?', were mixed but with a strong positive bias. Of the respondents, 66% said that the PCA would make them feel 'very happy', 17% 'happy', and 17% 'unhappy'. The response to the penultimate question determining if respondents would use the PCA over their current devices was encouraging with 72% saying, given the choice, they would use the PCA over their present devices; 14% said 'maybe', and 14% said 'no'. The PCA was not suitable for the needs of everyone at the College, and so the 'no' response was to be expected.

8.5.2 AAC users' perceptions of the *Waistpack*

		Really like it	Like it	Neither	Don't like it	Really dislike
What in particular do you think of the *Waistpack*?	Number	5	0	1	1	0
	Percentage	72%	0	14%	14%	0
		Very happy	**Happy**	**Neither**	**Unhappy**	**Very unhappy**
Would you be happy wearing the *Waistpack*?	Number	3	2	1	0	1
	Percentage	43%	29%	14%	0	14

Table 4: Responses of seven AAC users to the *Waist pack*

The *Waist pack* received a mixed response, perhaps reflecting the diverse needs of the different respondents. Responses were generally favourable: 72% said they really liked the *Waistpack*, 14% neither liked it nor disliked it, and 14% disliked it. The answers to the question, 'Would you be happy wearing the *Waist pack*?', were varied as the nature of the physical disabilities experienced by the respondents varied and this question, more than the others, was dependent upon the AAC users' physical abilities. The prospect of wearing the *Waist pack*, whilst desirable as an idea, was impractical for one of the participants as he had to be strapped to his wheelchair to prevent him hurting himself. Two of the respondents were actually wearing bum-bags whilst filling in the questionnaires.

8.5.3 AAC users' perceptions of the *Book*

The *Book* received the most comments; perhaps because this section of the questionnaire contained the most questions, but also because it related more to the AAC users' current devices (it incorporated the LLL icons, 128 keys, and a LCD screen). Table 5 presents the responses.

		Really like it	Like it	It's OK	Don't like it	Really dislike
What in particular do you think of the *Book*?	Number	4	4	1	0	0
	Percentage	57%	29%	14%	0	0

What do you think of the:		Really like it	Like it	It's OK	Don't like it	Really dislike
integral key-guard?	Number	2	2	2	0	0
	Percentage	33%	33%	34%	0	0
hinge?	Number	4	1	1	1	0
	Percentage	57%	14%	15%	14%	0
solar cell?	Number	6	1	0	0	0
	Percentage	86%	14%	0	0	0
keys?	Number	2	4	0	1	0
	Percentage	29%	57%	0	14%	0
weight and feel?	Number	3	2	1	0	0
	Percentage	50%	33%	17%	0	0
colour?	Number	2	3	0	1	1
	Percentage	29%	43%	0	14%	14%
materials?	Number	1	2	1	0	2
	Percentage	17%	33%	17%	0	33%
looks?	Number	5	1	1	0	0
	Percentage	72%	14%	14%	0	0

Table 5: Responses of seven AAC users to the *Book*

The most popular feature of the *Book* was the solar cell, with 86% saying they 'really like it' and the remaining 14% saying this feature was liked. The 'looks' of the ***Book*** were also popular with 72% saying they 'really like it' and the remaining 28% evenly distributed between 'like it' and 'neither like nor dislike'. The only categories to receive negative responses were:

- the 'hinge' (14% did not like it, 14% stated an indifferent response, whilst 57% really liked it, and 14% liked it);
- the 'keys' (14% did not like them, whilst 57% liked them, and 29% really liked them);
- the colour (14% really disliked the colour, 14% disliked it, 43% liked it, and 29% really liked it); and,

- the 'materials' (33% stated they really disliked the materials, whilst 17% really liked the materials, 33% liked them, and 17% gave an indifferent response).

8.5.4 AAC users' perceptions of the *Mobile* unit

The *Mobile* unit appeared the most popular of the three parts of the PCA, receiving no negative responses or comments. This was likely to be because it was very different to the AAC users' current devices, and therefore appeared to incorporate the most new features. Table 6 presents the responses.

Question		Really like it	Like it	Neither	Don't like it	Really dislike
What in particular do you think of the *Mobile* speaker?	Number	5	1	0	0	0
	Percentage	83%	17%	0	0	0
What do you think of the feature of: being able to whisper?	Number	4	3	0	0	0
	Percentage	57%	43%	0	0	0
having the voice come from you?	Number	4	1	1	0	0
	Percentage	66%	17%	17%	0	0
it looking like a mobile phone?	Number	5	2	0	0	0
	Percentage	71%	29%	0	0	0
What do you think about the feel of the *Mobile* speaker?	Number	5	1	1	0	0
	Percentage	72%	14%	14%	0	0

Table 6: Responses of seven AAC users to the *Mobile* speaker unit

The idea of the unit looking like a mobile phone was very popular amongst the respondents, with 71% saying they really liked this idea and the remainder saying they liked it. Most of the respondents showed delight at the idea of being able to have the device voice come from their person. The feature of being able to whisper was also highly regarded with 57% saying they really liked this facility and the remaining 43% saying they liked this feature. The tactile rubber material of the *Mobile* casings faired better than the materials of the *Book* with 72% of the respondents saying that they really liked the feel of it, and the remaining 28% evenly distributed between 'like it' and 'neither like nor dislike'.

8.5.5 Respondents' comments

The AAC users' comments are summarised below.

Respondent A

- Female
- 16years old
- Uses a Liberator with 32 large-format keys (as she has a visual impairment.)

Respondent A disliked the colour of the *Book*, stating that she wanted it in bright red and blue ("Red – bright outside. Blue inside"). With regard to the materials of the *Book*, she commented that "the plastic on the Liberator is just as good". She preferred the voice to come from the machine, and also preferred her current American voice (for some unknown reason she did not want to sound English), but also said she might like a Norfolk accent (as that is where she is from). She liked the idea of the *Mobile* looking like a mobile phone, saying it, "Would make me feel beautiful". She could not see very well, and asked whether the PCA could be larger.

Respondent B

- Male
- 20 years old
- Uses a Liberator with a head pointer

Few comments were received by Respondent B, as he felt the PCA was not fully appropriate for his needs (he had very limited control of his body movements). He did state that the PCA would make him feel "Happy. Good".

Respondent C

- Female
- 16 years old
- Uses a Delta Talker

Respondent C would very happily wear the *Waist pack*, "because it wouldn't be so heavy to carry" [as her present device]. She said of the *Book*: "It's small and it don't look like a communication aid", and, "It was light and the leather felt nice". She liked the colour, "but would like [to] have [a] choice", and thought it looked "very smart". She thought the *Mobile* was "modern".

Respondent D

- Male
- 18 years old
- Uses a Touch Talker

Respondent D gave very positive comments about the PCA. He thought the *Waist pack* " ... was small and looked good", but asked, "Could it be smaller? I would like to see a smaller bum-bag". The following comments regarding the *Book* were stated:

- "I like the size and the cover."
- "It was nice and light and the cover felt nice."
- "It looks smart and it's small"

He really liked the solar cell, "because it works with the sun and light' and liked the colour, "but would like more choice. Brighter".

He liked the size and feel of the *Mobile* because "You can hold it in your hand". [The tactile rubber material aided grip, and its size and form were suitable to be held.]

Respondent E

- Male
- 17 years old
- Uses a Liberator with a head switch

Respondent E had athetoid cerebral palsy, and so was restrained in his wheel chair to prevent injury. As a consequence the PCA was not really appropriate for his needs, and he stated that "the Liberator is the best on the market for my needs". He was very unhappy about the idea of wearing the *Waist pack*, and whilst he really liked the *Book*, he said "it is not practical for me". He wasn't able to hold the *Book* but said "it's small, and would be easier to carry [by others]". He also noted that the "finger holes are too short – not deep enough". He really liked the *Mobile* though, as the facility to whisper meant that "private conversations [are] possible ... It's light enough for me to hold [and it is] easy to carry around".

Respondent F

- Male
- 17 years old
- Uses a Liberator

No further comments were made by Respondent F.

Respondent G

- Female
- 19 years old
- Uses a Delta Talker

No further comments were made by Respondent G.

8.5.6 Discussion of questionnaire responses

Although there were limitations of the questionnaire, and only seven responses, the results, nonetheless, produced helpful insights. The PCA was well received and its key features were, on the whole, liked. Interestingly 72% said that they would use the PCA over their present communication aid, indicating that there is indeed a market for the PCA.

The fact that the responses to the materials and colours of the *Book* were mixed is encouraging, as it proves that the respondents were happy to state that they disliked something, thus adding validity to the results. It also showed the AAC users' discernment – they wanted to have a choice. The colour of the PCA can be easily modified, and using colour options to customise the PCA is a simple and inexpensive way to personalise the product and incorporate the AAC users' preferences.

8.6 Evaluation interview with one of the primary participants

A meeting was arranged with one of the primary AAC participants, his fiancée (who is also his carer), Dr. Bruce Baker, Dr. Colin Machin, and the author in London, to discuss the final PCA design, and to get the participant's feedback. The participant, as a Gold Ambassador (an expert user of Minspeak), was attending a presentation organised by Dr. Bruce Baker and Liberator Ltd (the distributor and representative of PRC's products and Minspeak) to promote the launch of a new AAC device, the Vanguard. Dr. Baker kindly took time out from the presentation launch to discuss the PCA with the author, and stated that he was impressed with how the PCA had developed.

After demonstrating the PCA in the meeting, the participant made various comments, and some of his responses were rather poignant. Figure 28 shows the author explaining the features of the *Book* to the participant during this interview. The participant's comments are discussed below.

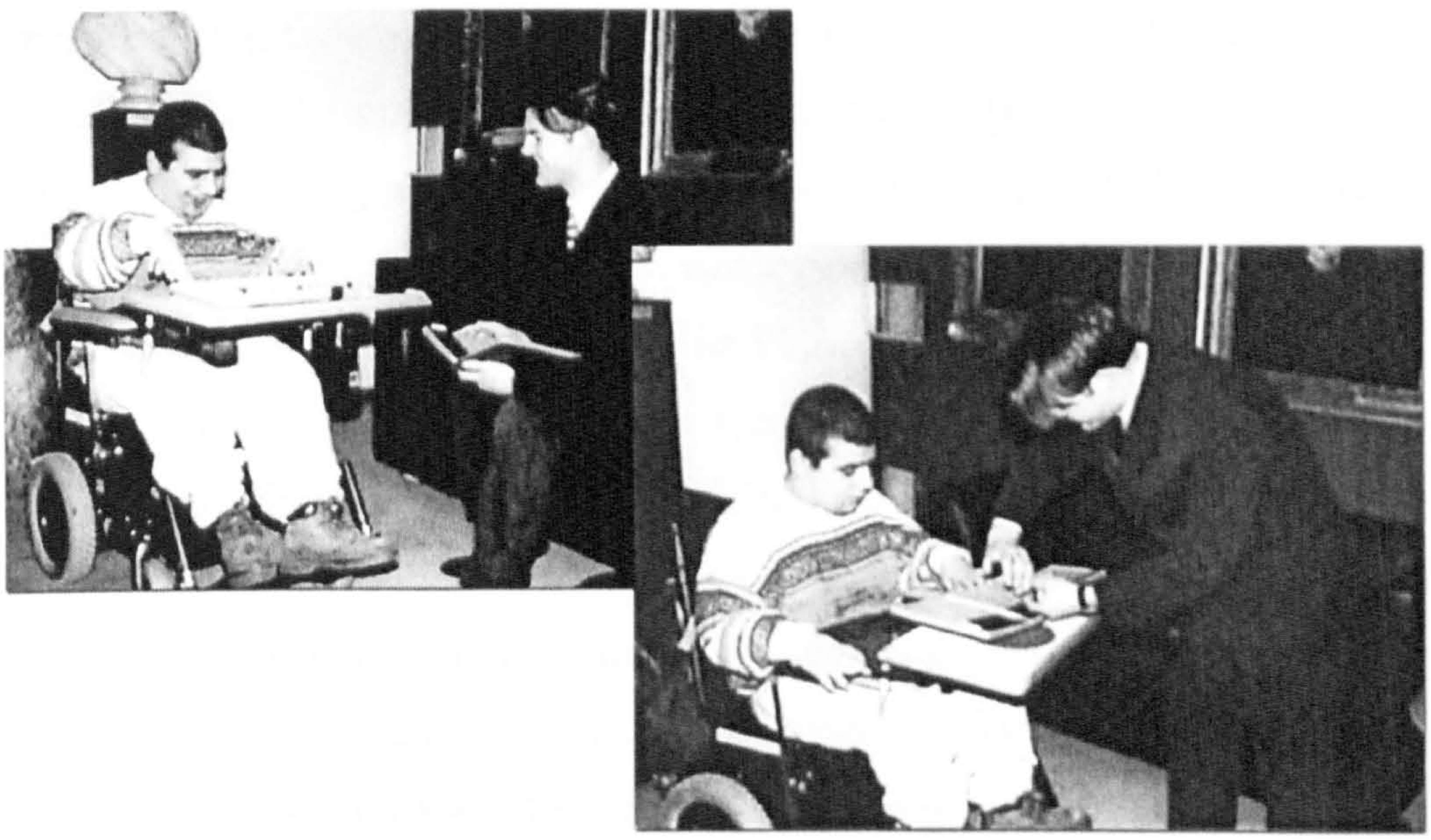

Figure 28: One of the primary participants commenting on the final PCA

8.6.1 The participant's comments about the PCA

The participant, whilst talking of the *Mobile* said, "they [makers of AAC products] need to do that because it is the future and it isn't saying you are handicapped." He continued saying,

> They [makers of AAC products] need to use more like that [the PCA] because they are not thinking. ... They do put stupid cost because they don't think about computers today and what they can do. ... The Vanguard is £6700. I can get computer for about £1500. You need to get that in Liberator because I do feel walking people [ambulant AAC users] do not get what they need.

The meeting continued with the others after Dr. Baker left to give his presentation. The participant valued the opportunity to comment on the PCA, and stated, "I have never been asked my opinion about their [PRC] products", even though he is an Ambassador for Liberator. The author explained that the participant's critical feedback was valued: it was probably more useful to find out from the participant what he thought was wrong with the PCA than anything positive he might say. The participant, however, said nothing negative about the PCA. The interview covered the same areas as the questionnaire, but was more conversational in style.

The participant liked the *Waist pack*, and said he would very happily wear it. He usually wore a bum-bag to contain keys, money, and other personal items. He raised the point that the facility to also carry these sorts of items in the *Waist pack* should be incorporated – he suggested perhaps having an extra pouch or creating a bigger bag to do so. Buying an off-the-shelf bum-bag (or several of them to "go with clothes") was viewed favourably by the participant as he liked the idea of choosing the look and feel of this component of the PCA. He did, however, point out that some bum-bags have fastening clips at the rear, which can be difficult to put on, and so if the *Waist pack* was to be custom-made it should have a simple fastening system towards the front of the belt. The padding and the soft feel of the *Waist pack* was liked as the participant felt it would be resistant to knocks, thus protecting the hardware, and preventing injury to the person using it. The participant thought the *Waist pack* was discreet and liked the fact that it was quite unlike other disability products.

The participant particularly liked the *Book*. He spoke favourably about the features, but the principal attraction was the semantic association and the shaping of meaning and metaphor into the concept. Not only did he believe that the public would perceive him as more intelligent if he used the *Book*, but he would accordingly be treated better. "It isn't saying you are special [disabled] and it does help people to understand more. It is a computer. It isn't from Government for handicapped people." He liked the idea that it might also serve people without disabilities, and appreciated the fact that the author carried it around. The participant was asked to push some of the buttons on the keyboard to determine his preference for the tactile feedback.

> I prefer the button with the 'click' feedback because I need to say I am talking, but I don't want to say I am to talk to all the people in the room. It isn't like my own because it is more quieter. I need to know I have pushed a button.

He mentioned that his current AAC device 'beeped' each time a key was depressed to provide audio feedback. Whilst he needed to know that he had depressed a button, he found that the 'beep' was slightly irritating, and was concerned that it distracted or disturbed others. He preferred the sound that the keys on the *Book* made as it was more discreet. The participant also discussed a key merit of having a book interface:

> I get little kids coming up and pushing the buttons a lot. I can shut the book and if I don't want them to see it I can shut it. I can say [by this action] "get the hell off – it's mine so get lost."
> ... I now have control.

The participant asked, "Can it have a key?" to which the suggestion of having a password instead was offered. "I love the idea of a password. I now have control", he said.

The participant's comments about the *Mobile* speaker unit were very much in line with those of the questionnaire respondents. He thought that the *Mobile* was "great"; that the tactile material provided extra grip and looked and felt "good"; and that the unit looked "awesome". The participant's fiancée commented that, "the mobile will make people look at him, not at the machine." The participant quickly added, "it is more like I am talking."

The participant finished with the following statement:

> That is beautiful because you are thinking about people. It isn't special.
>
> You aren't thinking, "How much can I get from it?" It is for all people. They [the public] need it. Not for handicapped people [it should not be seen as being solely for people with disabilities]. I do love you because you don't say "we can't do that".
>
> It's gone right because you've gone about it the right way – because you listened. I can't say more.

8.6.2 Scenarios of use discussed with one of the primary participants

Different scenarios of use were considered and discussed with the participant. The interview had taken place in a fairly quiet and private setting with good ambient lighting (and was typical of an indoor environment). In this environment the participant found the *Book* and the *Mobile* performed very well: he could view the screen, see the keys, and the volume and articulation of the *Mobile* was good. The meeting was adjourned to a nearby pub. En route to the pub the *Book* and *Mobile* were again discussed. The bright sunshine made seeing the screen of the *Book* difficult, but no more so than his current device. The participant, however, noted that he could reposition the *Book* to avoid glare and reflection. (This is not an ideal solution, but the problem is difficult to overcome: a polarising filter on the screen could be incorporated, or else a shroud could be used.) The *Mobile* was very difficult to hear above the traffic noise. Placing the *Mobile* by one's ear solved this, but again further work on refining the device should be carried out.

The pub provided a useful testing ground. It was fairly dark, noisy, and busy. The screen and keys of the *Book* could be seen adequately in the darkened environment, but the back-lighting was more effective at illuminating the screen than the keys (this problem can be resolved by better concentration and layout of the keyboard back-lighting LEDs). The participant's current communication aid was difficult to hear over the ambient noise in the pub. To hear him required crouching down and placing one's ear closer to the speaker on his machine. The *Mobile* when worn presented the same problem. The participant placed the *Mobile* in the centre of the table along with the rest of the groups' assorted valuables (wallets, keys, a mobile phone). The *Mobile* was positioned ideally so that as everyone leaned over the table the voice could be heard. Figure 29 shows the participant closing the *Book* in the top right image, and the *Mobile* placed on the table (the *Mobile* is bottom left of the photo and is out of focus).

Figure 29: One of the primary participants discussing the PCA in a social environment

8.7 Summary of the evaluative work on the PCA

A brief summary of the evaluative work on a selection of some of the key attributes of the PCA appears in tabulated form below. The table continues on from Tables 1 and 2 (Chapters Five and Seven respectively) and indicates how some of the features of the PCA, developed in response to the problems and identified needs gleaned earlier in the study, were evaluated. A brief statement of the main outcome of the evaluation and the recommendation for further evaluative work is also included against each identified need.

Problem or identified need	How synthesised in PCA (product features)	How evaluated	Outcome	Recommendation for further work
Physical				
Current AAC devices are hard to carry and can put ambulant users off-balance	• PCA weighs less than predecessor devices • Items broken up into separate components that are worn or carried (weight is distributed) • The majority of weight is worn centrally about the waist in the *Waist pack*	Concurrent evaluation with participants	*Waist pack* did not hinder movement when worn. One ambulant participant found it comfortable when wearing it throughout an interview and even suggested that wearing it made him feel more stable	Further field testing and use over prolonged periods required to test the wearability and comfort of the PCA
* AAC devices need to be more resilient to knocks and breakage	• Rugged metal casings used on *Book* which is bound in leather (providing good grip and abrasion resistance) • Padded bum-bag and resilient aluminium chassis protects electronics in *Waist pack* • *Mobile* made of rubber to resist impact and provide non-slip tactile properties	Empirical testing whilst designing, but not evaluated in the final prototype	The casings appear to be very resilient and tough	Destructive testing on sacrificial versions prior to production
AAC devices often breakdown	(as above) • Parts can be replaced with relative ease - standard parts such as batteries are used - designed for ease of assembly - modular parts used - computer hardware is easily upgraded	Empirical testing whilst designing, but not evaluated in the final prototype		Further field testing and use over prolonged periods required to test the reliability of the PCA
AAC devices run out of charge	• Solar cell incorporated • Low power PC/104 boards used • Power management incorporated • Standard rechargeable batteries used (spare batteries can be purchased relatively cheaply and are readily available)	Empirical and heuristic testing whilst designing	PCA runs for 2 hours in continuous use (3 hours was desirable, so only 67% of specification attained)	There is sufficient room in the bum-bag to incorporate an additional camcorder battery to provide a total of 4 hours continuous use with current technology Lower power chipsets can now be incorporated and more efficient batteries used to further increase the life in service

Perception of device				
AAC devices are perceived as unreliable	• More rugged materials and construction used than predecessor AAC devices, eg: - aluminium chassis containing electronic components in *Waist pack* - leather/fabric bumbag provides padding for electronic components in *Waist pack* - SPZ metal casings on *Book* - rubber casings for *Mobile* • *Book* and *Mobile* are splash proof	Concurrent evaluation with participants Participant evaluation interview (Questionnaire)	The PCA was perceived as being tougher and more resilient than predecessor devices	Conduct paired comparison surveys of current AAC devices and PCA
AAC devices are perceived as toys / machines	• Materials and manufacturing processes that provide high quality finishes without expensive production costs have been used • Noble materials used (leather and metal) to provide level of exclusivity • Product design takes cues from consumer electronic products	Concurrent evaluation with participants Participant evaluation interview (Questionnaire)	The positive associations of the components of the PCA were well received in concurrent evaluations, and the looks of the constituent components were liked	Conduct paired comparison surveys of current AAC devices and PCA
Interface				
Fingers slip on keys	• Integral keyguard on *Book* helps locate fingers • Tactile silicone buttons • Buttons are recessed • Resistant material of *Book* allows users to rest or place hands on *Book* without activating keys • LEDs provide icon prediction thus reducing the cognitive load of trying to remember locations	Concurrent evaluation with participants Participant evaluation interview (Questionnaire)	Participants liked features and found it easy to locate and activate buttons (No quantitative data were collected)	Field testing and use over prolonged periods
Keys are wrongly activated				Field testing and use over prolonged periods
Icons wear off keys	• Icons embedded in silicone rubber	Not evaluated (keypad manufacturers can guarantee this aspect)		
Fingers get sore from accessing keyboard	• Soft tactile silicone rubber used for keys • Increased travel of buttons than predecessor devices • Adopted recommendation from BS EN ISO 9241-4:1998	Concurrent evaluation with participants Participant evaluation interview	Participants found it easy to activate buttons and preferred the feel of them to their own devices	Field testing and use over prolonged periods Further empirical testing of ACC users is required to establish ideal forces required to activate buttons
* Tactile feedback on buttons needed	• Tactile feedback from silicone rubber buttons	Concurrent evaluation with participants Participant evaluation interview	Tactile and mechanical-audio (slight clicking sound) feedback preferred rather than the electronic sounding produced by predecessor AAC devices	Field testing with greater number of participants

System				
* Ability to be programmed by AAC users * Other software features / programs should be able to be added	Not dealt with directly, but this feature could be incorporated at a later stage. The use of Linux provides access to a wealth of free software that can be downloaded. The remote networking facility of the PCA (in this case via radio, but a technology such as Bluetooth could alternatively be used) allows information to be shared between users, and networks.			Identify strategies and approaches for AAC users to programme AAC devices independently
* Easy to learn how to use	Minspeak language system was incorporated as the students at the College were familiar with this language representation technique. Other software based systems of language representation could be incorporated at later stages, and alternative interfaces can be plugged into the PCA's *Waist pack*	Not tested, but discussed with AAC users, SLT, and communication s tutors at the College in development	The College's staff thought that AAC users would be able to transfer from their current AAC device to the PCA without difficulty Staff thought that the PCA might provide reluctant AAC users with the incentive and motivation to use an AAC device	Design and develop additional alternative interfaces for the PCA Include and trial other language representation techniques on the PCA
* Security of AAC users' information	• PCA components are camouflaged as everyday items • *Book* can be closed to keep material private • Contents and operation of PCA can be password protected	Concurrent evaluation with participants Participant evaluation interview	Password facility and ability to demonstrably close the *Book* were seen positively by participants	
* Increased memory / storage	• 1 Gbyte hard disc incorporated • More RAM can easily be added to PC/104 stack, and hard disc can be upgraded if desired	Participant evaluation interview	Features liked	
Situation				
Can't be used everywhere (particularly outdoors)	• PCA components are protected from the ingress of liquids (therefore can be used in the rain)	Empirical testing whilst designing, but not evaluated in the final prototype	PCA appears to offer sufficient protection from environmental conditions	Destructive testing on sacrificial versions prior to production
AAC devices block user's vision	• *Book* is slimmer and smaller than current devices and can be carried on lap • The *Book* can be moved out of the way if necessary	Concurrent evaluation with participants Participant evaluation interview	The *Book* was seen as being less of a physical barrier blocking eye contact with conversation partners than predecessor devices	Wheelchair mount needs further design and development

Glare from AAC devices make seeing icons and screen difficult	• *Book* can be moved more easily than current devices, as smaller, slimmer and lighter • Matt finish used on *Book*	Concurrent evaluation with participants Participant evaluation interview	Screen is difficult to see in sunlight	Further work needed • wheelchair mount could incorporate tilt mechanism • use polarised screen covers on display
* Need to be able to use in dark	• Back lighting on keyboard • Back lighting on LCD screen • LED array for icon prediction	Concurrent evaluation with participants Heuristic evaluation	Screen and keyboard can be seen in the dark sufficiently by AAC participants but some central keys did not illuminate as well as those on the perimeter	Back lighting on keyboard needs to be more evenly distributed
* Need to be able to manoeuvre AAC device (e.g. move device out of the way whilst eating) – particularly if AAC user is in a wheelchair	• *Book* can be closed and stowed away easily • *Book* takes up half the area of predecessor AAC devices when folded • *Book* is lighter, slimmer and smaller than predecessor devices • *Waist pack* does not get in the way when user is sitting	Concurrent evaluation with participants	Participants could open/close and manoeuvre *Book* and *Mobile* satisfactorily. The *Waist pack* bum-bag belt clip was at the back and was difficult to put on & take off independently	Design and develop wheelchair mount for non-ambulant users Bum-bags need to have fastening at front or side, not at the back
Unwanted attention drawn to users by AAC devices	PCA broken up into discrete camouflaged components	Concurrent evaluation with participants Evaluative interview with participant	The PCA was less prominent in a social setting than the participant's current AAC device	Conduct paired comparison surveys of current AAC devices and PCA Field testing and use over prolonged periods
Voice quality				
Lack of intelligibility				
Lack of intonation	Laureate voice synthesiser provides English sounding voice and greater intonation than the AAC users' current devices. The voice sounds less artificial that the AAC users' devices	Sound samples of 4 state-of-the-art voice synthesisers (some of which incorporated various male and female voices) played to AAC users and staff at Portland College	Laureate out performed other voice synthesisers	Incorporate features of HAMLET (Murray 1989) and develop an additional or integral interface to control emotional output of voice
Lack of expression				
Voice doesn't carry well	If worn the *Mobile* allows the voice to be projected and directed by the movements of the wearer	Not evaluated		Empirical testing, and field testing of use in a range of situations and environments

The voice is associated with the machine, not the person	The *Mobile* can be worn so that the voice emanates from the AAC user	Concurrent evaluation with participants Questionnaire Participant evaluation interview	This facility was well received	Field testing and use over prolonged periods
* Want to sound like family / friends	Laureate voice synthesiser provides English sounding voice and greater intonation than the AAC users' current devices. The voice sounds less artificial that the AAC users' devices	Sound samples of 4 state-of-the-art voice synthesisers (some of which incorporated various male and female voices) played to AAC users and staff at Portland College	Laureate was the preferred voice synthesiser	Additional voices can be recorded and programmed into the Laureate database – AAC users could pay to have a relative's voice recorded for their exclusive use
Other				
Reduce cost	• System modularity • Minimal parts • Use of standard parts where possible for internal components (batteries and hardware) • Designed for variable scale of production, with minimal set-up costs (cheap hard tooling and the use of computer numerically controlled processes (eg LASER cutting, CNC machining) provides manufacturing flexibility)	Heuristically	Predicted cost of PCA not fully established as dependent upon license royalties for use of Minspeak and Laureate PCA hardware came to £1500 - £2000	Business plane to detail such things as fixed and variable costs of production, distribution and servicing

Table 7: Summary of evaluation of PCA and recommendations for further evaluative work

8.8 Discussion and conclusions

The Introduction to this thesis stated that the success of a design may be judged by how well that design relieves or eliminates various problem(s) that have been set out to address. Judging the success of a design can be difficult, however. Design problems are multi-facetted and can often involve conflicting requirements (as discussed in Chapter Two). Lawson has discussed this in some detail, noting that "the best test of most design is still to wait and see how well it works in practice." (*op cit*, p90) Many works of architecture, for example, are evaluated by their users only after occupancy (as prototyping a building is extremely difficult). With regard to industrial design, however, Lawson's statement, whilst perhaps holding a degree of validity, is a little casual if no other form of evaluation is completed prior to production. Indeed such an approach would be careless, as failure after production can be commercially very damaging and very costly and difficult to rectify.

The evaluation of an artefact that has not yet reached a stage of commercial production, however, presents its own risks. There are no guarantees that something simulated (a model or prototype) will perform and function in the same way as the 'real thing'. Thus the results of evaluations based on simulated items must be treated tentatively. The level of caution that should be exercised decreases as: (a) the realism of the simulated item increases; (b) the number of participants increases; and (c) the item is used habitually.

First impressions of a prototype or a model are, however, equally valid as those formed of the real item, since a model or a prototype can provoke a person's expectations of a production version (this is of course dependent upon the quality and level of completion of the prototype or model). Of course, first impressions may or may not be misleading: this is a personal matter that is dependent on the constructs that individuals form when in first contact with a product. First impressions are nonetheless very important and influential. Purchasing decisions, for instance, are often based upon first impressions or impulse.

In conclusion, the PCA was well received by staff and students at Portland College. Because of the difficulties experienced in getting hold of Minspeak, the final PCA prototype was not fully functional and so user trials could not be performed. The functionality of the PCA, however, was proven by simulation (see section 6.4.2 in Chapter Six). A trial was planned in which the functional aspects of the Minspeak application program were to be simulated on the PCA, but the intended subject of this trial withdrew at late notice. Finding a suitable replacement subject proved difficult and so this avenue was not attempted as initially intended. This experience highlighted some of the difficulties of conducting formal evaluations of AAC prototypes and reaffirmed the experiences of some other developers of AAC systems (Higgenbotham & Bedrosian (1995); McCoy *et al* (1998); and McCoy & Hershberger (1999) for instance).

The process of design and development of the PCA involved on-going and iterative evaluation. AAC users and practitioners were consulted throughout the design and development of the PCA and their feedback upon design ideas influenced key decisions. Informal evaluations provided a quick and helpful method to further the development and to ensure AAC users' needs were accommodated in the design. Setting up more rigorous testing would have been too time consuming within this study, and would have exposed AAC users to unnecessary pressure. The final PCA prototype is a result of concurrent and cumulative evaluation: indeed, Chapter Six discussed some of the refinement of design ideas based upon such evaluative feedback from AAC users. These iterations led to the development of a product whose design was viewed favourably by the participants.

The evaluations based on first impressions of the PCA revealed encouraging and positive responses towards the device, but more extensive evaluations are desirable to conclusively establish the benefits of the PCA over predecessor devices.

Section Three

CHAPTER NINE

Discussion and conclusions

9.0 Introduction

The Introduction to the thesis included a list of several objectives that were met in the course of the research programme.

- To identify and explore the key problems and issues of designing for AAC users;

- To then offer procedural and specification-based resolutions (in the form of design recommendations), thus providing insight into how to cater for the needs of AAC users in design;

- To explore the efficacy of designed objects in raising the status, self esteem and pleasure of AAC users;

- To produce a prototype of a communication device for Portland College (referred to as the PCA), and present an empirical case study of designing for people with severe communication disabilities.

Additionally, Chapter Four identified the following research questions:

Questions relating to *matters of design*.

- What features would improve AAC devices?

- What features will satisfy users' needs, wants, aspirations, purposes, abilities and capabilities?

- How can the features be successfully meshed with technology to produce a product that is functional, desirable, economically feasible, manufacturable, and marketable?

Questions relating to *matters of designing.*

- How does one assess users' needs and wants for an AAC device?
- What assessment methods are available to the designer?
- How can one help users to identify their needs?
- What methods can be used to increase AAC users' involvement in the process of NPD?
- Ultimately, how should one go about designing for the needs and wants of AAC users?

This chapter draws the thesis to a close in relation to these objectives and questions. It presents the chief conclusions of the study and their implications. Broadly two substantive conclusions can be drawn from the study, both based upon the role that Industrial Design (and hence Industrial Designers) can take to improve AAC products (and, by implication, disability products more generally). First, that both the activity and the outcomes of Industrial Design have a valuable role in the empowerment and rehabilitation of AAC users. And second, that key principles have been identified that will enable designers to better identify, articulate and respond to the needs of people with communication disabilities (and the needs of people with disabilities more generally). The conclusions form a set of actionable principles and advice for designers working in the field of AAC, particularly designers with a strong responsibility for R&D (research and development). The conclusions to these research objectives and goals are discussed and summarised under the following subtitles:

- Complexities of designing for AAC users;
- Recommendations for designers;
- Overcoming sociological barriers by design;
- Translating and synthesising user requirements in the design of AAC devices;
- Empowerment through design and designing of the PCA.

Areas in need of further research are discussed at the end of this chapter.

9.1 Complexities of designing for AAC users

Chapter Two concluded that designing for the needs of AAC users is complex and problematic, noting that there is a lack of information and knowledge to aid the designer when designing for AAC users (and for people with disabilities more generally). The chapter discussed some of the wider contexts of the problems of designing for people with severe communication disabilities. This section revisits some of those issues and, in combination with the knowledge gleaned from the empirical case study of designing the PCA, identifies the key factors that a designer needs to be aware of if attempting to design for people with severe communication disabilities.

A number of difficulties were experienced throughout the design process, but those particular to AAC centre upon:

- contextual issues particular to the AAC (complexities arising from circumstance and situational context);
- complexities arising from the physical disabilities of AAC users;
- problems of establishing user requirements and of involving users in the process; and,
- difficulties of evaluating AAC prototypes and systems.

These are discussed in turn.

9.1.1 Contextual issues particular to AAC

Reviews of literature revealed the following contextual difficulties of designing for people with disabilities that affect NPD in AAC:

- the disability market is fragmented;
- there is insufficient financing for projects;
- there are problems associated with the implementation of new technologies;
- there is a lack of coherent and accurate information available to the designer;
- market size, demographic information and anthropometric data of user population are scarce or worse, inaccurate;

- there are inconsistencies of definitions of disability;
- there is ineffective communication between parties concerned in the assessment, design, development, manufacture, use and evaluation of AAC devices;

A designer entering into this field requires an awareness (and perhaps an understanding) of the disciplines likely to be encountered within it. It is necessary for the designer to gain familiarity with the nature of the field in order to proceed to design within it, even though understanding the technology and the language specific to the professionals involved in AAC is daunting. An awareness of the contextual issues particular to AAC helps the designer anticipate and accommodate the complexities likely to be experienced in designing for AAC users.

9.1.2 Complexities arising from the physical disabilities of AAC users

The complex range and nature of the disabilities of those people who could benefit from AAC devices presents perhaps one of the most complicated set of individuals in any market. Designing for this group's physical ability is very challenging for the designer. It is, however, not just the physiological and anatomical aspects of disability that challenge the designer and the person with the disability. Sociological and psychological consequences of physical disability have major implications on designing for AAC users. These issues were discussed in Chapter Two, and a paradox was presented: often the very devices designed to help people in fact compound their problems by drawing unwanted attention to their impairments – disability products often disable their users, not necessarily in a physical sense, but on a psychological and sociological level.

Subsequent chapters revealed that insufficient attention has been given to this important aspect, and that industrial design has a pivotal role in addressing this situation by designing artefacts that empower AAC users.

9.1.3 Problems of establishing user requirements and of involving users in the process

Many of the problems experienced by AAC users are difficult for the designer to anticipate, drawing the conclusion that designers are not able to use their own experience effectively when designing for such people. Further, there is little in the literature on designing for people with disabilities, or on its application in practical situations (let alone more specifically on its application to AAC). The designer is therefore faced with a problem: how to uncover and thoroughly understand the perspectives of people with disabilities. By ignoring this problem, the designer is in danger of using assumption to compensate for a lack of understanding.

For the study it was therefore imperative to involve AAC users in the process of designing. There were particular difficulties of doing this however.

Participation in the design process by AAC users is complicated in that they cannot talk. The articulation of their needs and the transfer of related data from the user to the designer are thus problematic. Traditional techniques for assessing user needs and wants typically rely on the user providing some form of feedback. AAC users cannot talk but instead typically rely on a communication aid to convey their thoughts. The very fact that an AAC aid is used in the communication process in assessing user needs can also detract from the quality and efficacy of the results. Further, many AAC users lack coordinated motor control, and so the representation and exploration of their ideas through non-verbal media such as sketches and models, or of the techniques described by Sanders (*op cit*), were not feasible for the AAC users to perform.

In this instance, the author engaged in designer-facilitated participatory design whereby the author stimulated, interpreted and synthesised participants' ideas in the form of sketches and models in order to more accurately articulate their needs. Trust and rapport were crucial in order to interpret and translate users' ideas with neutrality. Certainly it was time-consuming to take this approach, and there were a number of situational issues that complicated doing so (as discussed in this thesis). The results of this approach were very rewarding however – not only because of the useful information that was garnered, but moreover for providing the time and opportunity for the author to reflect more deeply upon the author's own designing.

9.1.4 Difficulties of evaluating AAC prototypes and systems

Evaluating the results of the design activities presented problems. Evaluation in AAC can be open to bias, as AAC users typically require a third party (e.g. a carer) to fill in (or even translate) documentation (such as a questionnaire). Interviewing AAC users can also present problems. If AAC users' communicative abilities are poor, familiarity of an AAC user's particular communication techniques is often necessary to ensure the answers are interpreted accurately. Product trials may require the AAC user to learn how to use the particular device, and so a period of acclimatisation and training may be required prior to conducting the trial. Further, as other researchers have noted (Higgenbotham & Bedrosian (*op cit*); McCoy *et al* (*op cit*) for instance), evaluating prototype AAC devices and systems can be costly in both time and money.

The process of design and development of the PCA involved on-going and iterative evaluation. AAC users and practitioners were consulted throughout the design and development of the PCA and their feedback upon design ideas influenced key decisions. Informal evaluations provided a quick and helpful method to further the development and to ensure AAC users' needs were accommodated in the design. Setting up more rigorous testing would have been too time consuming within this study, and would have exposed AAC users to unnecessary pressure. The final PCA prototype is a result of concurrent and cumulative evaluation. Further field testing and use over prolonged periods are desirable to evaluate the PCA prototype more comprehensibly.

9.1.5 Summary

Importantly, this thesis has identified and explored the key problems and issues of designing for AAC users, thus presenting, for the first time, a coherent picture of the situations a designer entering into this area is likely to face.

9.2 Recommendations for designers

Chapter Three revealed that there was little advice in the literature with regard to designing for people with severe communication disabilities or on the application of techniques to establish user requirements with this group of people. In response, Chapters Three and Five identified a range of tools and techniques available to the designer that are commonly used in design projects to establish user requirements. It was noted that these tools are useful only when bounded by a context; that is to say, they should be applied with care and not considered as hard-and-fast rules. In the case of designing for AAC users, particular care must be applied because of the situational difficulties discussed earlier in this thesis. The discussion in this section reflects on the experience of designing the PCA, and presents pertinent advice on the application of some of these techniques, focussing on what designers can do to improve their effectiveness when working in the field of AAC.

A number of techniques were used in the designing of the PCA to establish user requirements. Through reading, observation, social intercourse, discussion and interviews, a broad understanding of the needs, wants, abilities, capabilities and experiences of AAC users was established. Over time, a rapport was established with the students of Portland College. The nature of this informal and unobtrusive approach to requirements capture provided a much needed sympathetic comprehension of the nature of the problems faced by AAC users. The observational studies helped to foster an understanding and appreciation of the lives of the participant AAC users, and provided insight into how to conduct interviews with people who have severe communication disabilities. The processes of designing, and the 2-D and 3-D models thereby produced were important in the exploration and articulation of user requirements. Through consolidation of these user requirements, a PDS could be drawn-up which would form a reference for the concept development phase of the PCA project.

9.2.1 Observation

Observation of AAC users can yield extremely useful information and has a very valuable role in ascertaining user requirements. Whilst conducting observations the following should be noted:

- Do not sit in the corner and watch. This only looks suspicious and makes AAC users feel self-conscious and awkward (because they know they are being studied). Instead, observe from a position of involvement. Be active in classes and take notes if need be.

- Do not just observe AAC users' activities, but moreover study what they say, what they wear, what they like and dislike doing. Observe also their communication aids (how do they treat them, use them, abuse them?) How do others treat AAC users? How do others interact with users' communication aids? How do strangers react when they come into contact with an AAC user?

- Observe users in a variety of situations, and at different times of the day, week, and year. Observing users in different seasons revealed unique situations and requirements of AAC devices (e.g. AAC users often get cold hands in winter from accessing their AAC devices, whilst in summer fingers may become hot and slippery). Find out about routines and events.

- With the AAC user's approval, becoming a helper or assisting the AAC user's helper can not only reveal user requirements, but also help the designer gain an understanding of the situations and experiences of AAC users' lives.

9.2.2 Interviews

A variety of texts discuss good interview methods and techniques. There are, however, issues particular to conducting interviews with AAC users that an interviewer should be aware of – these are listed below.

- Prior to conducting an interview with an AAC user, it is worth finding out a little about both the AAC device and of the interviewee's situation (for instance, the nature of his/her disability and issues/topics that may cause distress or discomfort for the interviewee). Additionally, an understanding of the AAC user's communicative ability, including his/her understanding and comprehension of language, literacy levels and motivation to communicate can help the interviewer judge and construct questions that can be understood and answered by the AAC user.

- Try and gain familiarity with the AAC user's communicative strategies (such as the use of gesture, noises, signals and combinations of particular techniques) in order to discern an intended answer (in the same way that a nod or a wink may change the meaning of a statement, an AAC user may have other techniques to communicate which may not necessarily be that obvious to someone unfamiliar with the person). Observation of the AAC user in conversation prior to the interview can help glean such information. In some cases, in order to correctly identify the AAC user's communicative strategies, further discussion with those familiar with the AAC user (a family member, friend, carer, the SLT, or communication tutor) is advisable.

- It was found from the study that AAC users might say something because they know how to say it rather than necessarily saying what they mean (they may not know how to say what they mean). This can unfortunately lead to misinterpretation, and result in a solution that is inappropriate. To ensure the AAC participants communicate their requirements it is invaluable to gain familiarity and to build rapport with the AAC user.

- Be aware of environmental and situational factors that may affect the interviewee's responses or that may impede the interview – for instance bright lights may cause too much glare on the screen of the AAC device being used, or humid conditions may make the AAC user's fingers moist causing fingers to slip on the keyboard.

- Interviews can be both cognitively and physically demanding for some AAC users, particularly if they have severe physical disabilities or poor communication skills. In such cases interviews should be kept short, so as to not be too fatiguing. A typical interview session should last less than half an hour. Accordingly, it is better to conduct more than one interview if the content cannot be covered in one session. Conducting several interviews, each one building on the one before, also provides an opportunity for the interviewer and interviewee to build rapport.

- Questions should be straightforward and constructed using short, easily understood words. Use words commonly used by the AAC user (i.e. observe what words are used by the AAC user in conversations and phrase questions in such a way that familiar words can be used to answer the questions). Be aware, however, that AAC users may answer questions using words that they know, *because they know these words or phrases*, and not necessarily because these words communicate their real intent. (If one has ever sat an oral foreign-language exam, a pre-practiced phrase is always useful to say when the questions are difficult or one wants to impress the examiner. This situation can be comparable to conducting an interview with an AAC user – the interviewer can be seen to be examining the AAC user, and the AAC user often wants to impress the conversation partner.)

- In order to build on what AAC users say, use open-ended questions, backed up with closed questions if necessary. Repeat key phrases and be consistent with terminology.

- If open questions do not yield sufficient detail, offer closed questions, or even 'yes/no' questions in order to draw out information from the AAC user. The interviewer, however, must be judicious to ensure that leading questions are not posed.

- Allow an AAC user plenty of time to answer a question. Do not show signs of impatience if the AAC user is taking a long time to construct an answer. Respect that it is the AAC user's turn to communicate.

- Allow for flexibility and spontaneity during the interview so that it flows and sounds like a conversation as opposed to an interrogation.

- Do not finish AAC users' sentences for them. If AAC users have difficulty answering a question (perhaps they lack the communicative ability or are unfamiliar with how to access the word on their AAC device), re-phrase the question, or offer a closed question to get a more expedient answer. This is to ensure that the AAC user's confidence and independence are not undermined.

- Use design / product examples that AAC users are familiar with and can relate to ("what about making it like...", and so on).

- Use drawings and models to focus questioning and the AAC user's attention.

- Use solid models that are resilient enough to prevent damage that may be caused by an AAC user's uncoordinated movements or lack of control.

- Discuss the AAC user's ideas first, and then introduce your own.

- Do not falsely raise the expectations of AAC users, but rather raise their awareness and discernment.

- Use tact, and discretion.

- Take photos of sessions, and show them to the AAC users next time (to help both parties remember what was discussed (it can also be seen as flattering to those whose photo is taken)).

9.2.3 Reflection on interviewing with AAC users

Conducting more frequent interviews, but with fewer participants was beneficial for both the author and the participants – and ultimately for the study – for a number of reasons. A strong rapport developed between the author and the participants, permitting more open communication. This allowed, when necessary, sensitive and difficult questions to be asked with comfort, compassion and consideration, as mutual trust and respect had already been established. Thus, issues raised by the participants could be penetrated at depth (something more difficult and time-consuming to establish with a greater number of participants). The interviews also provided the participants the opportunity to spend time talking with someone who was keenly interested in their ideas and concerns, and hence they felt valued. The interviews also provided the participants with a form of symposium by which issues central to their everyday lives could be expressed and explained.

For the study, a key advantage of conducting several interviews over a period of time was that new and important areas for investigation emerged both between and during discussions. The time between interviews permitted the filtering of information and the author became more focussed and aware of the salient issues and problems in need of investigation. Over time the author gained greater insight as to what constituted the problematic situation facing AAC users and permitted more appropriate and timely lines of questioning.

Such findings may not have been apparent if only one 'snap shot' interview had been conducted. In essence, interviewing the same candidates periodically provided a more comprehensive account of their needs at different times.

9.2.4 Rapport

Building a rapport with these students throughout the duration of the study provided the opportunity to experience in an intimate way their frustration, hopes and everyday interactions. Being accepted into their social activities gave the author an opportunity to see, at close hand, different sides to these students when compared to their behaviour in a classroom setting. In addition, over the year key events took place in their lives: birthdays, parties, achievements, relationships, illnesses and injuries, and so on. These events provided a more complete picture of what the users required.

Socialising with the students at the College provided the author with the valuable opportunity to gain insights into AAC users (and people with disabilities more generally). Often pivotal information was gleaned from such events – particularly with regard to some of the difficulties AAC users experience in day-to-day life and of some of the shortcomings of their AAC devices (such as not being able to use them in the dark). Socialising in public settings also allowed the user to observe public reaction to AAC users and their devices, reconfirming the statement that AAC devices draw unwanted attention to their users.

To develop the rapport it was important to act upon what the AAC users discussed or stated during the observational and interview sessions regarding design ideas. This would establish trust between the students and the author. Of course, careful reflection was needed to ensure that whilst rapport was established, objectivity was maintained.

9.2.5 The role of design work in assisting AAC users to identify their needs

Sketches of concepts were shown in the interviews to solicit interviewees' thoughts and preferences. The author's ideas were deliberately left until last to ensure that the interviewees' perspectives and ideas were not shaped or manipulated by poor interview technique. In addition, it was important to reassure the interviewees that they were involved in the design of the device, and that their comments were valued.

Sketching the students and placing design ideas upon the same drawing helped to put the concepts in context. Further, drawings would help in the articulation of user requirements by transforming users' own mental models into recognisable and feasible sketched design ideas.

However, physical (3D) models allowed the AAC users to more fluently comprehend design ideas, and proved to be much more powerful tools for evaluating and discerning user requirements than verbal presentations and sketches. The hard MDF models accurately approximated the weight and feel of the intended designs, and although they were more time consuming to produce than softer foam models, the ruggedness they provided was necessary in this instance, as foam models were not durable enough to last the duration of the interview session. There is a great difference in how someone with cerebral palsy interacts with a hard or a soft material – typically the harder material can be used to help support the hand when performing a task. Hence, the MDF models were more useful in establishing whether certain tasks (such as reaching for a button) could be performed by AAC users.

Developing ideas through working prototypes added an important sense of realness to design concepts. Owing to their interactive properties, the prototypes discussed in Chapter Six proved important tools for eliciting user feedback. The prototypes provided important feedback: an action on the user's part resulted in a reaction from the product. Visual models rely on interpretation and imagination to comprehend the final item, whilst working prototypes are easier to perceive and relate to as final production items. Presenting prototyped parts of the PCA to AAC users at the College, and allowing them to try them out and comment upon provided more detailed and empirical feedback on design details than either drawings or solid models could provide.

Presenting and re-interpreting users' ideas in the form of sketches and models whilst designing had many benefits. Working with AAC users in this way permitted them to learn about design, and so in time the participants developed a greater awareness of, and ability to articulate their needs and conceptualise their ideas (albeit through the hand of the author).

The ideas of the participants were often bound by their knowledge of what they believed to be possible or, counter to this, participants would propose possibilities outside the practical constraints of the project. The designer can help users in this regard as the designer has the ability to articulate and 'specify', in functional terms, what is required. In this sense, the designer, knowledgeable in many areas, has a valuable role in articulating user needs. Often the AAC users' statements of their needs and wants became more comprehensive after consultation with the author. In some cases AAC users only became aware of an issue or problem affecting them once it was revealed through this process. The toileting example presented on pages 141 - 142 is an illustration of this – the participant had accepted that he needed assistance whilst toileting but realised, only after discussing design possibilities with the author, that he did not need assistance for the entire duration of toileting.

In generating and presenting solutions the nature of the problem(s) can be better defined. Design can help the process of articulation, making user requirements explicit. This was evident in the interviews; participants often did not know fully what they wanted until they saw it, or until they realised what was possible. Using design to help make needs and wants explicit has much to offer as a research method in that it can reveal more than interview alone. The discussion with one participant over the need to include an internal printer in the communication aid (page 141) is illustrative of the use of design work being used in interviews to more clearly articulate user needs. Whilst others have identified the value of the processes of designing and making in assisting users to articulate their needs (Dandavate *et al* (2000); Sanders (1999; 2000) for instance), research has uncovered no work that discusses facilitating AAC users in the processes of user participatory design. This thesis contributes to the operational knowledge base of design and disability, presenting both design recommendations and an empirical case study of designing for people with severe communication disabilities.

9.3 Overcoming sociological barriers by design

There are many barriers to be overcome within the field of AAC beyond the design of AAC devices.

> The enabling and liberating potential of AAC techniques will not be realised if:
> - attitudes are not positive
> - AAC users' views are not valued
> - communication is not seen as a joint responsibility
>
> (Scott & Murphy, 1995)

Although Scott's & Murphy's paper was targeted at AAC professionals, the public's attitudes towards AAC users (and people with disabilities more generally) needs to be more positive if 'the enabling and liberating potential' of devices is to be realised. There is a great need to change people's attitudes towards people with disabilities, as social doctrine and prejudice can handicap people.

> Willingly or not, designers, by the choice of how artifacts are designed, can affect society. To this extent, even without forethought, the designer makes choices, and these are affected by an underlying set of values. It is important to make this fact more salient. I am suggesting a value-laden approach to design that emphasizes an understanding and indeed the active involvement of the people who will be affected by the design. Our designs can shape society even inadvertently, and as a consequence we need to pay more attention to the longer-term effects our designs have on society.
>
> (Bannon 1986, p29)

Designers are in a responsible position: the products of their work can, and often do, shape and influence people's attitudes. Chapter Two noted that material possessions have an important role in establishing social identity as well as in the construction of selfhood. The chapter discussed the realisation that disability devices can in fact disable their users through negative associations, by social stigma, or more simply by communicating in an undesirable way. These issues shed light on a disputable matter that this thesis has in part sought to address. Goldsmith (*op cit*) makes a distinction between physical handicap and a second form of handicap caused by social doctrine (as discussed in Chapter Two).

> The first kind of handicap can be alleviated by props, usually of a physical character. The second kind is more damaging, in that its cause is culturally entrenched. It cannot be modified by physical remedies. The extreme position postulates that the disabled person is handicapped not on account of his disability at all, but because the cultural mores say so. It is the fault of our society and its competitive value system. To rectify the situation demands a social revolution and a rejection of the prevailing ethos. No amount of tinkering with superficial physical causes can assist. Indeed, the conventional strategy of modification and amelioration by compensation, in essence the strategy endorsed in this book, serves only to exacerbate the position, by reinforcing the already established evaluation of disabled people as deprived and disadvantaged.
>
> (*ibid*, p13)

Whilst the majority of Goldsmith's message is well justified, his point that the situation cannot be modified by physical remedies is disputable and provocative.

This is particularly so in light of the discussion in Chapter Two on sociological and psychological elements of disability. With particular reference to the work of Csikszentmihalyi and Rochberg-Halton (*op cit*) on *The Meaning of Things*, it can be argued the competitive value structure inherent in society can, in fact, be the very same system to offer a resolution to social and cultural prejudices. Competitiveness within the marketplace can lead to greater choice for the customer and improved products (Martin *op cit*). Also, with freedom of choice, the end-user of products becomes empowered (Joyce, *op cit*). Within the scope of industrial design and disability, perhaps the best example of where empowerment has been achieved lies with opticians. Spectacles not only aid visual deficiencies, they are also often a fashionable item. Indeed, wearing glasses can actually have a beneficial effect upon a person's social identity – the wearer being perceived to be intelligent by society, and not, as Goldsmith proclaims, "reinforcing the already established evaluation of disabled people as deprived and disadvantaged" (*ibid* p13).

Products have a social and cultural standing and, alongside this, people aspire to own or be associated with particular products. This goes for cult items, the latest fashions, and those products deemed "classic". As Goffman states, "first appearances are likely to enable us to anticipate ... 'social identity'" (*op cit*, p12), and hence clothing, artefacts and personal possessions (in addition to physical appearance and manner) constitute the constructs of a stranger's social identity. Clothing is an obvious example where the individual is placed into social and cultural groups based upon the observer's value judgements. Attire can be used to establish or impart social standing, or to express an individual's tastes, interests, aspirations and attitudes. Dressing up or dressing down is also a very obvious way in which an individual can attempt to change his or her perceived social identity.

Society has also established particular associations with certain products. The car is perhaps the most obvious example of a product that is a source of conjecture in which to establish attributes of the driver. It has often been stated, rightly or wrongly, that a car is an extension of its owner. For some a car is purely a utilitarian thing, but this is a rare attitude in western society. For most a car symbolises something about the individual. The association of certain vehicles, and even the language used to describe them is value laden. There are cult vehicles (such as Citroen's 2CV, or Volkswagen's Beetle), classic cars (the Mini for instance), cars that are expressions of wealth (Rolls Royce, Bentley), or cars that are sources of ridicule

(Lada, Skoda, Reliant). Sports cars evoke a sense of free-spirit and adventure which is then attributed to their owners. The imagery associated with a product acts as a strong lure and shaper of people's aspirations.

Csikszentmihalyi & Rochberg-Halton (*op cit*) take this point further, revealing that material possessions often define people.

> It is difficult to imagine a king without a throne, a judge without a bench, or a distinguished professor without a chair. In these examples the chair is an essential element of the role of a king, judge, or professor. In the rites of investiture the authority of these positions are given to all three through the symbols of chair and robes. In other words, the ideal of authority is invested in king, judge, and professor; that is, they are literally clothed with the vestments of the positions and can thus command the attention of their subjects through these objects. The original meaning of invest was "to clothe", in the sense of endowing...
>
> (*ibid* p15)

It is the author's contention that conventionally many disability products have addressed, at best, only utilitarian goals in solving problems associated with disability. Designers of equipment for people with disabilities have shown insufficient regard for communicative goals that deal with how such products are perceived. Paul Hogan's statement, presented in the introduction of this thesis, corroborates this when he notes of disability products that:

> No thought appears to have been given to the psychological impact of the design on those who have to use them. The majority of products ... are ugly, shiny and say in the most emphatic way to the purchaser, "You are a cripple".
>
> (Hogan, *op cit* p2)

It is proposed that disability products can be greatly improved by paying greater attention to communicative goals. Such communicative goals include raising status, prestige, desirability, self-esteem, and pleasure for their users. This is not just a case of re-styling, but an exercise in meshing needs, wants, aspirations, purposes, abilities and capabilities of potential users of disability products with technological and functional requirements. The PCA was designed to empower its users by being predominantly inconspicuous (that is the product has been camouflaged so as to not draw attention to its user), but when a conversation is initiated with or by the PCA's user the product enhances the user's perceived status and intelligence. That is, the public may perceive the AAC user to be of reasonable intelligence (to be reading what appears to be a book), to be able to talk and to also be sociable (to be carrying what appears to be a mobile phone). Further work to evaluate to what degree the public perceives the status and intelligence of PCA users, and to compare the conspicuousness of the PCA over current AAC devices is required to substantiate these issues. However, the evaluative comments of the participants indicate that they believe the PCA is less conspicuous, and one of the primary participants further stated that he believes the public would perceive him as more intelligent if he were to use the PCA, and in this regard the PCA has begot an important goal of raising self-esteem of a potential user.

The PCA was also designed to facilitate communication on a number of levels. Coming back to Harvie's definition of a voice being "the expression of yourself to others or anything that gives another insight into your personal world" (Harvie, *op cit*), the PCA not only provides the facility to say something but expresses, through product form and semantic association, qualities the AAC users at the College wanted to communicate about themselves. Within each of the constituent parts of the PCA, communicative qualities have been afforded into the design. The *Book's* form and the choice of materials had cues from consumer electronic products and also had strong visual associations with personal organisers, diaries and books – all of which provided much sought after appeal because of the implicit association of intelligence and communicative ability. The *Waist pack* allowed for personalisation by providing the opportunity for AAC users to cheaply customise or adapt the bum-bag to suit their clothing tastes. The *Mobile* unit adopted forms and cues from mobile phones – products that the AAC users at the College wanted to be associated with because of the status (at the time) of owning one, and for the implicit association mobile phones have with communication.

Whilst further studies are required to fully establish how successfully these qualities were afforded in the PCA, these positive associations were obvious to the AAC users at the College and were received well. In particular, and in the words of some of the participants who commented on the design of the PCA, "it isn't saying you are special [disabled] ..." (page 217); "it's discrete and unlike other disability products" (page 217); "[it] would make me feel beautiful" (page 213); "it looks smart ..." (page 214). Further studies would be required to consider the ramifications of AAC users being perceived to be intelligent, sociable and able to talk (indeed, could it be counter-productive if a conversation partner assumes that the AAC user can communicate at a more advanced level, consequently either placing too much pressure upon the AAC user to communicate or else feeling deceived or frustrated at the level of response?).

This study has shown that the product images and messages AAC devices communicate are extremely important determinants of product satisfaction in addition to the key function of being able to speak. Predecessor AAC devices have under achieved in this regard, but the PCA has made a step towards addressing this.

9.4 Translating and synthesising user requirements in the design of AAC devices

The Introduction to the thesis proposed that designing is about tackling problems. Three key components of tackling were identified – grasping, wrestling and finally overcoming. Problems of designing for Augmentative and Alternative Communication users (and more generally, people with severe communication disabilities) have been *identified* throughout the thesis. Distinctions have been made between matters of designing (as an activity) and matters of design (as product specification) and both of these matters have been *wrestled* with. The principles and actionable advice generated through the research enquiry have been *synthesised* in the PCA product, with the ultimate aim of *overcoming* AAC users' physical and emotional disabilities.

The successful translation of user requirements into a product requires open communication between the parties involved in its design. The industrial designer who is versed in technology-centred and human-centred disciplines provides an ideal mediator between the users and the separate disciplines involved in the development of high-technology products for people with disabilities.

The industrial designer is also ideally placed to take a fresh approach to the design and production of AAC devices. Often industrial design artefacts are consumer-oriented, and desirability is a key determinate of their success. The industrial designer places a high priority not only upon the function of an item, but also its form (and hence the semantic messages it conveys). Meshing the often complex and diverse requirements of user needs and technological feasibility is difficult, but a key skill of the industrial designer is making these connections; the results of which are often new and innovative.

9.4.1 Matters of design (as product specification)

The principle idea for the *Book* was to camouflage the technology and to attach to the product an association of intelligence, whereby those using it would be perceived to be literate and, hopefully, intelligent. A book carries more than just the association of intelligence, however. The information or stories contained within books, rather than the physicality of them, stimulates emotive or reactionary responses. In this way, the intention of the *Book* was to draw the public's attention away from the 'machine' and to focus upon the content of what was generated upon it and spoken by the PCA (in other words, what the user was saying). The association of books with story telling was also apt for the PCA, in that a story-teller can captivate an audience by reading from a book. The correlation between learning and books was also intended to be explicit, as the PCA was intended to be used as an aid for learning.

The *Book's* resemblance to a personal organiser or a diary was by no means coincidental. Both objects are used to store personal information, and have significant value to their owners. Likewise, the *Book* sought to foster such an association. The design of the *Book* had additional virtues as discovered through concurrent evaluations with AAC users at the College:

- avoidance of unwanted attention drawn to the user (to all intents and purposes the user is reading);
- a means of keeping private material private (the *Book* can be closed by users);
- the act of closing the *Book* allows a very demonstrative statement to be made: "I don't want to talk to you" (this was discovered when demonstrating the PCA to one participant).

Breaking the system up into discreet components is a distinct departure from the status-quo. It is tempting to suggest that advances in circuit packaging density, battery technology and power management will ultimately allow all the electronics to be housed within the PCA's *Book*. The separation of the various parts of the system, however, is an integral part of the design concept. The *Waist pack* is seen as assisting the semi-ambulant user in maintaining a better posture and provides a secure repository for the more expensive parts of the system. The *Mobile* speaker concept allows the user's voice to emanate from the correct part of his or her body or to facilitate a private conversation. The advances mentioned will, though, allow the unit to be thinner and lighter and will certainly offer extended endurance.

More generally, the PCA has inherent design features and has incorporated key principles that are equally applicable to other projects in the disability sector. These include:

- modularity of components;
- separation of interface, processor and output devices;
- camouflaging technology;
- affording meaning through semantics and metaphor (e.g. association of intelligence);
- using remote links to other components;
- using noble materials (metal and leather) for their longevity and patina;
- making use of standard parts (such as batteries) to minimise costs and provide greater availability of replacements;
- utilising standard hardware (upgrading is simple);
- push towards software over hardware solutions (e.g. using a software-based voice synthesiser).

9.4.2 Advances in technology

Since the completion of the PCA, significant technological advances have been made – particularly in the field of wearable computing. Most notably the miniaturisation of components and the development of more energy efficient chipsets offer substantial benefits for applications such as the PCA. Another significant advancement is in the development of digital wireless communication technologies, such as Bluetooth. Battery technology has, however, advanced at a far slower pace. Ultimately the incorporation of such advances in technology would substantially improve and enhance the principles and ideas inherent in the PCA, resulting in a better product in terms of it being lighter, cheaper, and more energy efficient.

Advances in technology also provide the designer with greater opportunities to accommodate additional features that could enhance user satisfaction. This study has gone some way to provide a useful briefing document outlining user needs and wants, and has established a firm basis upon which advances in technology can build upon principles and ideas inherent in the PCA's design.

9.5 Empowerment through design and designing of the PCA

The results of the study showed that both the process of designing and the outcome were considered successful and were well received by the AAC users at the College. The PCA provides not only a technological and manufacturable resolution, but contributes to the psychological and sociological well-being of AAC users.

The key to this success is believed to lie in the following:

- The originality of the PCA. Whilst the technology, broadly speaking, is simple and has nothing out of the ordinary, the manner in which this particular AAC device is packaged is seen as unique and novel. Breaking the system up into discreet components is a distinct departure from the status-quo. The *Mobile* can be worn so that the voice emanates from its wearer (and hence the voice is associated more closely with the AAC user). The *Waist pack* too can be worn, and can be easily and inexpensively customised – that is the chassis is designed to fit into a standard bum-bag, so users can house the PCA according to their fashion tastes. From a manufacturing perspective the component parts of the PCA require minimal investment to produce a high level of quality and finish, and the manufacturing processes are equally applicable to low-batch or mid-high volume production.

- The *Book*, *Waist pack* and *Mobile* were designed to empower users by being predominantly inconspicuous (that is the PCA has been camouflaged so as to not draw attention to its users by blending in with the user's everyday clothing and environment). This grants a much sought after degree of anonymity.

- The PCA can give AAC users a voice. In response to Harvie's definition of a voice ("the expression of yourself to others or anything that gives another insight into your personal world" (*op cit,* p137)), the PCA does more than providing the facility to say something. The PCA promotes AAC users as people, and does not reinforce, compound or emphasise their disability by drawing unwanted attention to them. The inclusion of the Laureate voice synthesiser provided the AAC users with an English sounding voice that was more appropriate for them (given that the AAC users lived in the UK), and that sounded more 'normal'. Additionally, the product has been designed to not appear as a communication aid but rather as a set of discrete and desirable items.

- AAC users have also had a voice in the creation of the PCA, as they were fully involved in all stages of design, development and evaluation. Such participation provided the author with substantial insight into the needs, wants, abilities and capabilities of AAC users. Moreover, participation ensured AAC users were involved in key decision-making and helped to make the AAC users feel valued.

- The author facilitated AAC users in participating in the design process by interpreting and presenting their ideas in the form of sketches, models and prototypes. The role of the designer in this process allowed AAC users to explore design ideas in a way that they had not been able to do before (unlike most participants described in user participatory design, the AAC users lacked the physical dexterity to create and explore in 2D and 3D). Translating users' ideas into 2D and 3D proposals helped articulate AAC users' requirements and allowed the smooth flow of conceptual ideas into reality. Further, presenting and exploring design ideas with users allowed them to see what was possible, and thus encouraged them to be more demanding of manufacturers.

9.5.1 The designer's role in the empowerment of AAC users

Contributors to the field of AAC come from a variety of professions. It is a multi-disciplinary field, yet one in which the industrial designer has made little contribution. Many SLTs and AAC users have outlined problems with equipment, yet perhaps have not realised that these could be remedied by involving industrial design. Many products in the disability sector have not been designed by industrial designers. There is thus a great need for industrial designers to work in this area.

There is also a great need to change people's attitudes towards people with disabilities. Designers may be in a position to do this: the products of their work can, and often do, shape and influence people's attitudes. The size of the market for products within the disability sector, and the scope and need for products within it, provide a tremendous opportunity for industrial designers to get involved and focus their attention on resolving the issue of poor products within the disability sector. There are opportunities to make money, produce better products, and ultimately direct problem-solving to the task of fulfilling human needs. By designing products with the needs of people with disabilities in mind, the industrial designer can offer much for the benefit of everyone.

There are many advantages of taking this approach. By widening the market to encompass as many potential customers as possible, whilst still meeting the requirements of AAC users, greater product numbers can be produced. In turn, production costs are reduced, and thus the price per unit can come down, and/or greater profits can be made. By having a wide selection of the population using the PCA, with different needs but performing the same task of communicating with one another, perceived barriers could be broken down. In essence, widening the market for such a product means the product is more widely known, accepted, and taken for granted. Hence, referring back to Thomas' observations of how people with impairments are received by society (discussed in section 2.3.1), it is as if one of the 'signals' providing "a visible cue to the public to anticipate an 'atypical' person" (*op cit*), is lessened. Further, this approach could provide an opportunity for AAC users and the wider public to better integrate, socialise and grow and learn together. One of the participants stated that he believes this to be true, and that he would feel more 'normal' and accepted as a result. An example of where the perception of a product has changed as the diversity of the population using it has increased, is the use of mobile phones. When mobile phones were first introduced as a consumer product they were seen as a status item: only the affluent could afford them. Now society's attitude is somewhat different; mobile phones are common place, and so attention is not drawn to people using them. In short, the transfer of technology and ideas from the disability sector to mainstream markets, and vice versa, helps all.

Designing for the needs of people with disabilities teaches a designer a great deal. Attempts to tackle complex problems and catering for the needs of people with disabilities develops and broadens a designer's understanding, knowledge and skills. The synthesis of this enlightenment may well result in better solutions and, hence better products, but unless more designers do this, this statement will remain speculative. To see the kinds of benefits and positive reception brought by a product such as the PCA, there is great need for industrial designers to increase their involvement in the field of AAC (and more widely in the disability field). These benefits and the positive reception revolve around the ideas that the product:

- becomes a more valued item to its user (knowing that users have been involved in the process means that hopefully users' needs have been taken account of in the design);
- is designed to be affordable;
- is designed to accommodate users' needs, wants, abilities and capabilities.

On initial encounter, the needs of people with disabilities often appear distinctly different to those of the so-called 'majority of the population'. Such a difference would appear to require special consideration in the design of artefacts for people with disabilities. Whilst to a degree this is valid, over-emphasis on the differences can create more of a problem than attempts to resolve them. The field of RT/AT has been dominated by the medical model of disability, and hence many disability products have been designed to repair, replace, or provide a substitute for what people are believed to have 'lost' by their impairments. Few disability products would appear to have taken account of the social or psychological impact their designs have upon their users. The importance of integration and acceptance of people with disabilities into society has been recognised by disability groups yet few products have helped to facilitate this. People, be they disabled or not, have the need to feel as if they belong to society, and products have an important role in the construction of social identity (Goffman *op cit*, Csikszentmihalyi & Rochberg-Halton *op cit*).

9.6 Areas in need of further research

The empowerment of AAC users, and more generally of people with disabilities, will require more than the involvement of designers. Societal change in this regard is somewhat Utopian. Educating the public, and making the needs, wants, abilities and capabilities of people with disabilities explicit, would be an ideal solution, but an arduous one. Entrenched attitudes are hard to change. However, the contribution that industrial design can make through the design of products that cater for people with disabilities is an important step towards societal change.

To help the industrial designer and AAC users in this regard, it is desirable to educate AAC users, and those responsible for the assessment of people with communication disabilities about what is technologically and practically possible in design (and thus raising all users' expectations of AAC products). This, however, is based on the proviso that those responsible for the design, manufacture and implementation of AAC products are also aware of what is technologically and practically possible in design, and of the requirements of users.

With regard to the PCA, further work is required to develop and produce several, complete versions of the PCA in order to perform more lengthy trials of use. Rapid prototyping of the components of the PCA is now relatively simple (although costly, and time-consuming), as much of the tooling and data to produce parts was generated in the production of the prototype. Getting hold of an operational version of Minspeak to run on the PCA would also be advantageous to conduct these trials (or alternatively, the development of a new language representation system would be required). Table 7 in Chapter Eight identified further recommendations for evaluative work on the PCA..

The design and development of additional discreet interfaces to permit a wider range of people with communication disabilities to use the PCA is also desirable. Further work to include the control of emotional characteristics on the PCA is an area that is certainly feasible and worth considering. Developments in miniaturising computer technology and wearable computing present exciting opportunities to develop smaller, lighter, and even more discreet communication aids. Indeed, there are some important connections between wearable computing and AAC that could provide a healthy research symbiosis – particularly with regard to discrete, yet resilient interfaces and wearable technology.

9.7 Endnote

At the commencement of this project, the author felt daunted by the prospect of designing for people with severe communication disabilities. There was disparate and inexplicit advice on how to design in this area and little information about the needs of AAC users.

Through the process of literature reviews, designing the PCA, and spending time with AAC users at Portland College, a unique understanding and appreciation of the problems experienced by AAC users was gained. This enabled the successful design and development of the PCA, fulfilling not only their communicative requirements, but also their psychological and sociological needs.

The author is now in the privileged position of being able to offer advice, through this thesis, to those involved in the design, development and implementation of AAC devices. This body of work is intended to assist designers needing to overcome all the inherent work difficulties present in the field of AAC, and provides an example of what is achievable with limited resources, but a commitment to problem-solving to meet human-needs.

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Appendices

Review of communication aids used at Portland College

Devices utilising Minspeak

The majority of the College's students were using devices that utilised Minspeak. The company who developed Minspeak, Semantic Compaction Systems, have very strong links with the Prentke Romich Company (PRC) who have been working in the field of AAC for thirty years. PRC are the self-proclaimed, 'world-leading manufacturer in augmentative and alternative communication systems, environmental controls, and computer access devices for people with disabilities', being three times the size of their nearest competitor. The Company's close ties with Semantic Compaction Systems has been a healthy symbiosis, with one company providing the technology, and the other the concepts and language. At the time this study commenced, PRC was the sole manufacturer of products that incorporated Minspeak.

Touch Talker

Mass: 2.7 Kg
Dimensions: 330 x 226 x 89 mm
Price: £2350

PRC introduced the Touch Talker in 1984 and it was the first commercial product to utilise Minspeak. Its simple 'box like' construction incorporates circuitry, a rechargeable battery pack, a built in speaker, a forty character display, and the *Smoothtalker* voice synthesiser which has a male and a female voice. An 8 x 16 keyboard matrix provides 128 membrane-keys that are used to select words and phrases. Optional keyguards and overlays can be used to reduce the number of keys to either 32 or 8 locations, in so doing, providing larger keys and reducing the functions of the machine. An appropriate MAP is selected for the particular user, and a corresponding keyboard overlay is fitted under the keyguard.

The device can be wheel chair mounted or carried like a case, although its weight prevents it from being truly portable for someone with limited motor control. A serial interface allows memory to be transferred to and from other machines, as well as permitting communication with other devices.

Light Talker

Mass: 2.9 Kg
Dimensions: 330 x 226 x 102 mm
Price: £2350

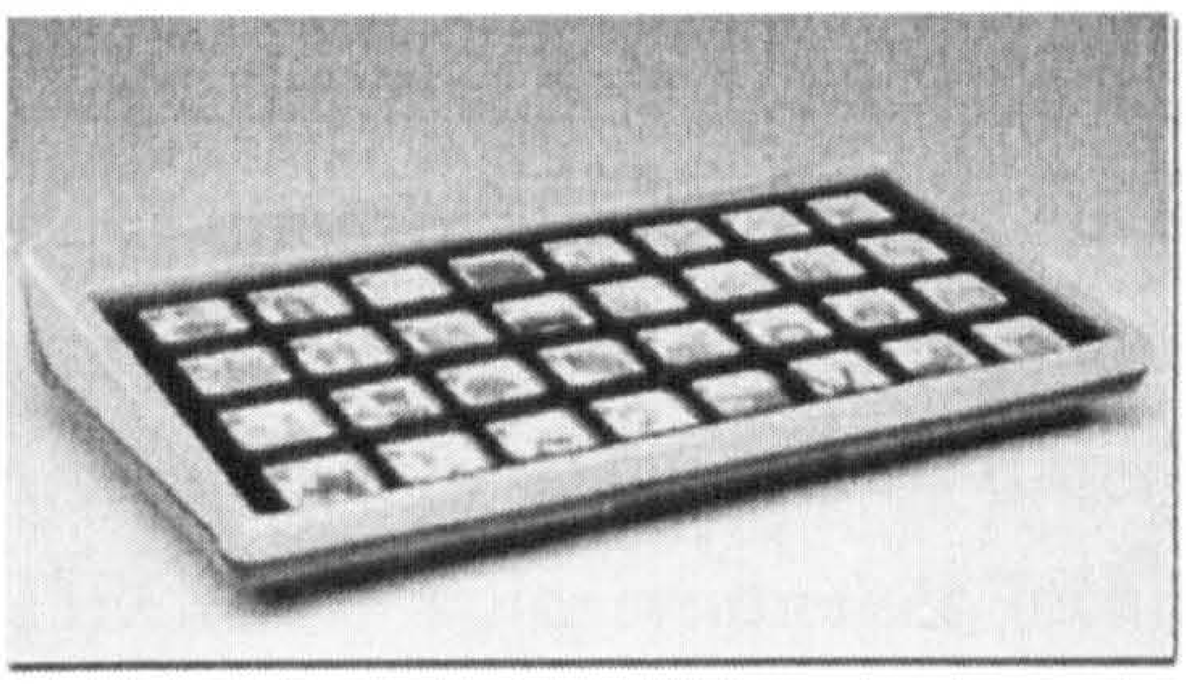
The Light Talker was launched the following year, and is essentially the same as the Touch Talker, bar the method of accessing the device. The Light Talker is primarily for those users who cannot operate a keyboard, but have some reliable body movement, such as the ability to move the head from side to side. The keys are activated by an LED sensor in the top right of each key, and are selected either directly using an optical head pointer, or by a scanning selection technique (the rows on the keyboard are illuminated in turn, and the user stops when the icon they wish to select is in that row; the same procedure then applies to the columns, the intersect being the desired key.)

Intro Talker

Mass: 1.8 Kg
Dimensions: 330 x 170 x 100 mm
Price: £640 - 1192

1988 saw the arrival of the Intro Talker, a 32 key device incorporating digitised speech to output recorded messages. This requires the messages to be pre-recorded by a helper, and can be used individually or recalled as sequences. The device is limited in its facilities, permitting only 256 coded entries and no more than two minutes of poor quality recorded speech, but can serve as a useful introduction to using the more expensive Touch Talker.

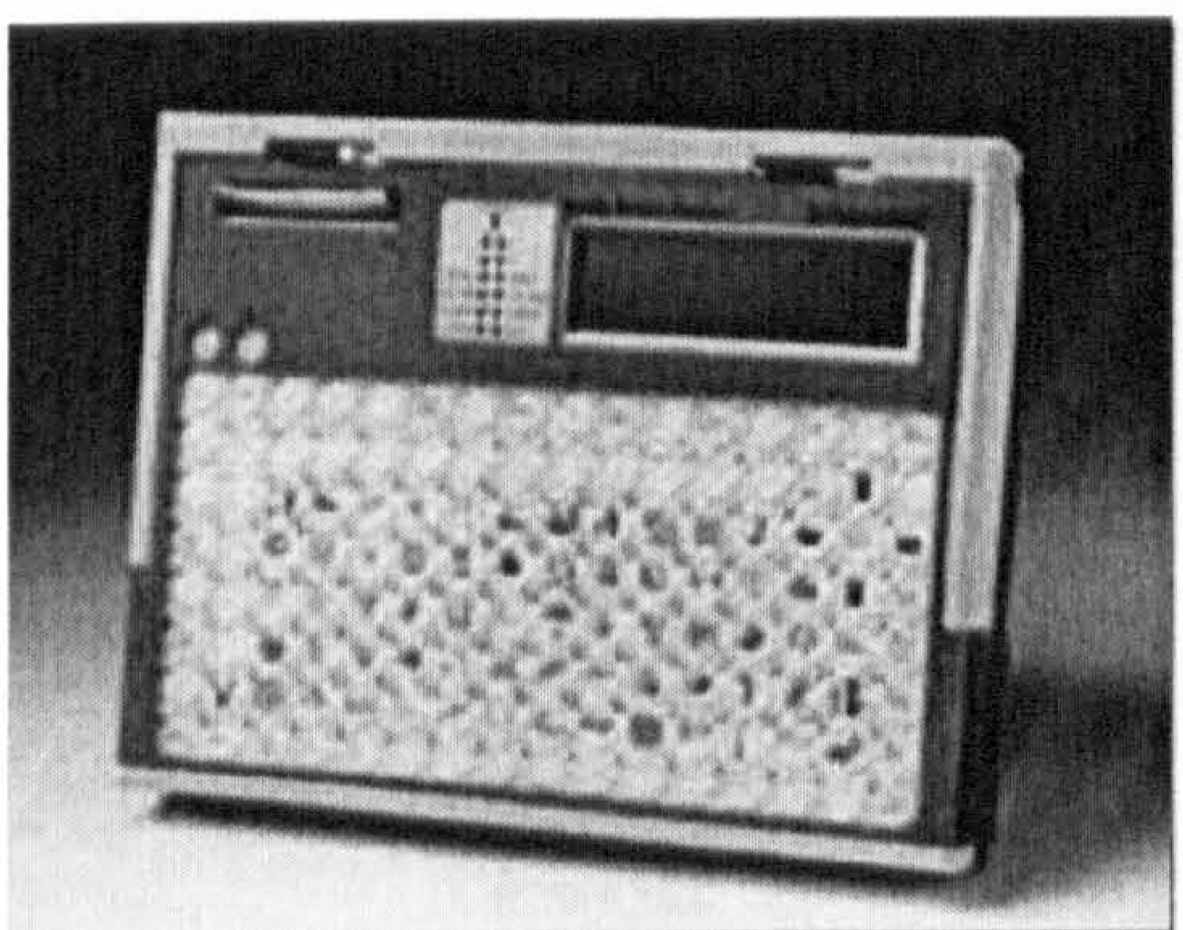
Alpha Talker



Mass: 1.3 Kg
Dimensions: 345 x 210 x 50 mm
Price: £1295 - 2090

The Alpha Talker, introduced in 1993, was an upgraded version of the Intro Talker, and was brought in to replace it. Improvements to speech quality, and memory were made, permitting up to 25 minutes of digitised speech to be stored. Icon prediction is also included along with a feature permitting only those keys that are lit to be selected, thus reducing unwanted activation and increasing the overall speed of word production.

Liberator



Mass: 3.6 Kg
Dimensions: 330 x 260 x 90 mm
Price: £5800 - 7000

The Liberator, to some extent, superseded the Touch Talker and Light Talker, permitting access by various methods and in so doing ensuring its use by a wider audience. Introduced in 1991, the Liberator was the flagship of the company, incorporating many more features than its evolutionary predecessors. Icon prediction, that is the illumination of the next set of keys in a sequence, is an important feature, proving an excellent learning tool and memory aid, resulting in the user having to remember less whilst increasing the accuracy of use.

A larger eight line display shows what is to be spoken out, as well as allowing the user to edit text if necessary (e.g. defining the pronunciation with the use of the on board speech dictionary), and includes other features such as displaying the date and time. An internal 'till-roll' printer can produce a written record of messages, and a serial link is provided to use an external printer if desired.

The Liberator can access other computers and peripherals, allowing the user to write documents, lists and letters; operate a standard Personal Computer (PC) with the

Liberator acting as an alternative input device; and save or down load the contents of the memory to another machine or computer disk.

Four different vocabulary sets can be stored, permitting either four different users to use the device, or a single user to make use of different MAPs dependent upon the situation they are in. Ten different voices are provided on every machine by a DECtalk™ voice synthesiser, including male, female and children's voices.

The increase in features, however, comes at a cost - increased weight and a substantial increase in price.

Walker Talker

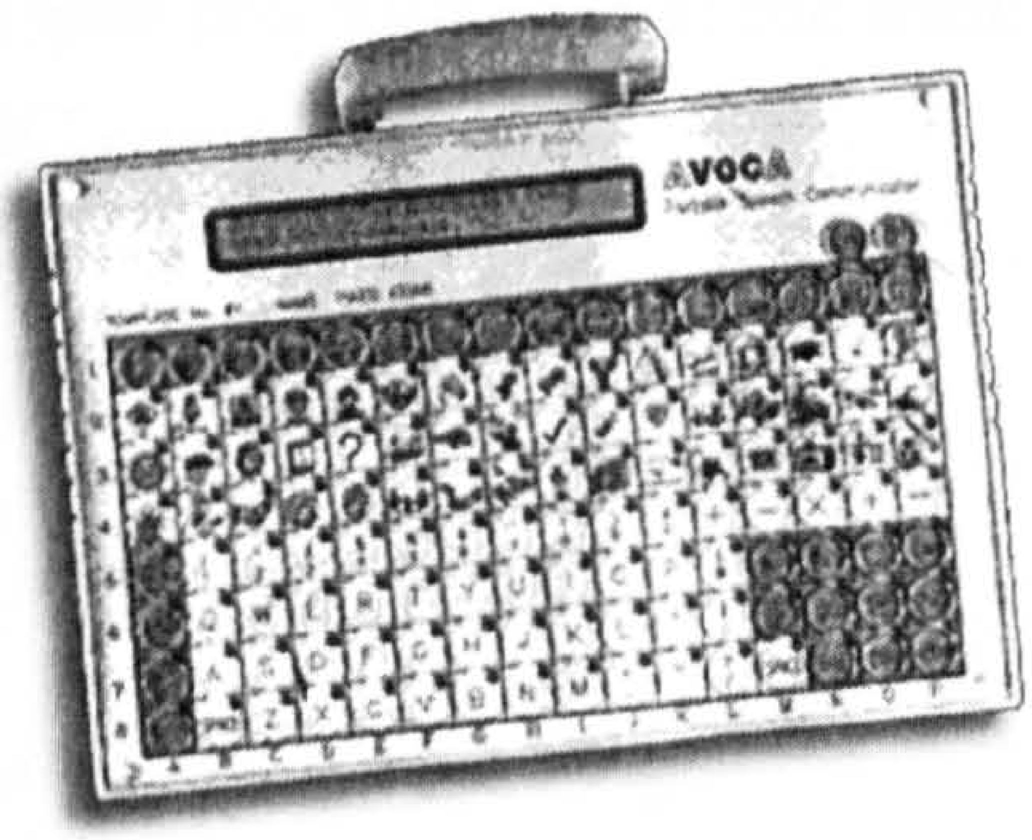
Mass:	0.9 Kg
Dimensions:	340 x 67 x 35 mm
Price:	£640 - 1192

The most portable product in the PRC range, the Walker Talker is a digitised speech aid that is worn on a belt around the user's waist. It has a 16 location membrane-keypad and makes use of the Minspeak symbol set to provide up to two minutes of speech. This product is very limited in what it allows a user to say, as only 16 messages can be stored. At £40-74.50 per message, its benefits are questionable.

Non-Minspeak devices

Other communication devices were used by the College's students and, although these were less prevalent, it is worthwhile describing them here.

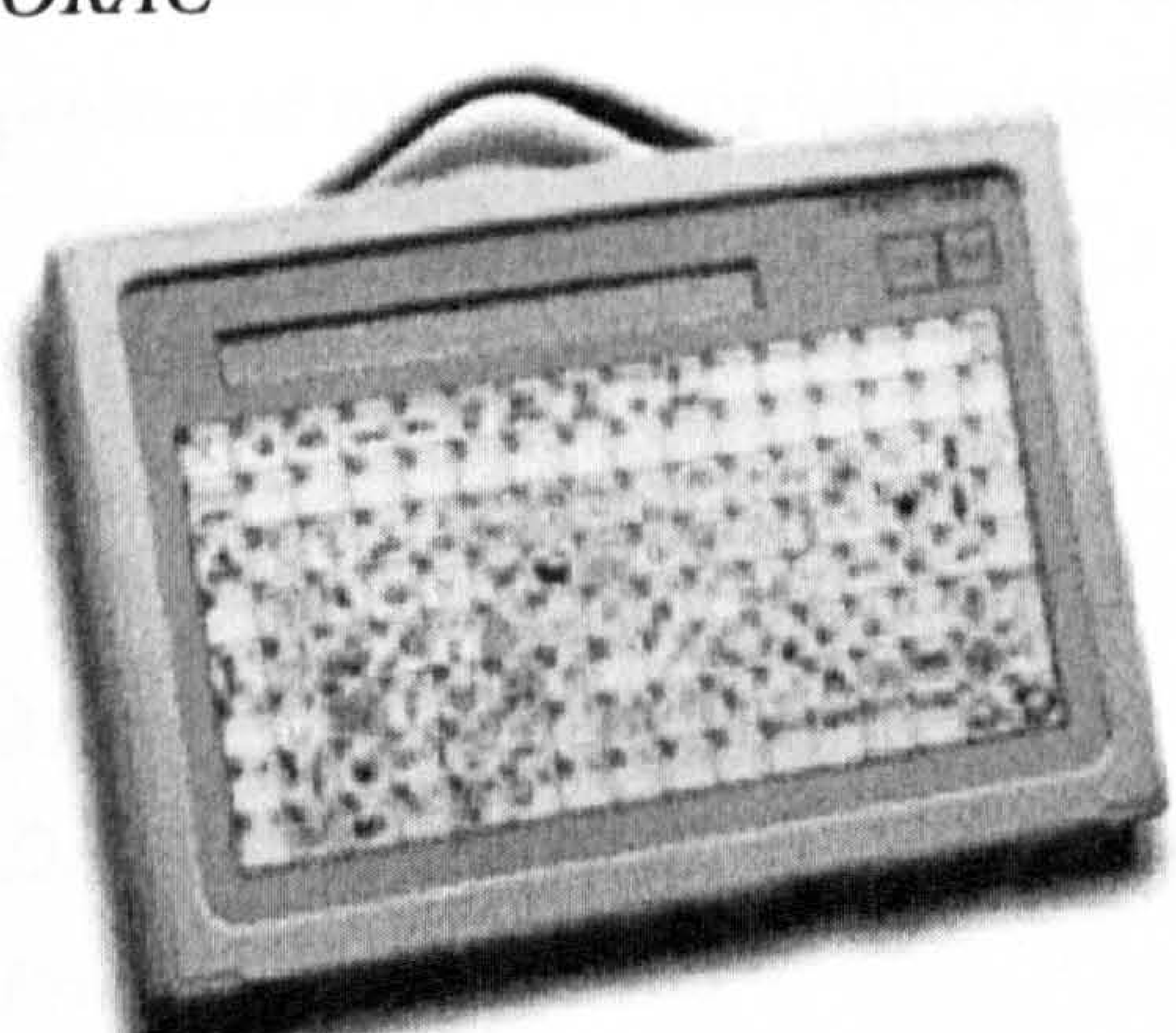
AVOCA



Mass:	4.0 Kg
Dimensions:	340 x 235 x 105 mm
Price:	£2700

The AVOCA portable speech communicator, available from Elfin Systems Limited, appears remarkably similar to the Touch Talker, even down to the LCD, handle, graphics and on/off switches appearing in the same places. The device makes use of an 8 x 16 matrix key-pad with an LED in the corner of every key (to the top right as opposed to the top left as is the case on the Touch Talker). The AVOCA is targeted at both literate and illiterate users: 48 of the keys show icons that when selected speak out pre-stored words and phrases through the voice synthesiser, whilst 64 keys form an alphanumeric keyboard permitting words and phrases to be typed in.

ORAC



Mass:	2.3 Kg
Dimensions:	290 x 200 x 70 mm
Price:	£1120 - 2350

The ORAC also appears very much like the Touch Talker, with similar features and design. The ORAC is a cheaper version though, as it does not include Minspeak and has its own simple voice synthesiser, ORAtalk, which has only one voice. (The option to have a DECtalk™ voice synthesiser is available, but will cost a further £1230.) Both digitised and synthesised messages can be stored by recording them (either through a microphone for digitised speech, or by typing in text for synthesised speech) and recalled by selecting one of the 128 touch-sensitive keys with the corresponding icon or text associated with that message. Plastic sheet overlays can easily be adapted to provide an appropriate vocabulary set tailored to the particular user. These overlays are simply inserted into a transparent wallet that rests over the keypad.

The inclusion of both synthesised and digitised speech is an asset of this device, as it allows a user to record sounds (eg particular film stars) so that its users can do such things as perform impressions or interject humour into conversations. Output jacks are also provided so that the memory can be transferred and updated from an Acorn BBC computer.

VOIS 136

Mass: 1.6 Kg
Dimensions: 420 x 225 x 85 mm
Price: £2600

The VOIS 136, produced by Phonic Ear Inc., (one of the pioneers of AAC devices) is another communication aid that utilises a 128 membrane keyboard. Five levels are provided to store utterances; the first of which stores phonemes, morphemes, words and phrases. These are then used to program utterances, which can then be stored on one of the other levels. The great advantage of this method of word and sentence production is that it permits a user to program what they want to say based on the sound of the words. Hence, both literate and illiterate users can produce utterances by a process of trial and error with relatively high success in short periods of time.

VOIS 160

Mass: 2.7 Kg
Dimensions: 420 x 210 x 32 mm
Price: £2600

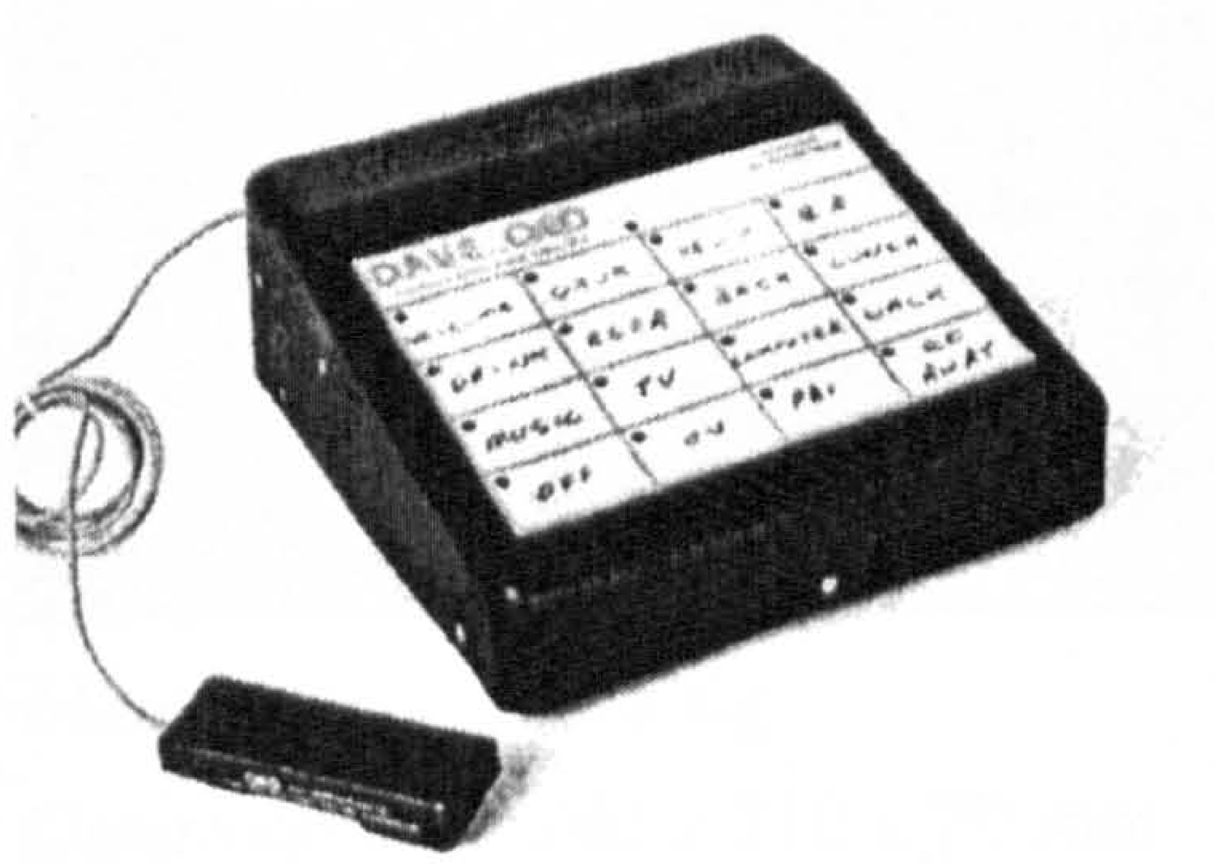
The VOIS 160 is a more advanced model than the 136 incorporating a DECtalk™ voice synthesiser with a choice of ten voices, and the ability to adjust the speed, pitch, intonation and volume of the synthesised speech. Phonic Ear reduced the number of keys to 104, and the addition of a liquid crystal display aids the editing of words and phrases. An additional sixteen levels are also provided to store words and phrases. These can be divided up so that each level may represent a subject category.

Macaw II

Mass:	1.2 Kg
Dimensions:	290 x 200 x 65 mm
Price:	£900 - 2500

The Macaw, and later the Macaw II, by Zygo Industries, is a 32 key communication aid relying on digitised messages that have to be stored by an appropriate person (e.g. a friend, carer or language tutor). It is essentially a digital tape recorder, with 32 locations to store up to two minutes of messages and phrases (a memory module can be added to provide up to eight and a half minutes of speech).

D.A.V.E

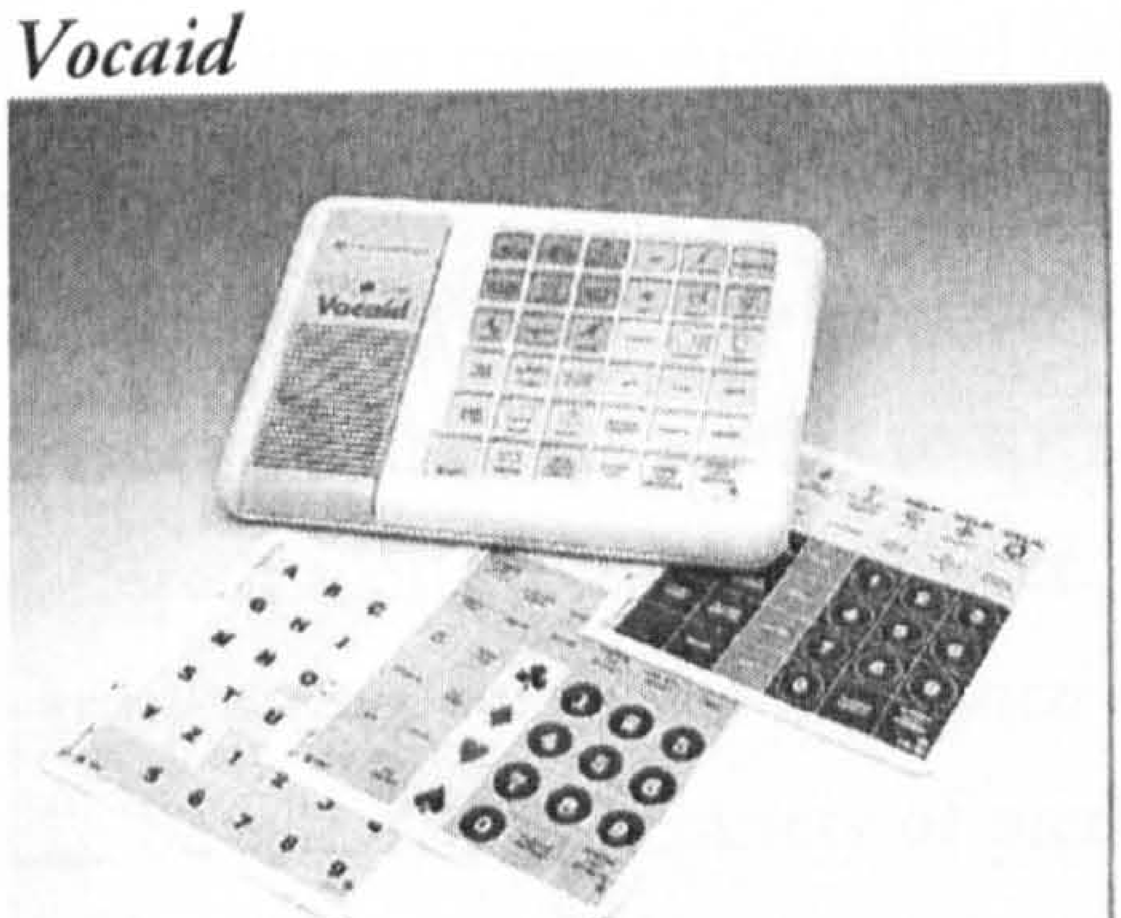


Mass:	1.8 Kg
Dimensions:	240 x 240 x 80 mm
Price:	£500 - 550

The Digitally Aided Voice Emulator, or DAVE, is a sixteen location keypad mounted on a box, that permits one minute's worth of digitised speech to be recorded and played back. No pre-set icons are provided, but the panel can be drawn on to indicate the locations of stored phrases.

The device is limited and heavy.

Vocaid



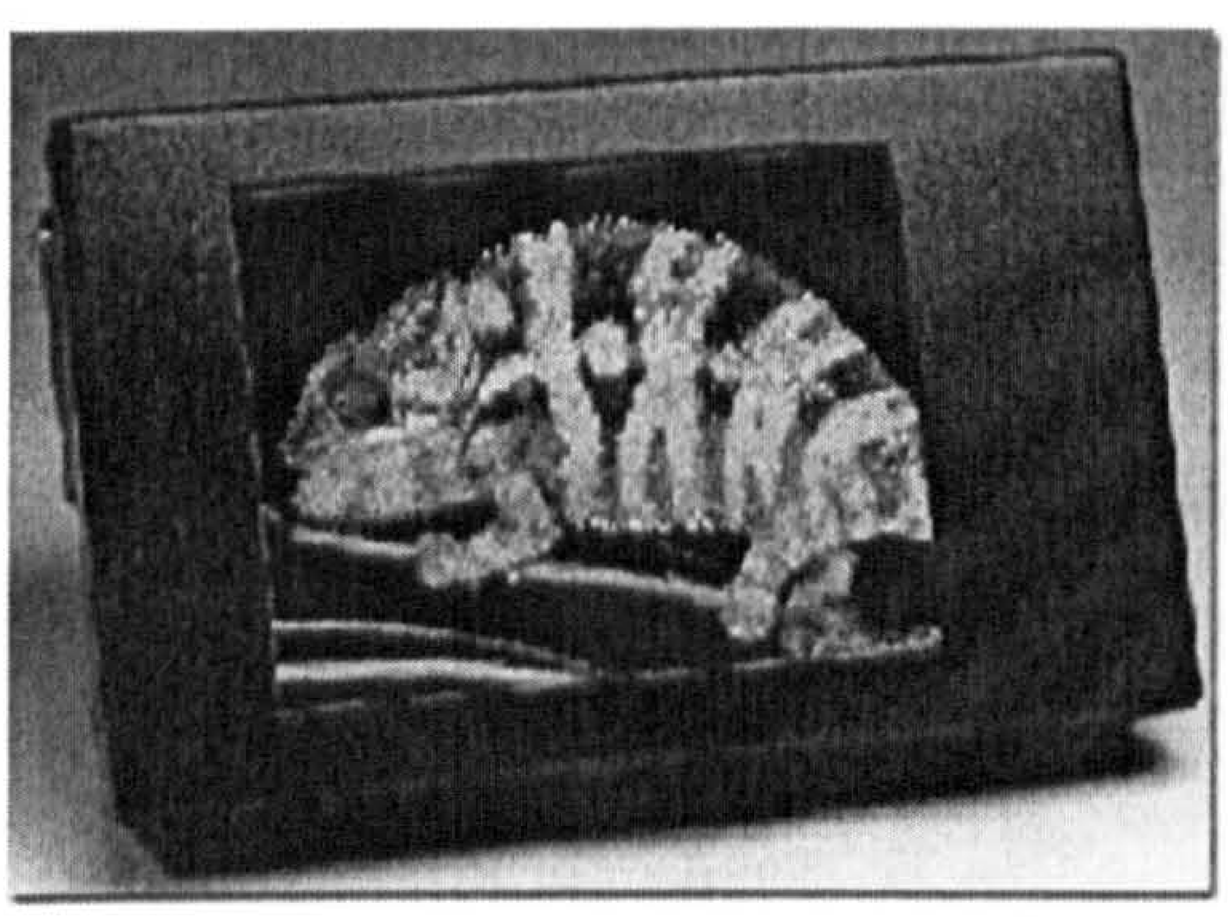
Mass:	1.4 Kg
Dimensions:	360 x 270 x 40 mm
Price:	£95 - 170

Designed by Texas Instruments, the Vocaid is similar to the Speak & Spell and incorporates the same technology. This communication aid uses pre-stored digitised utterances that are selected by the use of overlay cards. Different overlay cards can be used dependent upon the circumstances of the conversation, with each card providing thirty-five messages. The Vocaid automatically recognises which overlay is in use, and accesses the corresponding messages. This device does not permit additional vocabulary to be added, and so is somewhat limited in its practical value. However, it is relatively cheap and light weight, and benefits from Texas Instrument's expertise in producing consumer products.

Dynamic AAC devices

Dynamic AAC devices have a shorter history, but they are becoming increasingly popular.

CAMeleon



Mass:	3.0 Kg
Dimensions:	280 x 210 x 70 mm
Price:	£5650 - 6420

Cambridge Adaptive Communication produced the system that Stephen Hawking uses, but, with the advent of the CAMeleon, have produced an iconographic based system suitable for use by illiterate people.

The CAMeleon is based upon an IBM-compatible PC with a 486 processor running at 33 MHz. The device has a 130 MByte hard disk, 4 MBytes RAM and a colour LCD monitor. The CAMeleon uses the *Talking Screen* picture and symbol based speech output program provided on *Words+* communication software to produce speech, which is output through a *MultiVoice* speech synthesiser. The *MultiVoice* offers nine synthesised DECtalk™ voices, with the facility to create customised voices.

The user can select the number of icons that appear on any one screen, and can choose whether the icon is to speak out a message, or go to another screen to display different icons related by subject. Communication material is thus stored and built up by a user (with the assistance of a helper) in an hierarchical fashion. The icons can be selected by a variety of methods and, as the CAMeleon is essentially a PC, any standard PC peripherals and interfaces can be used. The most commonly used interface for this device is either a scanning switch, or a touch sensitive screen.

Dynavox

Mass:	4.7 Kg
Dimensions:	330 x 270 x 125 mm
Price:	£3495 - 4925

The Dynavox is similar to the CAMeleon, and incorporates the same features but with the addition of the DynaSyms 2000 Software Package providing a library of animated graphics for action words. The use of dynamic icons is a novel and interesting approach to language representation, and doubles as a teaching aid.

The CAMeleon and the Dynavox are easily adaptable devices that can incorporate any PC software, and so provide a useful platform that can accommodate new software developments. These products are demonstrative of an important, and somewhat obvious, progression of Communication aids.

APPENDIX II

Informal interview protocol

Informal interviews were held with fifteen Portland College students. The interviews were held under the guise of chats so as not to intimidate the interviewees and were for the most part conducted during class times.

Open-ended questions were offered first in order to encourage the interviewees to respond as freely as possible. Since the students' communicative abilities varied, it was usually necessary to follow-up the open-questioning with questions of the same essence but of a closed nature. This approach resulted in a good range of responses from the students.

The interviews were structured to first find out about the interviewees, and then find out what the interviewees thought about their communication aids. Once this was established, the questioning was then focused upon what the interviewees would want from a new communication device. When the interviewees suggested ideas it was typical for the author to take the initiative and respond with questions to draw out more specific details. After the interviewees finished discussing their hopes for a new communication aid, the questioning then moved to a process of obtaining feedback on the author's own design suggestions.

Design work, in the form of sketch work, models and other items were used towards the second half of the interviews to present the author's design ideas to the interviewees and to explore and discuss further ideas as they emerged in discussion. The role of the design work was also to help:

- solicit interviewees' thoughts and preferences;
- focus the interviewees upon particular points being discussed, and relevant issues at hand;
- the interviewees think about alternative possibilities to their own preconceived ideas;

- the interviewees compare and consider the author's proposed ideas in relation to their own AAC devices;
- represent ideas in a more tangible and interactive form (largely through physical models) than was possible with discussion alone.

The author's ideas were deliberately left until last to ensure that the interviewees' perspectives and ideas were not shaped or manipulated by poor interview technique. In addition, it was important to reassure the interviewees that they were involved in the design of the device, and that their comments were valued.

The questioning from here on was concerned with gaining feedback on design ideas. Sketch work was shown to the interviewee and the ideas were briefly presented and explained.

Structure and script

- Hi, I'm Jon

  Pause and wait for a response before continuing.

  I'm a designer, and I have been asked to design a new communication aid. I was wondering whether you could help me by telling me about your communication aid – would that be OK?

  Pause and wait for reply. The answer may be a simple yes/no, or else the AAC user may start to talk about his/her communication aid

- Can you tell me a little about yourself – where are you from?

  This question may be redundant, as the earlier response may have already covered this.

- Can you tell me a little about your communication aid?

- How do other people respond to you when you go out and use your *communication aid*?

  Refer to the communication aid by its product name from here on (e.g. *Touch Talker, Liberator*)

  Prompting was often necessary, in which case a scenario was proposed (such as going shopping).

  Say, when you go shopping, what are people's attitudes towards you like?

- What do you like about your *communication aid*?

- Is there anything that you dislike about your *communication aid*?

> Depending upon the answer, the order of the questioning from here on would change to ensure that the interview was more conversational than set. Where possible the questions would be adapted to focus upon issues raised by the interviewee. The following questions were typical of those asked to find out more about the interviewee's thoughts about his/her communication aid

- What features do you use most often?
- What features do you use least?
- How often do you have to replace batteries?
- How long does it take to charge the *communication aid*?
- Does it ever breakdown?
- What do you do if it does breakdown?
- What do you think about your voice?

> The questioning from here on was focused upon what the interviewee would want from a new communication device.

- What about having an accent – would you like to sound more like (insert the colloquial term for where the interviewee is from)?
- What about having intonation in the voice – you know, sounding happy, or sad, or pissed off!
- If I were to design you a new communication device, what would you want it to be like?

> Expand upon the answer, asking for the interviewee's ideas.

    - What should it look like?
    - What colour should it be?
    - How big should it be?
    - How would you carry it around?

> More specific ideas were also sought, dependent upon the interviewee's answers. For example, if the interviewee says that he/she wants the voice to sound as if it is coming from him/her rather than from the machine, the question "what should the speaker look like?" was posed.

- What other features would you like?

The questioning from here on was concerned with gaining feedback on design ideas. Sketch work was shown to the interviewee and the ideas were briefly presented and explained.

- What do you think about these ideas?

- Which do you prefer, having one complete device, or breaking the device up into separate parts – a separate speaker, an interface and a computer processor?

- What do you think about the ideas for the separate speaker?

An open question

- Which idea do you like most:
    - the 'broach'?
    - the speaker that sits in the book, but can be removed?
    - the 'mobile phone' ?
    - the 'pager'?

Closed questions

- What do you think about the ideas for the interface?

- Which idea do you like most:
    - the 'book'?
    - the 'Filofax personal organiser'?
    - the 'laptop computer'?
    - the 'palmtop computer'?

- What do you think about using an alternative interface to the keyboard?"

Such as gloves, discreet head switches, a tongue palette, eye movement monitor.

- What do you think about the ideas for the computer processor?

- Which idea do you like most:
    - the 'bumbag'?
    - the 'personal stereo'?
    - the 'hip mounted housing'?

- Do you have any questions you'd like to ask?

The interviewer thanked the ACC user.

APPENDIX III

Transcript of informal interview with a participant

22nd March 1995
The participant uses a Touch Talker with Blissymbol Component Minspeak Words Strategy (BMW) application program.

The participant's responses are in black text.

- Hi, I'm Jon

- Hello, I am [redacted]

  I'm a designer, and I have been asked to design a new communication aid. I was wondering whether you could help me by telling me about your communication aid – would that be OK?

- Go for it

- Can you tell me a little about yourself – where are you from?

- Hello, I am [redacted]. I am 21 years old. I live in Kent. I am from Bahrain.

- Can you tell me a little about your communication aid?

- I use a Touch Talker. I got it when I was 15 years old. Touch Talker is like a computer. I am ambassador for Liberator.

- How do other people respond to you when you go out and use your Touch Talker?" Say, when you go shopping, what are people's attitudes towards you like?

- In the bank, [the teller] can't see you and sound doesn't project over counter and through the glass. I think they look down to me.

- What do you like about Touch Talker?
- I can talk about

He raises his hands in the air and smiles to gesture "anything I want".

- Is there anything that you dislike about your Touch Talker?
- It's big ... heavy
- What features do you use most often?
- I talk and I write
- What features do you use least?
  [no response]
- How often do you have to replace batteries, and how long does it take to charge your Touch Talker?

The Touch Talker has to be recharge 2-3 times a week, and it takes 5 hours to do so. He is without a communication aid during this time and has to rely on a picture board.

- Does it ever breakdown?
- Sometimes.
- What do you do?
- I wait. I use a picture board.
- What do you think about your voice?
- I have six different voices on my talker, but they're crap
- Would you prefer it if you had an accent?
- Definitely
- What about having intonation in the voice – you know, sounding happy, or sad, or pissed off!

Go for it
A mood button – angry
Volume control
My voice

He frowns, and then smiles, and uses his hands to gesture that a range of emotions would be good

- If I were to design you a new communication device, what would you want it to be like?
- Like computer. For handicap people, but not look like for handicap people. Less heavy. My voice.

- What other features would you like?

> He has no way of talking in the dark, and so suggests that having some way of seeing the device in the dark would be desirable.

- Which do you prefer, having one complete device, or breaking the device up into separate parts – a separate speaker, an interface and a computer processor?

- Separate voice – good. Some people like having a voice coming from head.

- What do you think about the ideas?

- Go for it. It can be for all people, but it has got special for handicapped people.

> He likes the idea of the PCA to help him look more intelligent – he especially likes the idea of carrying a book or a 'Filofax' around (as it would make him feel important). He prefers the book sleeve to be hidden.

- What do you think about using an alternative interface to the keyboard?

- Good – will allow faster talking in shops.

- Do you have any questions you'd like to ask?

- What cost?

APPENDIX IV

Transcript of informal interview

24th May 1996

The aim of the interview was to gain:

1. The participant's thoughts on the use of AAC language representation systems other than Minspeak;
2. feedback on some design concepts; and
3. an indication of the approach he thought should be taken with regard to the PCA's future development (to either develop from scratch, adapt a current product, or to collaborate with a manufacturer of electronic goods).

> Various projects carried out at the MicroCentre at the University of Dundee were discussed.
>
> The participant was enthusiastic about the ideas of using pre-stored phrases, being able to communicate faster, and to have emotion in speech.

Q Would you use PAL[20]?

A Seen it, but I don't like it.

Q Do you think others would benefit from it [referring to other Minspeak users]?

A It is good for learning ... but not outside ... it is slow.

> After discussing HAMLET (see Murray & Arnott, 1990), the conversation led onto how emotion could be represented on the PCA

Q How could we do it? What do you think would be appropriate?

A Use punctuation marks – question mark, exclamation mark, period [full-stop]

Q What about using bio-feedback, say based on your heart rate, your body temperature, the conductivity of your skin etc.?

A No. Because some people are angry all the time with a person.

Q What's do you think about other AAC devices?

---

20 Predictive Adaptive Lexicon, see Alm *et al* (1992b, 1994), Morris *et al* (1989), Newell (1990a) and Newell *et al* (1990b)

A Like toy

Q Why?

A Because they look like toy

Q What about adapting present systems so they can be used for this purpose – for instance what about using an Apple Newton?

A Right on. Help people to understand about our talking because they're using it. People not go away, because they've seen it

Q What about getting a computer manufacturer interested in the idea of the PCA, and getting them to develop it as a product for everyone – a universal product?

A Not IBM, because it is going down. I think a company wants it because it is a new computer for children.

Q What about developing it for the able-bodied – as a translator say, English to French?

A Make lots of money. You not forget me. A company can say it is good for future. British Telecom – they want more communication for their business. Because they're giving billion pounds for new communication in computers. You could put in books for children – they can read and listening for it helping English.

And if BT want it we can put help call [for hospital and police] in it for handicapped people if they want it in.

I think it is helping Government in costs
Go for it.
Give BT twenty percent – we want to say it's good business.

APPENDIX V

Transcripts of informal video interviews with a participant

19th July 1996

The participant is talking with Cheryl (speech and language therapist) and Sue (communications tutor). The grey text is spoken out by the participant's communication aid as he constructs sentences. The markers to the right of the text indicate each minute that passes (this gives some indication of the time taken for the participant to construct sentences). The participant was filmed on three occasions throughout the day.

First informal video interview
Video position 0.10 – 13.20

Participant: Hello ... I am ..[redacted]– Hello I am [redacted]I am ... 22 ... years ... old. I am ... finishing ... Portland College ... on ... August ... 1st – I am 22 years old. I am finishing Portland College on August 1st.

Hoorah! — 1 minute

What ... do you ...want ... me ... to talk ... now?

Cheryl: What about how your communication developed through your life.

Sue: Or has it!

Participant: I was ... using ... my ... body ... talk ... and ... I (2 minutes) wasn't ... writing ... English ... like you – I was using my body talk and I wasn't writing English like you. And ... I ... see ... a ... Touch Talker ... I was (3 minutes) ... 15 ... years ... old ... and ... they ... thought ... I can't ... learn ... about ... the ... Touch Talker ... because ... I was ... old ... and ... they ... thought ... I can't ... learn ... English – And I see the Touch Talker I was 15 years old and they thought I can't (4 minutes) learn about the Touch Talker because I was old and they thought I can't learn English. I ... I was ... learning ... about ... the symbols ... it is ... like ... pictures – I was learning about the symbols, it is like (5 minutes) pictures. And ... I can't ... say ... more ... because ... I ... not ... think ... to ... say ... more.

Sue: What about ... can you say a little bit about the Ambassador Scheme you're involved in?

Participant: I am ... ambassador ... for ... Liberator. ... It is ... a
... company ... I do ... go ... 'a' 'r' 'o' 'u' 'n' 'd' ...
to ... schools ... to teach ... about ... Touch Talkers 6 minutes
... because ... it is ... new ... for ... the ... teachers
... and ... students ... they are ... learning ... about
... Touch Talker – I am ambassador for Liberator. It
is a company I do go around to schools to teach 7 minutes
about Touch Talkers because it is new for the
teachers and students they are learning about Touch
Talker. And ... I am ... like ... a ... teacher ... for
... students ... and ... their ... family ... if ... they
... not ... see ... a ... Touch Talker – And I am like 8 minutes
a teacher for students and their family if they not see
a Touch Talker before. Some ... time ... family ...
say ... our ... child ... can't ... learn that ... because
... they ... family ... not ... have ... got ... 9 minutes
computer in ... their ... home ... and ... it is ... * ? *
... Touch Talker ... is ... like a ... computer – Some
time family say our child can't learn that because
family not have got computer in their home and 10 minutes
Touch Talker is like a computer. And ... I ... think
... that ... is ... because ... they aren't ... sure of ...
computer ... not ... the child – And I think that is 11 minutes
because they aren't sure of computer not the child.
And ... I ... think ... it is ... getting ... better ... but
... I ... think ... Liberator ... want ... more ... help
... from ... the ... Government ... want more help
from the Government – And I think that is because
they aren't sure of computer not the child and I think 12 minutes
it is getting better but I think Liberator want more
help from the Government. Thank you ... for ...
listening ... I am ... going ... now ... because ... I
haven't... got ... time ... *[laugh]* because ... the... 13 minutes
'n' 'e' 'w' 's' ... is ... on ... next – Thank you for
listening I am going now because I haven't got time
because the news is on next.

Second informal video interview
Video position 13.24 – 23.00

Participant: What ... am I ... going ... to ... talk ... first ... Sue

Sue: What are you going to talk about first? What are your plans when you leave Portland?

Participant: I am ... going ... to ... Kent ... to live ... there ... and ... I am ... going ... with ... my ... love ... 14 minutes

Sue: *[interjects]* I can't come with you!

Participant: I am going to Kent to live there and I am going with my love.

Sue: [redacted] I can't come with you, sorry, I have to stay here

Participant: Are ... you ... joking ... me?

Sue: *[Laughing]* Yes I'm joking you. Who's your love?

Participant: [redacted]

Sue: Ah, isn't that sweet.

Participant: Cheryl ... you are ... on ... there... now *[laughs]*

Sue: *[laughing]* This is supposed to be spontaneous ... over to you Cheryl. 15 minutes

Cheryl: I'm ... I'm lost for words. I was going to say though, you know my grandfather used to live in Kent. He used to be a bus driver. No he wasn't, he was a bus conductor.

Participant: *[to Cheryl]* I ... like ... your ... beautiful ... car.

[laughter]

Sue: You are so mean.

Cheryl: I'm just called Allegro-Woman!

Participant: Are you ... can you ... do you ... 'p' 'a' 'y' 't' 'a' 'x' ... 16 minutes

Sue: He's very cheeky

Participant: ... on ... it ... because ... it is ... very ... new ... Do you pay tax on it because it is very new?

Cheryl: Yes I do pay tax on it *[laughs]* ... but it is not quite old enough to stop paying road tax.

Participant: And ... Sue ... you have ... got ... problem ... 17 minutes

[Laughter]

Sue: Don't talk about that!

Participant: ... car.

Sue: Yes [redacted] I've got a hole in m' radiator, and I have just found out it's gonna cost me ninety-five pound to get it fixed ... plus labour!

Participant: Because ... you are ... driving

Sue: ... he's going to tell me off about my driving

Participant: ... fast

Sue: Huh, I said it! I don't know how it happened. Actually I do, I've got to confess

Participant: Portland College ... student ... was ... front ... of ... you ... you aren't ... you didn't ... stop 18 minutes

Sue: Did I run him over?

Participant: ... am I ... correct ... about... that – Because you are driving fast Portland College student was front of you. You didn't stop. Am I correct about that?

Sue: Is that how I caused a hole in my radiator? ... I'm gonna find out who it is and bill them for the damage they've done to my car! So you're going to have tell me who it was. Very inconsiderate of them!

Cheryl: Do you know you're waving around a screwdriver?

Sue: Oh, yeah, I was trying to put it down! ... Are you going to get a car, anyway, with all this talk about cars? 19 minutes

Participant: Yes ... a ... 'v' 'a' 'n' ... because ... we want ...

Sue: *[laughing]* ... to sell your fruit and vegetables!

Participant: ... to have ... vegetable ... 'v' 'a' 'n'

Sue: Oh, you were going to say you wanted to sell your own fruit and veg! Right, which one's the fruit and which one's the vegetable!

[laughter]

Participant: I am … the … vegetable

Sue: I cannot believe … well we know that, yes!

Participant: … and … [redacted] is … the … fruit — 20 minutes

Sue: Do you know what a fruit is if someone calls someone a fruit?

Participant: *[makes an expression]*

Sue: I just thought I'd check that.

[laughter]

Cheryl: Is [redacted] able to learn to drive?

Participant: Yes … she did … have … any … *(oh bugger)* … 2 … 't' 'e' 's' 't' 's' … she didn't … get … any … where … with … them … because … I … think … the … people … weren't … sure … about … her … because … she is … handicap – Yes she did have two tests she didn't get anywhere with them because I think the people weren't sure about her because she is handicap. — 21 minutes

Sue: Is she going to take it again? — 22 minutes

Cheryl: Do you mean tests or …

Participant: Yes, go for it

Cheryl: Tests or lessons?

Participant: *[vocalises agreement to tests]*

Cheryl: Third time lucky then

Participant: Is it … the … 'n' 'e' 'w' 's' … time – Excuse me please, is it the news time? — 23 minutes

… good bye from me and from them

Third informal video interview
Video position 23.00 – 32.00

The participant was using his communication aid without the Bliss symbol overlay on the keyboard.

Participant:	Where ... my ... (he vocalised "oh bugger") Bliss Symbolics ... are – I am forgetting to where my Bliss Symbolics are.	
Sue:	You are forgetting where the symbols are without the overlay? You'll be fine.	
Participant:	I am ... forgetting ... now ... because ... I am ... the ... 'a' *(oh bugger)* ... Excuse me please ... I can't ... use ... my ... intact ... Touch Talkers *(oh bugger)* ... Touch Talkers ... because ... my ... hands – Excuse me please I can't use my Touch Talker because my hands	24 minutes - 29 minutes
Sue:	... keep on slipping?	
Cheryl:	Because it's so hot.	
Sue:	Well we'll try again when it's not so hot.	
Participant:	Because ... I am ... vegetables	
[laughter]		
Sue:	Because I am vegetables – shut up! It's because it's hot and your fingers are slipping down. But next time we will put the key-guard on without the pictures and that will ensure your fingers don't caught.	30 minutes
Participant:	Thank you ... for ... listening ... to ... me ... again ... but ... I am ... going ... because ... I want ... I ... *(oh bugger)* ...my ... food – Thank you for listening to me again but I am going because I want my food. Thank you.	31 minutes 32 minutes

APPENDIX VI

Formal video interview protocol

(The script for the interview was written by Cheryl Davies, Portland College's speech and language therapist.)

Objective To provide a record of student achievement, and to note and record students using their AAC devices

Aims To observe and record:

- access method;
- speed of access;
- interaction skills
  - eye contact
  - turn taking
  - gestures;
- knowledge of vocabulary;
- 'repair strategies' - e.g., answering a question with, *"I don't know"*, or *"Can you repeat that"*;
- initiation of conversation;
- level of prompting required;
- ambiguities;
- level of difficulty in accessing machine.

Procedure

The interview team (consisting of a speech and language therapist, a communication tutor, and the video camera operator) introduced themselves to the AAC user, explaining what was being done and why. The AAC user was then asked whether he/she had any objections to the interview taking place.

Script

Camera zooms in on the AAC device to show the student's method of accessing it. The camera then pans out to frame the interviewer and the AAC user.

- If visitors were to come into the room, how would you greet them and introduce yourself?

  The AAC user will typically access pre-stored phrases

- Can you remind me where you come from?

  AAC users will typically have stored an answer to this question themselves (or have been assisted to do so)

- Can you count to five please?

> This is a good measure of AAC users' speed of accessing their devices. Numbers are typically stored in a sequence, and so this exercise is also useful to assess AAC users' sequencing skills.

- Can you tell me the days of the week please?

> A similar exercise, but with a little more complexity if using a Minspeak program.

> The interviewer shows the AAC user a picture. The camera zooms in, and pans out to frame both the AAC user and the picture.

- Can you describe what's happening in this picture?

> This requires analysis and thought. This question is open-ended so as to encourage the AAC user to think of::
> - what they want to say;
> - what they can say; and
> - how to say it using their AAC device.

> If the AAC user says very little, then prompt if necessary a further two times.

- Can you tell me about your family?

> Again an open-ended question, but the subject matter is one in which the AAC user is more familiar with answering. This question can be answered in a matter of fact way (*"I have two brothers and a sister"*), or by using more descriptive sentences (*"My mother makes great biscuits ..."*). How AAC users answer this and the next question can shed light on their motivation, ability, and willingness, to communicate (and also their confidence in doing so).

- What did you do last night?

> An open-ended question, but this time the answer should be in the past tense.

- And, have you any plans for this weekend?

> Future tense

> After the AAC user has said what he/she is going to do at the weekend, a long pause is initiated by the interviewer, so as to prompt the AAC user to take a more dominant role in the conversation (i.e. ask a question of the interviewer). If the AAC user does not respond, the interviewer then says:

- I'm doing something special this weekend

This is a more direct and obvious ploy to get the AAC user to lead the conversation. The interviewer will respond accordingly by telling the AAC user about weekend plans.

The interviewer thanks the AAC user and the video is switched off.

APPENDIX VII

Product Design Specification

By way of stating the performance requirements of this project, the following is the initial Product Design Specification.

Aesthetics

Appearance

The product's appearance must be compatible with the social environment with which it interacts. Whilst being fashionable now, the device must also be of a style that will not become dated as rapidly as many general consumer products do.

Feel

The use of tactile and/or textured materials should be considered in the design to aid grip, resist impact forces, and provide a perception of durability.

Perception

The product should convey positive images, and not draw attention to the users' disabilities. The device should not be toy-like, or convey patronising associations.

Competition

There is a number of manufacturers and service providers within the AAC market. The intention is to not deliberately set up as competition during the design and development of the PCA.

Constraints

To prevent Portland College's students (and others) learning a new language system, and due to the limited time for this study, the incorporation of Minspeak is requisite.

Costs

The device should have a retail cost of less than £6000. The cheaper the item is, the more likely it is to succeed in the market place. The device must offer value for money.

Ergonomics

Physical

The product must be compatible with the anatomical and anthropometric dimensions (both static and dynamic) of users, and with the physical constraints of the environment in which the device will be used. *The device should not cause discomfort for its users.*

Users range from having mild – severe limitations of muscle coordination, dexterity and control, and consequently:

- the device should provide the facility to aid coordinated and intentional actions (as users may experience problems with fine hand movements);
- the device should be resilient to knocks and abuse;
- the device should prevent the ingress of saliva (from drooling) or other fluids.

If keys are to be used as a mode of access, the force required to activate them should be sufficient to prevent error, but not to the point where sustained use may cause fatigue, general soreness, irritation or compression of muscles, tendons and nerves in the fingers. Sizes of keys/buttons and the force required to activate them must be appropriate for the functional abilities of those using them. (BS EN ISO 9241-4:1998 recommends the force required to actuate a key on a keyboard should have an upper limit of 1.5N and a displacement of 2mm to 4 mm. The appropriateness of this standard for this application will have to be determined by further empirical studies.) Feedback indicating when a key has been activated is needed. Tactile feedback for key depressions is desirable over auditory feedback.

Cognitive

The device should be useable by people with small or large vocabularies.

Sensory

Additional disabilities may be encountered – vision and hearing impairments are common, and so the ability to adjust visual and auditory feedback is desirable.

Psychological aspects

Some AAC users are not motivated to use current devices. Anything that the product can do to redress this should be considered in the design. The product should not compound negative associations of disability.

Environment

The device is likely to be mainly used within the UK. As the product may be taken outside the UK, and if it were to be marketed globally, other weather conditions and temperature ranges should be considered. Ideally the device should still operate between the following temperatures: -28°C (Winter in Europe) – +44 °C (Far East). The device should be capable of being used in a variety of ambient lighting conditions – from very low light to bright sunshine. The device is likely to be exposed to sunlight; hence the materials should be UV stable, and the user should be able to operate the device in bright conditions. The device may be used in humid conditions. The device is likely to be exposed to rain (or else saliva, and other liquids), and hence should be splash-proof.

Features

The facility to use standard computer peripherals (eg a printer) is desirable.

Legal implications

Any discussion with external parties concerning the design of the PCA must be conducted in confidence and will be subject to the signing of an Intellectual Property Rights agreement. Loughborough University and Portland College have stakes in the Intellectual (and possible future commercial) Property.

(See also Patents.)

Life in service

The device should withstand an operating period of 3 hours in continual use per day. The device should ideally be capable of operating for a period of 16 hours per day in a combination of standby and continuous use modes.

Maintenance

The product should require the minimum of maintenance. Facilities should exist for fast, efficient and inexpensive (preferably free) servicing and repair. If being serviced or repaired a replacement device should be made available (if possible with any settings that the user may have made being loaded upon the replacement device).

Marketing

It is desirable to market the device as a product for all, and not just for people with communication impairments.

Materials and processes

The product must be durable, and so durable materials should be used. There is no restriction on manufacturing processes, bar their economic feasibility. For the purposes of this project, initially just a prototype is required, but the materials and processes used for the production of the prototype, where possible, should simulate those used for higher volume production.

Packaging and transport

Packaging should be kept to a minimum for environmental reasons. Ideally packaging of the product could provide jobs for people with disabilities.

Patents

US, UK and European (including some World) patent searches applicable to AAC devices were conducted in March 1996. The following patents maybe applicable to this project:

Three patents, assigning Bruce Baker, Richard Creech, and Kenneth Smith as inventors, refer to a *System for method producing synthetic plural messages.* These patents have been filed on different dates, but each have the same abstract and title. Patent numbers 4661916; 5309546; and 5317671 were filed between 1985 and 1991, being granted between 1987 and 1994. These patents are in force until 2014, but the portion of the term of the latter patent subsequent to April 28, 2004 has been disclaimed.

Patent 5097425, for a *Predictive scanning input system for rapid selection of visual indicators,* is assigned to Semantic Compaction Systems. The other inventors are: David Hershberger, Edward Gasser, Clifford Kushler and Barry Romich.

Bruce Baker, Robert Conti, David Hershberger, Donald Spaeth, Jeffrey Higgenbotham and David Kushler have a patent in their names for a *System and method for automatically selecting among a plurality of input modes* (US Patent 5210689).

As the design of the PCA is likely to encompass some of the techniques mentioned within the abstract of these patents, it is most evident that the PCA may encroach these patents.

A patent in the name of James Hollander (US Patent 5029214), entitled *Electronic speech control apparatus methods,* refers to a method for controlling emotional qualities of utterances electronically. This patent may have some future bearing on the design of the PCA if emotional aspects are to be included.

Product life

The PCA should have a life span of at least three years, and should still be a viable system six years hence.

Quantity

For the purposes of this project, initially just a prototype is required, but with the possibility of the product being manufactured for the World Market. The manufacturing should make allowance for this.

Safety

The electrical components should be shielded from the ingress of liquids (saliva, water, drinks) and foodstuffs. Hence the device should be splash proof.

(See also Standards and specifications.)

Size and weight

The device should be appropriate to be carried by and ambulant AAC user. The device should weigh less than 60 Newtons (6kg). The unit should be easily portable (e.g. no larger or heavier than a notebook computer). The unit can be hand held or worn on the body so long as it does not hinder movement.

Standards and specifications

The device must comply with all relevant standards including:

- BS EN 29241-3:1993 (ISO 9241-3: 1992)
  Ergonomic requirements for office work with visual display terminals. Visual display requirements.

- BS EN ISO 9241-4:1998
  Ergonomic requirements for office work with visual display terminals. Keyboard requirements.

- PD 6582:1993 (CENELEC R110-002:1993)
  Electromagnetic compatibility (EMC). Guide to generic EMC standards

- BS EN 50088:1996
  Safety of electric toys

(this standard maybe judged appropriate for this particular application as the durability required of children's toys can be considered comparable to the treatment an AAC device by people with severe motor dysfunction)

- *The General product Safety Regulations 1994,* produced by the Consumer Safety Unit, Department of trade and Industry.

User

The device is intended for ambulant adults, and an allowance must be made for their motor limitations. The device should also meet the needs of other aphasic adults with more severe physical disabilities. The product should be suitable for non-speaking and illiterate adults. The device should also cater for those who are non-ambulant (i.e. constrained to a wheelchair). The device should be suitable for use by both sexes.

Ideally the device should be suitable for use by a wider population. Thus:

- the device should be appropriate for use by people with some literacy skills;
- the device should be suitable for use by non-speaking children, and adults alike;
- the product need only incorporate English; a platform for the incorporation of other languages is, however, desirable so as to be competitive in the world market;
- the device should be suitable to be used by someone who cannot read or spell and may never be able to learn to do so.

(See also Ergonomics.)

APPENDIX VIII

Assessment of user perception and satisfaction questionnaire

Loughbo
Universi

Department of Design and Technology

Interview with: Date:

I agree to this interview taking place. I understand that what I may say may be used for research or to compile a report.

The researchers have explained that they will make every effort to respect my confidentiality and anonymity.

Signed

(Signed on behalf of

Assessment of user perception and satisfaction

Subject Number ....

Name: .... Age: ....

Sex: M F

Ambulant: Yes No

Type of communication aid used: ....

(Hand over the PCA to the interviewee to examine and use at any stage. Get the interviewee to open the book and feel it if appropriate)

What do you think of the PCA?

1	2	3	4	5
really like it	like it	neither	don't like	really dislike

Comments:

I'm going to go through parts of the PCA – I'd like you to rate your feelings and make comments.

What in particular do you think of the Bum-bag?

1	2	3	4	5
really like it	like it	neither	don't like	really dislike

Comments:

Would you be happy wearing the Bum-bag?

1	2	3	4	5
very happy	happy	neither	unhappy	very unhappy

Comments:

What in particular do you think of the Book?

1 really like it | 2 like it | 3 neither | 4 don't like | 5 really dislike

Comments:

What do you think of the ... (circle any features the interviewee states without prompting)

- integral key-guard?

1 really like it | 2 like it | 3 neither | 4 don't like | 5 really dislike

Comments:

- hinge?

1 really like it | 2 like it | 3 neither | 4 don't like | 5 really dislike

Comments:

- solar cell?

1 really like it | 2 like it | 3 neither | 4 don't like | 5 really dislike

Comments:

- keys?

1 really like it | 2 like it | 3 neither | 4 don't like | 5 really dislike

Comments:

- weight and feel?

1 really like it | 2 like it | 3 neither | 4 don't like | 5 really dislike

Comments:

- colour?

1 really like it 2 like it 3 neither 4 don't like 5 really dislike

Comments:

- materials?

1 really like it 2 like it 3 neither 4 don't like 5 really dislike

Comments:

- looks?

1 really like it 2 like it 3 neither 4 don't like 5 really dislike

Comments:

What in particular do you think of the Mobile Speaker unit?

1 really like it | 2 like it | 3 neither | 4 don't like | 5 really dislike

Comments:

What do you think of the feature of ...

- being able to whisper?

1 really like it | 2 like it | 3 neither | 4 don't like | 5 really dislike

Comments:

- having the voice come from you?

1 really like it | 2 like it | 3 neither | 4 don't like | 5 really dislike

Comments:

- it looking like a mobile phone?

1 really like it | 2 like it | 3 neither | 4 don't like | 5 really dislike

Comments:

What do you think about the feel of the mobile?

1 really like it | 2 like it | 3 neither | 4 don't like | 5

Comments:

Given the choice, would you use the PCA over your present device?

YES NO MAYBE

Comments:

How would the PCA make you feel about using a communication aid?

1	2	3	4	5
Very happy	Happy	neither	Un-happy	Very un-happy

Comments:

Thank you very much.

Notes