Chapter one

Tactile Graphics

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1.1 The need for graphic skills

Pictures and diagrams are a means of communication which fully sighted people take for granted, and on which modern society relies. If people who arc blind are to take full advantage of available educational, leisure and employment opportunities It is important to find adequate substitutes for all kinds of graphic displays.

The means are available to create various forms of tactile representations which can be understood by blind people, and even by those whose impairment was congenital. This book assesses the extent to which tactile displays can be substitutes for pictures, describes the way in which they should be used, and illustrates ways in which people who are severely visually impaired can be better equipped to obtain reliable information from them. In doing so, it examines the perceptual channels through which such tactile displays are read and interpreted, describes the associated experiences which are pre-requisite to full understanding and the type of educational programme which can enable blind children to acquire facility and confidence in the use of pictures and diagrams in their tactile form.

1.2 Pictures

If the word 'picture' is used in its most wide-ranging sense to denote any display in which information is given spatially rather than verbally it will encompass a vast range of graphs, symbols, maps and images on the one hand and will serve a wide variety of communicative intentions on the other.

Thus the conventional symbol for the toilet facilities fordisabled people advertises their presence with a stylised side view of a wheelchair and its occupant which is intended to be easily recognisable by people in the countries where it is used. Although this is generally so, there is no doubt that the reader would need to have met sufficient numbers of these wheelchairs and symbols of this nature to he able to guess what the symbol means. Some other symbols of this type are much more ambiguous. For example, the symbol based on the front view of the human eye with a diagonal line across it which announces the availability of help for visually impaired people is obviously linked to the eye in some way, but precisely what it means is much more difficult to guess. So symbols of this type do require users to be educated in a particular code, if not symbol-by-symbol at least to the extent of adopting a particular frame of mind in approaching the symbols.

The medical temperature or blood pressure chart indicates higher and lower temperature or blood pressure by raising and lowering the graph line, and traces the progress of these phenomena by a zig-zag. By convention the vertical or 'y' axis usually represents the measured effect of whatever controlled variable is plotted on the 'x' axis running across the chart. Mathematical information of this sort can be very precisely plotted so as to allow accurate reading from the graph by noting the coordinates at anyparticular point on the trace.

A statistical pie chart registers shares of a total by larger or smaller slices from the pie. The statistical symbolism of this type of presentation is very obvious but precise measurements are difficult to read back from the chart.

Process diagrams or flow-charts show the inter-relationships of stages in the process by lines of connection and direction. They are widely used for purposes as diverse as showing the chain of command in all organisation; demonstrating the steps in a biochemical process; or describing the manufacturing processes to he followed in producing an engineering product.

Simple maps indicate environment on a notional bird's eye view with conventional symbols. Maps can be made to various degrees of sophistication and in the case of the more complex ones such as the smaller scale, Ordnance Survey maps such features as contours may require considerable training to read whereas coastal outlines, roads and rivers nay be relatively simple to understand. There are also many occasions when instrument readings such as weather or seismic data are plotted on maps as a visual or spatial way of representing variations in the physical data. To read them intelligently requires full understanding of the underlying phenomena, of the way they are recorded, and of the implications of the data. To be able to read this kind of map one must acquire knowledge which goes far beyond the ability to discriminate and identify the shapes and symbols on the page.

These are just a small selection of the ways in which information is conveyed diagrammatically. Yet none of these examples begins to consider that world of pictures which is generally thought of as 'Art', and covers a vast spectrum of the 'old master' in oils, through pastel sketch, etching, water colour to cartoon and every school from the consciously representational to abstract and pop-art. With these pictures, style and historical or cultural development Influence the way the picture is perceived. (Gombrich, 1960, pp 264 -275) These factors influence not only the way the artist responds to what he sees and tries to depict, but also the way in which the viewer reacts to and understands the picture. (Artist and viewer may, of course, he separated by centuries of time.)

With the scope and intentions of pictures being so varied, what then is the potential of two-dimensional and three-dimensional representations when they can only be read by touch in the way that a blind person would?

It must be established from the outset that even in that subset of visually impaired people who have no vision at an there are two quite distinct groups of people: those who are Late Blind who may have distinct visual memories which may be depended upon in concept forming, and those who are Congenitally Blind and have no such memory. There has been a tendency in the past to postulate limits to the understanding of congenitally blind people that now appear to be quite unwarranted in the light of experience and more careful research. (Birns, 1986). Undoubtedly those who are congenitally blind begin their lives with the disadvantage of a much reduced and biased sensory experience and if this is not overcome by adequate educational measures a severe educational and cognitive handicap can occur.

However, many of the most damaging aspects of this can be minimised by providing rich enough tactual and conversational opportunities during and beyond childhood, and among such measures tactile pictures have their part. Well educated congenitally blind children cannot overcome their disadvantage entirely - one would be foolish to pretend otherwise - but their effective educational performance can come very close to that of the late blind in most respects and can enable them to lead full and interesting lives open to new perceptual opportunities. These educational questions will be re-examined in more detail later in this book.

1.3 Representations for the touch sense

That touch is the Cinderella among the senses becomes apparent from a cursory glance

at the contents page of any handbook of perceptual psychology. The small proportion of such a book devoted to touch echoes the relative proportion found in academic publications as a whole, and it also reflects the general pattern of research activity and public interest. It is significant that David Katz 'World of Colour' which deals with visual phenomena has long been available in English translation, whereas his influential 'Aufbau der tastwelt' on the subject of touch call still only be read in Its entirety in the original German. (Katz, 1925 and 1935)

There is a corresponding deficiency in the development of tactile educational resources, despite a conviction by developmental psychologists that tactual input is a potent factor in every child's early development and in the establishment of effective psychomotor pathways in skill learning. Indeed visual information only takes on its full significance for the young fully sighted child when he/she is able to relate it to the tactual world. (Bower, 1974) Some of this deficiency of resources is caused by the relatively low number of children who would appear to benefit, so that potential producers are not encouraged by any prospect of commercial advantage.

In the more specialised area of tactile illustrations for those who are severely visually impaired, examples of the genre are nowhere near as numerous as the great variety of visual illustrations even though experience of using tactile media in education and knowledge of presently available technology leads the present author to believe that *we* exploit only a trivial fraction of the potential of this means of communication. Despite progress in the understanding of tactual perception made by researchers over a range of disciplines, our understanding is still patchy and seemingly more prone to make wayward turns than in other branches of psychology.

Yet much of knowledge deals with structures and processes whose stages and inter-relationships are most clearly described by some two or three dimensional pattern, Words alone, If they are to provide an adequate description, may be cumbersome by comparison with a sketch, however crude it may be, this book attempts to extend the available knowledge of the use and understanding of tactile representation in formal and personal education by drawing together some of the experimental results of researchers, teachers and users, including results or the author's own research, and by describing and discussing the relevant design and pedagogic issues.

The literature referring to tactile graphics is complicated by the fact that much research on tactile illustrations is based on the use of illustrations of poor quality and outdated style, and the pessimistic question of Merry and Merry (1933) as to whether tactile pictures have any use at all is an extreme but not isolated instance of this. Views of this kind are even now occasionally repeated uncritically.

From the practical point of view it is also important to consider tactile features in context, because the context in which they appear has a marked influence on their effectiveness, or indeed on the meaning that people attach to them. (Hinton, 1988a, p13) Controlled experimentation has often considered picture components in isolation, (Nolan and Morris, 1971; Lederman and Kinch, 1979) yet when set within an illustration their effect may be different. (Hinton, 1989a)

The teaching environment in which they are used is also a vital factor for effectiveness. The writer's own earlier trials of tactile diagrams confirmed that the performance of this type of teaching resource was much better where the pupils were put at ease and were given adequate support than where they were left to flounder on their own. (Hinton, 1988a, p.15) This book will attempt to link together and evaluate all of these factors in the use of tactile media.

1.4 What is the nature of a tactile diagram?

As tactile diagrams and pictures will be referred to frequently throughout this book it is necessary to give a straightforward description of their nature.

Historically the tactile maps and diagrams that were first produced were collages of textured materials which were intended to be felt directly. Obviously, as soon as education of the visually impaired took place on a scale bigger than one-to-one it became a very laborious task to create enough copies of each diagram for each student to have one, although this is plainly essential for a comfortable working environment. When the thermoform machine for polymer sheet became available for the reproduction of Braille text it was realised that this process also offered a means of reproducing copies from a master diagram, and this method became adopted as a standard

technique in the 1960s, with the quality of master diagrams at that time rarely matching the potential of the means of reproduction. Not surprisingly there was much doubt among teachers about the usefulness of tactiles to blind children, despite the efforts of pioneers like Pickles (1968) to improve standards and clear evidence from pupils themselves that tactiles could be useful when properly designed and presented.

In the thermoform (sometimes called vacuum formed) method of reproduction the master diagram is placed on the work-platen of the machine with a thin sheet of a polymer such as PVC damped over it. The work platen is then slid under an electric heating element which warms the polymer to soften it. After a suitable delay, set by the switch panel of the machine, a vacuum pump is switched on automatically, and this draws out air from beneath the polymer sheet to draw it tightly down onto the master diagram so as to follow its contours exactly. The work-platen is then withdrawn from the heating element, and after· cooling the copy is gently stripped off the master mould. By repeating the process, many copies can be produced from a single master mould. Although there may be slight changes in texture and some loss of definition in comparison with the original mould, an experienced designer can allow for this in making the original. This method of production is still highly relevant to today's educational needs, despite further technological advances, because the greater variation in form, relief and texture which it offers will permit good discrimination of complex subject matter.

1.5 Microcapsule (Zychem) diagrams

An alternative method which has come into vogue since 1980 is the use of microcapsule diagrams (currently produced by Zychem), although 'swell paper diagrams' is another term which some people use. The special coating of the paper used for these diagrams contains minute PVC microcapsules of an organic solvent. When a black-and-white diagram is photocopied onto this paper and then heat treated, the black lines of the diagram absorb more heat than the white areas and cause the microcapsules to expand so that the lines of the diagram swell up above the general level of the paper to create a tactile shape.

Unfortunately every line is raised to the same extent so that while this method of production is useful for many diagrams of an open texture, diagrams of a more complex structure tend to he much more difficult to decipher unless they are expertly designed. Despite this, the process is widely recommended, often for unsuitable tasks, and the reason for this is largely speed and ease of operation. The process can also produce images which are visually clean and appealing, however unsuitable they are for a blind user.

In the author's work this kind of diagram really comes into its own when the original diagrams are computer generated, and a production unit based around computer graphics facilities can be very responsive to a variety of educational needs.

1.6 Drawing on German film

A third method of producing a tactile picture involves a material known as 'German Film', although there are earlier materials with similar behaviour known simply as 'drawing film', Sewell film or Melinex. 'German Film' itself is a translucent and lightly textured polymer sheet which was originally developed as a backing-sheet for medical wound dressings. All of these materials lift lip to form what can best be described as "a touch-detectable scratch″ when drawn upon with a simple scriber or ball-point pen on a soft rubber backing pad. Unlike the other two methods this is a way of producing a sketch rapidly during an actual lesson, and it can also be used after practice by blind pupils to make their own drawings. Its use for both purposes will be described alt various points in this book. Its use complements the other two processes which are for more formal teacher presented diagrams. The German film method lends itself well to the active, two-way learning encounter. Here again the line produced is less distinct and of uniform height above the page.

1.7 Scanning and learning

Much of the published intensive research on tactile diagrams (Nolan and Morris; Berla; Bentzen) has been directed at discrimination, scanning and tracking needs and has been carried out in the context of a controlled experiment involving a simple texture or symbol matching test, a tracking test (often on a carefully devised 'pseudomap') or some kind of scanning exercise.

Such controlled experiments are a necessary step in the process of learning about tactual displays in general, and particularly about map-like formats. The important information which is gained by this kind of research does not, however, tell the **whole** truth, even about map use, and particularly where the more **pictorial** forms of display are in use, new contextual factors operate within the overall perception. A whole new series of considerations has to be addressed when the tactile is being used convey real information in the classroom.

A similar situation is met by mobility specialists who use a tactile map to provide way-finding information (Bentzen). For example, a given texture or symbol must be not only discriminable, but meaningful in the context in which it is used.

In picture format it is also clear from the author's observations between 1985-1992 that with experience and confidence a blind person may recognise features of a picture (or an object) quite rapidly, and without first going through a process of exhaustive exploration and introspection. Teachers and lecturers working with blind students occasionally say, 'Well of course, tactile pictures are read just like braille. The fingers scan across the page serially from left to right, and then finally interpret what is felt.' None of the writer's observations suggest that this is generally so, although it is possible to think of a few diagrams whose structure would cause the reader to work in such a manner. What generally seems to happen is that structures and components quickly emerge from the picture as a gestalt during the preliminary touch of the page, and that meaning is then attached to these by the reader. Recognition can be in some cases quite rapid - so rapid that it appears to be instantaneous.

As this book will stress repeatedly, this recognition only comes as a consequence of more fundamental handling experience, operating un two levels:

a) the level of simple shape in the geometrical sense; and
(b) the level of form and organisation as found in the subject matter under study.

For example: a picture of an apple is identified first as a slightly deformed circle or sphere and then it is recognised within a subject context as fruit and apple. As the percept takes shape at each level the reader may need to check the presence or absence of additional minor features to select the most likely contenders from and range of possibilities before eventually arriving at a diagnosis.

1.8 Method of reading tactiles

There are fairly definite strategies for the reading of braille text, which are universally taught in order that the reader keeps his/her place and doesn't overlook anything. This may include the co-ordination of two hands, or the use of one hand as a place marker while the other reads. It is more easy to miss things by touch than when reading visually. Berla (1972) Investigated the use of similar reading strategies for tactile maps and did not reach such clear-cut conclusions. His only generally applicable conclusion was that **some** systematic strategy was beneficial in ensuring that important features were not overlooked, but of several possible approaches which he encountered, it was not very important **which** one was adopted as long as the reader was in some way systematic. Unsystematic readers tended to make errors and overlook things.

Berla's tactile maps, like most such examples, were in a clearly defined rectangular format. Not all tactile pictures are framed in this way. In fact the frame could often simply add to the clutter on the page. Unframed diagrams naturally need to be approached with even more flexibility, although the need to ensure that the preliminary handscan is all inclusive is still important.

As will be described elsewhere, when a more experienced blind user approaches on of the more pictorial representations, rapid conclusions can be drawn from an early partial exploration of the picture, and this may be sufficient to convey the necessary information. Part of the person's education needs to be directed towards strengthening the judgement which allows the reader to decide when enough information has been obtained or when, conversely, a display needs to be explored more thoroughly. A blind reader needs to learn to take risks, backed up by considered judgement, in order not to be permanently handicapped by slowness.

All of the types of diagram discussed in the first few pages of this book have their tactile counterparts. The ease with which they can be read will depend upon whether they are

closely related to things that can be felt with the hands or whether they have some obvious variant which can be learned and associated with mathematical or other information. Every new situation may require its own special kind of information but the reader must be taught to approach all diagrams and pictures in a manner which is likely to extract any necessary information from the tactile page. The features of an adequate educational curriculum to make the best use of these diagrams will be discussed later in this book.

1.9 Pictures as a visual phenomenon

This book will sometimes consider pictures as a visual phenomenon besides dealing specifically with tactile pictures and tactual perception, because the overwhelming majority of the writing on picture perception deals with the pictures of the visual world. It would be unwise In make too great a digression in this direction, but there is copious information on the perception of pictures and natural scenes from those concerned with perception in animals (Sutherland, 1963); from those concerned with cognitive research (including more recently those whose interest is related to object recognition by computers and in aspects of artificial intelligence) (Watt 1988) and finally from those interested in picture perception from an artistic and historical standpoint. (Gombrich, 1960).

Because these insights contribute to our understanding of how a visual image is understood they have potential relevance to our response to other (eg tactual) sorts of image and some of them will be discussed further in Chapter Seven of this book.

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Chapter 3

Tactile Graphics

CHAPTER TWO: Tactile diagrams in educational use

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2.1 Past availability and quality of tactile pictures

No discussion on the use of tactile pictures in the education of visually impaired children would he complete without a mention of the situation as It has been until recently.

Until the writer began full-time research on tactile diagrams in January 1985, there was no-one in the UK working on tactiles who was able to combine an educational perspective with the necessary technological and design ability, and to underpin this with a framework of research. The physical quality of diagrams available from (mainly) charitable sources was not as good as the available technology allowed. Reasons for this included lack of design skill, but more seriously a situation where producers frequently lacked knowledge of the educational environment in which such diagrams would be used.

The best diagrams available tended to be made by teachers of the blind, but the many other demands on their time meant that such diagrams were few in number. Demand outstripped supply, and there was no effective co-ordination of supply. The sterling work of pioneers such as Pickles (1968, pp118-l54) heralded improvements in all kinds of diagrams, but still the quality of master diagrams was not exploiting the potential of the thermoform method of production to the full.

The situation with maps was not as bleak as for other kinds of diagram, and the work of the Nottingham University Blind Mobility Research Unit (James and Armstrong, 1975) led to the development of a standard map kit (James, G A, 1972) which had Its parallels in similar ventures overseas. (Barth, 1982)

The Nottingham Map Kit was often used for other types of diagram, Sometimes unwisely in the present writer's view, and its influence was widespread. This is an example of the way in which ease of use can be the determining factor for a hard pressed practitioner, so that effectiveness of the medium can become a secondary consideration.

Following European seminars on Town Maps and the coordinated activities of working parties in a number of European countries (Hebecq, J-P, 1983), a European mapmaking kit, known as the Euro-Town-Kit was compiled, and is now produced by the Deutsches Blindenstudienanstalt in Marburg. (Deutsches Blindenstudienanstalt 1989) This incorporated the best symbols from the Nottingham Kit and other such sources after thorough evaluation by the working parties but is rather expensive.

Of the material freely available in British educational establishments Mobility and Town maps were thus largely an exception to the generally indifferent quality of tactile diagrams (which is not to imply that there is not room for improvement in maps also). The effect of this general weakness was to give many blind children a bad impression of the value of tactile diagrams as a tool for learning, and sometimes to cause them to

abandon them as a serious source of information. This has become apparent during the writer's conversations with older blind pupils and adults on vocational training courses and in continuing education.

Many teachers also gained a false impression of the ability of their pupils to understand and use tactile presentations, (partly because of the quality of teaching material they were provided with), and thus became half-hearted in the way they employed them in the classroom. Thankfully there were shining exceptions to this generalisation, but it appears that at a time when pictures and diagrams were becoming much more numerous and important in mainstream educational publishing (Mackean, 1962, was one of the early examples, and has run through many revisions) tactile pictures and diagrams were failing to communicate much vital information to blind students. The writer's observations of the educational careers of a number of students would seem to confirm that the shortcomings in diagrammatic material were one factor although certainly not the only one, in narrowing curriculum provision, in restricting examination choice, and hence ultimately in reducing career options for blind pupils.

The effect on the careers of individual pupils can best be illustrated through the experience of a congenitally blind Scottish seventeen year-old preparing for university entrance who was questioned by the writer after three days of educational research at her school involving a number of children aged from eleven to eighteen.

This pupil bad recently used tactile diagrams a great deal with teachers who were skilled In their use, and had become fluent in extracting information from them, and thoroughly at ease in using them. When the writer asked about her experiences of tactile diagrams in her earlier education this girl explained that she had met her very first tactile diagram in a geography lesson at the age of thirteen in circumstances that she described with great precision. She described how excited she had been by what seemed to be a completely novel means of communication. It is difficult to imagine the education of any child with full sight limping through thirteen years without the benefit of pictorial modes of description.

Thankfully improvements are now taking place quite rapidly, and information about these spreads freely. International conferences convened by organisations like those concerned with visual impairment and special education and the International Cartographic Association provide a good forum. In fact, one of the ICA's constituent bodies, commission VII, (Wiedel, 1983; Tatham and Dodds, 1988) has been set up specifically to develop tactile maps and diagrams, and it takes a broader view than its cartographic origins would suggest. It also publishes an international newsletter called 'Intact' for those interested in tactile graphics.

2.2 Young blind children using pictures

In the following sections, which report on some of the author's research with blind children under the age of seven, any child whose work is mentioned can be assumed to be either totally blind or having minimal residual vision unless otherwise described. Where information about congenital or, conversely, late blindness is relevant to the situation of individual children it will be mentioned.

A few of the activities have been pursued with children who have rather more vision and their degree of residual sight is mentioned in the record. The research activities did not take place chronologically in an order which follows the natural teaching order of the activities described so this will be discussed separately.

One of the first investigations was of the effectiveness of simple bold thermoformed tactile pictures in conveying information to very young children. It should be said at the outset that a number of teachers of the blind have asserted that very young children cannot cope with tactile pictures. The examples used in this instance were a few specially produced pictures which were almost relief sculptures of the things depicted. To these were added a few pictures from the writer's existing catalogue of diagrams for secondary age children, chosen in this instance fortheir relevance to the everyday lives of the very young, and their inherent interest for this age group. (See diagrams in appendix).

These included bold pictures of an egg in stages of preparation for an egg cup. This was almost unanimously recognised in tactile form by children whose ages ranged from 3.5 to 6. Of the two exceptions, the first was a very bright 4.5 year-old who guessed that the first picture was an egg, but offered an alternative hypothesis 'it could he a round

bar of soap'. This suggestion was highly significant because it demonstrated the potential for ambiguity in all illustrations, and tactiles are even more vulnerable to this than visual illustrations. This is well illustrated in some of the work of Kennedy and Domander (1984) and Pring (1987) but whereas they continue to investigate this as an interesting psychological phenomenon, the educator's whole approach to the production of tactiles, and even the choice of media for these, must be to be aware of this possibility for ambiguity and to design the illustrations so as to eliminate or at least minimise it. Sometimes this means structural considerations, and at others it can be accomplished by suitable captions or accompanying text to narrow the options a little.

This small boy's alternative postulate for the egg picture was also interesting as an illustration of strategy in an intelligent blind person: what possibilities spring to mind and which do I feel is the most likely? (The boy in this instance was quite prepared to choose the eggas being the most likely of the two possibilities.)

The other exception, a child who found the egg picture very difficult to identify and was completely unable to understand the egg-cup in the third picture of the series, was found to have an overprotective mother who was fearful of him spilling egg yolk down his clothes, so she always fed him when he had a boiled egg. Consequently he had never handled an egg-cup, and did not know that an egg on a flat table would tend to roll. This underlines the importance of varied and extensive handling experiences for younger blind children which are a prerequisite for intelligent tactile picture use later.

2.3 Introducing maps

Another way of introducing 5-6 yearr-olds to tactile displays is by the use of simple maps. Some researchers such as Spencer and Blades (Spencer et al, 1989) have worked extensively in this area, but their work is particularly related to mobility and navigation. The writer's interest is more simply in children relating a tactile diagram or map to some other reality. First introductions have been of various types, all of which have been effective in an appropriate teaching context. These include exploration of the features of a hamster cage, followed by presentation of a simple map whose only braille information was Hamster cage. Lower floor. Upper floor. (The two floors of the cage were shown separately.) Each feature of the cage was correctly identified by two blind 5 year-olds from their memory of the cage which they had examined a week previously. Follow-up work in this instance involved similar mapping of their mainstream classroom which was begun by the researcher and completed by following the two children's own instructions.

Mapwork with younger children can also be given an adventure setting by the use of a classroom sandpit or sand tray. During the course of the writer's research with blind children aged live and six years old a classroom sandpit on a stand was designated as 'a treasure island'. (Hinton, 1991) It was provided with a few boxes of distinctive shape as landmarks (cube, cylinder and triangular prism) and also a small dish of water which was suggested as a pond. The treasure was a small coin in a tiny plastic box which was secretly buried for each child to find. In each instance the child was provided with a thermoformed map showing the positions of the landmarks against a sandy texture. The position of the treasure was indicated by a small raised star symbol. A number of alternative layouts were prepared, varying both the treasure position and in some cases the position of the landmarks. This allowed the task to be made easier or harder for individual children as desired, or for the same child to have more than one attempt.

Children were instructed to explore the map thoroughly, and then to check the positions of the landmarks in the sandpit to see if they matched. (The map was in this instance presented right way up.) Children were asked not to dig for the treasure until they were sure of its position from the map information. They were then allowed to dig in one place only.

In fact every child in this particular group found the treasure at first attempt, although younger children were given maps in which the treasure was easy lo pinpoint, while older children, and those with enough residual vision to allow a good oversight of the sandpit were given a more demanding layout, probably involving a crude distance estimate from relevant landmarks. This exercise was carried out within a developing programme of map, picture and shape work, and for educational reasons it was important that each child found encouragement as well as interest in the activity. For this reason, and because of the varied degree of impairment within the group it was not assessed quantitatively.

2.4 Drawings from life

In Chapter Six of this book the writer will discuss in detail the shortcomings and difficulties for blind users inherent in line drawings. These difficulties have to do with the fact that a raised line in a tactile diagram will emerge as a structure in its own right and will have a meaning (possibly the wrong meaning) attached to it by the reader. It may, for example, be perceived as a 'wall' surrounding a void. When areas of a diagram are given a textured infill, the line indicating the limit of this (always given in visual illustration) may be unnecessary and confusing.

Despite their incompleteness as a communication aid for blind users tactile line drawings do have a place in education, not least as a way of acquiring some understanding of the conventions of visual illustration which may he useful as a quick means of representation on German Film.

There is a social dimension to this in that the vehicle for communication should not be allowed to differ too wildly from that in regular use without a very strong reason. This could cause unnecessary educational isolation for the user.

In one phase of the author's research blind children were encouraged to make their own drawings on (German film of objects which they had been shown or had collected during other lessons. The justification for this activity was partly the need to increase their general repertoire of understanding of tactile pictures and their connection with the real world which they experienced, and also the educational need to maintain a lively and stimulating context in which picture skills can be developed. In the latter case there is a need to practice and repeat some of the necessary operations. It is important that the circumstances in which such operations are practised do not become dull and uninteresting, but that the desire to record things that the child has experienced gives purpose to the drawing activity.

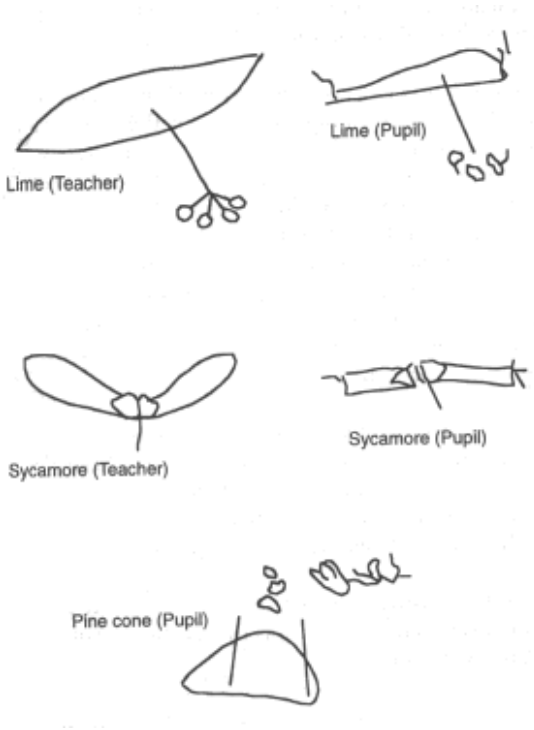
At a more fundamental level it is necessary to practice the control of the drawing instrument and the fluent drawing of straight and curved lines. (Sections 4.4 and 5.2).

The stimulus for these drawings can be a professionally produced thermoformed picture, or a real object which pupils have been able to handle and examine. Examples illustrated include attempts to show the outline shape of an egg: the winged fruits of sycamore and lime; and a child's attempt at representing a fir cone.

Fig 1: A six year-old blind girl's successive attempts to draw an egg on German film

The egg pictures illustrated in Figure 1 are a reproduction of one child's work page, showing repeated attempts to render a satisfactory egg outline. The standard was set by the child, and not by adult intervention, although the researcher did comment on successive attempts by way of helping the child to direct her efforts. In fact from the beginning she was conscious of imperfections in her own drawing, and decided for

herself what needed to be done to brinug about an improvement.



The two tree fruit drawings were copies of the researcher's own line drawings (also shown), although in each case the child was able to feel the real fruit as well. This particular child was being shown how a simple line drawing could be used to show features of the read thing.

The pine-cone picture (Figure 2) was made towards the end of a lesson with no opportunity for further attempts. In this case the pupil was not given a teacher drawing as an example to imitate. It became clear that the child had not fully understood the structure of the cone. Some of the important features of its architecture were inaccessible to the child because of the closeness of the cone scales. The pupil really needed a larger example at this point so that the origins of the scales and the central column of the cone could be appreciated with the fingers. In the example given the child could only feel isolated bosses of the scales with no clear connection between them, so her picture is probably an accurate representation of what she was able to feel of the fir cone.

This illustrates the need for a thorough structural appreciation before drawings are attempted. Teachers need to ensure that the right opportunities arc presented for this to be achieved, and to beware or expecting the child to represent features which the teacher has been able to appreciate mainly through vision rather than touch.

In this kind of drawing activity it was frequently observed that the structural understanding of the pupil was much greater than the quality of the illustration suggested. One significant observation that the author has made repeatedly in drawing with blind children is that their perceptual ability is far beyond their executive ability in the early stages. They are usually immediately aware of the shortcomings of their own drawings and suggest how improvements can be made even when there are major manipulative problems to be overcome in reaching the desired result. Teacher criticism is not necessary.

The control problems to be overcome by a blind child learning to draw have been discussed elsewhere, as has the need to give adequate opportunity for practice. Only by frequent use of the drawing apparatus can the pupil's drawings become matched with her/his perceptions.

Another approach to the reading and drawing of diagrams and maps which was tried was the teaching plan developed by Yngstrom (1988).

This has been described separately in Section 4.4 where it is discussed particularly in relation to congenitally blind pupils, because of the many control skills etc which need to be learned through systematic teaching if this useful teaching plan is to be followed

successfully.

2.5 Simple plane geometry

Alongside some of the other work, young children need to learn the characteristics of some of the simple plane shapes such as the square, circle, triangle· and rectangle. These were introduced by means of some of the standard templates sold by educational suppliers for mainstream school use. These were used as templates for tracing onto German film, and later for free-hand drawing. A useful intermediate stage was to present the child with an incomplete shape for identification and subsequent completion. The amount to be contributed by the child can be varied according to need.

Important teaching points included the need to verify the starting and finishing points of the section to be added, and to ascertain whether a straight line, a bent line or a curved line is required.

In locating the required addition, the blind child is of course unable to be guided by the constant visual feedback enjoyed with full sight. In substituting touch monitoring for this lack of vision, the successful blind draughtsman needs to replace the frequent and regular touch checks, which can give a 'stepped' result from small corrections of alignment and counter corrections with a confidence of line born of kinaesthetic practice.

The task is successfully completed by confident assessment of the parameters of the line which is needed to complete the shape, followed by fluent insertion of the completion line. This can only be achieved by a draughtsman who has felt the necessary movements many times and knows what the sequence should feel like. This problem is discussed in relation to the special needs of congenitally blind children in Chapter 5.2

2.6 Solid shapes

Congenitally blind people need to learn the significance of viewpoint or aspect, when correlating an illustration with a solid object. If the hands are the only means of 'looking at' the object, they will most likely become aware of a greater proportion of its surface than could be seen by the eye from a single viewpoint. In trying to illustrate what they understand of an object they may include what the visual artist would describe as 'hidden detail'. This is well Illustrated by some of the drawings reproduced by Kennedy. (1982, p.322)

However, the writer's observations of young blind children confirm that by continued use of appropriate educational resources and the opportunity to discuss what they find, blind people can quickly appreciate the predicament of the sighted person and begin to learn and to be able to estimate what could he seen from one side, (particularly when the viewpoint corresponds to the standard 'elevations' of the architect or draughtsman). Unusual viewpoints may introduce angular judgements which are too difficult for a person working entirely by touch.

The author's classroom research demonstrated that congenitally blind children as young as five could understand the changing face of a rectangular box (cuboid) depending on the direction from which it is viewed, and could successfully demonstrate this with free hand drawings on German film. Similarly, a child would describe circular and rectangular aspects of a traditional cocoa tin, and be capable of illustrating these.

The writer would teach this by deciding on the viewpoint and then pointing the index finger towards it from that direction, so as to feel round the shape from that side. Some children need very little reinforcement of this, and can give quick responses to questioning, whereas others find the necessary thought process hard. It depends partly on the intelligence and maturity of the child and partly on the richness of the child's previous experiences.

Kennedy has done some interesting and useful research on drawing strategies adopted by congenitally blind adults to show hidden three-dimensional aspects or moving parts of solid objects. These include such strategies as to display even the rearward facing sides of a solid object (which would be hidden from normal vision) as in the opening out of the sides of a cardboard box. (Kennedy, loc cit, pp 322-324) or, in another context, showing the motion of the spokes of a wheel by curving them or by an esoteric code reminiscent of a wisp of smoke around the wheel. (Ibid, pp 327-328) Here again, Kennedy is a psychologist investigating the cognitive process whereas the educator attempts to devise a learning sequence which will produce a useful and reproducible

result. Valuable though these experimental insights are, it is important that blind people who use drawings can employ them for two-way communication. To do so they need to understand the relationship between the drawing and the object, and the significance of any drawing conventions they employ. This includes ultimately an understanding of where, if ever, these conventions differ from those habitually used by people with full vision.

Drawing with the finger or otherwise feeling round the shape is part of the necessary learning process as is plenty of plane geometry shape work.

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Chapter 4

Tactile Graphics

CHAPTER 3: A simple experiment as a key to teaching strategy

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3.2 Interpretation of results
3.3 General discussion of the experiment
3.4 Language as a tool for directing action
3.5 The importance of experience 'on the ground'
3.6 A consideration of these observations in Piagetian terms
3.7 'Conjecture and refutation'

3.1 The nine cup layout

Before children who are blind can correlate pictures or maps with any kind of external reality they need to develop an awareness of shape, direction and distance. An understanding of scale can be developed as the child matures, although the first clues to this will dawn naturally on most children. Comments like, 'You realise I couldn't draw the whole room on this piece of paper, so I have had to shrink everything down to fit' will help in the early stages. Directional sense can be developed through exploration opportunities, through games and through activities which involve making connections between plans or maps and the environment.

As a simple and controllable spatial exercise with a map the author used nine identical plastic cups in three rows of three open side downwards on a table (usually on a clingy rubber mat to prevent the cups sliding about unnecessarily during handling). Each cup had a blob of Blu-tack adhesive rubber within it which could be used to hold a small coin or other hidden object. Although the cups were of three different colours; blue, pink and green, these were used at random and children with residual vision were warned to disregard colour when making choices.

The task was to decide under which cup objects were hidden by extracting the information from a thermoformed diagram. This consisted of nine raised discs, mainly smooth in texture, with the cup containing the 'treasure' being indicated by a rough sandpaper texture. The child was asked to decide which cup or cups contained the treasure and then asked to choose the cup by first touching it, and then to confirm the choice by overturning it.

At the first stage only one cup contained a hidden object. With more proficient pupils two cups at a time could be used and the pupil asked to choose the two cups simultaneously. Later, a few of the cups could be used in a more abstract or random pattern because it was felt that it may be more difficult to retain a mental picture of this kind of array. which would therefore represent a further stage of development.

The original task with nine cups was also found to be too difficult for some of the children in this group so the teaching aims were sometimes modified during the course of lessons. Thus with one pupil a smaller array of cups to gradually extend the skill of the pupil. Similarly when another was having difficulty in translating the 'map' information for the task of the cup-choosing, the map could be placed in dose proximity and in front of the array of cups to make one-to-one correlation easier. (It must be noted that even at this stage this pupil's eyesight was still not good enough to allow the pupil to see the map and the full array of cups simultaneously. A hand movement was still necessary.) So the original test was broadened into a teaching programme for the children concerned.

3.2 Interpretation of results

This simple experiment gave some interesting results which helped specify the hierarehy of sub-skills which make for success in this task, or indeed in any collection and use of spatial information from a tactile display. Simple numerical results **could** have been recorded, but this approach was not adopted because:

(a) any bald numerical results would have been highly specific to a particular group of children and classroom environment and difficult to extrapolate to other teaching situations in any meaningful way.

Also:

(b) this activity constituted a genuine teaching experience for the children concerned, so that each child was dealt with in a sympathetic and supportive way, and led on to greater and greater success. At the same time the skilful teacher/researcher could gauge each child's weaknesses and specific problems and use this information to guide remedial action.

It would not be appropriate here to describe detailed case: histories for individual children although more detailed information has been published elsewhere (Hinton, 1991). Instead. The pattern of development which emerged is discussed in broad terms. The timespan of this investigation was about four months.

3.3 General discussion of the experiment

The children's individual progress illustrated some of the sub-skills which are important for success with this task.

Firstly, the child must be capable of listening to and reacting to simple instructions. With children in the five to six age group it is quite usual to meet a few children who while being basically intelligent and co-operative are not at a sufficiently mature state of development to be capable of responding fully to the instructions given by the teacher. It is possible to deal with this problem by breaking down the instructions into smaller steps, or by simplifying the whole task, as was done in this instance by offering a smaller array of cups.

There may also be children whose attention span is not very long, or who do not listen very well, and perhaps are prone to distraction, or whose general intelligence is not adequate for the task. As has been mentioned, most of the writer's researeh interviews were also teaching sessions for the children concerned. For this reason, stark statistical differences were not left unattended to, but each child's contribution was accepted, and suitable guidance was offered so that the child's experience could be extended and its performance improved step-by-step without more ado. Although important in the teaching of the children concerned, it of course had an effect on the presentation of researeh data of tending to blur the differences and narrowing or even obliterating the final range of results.

Another limiting factor for performance was the willingness of the child to explore the tactile map so as to find the information which first identifies the target cup. Most of the children were happy to attempt this and persistent in examining the map until the marked discs were identified. Any further differences between pupils then resulted from differences in their spatial sense, and ability to remember an array or the position of the target. Short-term memory must also be considered in this connection and is discussed in Section 4.2 of this book. The one child who was half-hearted with the actual map had a background of some deprivation of normal activity which inhibited her use of her hands. Her teacher had already done a great deal to improve this situation and the child showed every sign of overcoming this weakness in her development.

When children had obtained the positional information from the map, the two remaining factors for success were remembering the information for long enough to transfer the hands from the map to the array of cups, and coupled with this, having a sense of direction and position sufficient to act upon this information. Blind children of similar general intelligence do vary in their sense of position and ability to navigate accurately. The map-makers and environmental psychologists have explored these differences in some detail, and they are of course found also in fully sighted children. A book by a

researeh team at the University of Sheffield (Spencer, Blades and Morsley, 1989) discusses the whole question of children's spatial ability and Morsley has particularly investigated this in blind children.

3.4 Language as a tool for directing action

Some children are able to describe their strategy for locating the target, which appeared to consist simply of counting cups from the left-hand side of the array to the target. No other strategies were described, and it was not felt to be educationally justifiable to interrogate the very young children in this group to discover if other strategies were in fact used.

It is clear that language becomes increasingly important in the years leading up to school entry. Thus the children who were able to talk about their strategy for remembering and correlating the position of the target from map to table would appear to be in a stronger position to make an accurate location than children who appeared to be less mature and less able to describe the experience. However, one should not fall into the trap of ignoring personality differences in making judgement on this kind of activity.

From working with one pupil over many weeks the author became aware that this child was of a quieter and more self-contained disposition, not so prone to voice her thoughts in public as some other pupils. The mere fact that her strategy was not made public did not mean that a similar cognitive process was not being performed, and visual observation of her actions in fact suggested that it was.

The development of language use and the understanding of the language which allows place, relationship and action to be described becomes a powerful tool for the control of action and for relating that action to a current position and a desired end. The children who appeared to be less mature in the group described above appeared sometimes to be acting instinctively and their actions in response to the tactile map seemed to be almost as likely to be wrong as right.

The final factor affecting the children's performance in the nine cup task was the possession of sufficient residual sight, however imperfect, to allow an impression of the whole array of nine cups to be viewed simultaneously. Such a level of vision conferred a great advantage. Note, however that the child still has to retain in mind the information from the tactile map. No child in the group described had sufficient vision to see that as well, and neither did any child feel the tactile map while they were actually choosing the cups.

It is appropriate here to refer back to the more random or abstract type of array used with some of the more proficient children. This in fact presented a less difficult task than was surmised originally. It appears that with this type of array, once children have identified the target on the diagram they are able to keep in mind a much smaller sub-group from the array which contains all the relevant landmarks for locating the target cup. With such a stratagem it is not necessary to remember the whole array. In this connection a quotation from Mackworth and Morandi (1967, p551) is noteworthy:

The perceptual process is continuously trying to find simplifying regularities and consistencies to detect and discard unwanted, redundant stimuli which may overload input channels.

As these 'simplifying regularities and consistencies' emerge they act as a kind of pictorial or structural mnemonic which enables chunks of incoming information to be held and handled in short-term (or indeed long-term) memory more easily. Masses of information, whether tactual, visual or verbal, which appear to be largely formless or structureless, or whose structure is diffuse and monotonous, are very difficult for the nervous system to deal with. This applies to the higher cognitive structures of the brain as well as to the more immediate perceptions of the peripheral nervous system and the operation of short-term memory. (See Chapter Four)

The results from this very simple investigation suggest that it would be a simple matter to devise a series of educational experiences, many of them capable of being confined to the table top. in order to develop the spatial ability of visually impaired children and provide a worthwhile supplement to the larger scale activity of the mobility teacher. This particular task is also useful diagnostically to assess development over this short age bracket (say four to seven) in order to choose a suitable level of activity.

3.5 The importance of experience 'on the ground'

In seeking to develop the spatial understanding of young blind children it should also be noted that there is evidence from experiments on kittens that an animal which is allowed free exploration develops better understanding of its environment than an animal which is passively transported over the same ground. (Held and Rein, 1963) In a similar way, disabled children who are pushed everywhere are less sure of the direction which they must lake to get to a desired destination in, say. their school than able-bodied children or disabled children who propel themselves. (Foreman and Gell, 1990) The conclusions of this experimental work are echoed in researeh on mobility maps with students in higher education where there was better understanding of tactile map information by those students who were active explorers, than by those who were by habit less independent. (Casey, 1978)

Restricted in scope though this experiment is and limited though the learning potential of the equipment is, it shows among other things how such a simple formative evaluation of the child's ability can be a useful guide to development activity.

3.6 A consideration of these observations in Piagetian terms

Piaget spoke of generalised abilities which allow certain basic reflex actions to take place as 'schemata'. At birth these schemata control the basic reflexes such as grasping. sucking and looking.

Any new event in the child's environment is responded to if possible by being 'assimilated' into one of the schemata of the current cognitive structure, eliciting then a stock response. Such assimilation does not constitute learning, for learning implies expansion of the cognitive structure; a modification or extension of one or more of the existing schemata. This process Piaget calls 'accommodation'. In fact there is a sense in which all learning depends on failure, a failure to solve a problem by existing behavioural patterns (Piaget would describe this as a failure to assimilate the experience). Optimum conditions for learning come from experiences which are mildly challenging so that an amount of assimilation is possible which is reassuring and encouraging for the learner, while at the same time accommodation is necessary to take full possession of it, thus extending the cognitive structure. If the challenge is too great it may overwhelm and bewilder the learner; if there is no challenge or too slight a challenge, learning will not take place or will be minimal.

In dealing with individual children's responses the teacher/researcher was trying to achieve optimum conditions for learning for each child, though admittedly acting at the time with the intuition which comes of long teaching experience.

Piaget would have no difficulty in explaining in these terms either Held and Hein's data from the experiment with kittens (Held and Hein, 1963) or Foreman and Gell's findings with disabled children (Foreman and Gell, 1990) or indeed Casey's experience with blind college students. (Casey 1978)

Only by building up a wide range of schemata, in these three cases from active exploration, can the kittens or people concerned hope to make sense of their surroundings. To continue to learn the child needs to experience situations in which he/she can observe that hi her existing schemata are too narrow or in other ways imperfect so that the existing structures are modified or extended to accommodate these new situations. If the child's experience is not broad enough, and if the opportunity to explore is not given, the exceptions to existing schemata will not become apparent.

The next chapter of this book discusses the same situation in rather different terms in discussing the effect of long-term memory on tactual perception.

Piaget also describes the increasing utilisation of cognitive structures in responding to the environment as a child develops, with consequent lessening of the need for the environment to be 'here and now'. Piaget's word for the process is 'interiorisation', The building of more elaborate cognitive structures make more complex problem solving possible. Thought itself becomes a tool with which to respond to and manipulate the environment, Piaget, in fact, described stages of development, thus:

- Sensorimotor stage
  A very egocentric stage in which objects seem not to exist for the child when they

cannot be seen or felt directly.

- Stage of pre-operational thinking
  In which rudimentary concepts are established but in which things call be wrongly classified by transductive logic,
- Stage of concrete operations
  In which children can solve quite complex operations as long as they are dealing with concrete objects and real events,
- Stage of formal operations
  On which children can deal with hypothetical and abstract situations.

Maturation in the physical. neurological and genetic sense is important, but Piaget also emphasises repeatedly the need for cumulative experiences with the environment.

He originally put forward this classification in a paper entitled 'Les stades du developpement intellectuel de l'enfant et de l'adolescent' at the 3rd Symposium de l'Association de psychologie scientifique de langue francaise in Geneva in 1955, but it is cited repeatedly in English translations of his later works (Piaget and Inhelder, 1967, p 454) and in later commentaries on his theories. (Gruber and Voneche, 1977; Inhelder et al, 1987, p 141; Hill, 1990, p 115).

By the chronology which is usually given for Piagetian stages one would expect the children who participated in the experiment described above to be completing their transition from pre-operational thinking to the stage of 'concrete operations' and the observations seem to bear this out. Their increasing facility with language, not only to describe objects, but also to specify (and indeed to remember and control) actions is likewise a notable feature of development in this age group.

3.7 'Conjecture and refutation'

Karl Popper's view of the learning process may also be considered in this context. Popper believed that 'we have been born with the task of developing a realistic set of expectations about the world'. (Berkson and Wettersten, 1984, p 16) Berkson and Wettersten summarise Popper's view thus:

Because we do in fact learn by conjectures and refutations in an effort to solve problems, the best way to make progress in the growth of knowledge is to focus on and articulate problems, to conjecture solutions boldly and imaginatively, and to assess the proposed solutions critically. (Berkson and Wettersten, 1984, p 27)

Popper would therefore applaud a 'problem solving' approach to learning. While this may not be practical or advisable as an all-embracing strategy for the education of visually impaired pupils, the writer nevertheless believes that one way to broaden the outlook of blind children is to encourage them to make, and then evaluate, reasonable hypotheses regarding the things they encounter. It is very easy for a blind child to become inhibited by the fear of 'making a mistake', This problem is discussed again in section 4.3 of this book.

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Index
Chapter 5

Tactile Graphics

CHAPTER FOUR: Questions of memory and strategy

4.1 The influence of memory
4.2 Short-term memory
4.3 Speed and accuracy in scanning
4.4 Using Yngstrom's methods with 4-6 year-olds
4.5 Memory and experience

4.1 The influence of memory

Any perception based on tactual input has two components - a sensory component and a memory component. Even if other modes of sensory input are excluded, the haptic sensations arriving at the central nervous system only partly account for what is perceived, because these sensations are integrated with the subject's memory of previous experience, (most powerfully with previous tactual experience) and are then attended to, identified, evaluated and responded to in the light of this experience. It follows that variations in previous experience may he expected to modify the perception. it also follows that any outside influence or supplementary information which may alter the subject's expectations will also have a marked effect on the perception.

To offer a simple explanation of this: Within the total darkness of one's own bedroom, stretching out one's hand may cause a fingertip to collide with, say, the top of an alarm clock on a bedside table. In these familiar surroundings which signal a specific 'expected environment', well-known and precisely located objects can be identified or predicted with a surety which cannot be explained solely on the basis of the meagre sensations of that brief touch. One has a strong perception, not only of the actual objects touched, but a knowledge of the environment constructed largely from a memory of surrounding familiar objects and furniture.

Contrast, then, the experience of Sammy Mountjoy, the central character from William Golding's novel. 'Free Fall'. (Golding1959 pp 166ff). He is blindfolded and imprisoned in a small cell. The last words of his inquisitor, Halde, which remain on his mind are 'If necessary, I will kill you.' In this frame of mind, his ceil becomes a possible anteroom to a torture chamber and a moist, slimy lump on the cell floor is identified as a piece of decaying human flesh, possibly from a previous victim. It is only when he is released from his place of confinement that a backward look reveals that the cell is merely a hastily cleared broom cupboard and the 'human flesh' nothing more sinister than a wash leather inadvertently left behind. His mind had created bizarre Identities for the objects he had felt in the darkness.

This account. although fictional, is a valid statement of experience, and these two lighthearted examples, the first homely and familiar, and the other bizarre and threatening. offer a clue to the range of possibilities for a blind person reading a tactile display. Sensations received through the fingers at the time of reading only partly account for what is perceived, although by careful design what is provided on the page may derive the utmost advantage from what is contributed from memory.

The author carried out simple experiments with blind children from four to six years old in an attempt to evaluate the relative contribution of touch sensors to the identification of familiar objects by artificially restricting the amount of finger contact to the tip of the index finger and the opposing thumb as in the picture. The fingers were held by the experimenter's hand to prevent any perceptible sideways movements, but allow a small freedom of pressure. The objects and contact points are listed in Figure 3 and the results

are given. Except for the two slight variations listed, the identifications were unanimous, and for the ball two additional bits of information were offered by some of the children.

Object	Contact point	Response	Further question or action	Further response
China cup	Bottom of handle where it joins cup	Five said "a cup" one said "a mug"	If "mug", allowed to feel bottom of vessel	"Oh no, it's a cup!"
Ballpoint pen	Middle of barrel	Four said "a biro" one said "a pencil	If "pencil" asked what pencil is made of and then "is this wood?"	"No it's plastic. It must be a biro"
Soft ball of tennis size	Surface	Always "a ball"	Always "a Ball"	All said " a soft ball". One also said "it's a sponge ball. An old one, because the paint is flaking away".
Ballpoint pen	Cap and clip	Always "a biro"	Always "a biro"	

Fig 3: Identifications made by six blind children aged 4-6 from a restricted contact with everyday objects.

Plainly, complete identification of the items given would not be possible from the restricted contact allowed without considerable previous handling experience of the objects, or to put it another way, it would be impossible to construct a perception of these objects from the available sensations alone.

Similar results are found with tactile diagrams and pictures and the result will vary according to the richness of the subject's previous experience and the extent to which this is relevant to the picture or can be brought to bear upon the picture. A variety of responses are found which are often so specific to the subject matter that no useful purpose would be served by quoting individual examples, but to attempt some systematisation of these, consider three possible cases:

(a) Diagram not met before by subject, nor any similar diagram.

(b) Diagram not met before, but similar or related diagram has been used previously.

(c) Diagram or an exact copy met before.

The normal results from these three possible situations appear to be as follows:

(a) The subject will understand the diagram if it bears some similarity to objects from his/her real world and this similarity is sufficiently obvious to the touch. The wider the subject's handling experience, particularly if this has included tactile pictures, the more proficient is he/she likely to be.

b) Similar results to case (a) with greater chance of success the more obvious the similarities are. Any clues from braille titles, tape or oral instruction will enhance the effect of the diagram.

(c) Recognition can be instantaneous from very slight contact. There is frequently no need for full scanning of the picture. Serial reading of the shapes as in reading lines of braille is not required.

Very frequently an almost instantaneous identification can result from contact with a tactile picture. It needs to be emphasised that such a quickness of identification is only

possible if the blind person is prepared to risk what Millar (1974) describes as 'a trade-off between speed and accuracy'. The subject relies on the picture (or object) not possessing bizarre and unpredictable distortions in the spaces between the finger contacts. With one of the familiar objects described in the simple experiments above, the subject is making the reasonable judgement that there is no surrealist embellishment attached to the cup handle, for example. This would be very unlikely in everyday life, although theoretically and practically possible.

This behaviour also accords with some of the postulates of general information theory in which expected sequencing or juxtaposing of elements discovered can help to narrow down the number of possibilities to be eliminated, and thus reduce the information processing load (Attneave, 1959, Chapt 2), as can the possibility of aggregating the information into easily remembered groups or patterns, which also assists memory. (Ibid, p.82).

The operation of the mind in this sort of context was summed up in a quotation from Maximus Tyrius, quoted by Gombrich (1960, p 170):

"The mind, having received of sense a small beginning of remembrance, runneth on infinitely, remembring all what is to be remembred." -*Maximus Tyrius 'Philosophumena'*

When we are presented with a mass of sensory information which at first seems to be formless we try to discover some pattern or rhythm in it; to make some sort of sense out of it. This is something we try to do from birth. Our attempts are very diverse, and the school of gestalt psychology, is founded upon them. In addition, visual an often makes use of this behaviour for successful communication of creative ideas. These may range from cartoons and caricatures to sparse line drawing styles or tricks of colour and shading. To a large extent they are part of the very stuff of visual art which is admirably described by Gombrich in his book entitled 'Art and Illusion' (Gombrich, 1960, Chapt 7).

With tactile pictures, as with visual art, the reader's memory and imagination can be stimulated in such a way that they can be encouraged to run ahead. and even perceive things that are not really present at all. In this way tactile communication can be enriched. These phenomena will be referred to in relation to specific educational diagrams and pictures later in this book.

4.2 Short-term memory

These comments on memory so far refer entirely to what is known as 'long-term memory', namely the memory store which is retained, and can be reflected upon and brought into use as required. There is also a phenomenon known as 'short-term memory' which acts while manipulations and explorations are actually in process and which enables individual sensations or sensation arrays to be integrated and interpreted without appearing to register in any permanent sense in the brain.

Long-term storage may in fact generally involve a strengthening of the memory trace by repetition of the event, either directly or by mental 'rehearsal' after it has occurred. Millar (1974) found that short-term memory impressions decayed both after an unfilled delay of time and under the influence of attention-demanding distractors, but that there was no statistical interaction between these two effects.

Her data appeared to support the hypothesis of Gilson and Baddeley (1969) of 'a tactile impression which delay degrades or makes less accessible and a longer term process requiring capacity with which distractors interfere'. (Millar, 1974, p 262)

This short-term memory is vitally important for the environmental understanding and tactual learning of blind people. Hinton (1984, p 21) drew attention to the problem which blind observers have in bringing overall coherence to a series of tactual observations which are, from the nature of their method of collection, fragmented. Even within the bounds of a single page there is a problem for a blind reader in relating diagram components to each other; in drawing them together to make a recognisable form or 'gestalt'. It seems to be the short-term memory which holds the available information until this gestalt emerges from the welter of incoming touch sensations. This process is necessary whether the features spread beyond a hand's-breadth so that they have to be sampled successively, or whether they can be held simultaneously, but are detected by separate nerve endings.

4.3 Speed and accuracy in scanning

In much the same way that rapid judgements of the identification of concrete objects can be made by a spatially restricted touch, judgements can be made rapidly from sequences of sensation in the scanning of objects and diagrams. Often at even greater speed in fact, because of the richer array of sensations collected.

Millar's comments (Millar, 1974) about the trade-off between speed and accuracy still apply here of course. No blind person could keep up with the pace of modern life and education without being prepared to risk occasional errors from snap judgements, or to quote Millar, (1975): 'Sacrificing some accuracy for speed is more economical when dealing permanently with relatively slow inputs' .

Education must provide the person with the skills and experience to be able to consider a sufficiently wide selection of alternatives for each life situation, and the maturity of judgement to decide upon the necessary limits of this selection. Part of early education should provide blind children with the security and lack of embarrassment from possibilities of destructive assessment by teachers. This would encourage the child to advance reasonable postulates on the basis of the available evidence, and then take steps to collect additional specific evidence to allow them to eliminate some of the possibilities.

Classroom experiences lead the writer to believe that far too often, because of their experiences of pressure from unskilled teachers or over-ambitious or ill informed parents, blind children can be afraid to put forward a suggestion because of the fear that they may 'make a mistake', and thereby earn condemnation. Because of this inhibiting fear of being put into a situation where they appear to be unintelligent or stupid they are not willing to 'have a go'. Many learning situations can thus unnecessarily remain entirely passive and didactic if the opportunity to make an attempt or to 'put up a suggestion as a basis for working' is not provided. It is vital that teachers should find ways of breaking out of this vicious cycle of inhibition and resulting passivity, and that parent counselling makes the parents of blind children aware of this problem at an early stage.

4.4 Using Yngstrom's methods with 4-6 year-olds

Arne Yngstrom is a Swedish teacher with a particular interest in orienteering as a sport and a recreational activity. In recent years he has devoted much time to finding ways in which young people who are blind can be taught to take part in orienteering activities. To do this, of course, they need to learn to relate their personal mobility and space awareness concepts to some type of map.

Yngstrom's teaching methods follow a carefully thought out sequence from tracing round the fingers of the child's own hand on German Film, and on to relating simple table-top models to a drawn plan, before small scale navigation through an obstacle course with the aid of a map, and so on. (Tatham and Dodds, 1988, p 91-108) The various stages develop the child's understanding of a 'map' as a representation of a reality which can be separately experienced.

There is no doubt that Yngstrom's teaching methods with young children are soundly compiled and contain much that is of value to young children. They have also been an inspration to many teachers and a stimulus to researchers. This is not to say that his published lessons are in any way complete as a line of approach with all blind children in the target age group. In fact very few blind children, and those only with a particular background of parenting and experience. can begin the Yngstrom lessons without preparatory training in manipulative and control skills, and Yngstrom pre-supposes a certain minimum of basic mobility skill. The children should have some knowledge of parts of the body, and the ability to find and recognise these in other people as well as themselves. They also ought to have a little experience with simple geometric shapes, and the recognition of everyday objects by touch.

If pupils are to trace and draw on German Film in the way that Yngstrom describes they must first learn to hold and manipulate a pen. This skill alone is harder to acquire for a blind child, who hasn't the ability to observe the teacher's pen grip while attempting to imitate it as a fully-sighted child can. It is a matter of feeling the grip; retaining the model in memory; and then attempting to copy it. Careful teaching is required to achieve this, and since the pen would not normally be used for writing there would not be so many opportunities to practice. Yet there is great value in drawing activity for the blind child, for the need to draw causes more careful tactile observation of real objects

and also helps the pupil to understand tactile diagrams which are later presented for teaching purposes. Besides which, every blind child I know who has tried to draw has found great fun in doing it!

In continuing the kind of development that Yngstrom's methods foster, it is also necessary to be able to trace round a template accurately by following its shape closely. It is necessary to make a consistent and distinctly raised line on the film by holding the pen upright and controlling the pressure on the mat. Too much pressure and the pen digs into the mat; too little pressure and no tactile line is left behind. In this connection it should be mentioned that during work with blind children between 4.5yrs and 6yrs old the writer observed that these children appeared not to show a preference for either right or left hand as early as fully-sighted children in this age group, and this lack of a favoured hand could hinder the development of a firm and controllable pen grip.

In the absence of sight it is vital that children get plenty of practice in the sensorimotor or kinaesthetic sequence experiences which result from following particular simple shapes. This can best be done in the early stages by laying aside the pen, and drawing round templates or objects with the index finger. The shape should be followed repeatedly in this way before any attempt is made to draw round the shape on German Film. Experience in relating an outline on film to the concrete three-dimensional shape should also be provided, and this is something which Yngstrom emphasises in his publications. (Ibid, p 94) It must he remembered that silhouettes (in conditions of reduced light) and outline representations are very much part of the visual scene, but are not really part of the blind person's normal experience. So if outlines are to be used the correlation of outline to solid object must be learned. In the classroom it is useful to provide a selection of objects of the brick and cocoa tin type and to present them to the pupil in various orientations, asking the two-dimensional shape from a given viewpoint. Many five year-olds do this with ease, but some can only make the necessary leap of imagination after careful teaching.

4.5 Memory and experience

To recapitulate the concerns of this chapter:
What is contributed from the pupil's memory forms a vital part of what is perceived from a tactile picture, or indeed from anything handled by a blind person. The reservoir of tactual experience on which that person can draw will be enhanced by wide-ranging touch experience of all kinds (aided by what is experienced by the other senses). This needs to be begun in the child's earliest years if possible, and can be further strengthened by imaginative and carefully presented educational experiences at school. Yngstrom's methods (described above) are a good example of how part of this experience can be offered. Other suitable learning activities are discussed in Chapter 9.

In discussion about tactile diagrams and other spatial concepts the congenitally blind are said to be a particularly disadvantaged group by 'having no visual memory'. The next chapter will discuss the educational implications of congenital blindness and the extent to which this type of statement is now appropriate.

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Chapter 6

Tactile Graphics

CHAPTER FIVE: Congenital Blindness

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5.2 The educational significance of congenital blindness
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5.1 The usual pattern of development of tactile-kinaesthetic ability in young sighted children

Before considering some of the effects of congenital blindness on a child's development it is worth summarising briefly the normal pattern of tactile-kinaesthetic ability in young children as described by Williams, (1983).

Most of the ability in tactile perception develops by the age of five. There are no differences among five to eight year-old children in the ability to locate single point stimuli, but four year-olds are less accurate. There is unfortunately no information on developmental changes in the two point limen test. Only 50% of five year-olds are able to tell consistently when different fingers are touched simultaneously or sequentially. There is a steady improvement in this ability from four to eight but little improvement thereafter.

Three year-olds tend to explore an object by grabbing and patting it, but four year-olds begin to move their hands in meaningful exploration. Five year-olds are more systematic and by six the child uses the fingers to examine special features of an object and discover relationships. There is little apparent difference in ability to compare shapes between the ages of five to eight except that eight year olds are slightly faster. Ability to reproduce designs drawn on the back of the hand improves continually from four to eight year-olds.

Eight year-olds are much better than five to six year-olds in their ability to reproduce a given limb movement. When blindfolded, five to six year-olds are generally unable to keep a straight path throughout a 20ft distance, whereas eight year-olds are significantly more accurate.

Six year-old children with more advanced tactile kinaesthetic ability are superior to those with less well developed tactile kinaesthetic abilities in both gross and fine motor tasks. The differences in performance in the fine tasks are much greater between the two groups of children. By the age of eight, the differences are very slight. Although for younger children the level of tactile kinaesthetic functioning is not an important factor in the level of achievement in reading or conceptual development, it is much more important with older children (twelve to fourteen years). Williams (loc cit) believes that it is possible that poor tactile kinaesthetic development reflects weak cortical development which does not hinder simple motor tasks, but affects higher order cognitive operations much more severely.

In connection with research described in this book there are just three aspects of this developmental sequence which deserve immediate notice. Firstly, there is little apparent difference in ability to compare shapes between the average five year-old and the average eight year-old, except increased speed. This suggests that difficulties with descriptive tactiles presented to children at this age and beyond should not stem from a simple inability to discriminate and compare shapes. There may be difficulties related to the type of information presented.

The second point that may be noted is the improved ability to reproduce designs drawn on the back of the hand between the ages of four and eight. It seems reasonable to suppose that this runs parallel to a general improvement in drawing ability. With blind children, as has been mentioned in the previous chapter there are all sorts of hindrances to the development of the necessary skills, but the exploratory and drawing experiences which have been suggested in this book as being suitable for children in this age group should support and enhance this development in blind children.

Finally, the impact on higher order cognitive tasks of poor tactile kinaesthetic development is noted. Where blind pupils have been taught in a way which does not strengthen tactile kinaesthetic ability, often because some of the more practical and manipulative activities have seemed less important for blind children than the acquisition of information, it seems likely that cognitive development may also suffer, at least by the age of eight. It is unwise to generalise about this for all visually impaired children, but it appears that schools should put more stress on the systematic provision of opportunities for the development of tactual ability in such children and that this is likely to this is likely to aid the development of many higher order reasoning skills as well as manipulative skills.

5.2 The educational significance of congenital blindness

In the past a great deal has been written about the insurmountable difficulties of congenital blindness. Much of this writing has been unnecessarily pessimistic and some of the assertions made about the predicament of the congenitally blind are not in fact borne out by carefully investigated facts. (Birns, 1986; Cromer, 1973) Controlled experiments do not suggest that congenital blindness imposes any further limits on a blind person's general performance, given an adequate education, than late blindness, although it is admitted that the congenitally blind person works against a sensory shortfall which needs to be overcome by careful provision. It is also clear that there are individual differences in performance which override the late blind/congenitally blind division. Some of these may be the result of differences in earlier educational experiences. [Tobin, 1972, p 196).

It was a commonly held belief among some teachers and others, including the less fortunate congenitally blind people of an earlier generation, that 'the congenitally blind cannot understand tactile diagrams' but careful work and observations under conditions which are fair to the blind person show that this is far from the truth. The present writer has worked with some congenitally blind teenagers and younger children who are highly proficient in using diagrammatic forms of representation, not only as an aide memoire after careful schooling, but freely, imaginatively, and with genuine understanding.

Many congenitally blind people of an older generation went through a more didactic educational system in which rote learning was a notable feature. When they complain of difficulties with diagrams, their complaints need to be taken very seriously and met with sympathy and tact, but in the writer's experience rarely denote an insurmountable lack of ability. There is simply a lack of the type of preparatory experience which would lead to success. Happily, some of these people have found enjoyment and interest to a degree in illustrations for leisure pursuits which are now becoming available. (eg; Hinton, 1986 and 1989b).

What differences do need to be borne in mind therefore? There are some visual concepts such as colour, light and shade which can only be approached by the congenitally blind person through some mental effort unsupported by direct sensory experience. Despite this, such concepts as colour can be partially understood by association, and perhaps by some inexplicable imaginative construct understood by each congenitally blind individual only according to his or her personal definition. They become, therefore, concepts which are virtually impossible to describe and yet may be convenient to use in conversation.

Beyond such necessarily visual phenomena, most concepts can be learned by direct sensory experience if adequate opportunities are provided for direct encounter. However such encounters may not occur naturally in everyday life. It is thus vital that this type of opportunity is provided in the home or in formal education, particularly for the young congenitally blind child, and that objects which are not directly approachable because of their size, or for reasons of safety, are presented through some 'reality substitute' such as a model.

To cite two examples which are relevant to this discussion: A congenitally blind 14 year-old in the north of England was found to be unaware that the body shape of men and

women was different and was therefore unable to begin to understand their differing reproductive function. At his age it was obviously a fairly urgent matter for his teachers to ensure that this lack of understanding was put right, and the writer was involved with the Health Education Authority in providing suitable teaching materials for this purpose. (Hinton, 1988c) One can understand why the boy mentioned had not acquired this knowledge, because to understand the secondary sexual characteristics and body shape differences of human beings he would need to feel live human bodies or good models. He was debarred from direct experience of this by normal etiquette and taboo, particularly where the opposite sex was concerned, and apparently models had never been provided for him. Small wonder that another such pupil once confessed to a sympathetic female teacher that in his early teens he deliberately contrived to fall against a female member of staff occasionally for no worse motive than wanting to obtain some of the morphological understanding which he knew he lacked.

Even where adequate models are provided by an understanding teacher in a sympathetic environment there is a degree of embarrassment which prevents a blind student from exploring parts of the model in public with the intensity which may be necessary for acquiring full understanding. This is why such students need a degree of privacy in this study which can only come from individual use of the teaching materials.

A completely different aspect of the problems which exist for congenitally blind students was the blind 9 year-old boy already mentioned who was found by the writer to have no knowledge of egg-cups, because when he ate a boiled egg his mother always fed him for fear of getting egg on his clothes. Hence, he had never handled an egg-cup, and probably had never handled an in-shell egg. So he did not realise that the egg would tend to roll on a flat table and so was normally held in a special vessel called an egg-cup. An illustration of an egg-cup thus meant little to him.

Such illustrations underline the need for wide-ranging handling experiences from earliest childhood, and for parents and teachers to be aware that such experiences need to be provided in a deliberate and cumulative manner.

Another characteristic of this condition is that the child does not have the strong visual role models to copy which are so potent in shaping the techniques and behaviour of fully sighted children. This can weaken the drive to attempt early activities such as standing upright and walking, for example, and at school it can also make such tasks as the controlling of a pen, scissors or other implements more difficult to learn.

The acquisition of an adequate pen-grip, important for a blind child learning to draw on German film, is a dear example of the kind of difficulty. For the fully sighted child it is possible to adjust the grip on the pen while looking at the teacher's pen-grip in a way that can give relatively quick results. Blind children can only feel the teacher's grip, aided by suitable instructions from the teacher, and then have to try to retain a mental model of this grip while attempting to recreate it. It can be done, but with a lot more difficulty and after more trial and error than most fully sighted children would need.

This problem also affects such activities as the drawing of straight lines free-hand as a preliminary to other drawing activities. In classroom work in connection with this project it has been found helpful to practise straight lines by constructing a 'fence' for which the teacher draws two horizontal lines about 5 cm apart. This gives the child a definite starting and finishing mark for a series of vertical lines, and a mildly interesting context in which to work. The close span of the two horizontal lines avoids the complications of forearm drag during the drawing of each line, and also reduces the chance of wandering which a longer line without parallel reference points would present. The distance can of course be increased as the child's skill develops.

Similar problems can occur with tasks such as drawing round a template. Here part of the problem, in the absence of visual feedback, is that the sensation of drawing the shape needs to be experienced as a psychophysical sequence. The actual kinaesthetics of the operation need to be experienced by the child's joints and muscles. This is of course even more important in the earlier stages of learning these skills.

In a teaching session the writer would normally get the child to draw round the template with the index finger 'to see what it feels like' before using the pen. To remain in close contact with the template requires some inward pressure, and the direction in which this needs to be applied will change as the pen progresses around the shape. The pupil can only avoid skidding away from the template by being aware of what is coming ahead of the pen. This knowledge comes partly from experience, and partly from the use of a

finger of the free hand to feel ahead of the pen. (Some more dextrous pupils may use the lower fingers of the hand that holds the pen.)

Similar teaching techniques may also be necessary with blind children with some history of vision, depending on individual needs. Only by adequate interpretation of the kinaesthetic feedback using experience built up through plenty of practice can the blind child's drawing skill be consolidated. It is also important that teachers do not restrict the use of items like German Film for reasons of economy. A child with normal sight lays down the foundation of drawing technique in early childhood by 'scribbling' on countless scraps of paper. Thus fully sighted children in a nursery school go through a progression of making enjoyable hand and arm movements with paintbrush or crayon in hand (perhaps even with finger-paints), so that the movements are traced by lines or patches of colour on a sheet of paper. Then at a later stage these shapes have simple meanings attached to them by the child, who then begins to feel the need to refine and develop the link between the marks and what is depicted so that the meaning becomes clear to an audience. The opportunity to experiment is vital for the acquisition of control and fluency. It is not unusual for the blind child who is encouraged to draw in school (and not all such children are) to find that there is no opportunity for experimenting between formal lessons. The writer has found it necessary in teaching to provide the child with a few spare sheets of film for free practice in spare moments in class or even to take home to show parents or to work in privacy.

With regard to opportunities for direct contact with concrete objects, there are of course particular problems with objects which are inaccessible for safety reasons, or because their size is too vast or too minute to be detectable. Here the only thing that can be done is for some kind of reality substitute such as a model to be provided. With all models or tactile pictures it is important for the child to be aware of the relationships of scale. It is often helpful to make some anthropomorphic comparison to make clear the real size of the object depicted. If extremes of size make this impossible then a description of size or magnification reduction should be provided in some form appropriate to the subject matter and to the educational development of the pupil concerned.

It is also important to ensure that the child's experiences are not entirely formal and instrumental, but after also opportunities for imaginative and creative activity, Anderson (1984, p 209) suggests, apparently paraphrasing Olson (1981, p 375), that:

the curricula of nursery and primary schools should encourage congenitally blind children to investigate more creative or novel uses for common objects rather than simply to use the objects in a stereotyped, prescribed manner. If the creative tendencies of these children are to be enhanced, the children need to be challenged and encouraged to explore the properties and uses (real or potential) of objects, individually or in combination. Since blind children cannot imitate the exploratory and play behaviour of other children whom they cannot see, teachers and parents must model ways to explore and assist them to invent or discover new and different uses for objects.

From the writer's own experience of visually impaired children in school during continuing research it is clear that much is being accomplished along these lines in present day schools. There is also a heart-warming readiness on the part of sighted peers, or children with more residual vision, to involve a blind child in play activity. Nevertheless, it is still true that it is the tendency of the condition of congenital total blindness to cause passivity, and this needs to be overcome if the child is to lead a full life.

It is also true that in the competition for time and resources in the educational curriculum, creative, imaginative and play opportunities lend to be given low priority. The congenitally blind child loses more from this situation than does the child with full vision.

5.3 Older congenitally blind people and their understanding of a scene

Much of the present writer's earliest work with tactile pictures as distinct from the more stylised graphic displays involved the depiction of objects or parts of objects in isolation. Such pictures can take the form of a simple plan, elevation or section and therefore be free of the complications of perspective which influence the depiction of a scene in pictures for fully sighted people. It cannot be too strongly emphasised that perspective is a purely visual phenomenon and is completely beyond the normal experience of a congenitally blind person, although the analogous fading of sound with increasing

distance is a phenomenon of which blind people are aware, and this can be used as an illustration, The decreasing angle from the horizontal of a sound producer as it moves further away is also used by the writer in teaching about perspective to blind adults. The voice of a tall person close to the hearer appears to come from a high source, whereas as the speaker moves away the source seems to become lower and lower as well as more distant. (See Figure 4). The parallel is easy for an adult to understand.

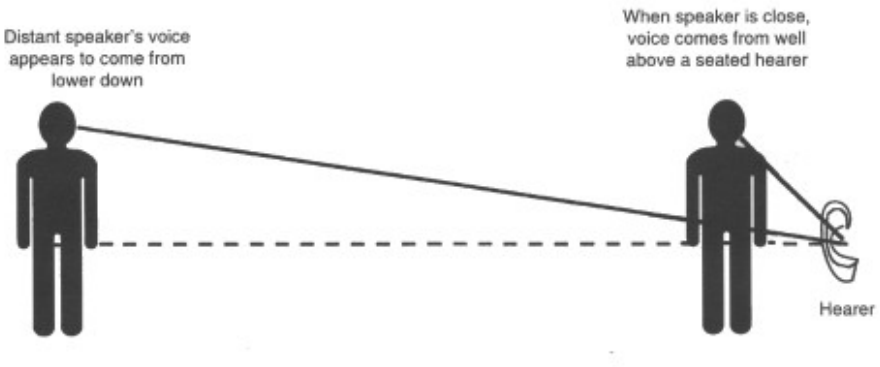

Figure 4: An auditory analogue sed in discussing perspective with congenitally blind adults

Perspective will be discussed in more detail in relation to visual picture perception in Chapters Six and Seven of this book. What has also been interesting in the writer's recent work with congenitally blind adults has been the discovery of more obvious features of pictures which are almost universal in the experience of the fully sighted and yet completely unknown to the congenitally blind person.

One example is the depiction of people facing in directions other than towards the artist. A very intelligent 40 year-old man who was congenitally blind was shown a tactile representation of a painting in which a woman was depicted from her back view. He became absorbingly interested in this picture because he said it had never occurred to him that an artist or photographer might show someone's back view. Yet the more he thought about it the more he realised that this viewpoint not only told him a great deal about the arrangement of the room, but also helped to explain the social relationships between the woman and the people with whom she was in conversation.

Another feature of visual pictures which is really one of the fundamental aspects of perspective is the way in which nearer objects are shown towards the bottom of the picture, and more distant objects towards the top. This is something which congenitally blind people have to be taught to interpret. It is outside their normal experience, unless they have useful residual vision. Bach-y-Rita (1972) and his colleagues (Guarnerio, 1974, p 103; White et al, 1970) had to deal with this problem in their TVSS training and the writer has had to teach users of tactile representations of paintings to understand the same phenomenon.

For the blind person objects are related in space by their distances and directions from each other in absolute three-dimensional terms. Where the distance overall is greater than the subject's arms can stretch the distances between features may be understood in terms of the distances travelled in getting from one to the other. Thus for the blind person there may be a passage of time between observations of one feature of the landscape and another, while for the fully sighted person the distance may be traversed by the eyes almost in an instant. It is the lack of this instant scanning which is perhaps the severest loss for blind students doing environmental fieldwork; individual features may be examined and assessed with ease, but to absorb their spatial relationships with any accuracy may be very difficult. Maps and diagrams help a great deal with this problem.

Both von Senden, and Gregory and Wallace (1963) were able to work with congenitally blind people whose sight had been restored after eye surgery. Gregory (1974, p 92) reports on such subjects responding to standard perception tests and visual illusions as well as to objects from their everyday environment. Gregory found a frequent referral back to tactile experience obtained while they were still blind, and often an inability to identify objects until they were verified by touch. (See also the closing pages of Hocken, 1984.) Subjects were able to describe features of an object which they could see without arriving at an identification of the whole object. Gregory also found that in the early

drawings drawings of sight recovered people features were sometimes exaggerated according to their tactile importance, and the artists could have great difficulty in representing features which they had not had an opportunity to touch. (Gregory, 1974, p 102).

In some cases drawing skills improved along with other abilities in the newly found world of vision, (Ibid p 105) but there were cases where reliance on tactile information could never be completely abandoned. (Ibid p 106).

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Chapter 7

Tactile Graphics

CHAPTER SIX: Effects of picture format

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6.1 Outline pictures

Kennedy is particularly interested in the perception of outline images. (Kennedy 1974, p 106ff) He describes various examples of tactile pictures, including some actually made of distracting and confusing elements (like shells). He concludes that drawings and particularly outlines must be kept simple. However, it appears to the writer that he oversimplifies the conclusions which he draws from some of his earlier small scale experiments, and overrides differences in the experience of his subjects. (Ibid, p 152) Also his statistical conclusions seem unproven, because he does not isolate and control against a number of possible causative factors. For example, he does not deal with the problem of scale in comparing a fork drawing with a diagnosis of 'a hand and arm' (for example). Neither does he take into account the atypical shapes given to some objects in the illustrations he used.

Kennedy's main conclusion, based on use of four plane outlines (hand; fork; man-with-arm-raised; flag) and four projective line drawings (face; cup; man-with-arms-crossed; table) was that there appears to be some deep-rooted human capacity to understand outline depictions of solid objects, a capacity shared by sight and touch. (Kennedy, 1974, p 152) Here again, the possibility of previous relevant experience with pictures is not discussed. The writer's contact with old and young congenitally blind and early blind people provides evidence that practical experience of pictures and conversation relating to pictures undoubtedly takes place, even if these experiences are generally casual and not pedagogically organised. They quite clearly could affect the results of experiments like those of Kennedy.

According to Kennedy's description, brain cells outside the main touch and vision pathways, but with access to both, deal with discontinuities in either vision and touch and accept lines as equivalents of the discontinuities. (Ibid p 112). Picturing was discovered by early people and not invented by them.

The writer believes Kennedy's interpretation (Ibid, p 154) to be too simplistic and to gloss over some other possible explanations for results which are after all generalisations from a rather small sample. It is quite plain from the writer's fieldwork on the development of touch perception in children up to the age of nine that the ease of interpretation of straightforward modes of tactile illustration has a lot to do with the degree of exposure to the crucial shape. For example, the writer included within a selection of tactiles used to assess the ability of 4 to 6 year-old blind children to identify tactile pictures without textual support, two sectional diagrams of fruit which were in fact produced for GCSE examination courses.

The first, of an apple, was correctly identified by children down to the age of three-and-a-half (the youngest children worked with). The researcher cannot remember any blind child failing to identify the subject of this picture, although not all of its components were understood by the younger children. It was found, however that the children were basing their diagnosis mainly on superficial characteristics such as the basic shape, and the presence of a stalk. In this diagram the bold presentation permits no likelihood of figure/ ground confusion and similar misunderstandings.

It was interesting that the comparable diagram of a rose hip was hardly ever identified by younger children without recourse to accompanying Braille text, although this diagram was similar in its style. The researcher believes that this was simply because the rose hip is not a fruit with which young children, and particularly young blind children are very familiar. They were aware of the existence of such a fruit, and perhaps had drunk rose hip syrup, but rarely if ever handled the fruit.

Pring, another researcher who uses mainly outline drawings similar to those of Kennedy, recognises a conflict between 'views expressed within the framework of visual perception' and the way the sense of touch operates. (Pring, 1987, p 38) The writer's classroom experience suggests that with the simple planar diagrams produced on German film (which gives very similar results to the Sewell board which Pring used) the ability to identify and interpret a picture depends very much on the form and complexity of the drawing. When this is done successfully without textual or teacher support it is often by the use of relatively superficial features of the drawing, and as Pring discovered, a simple confusion over components of a drawing can lead to early confusion between the stalk of a flower and the handle of a toothbrush (to use Pring's example). (Ibid , p 42).

There is a strong tendency for line drawings of this sort to rely heavily on artistic conventions established for visual art where the image is supposed to be related to the view of the real world perceived by the retina receiving focused light through the eyeball. (Reed and Jones, 1982, p 270; Gombrich, 1960, p 213) While some of these conventions may pertain to and be relevant to the hand's impression of the world, and others have for the time being an ease of manipulation which permits convenience in educational use, still other conventions are less relevant to the hand's sensations, and may be very difficult for a blind person to comprehend. It may in fact be a hindrance to general understanding that such comprehension should be attempted.

Kennedy's resonant phrase 'Lines depict visual discontinuities' is, however, useful as a descriptor of line drawing (Kennedy, 1974, p 132), and Kennedy in his work on visual art discusses the various types of discontinuities of colour, texture, orientation, illumination and the way in which they may be depicted and understood in visual line drawings. (Ibid, p 106ff)

The much earlier work of Merry and Merry (1933, p 148-163) has already been cited as an example of sweeping generalisations being made on the basis of responses to diagrams of poor quality. They also found that after practice their subjects identified fewer pictures than at the beginning. Among other shortcomings their investigation did not check the possibility of a drop in motivation, and they therefore drew unfavourable conclusions about the ability of the blind to understand haptic pictures. The Nuffield report on the teaching of Mathematics and Science to the blind (Fletcher, 1968) echoed this pessimism despite quoting in an appendix blind students who said that pictures are recognisable and interesting.

Millar (1975) was concerned mainly with the cognitive process but she also had blind children drawing people, which they did recognisably on many occasions and her work demonstrated the benefit of some teaching and experience to her blind subjects.

Kennedy and his collaborators presented a number of simple drawings to adults and recorded a high recognition rate. (Kennedy, 1982, p 318) Although their blind subjects tended to be less adept at this some could be better than their blindfolded sighted subjects.

Once again the previous experience of subjects was not known, and as Tobin points out, (1972) this experience is relevant to the interpretation of results. When making their own drawings of three-dimensional objects Kennedy's blind adults and children often used 'bulky line', 'enclosing line' or 'fold out' techniques to show depth. (Ibid, pp 320 ff) There was also some (apparently instinctive) use of thick and thin lines for near and far portions, although the educational backgrounds of people who used these techniques

cannot be checked. Also from actual pointing and movement tests Kennedy found some suggestion of knowledge of perspective phenomena, but seemed unable to discover whether this was learned or intuitive behaviour. Kennedy fails to give a reason why this behaviour should be intuitive in congenitally blind subjects. Some of the adults also made use of additional graphics to indicate movement, including representations of footsteps, bending wheel spokes and a 'smoky spiral' (the author's term, not Kennedy's). Kennedy tries to differentiate between what is literal in these techniques and what are metaphors. (Unsuccessfully in the writer's estimation).

Kennedy also describes a system devised by Campbell and himself to show features such as slope and concavity. (Ibid, p 330) From the writer's educational experience with blind students this system, though logical, would appear to be an unnecessary complication and one which contains features which are themselves possible causes of further confusion. Kennedy only illustrates the use of this system by an ex extremely simple example, whereas the writer has designed and used many hundreds of tactile diagrams which have been found to be effectively interpreted by blind children and older students, and in many such diagrams Kennedy's code would be hopelessly submerged.

Kennedy's judgement is that a display can be so simple that it does not contain enough information to clarify lines, and yet it can be serviceable. The writer would agree that local difficulties can sometimes disappear if the over-riding message of a tactile picture emerges clearly, but this kind of experience cannot be universally assumed and it should certainly not lead the picture designer to ignore possible sources of confusion in picture components.

6.2 Format adopted in the present project

In the writer's own work simple outline drawings have been found to be insufficient for effective educational use except for very simple subjects such as plane geometry, and outlines well known to the pupils.

The hand and other touch sensors are equipped to receive three-dimensional information about the three-dimensional world, and making sensitive diagnoses from this information. Such information can include surface texture and assessments of movement, weight, and temperature, as well as details of gross shape. Accordingly it is found that tactile diagrams which include appropriate textural information, and strong indications of the third dimension, including concave and convex surfaces, will be helpful.

The eyes can assess the three-dimensional world from what is essentially a two-dimensional image, but in vision the two-dimensional image is enriched by light and shade, and contains modulations and gradients of colour which are often difficult to analyse and describe, but can nevertheless be interpreted and used by unsophisticated people and by young children.

To this is added perspective information, and sequential information during scanning. Although vision is often described as instantaneous in comparison with touch, this statement is only true in a very loose sense, because slight alterations of image obtained sequentially can yield important information about the shape and orientation of objects in the real world, and about their spatial relationships to one another.

In the writer's earlier work on biological tactile diagrams It was found that bold multi-layered relief with convex and concave shapes was needed to convey adequately the rich anatomical information that was sometimes required. (Hinton and Ayres 1986; Hinton 1988a p.26)

People with full vision often see and make use of silhouettes in conditions of bad illumination. Totally blind people never encounter such a flat two-dimensional image. The world encountered by the fingers always has information from the third dimension added to it. Even the suggestion or hint of this third dimension as in, say, a reduced-relief diagram may be straightforward and obvious in use.

Thus the reader may surmise that a structure is shown whole or sectioned according to whether it is depicted with a concave or flat surface. For the same reason concave or sunken channels are often used on a diagram to indicate the presence of a duct or tube, instead of a raised strip or a convex ridge. Although such sunken areas are still uncommon in tactile pictures they are often a more logical and helpful way of dealing with the subject matter, and if of sufficient size, no more difficult to finger-track or

interpret.

Map-makers habitually use standard textures and symbols. Although standard techniques are used in the work being described where possible, and it is particularly important that textures for identical structures in a linked series are followed throughout the series, it is not always possible or desirable to adhere to a standard symbol. In such work, it is the diagram context which is important, and individual textures are interpreted in relation to what is found around them, (Hinton, 1990) perhaps with the help of Braille or other annotations. Thus, standard textures become less important, whereas appropriate and meaningful textures are vital to the understanding of the diagram and its components.

6.3 Line-of-approach and preliminary scanning of tactiles

The line of approach to a tactile diagram is important to the reader's clear understanding of the contents. In his survey of tactile map reading strategy Berla (1972, p 217) found that some systematic procedure was essential if important features were not to be overlooked. Berla did not, however, find that any single strategy was the sole answer, but that any of a number of possible approaches chosen by the reader's personal preference or sometimes by the specific demands made by a particular diagram would suffice. (Ibid, p 286)

Maps are generally, though not invariably, framed within a rectangular border which may also bear co-ordinates and indications of North, whereas the majority of the tactile displays designed by the writer are unframed. The reason for this is that the frame often contributes no useful information to the readers perception of the diagram, but simply adds to the clutter on the page. It may therefore help to confuse the blind user. The whole question of clutter is one of the bugbears of tactile diagram design. The problem is exacerbated by the presence of Braille on the page. Vital though this tactile code is, it is very bulky in comparison to print, and its very bulk may be the overwhelming consideration in tactile diagram design. The problem becomes particularly acute in Higher Education where the display may involve complex now charts and process diagrams. The designer is also entrapped by standard page sizes, and to a certain extent by what the reader's hands can comfortably span, so the space available is limited. Diagrams at that educational level may thus become multi-page presentations which may then require considerable duplication of information for the user's ease of reference.

Diagrams are generally provided with a Braille title and this is almost always at the top of the page, so any instruction regarding the line of approach to the diagram may naturally follow this title. In the absence of such an instruction the natural way to approach tactile diagrams is often from the edges of the page inwards.

As with vision the first cursory (hand) scan is important in discovering the meaning of what is on the page. It is possible to manipulate components of a tactile presentation to bring desired features into prominence, thereby helping (he reader attach importance to such features in seeking to understand the diagram.

There are three main contrasts which are available to the designer for this purpose. The first is high and low relief, with higher relief tending to be more prominent. The second is rough and smooth texture, and in general rough texture is the more prominent. Both of these two contrasts are pan of the stock-in-trade of most tactile diagram designers although the writer is noted for the variety of relief which he employs in tactile diagrams. The third contrast which is even more characteristic of the writer's personal style and has been consciously adopted following a great deal of classroom observation and research, is the contrast between concave, flat, and convex shapes. In this case the prominence comes from the novelty of a particular form amongst its surroundings. (Hinton, 1988b, p 10).

At the most basic level it is these contrasts which the writer is able to use to avoid the figure/ground ambiguity which was a source of confusion for Kennedy and Domander's blind subjects in their use of certain tactile line drawings. (Kennedy and Domander 1984, p 216).

In the writing of scripts for tape recorded notes, or in the preparation of oral comments to assist a blind student in the examination of such a tactile it is often useful to use such prominent features as a starting point, and also as a continuing point of reference for the location of other less obvious features of the picture. (Ricker 1981, p 297) It is

important that a sighted teacher or picture designer keeps in mind always the sensations that the picture would evoke in a blind person. Some teachers find it necessary to blindfold themselves or shut their eyes, although with experience one learns to be aware of the needs of a blind reader even when working with one's eyes open.

6.4 Audio scripts for use with diagrams

The method which we generally adopt in preparing audio scripts to accompany the more complex diagrams owes a great deal to the work of Ricker at the University of Georgia. His paper (Ricker, 1981) gives further details of the experiences and reasoning which gave rise to his approach.

The summary of this approach which follows is reproduced with the author's permission.

1. A brief preliminary overview of the diagram should precede detailed observation of the diagram. The individual elements of the diagram should be examined first, working from the outer to the inner part.
2. Each component of the diagram should be located before it is described, and the description should precede the discussion of the component.
3. The amount of information included in the script should be controlled carefully. Readers should receive enough information to form a mental image of the object or process depicted in the diagram. Additional information should be supplied by separate tapes, Braille or large print.
4. The script should include a signal that informs readers when it is appropriate to stop the tape to obtain extra time for review.
5. A summary should be included to help the readers review what they have just seen with their fingertips. While listening to the summary, readers try to conceptualise the information they are hearing rather than examine the diagram with their fingertips.
6. A written glossary of pertinent words should accompany the diagrams. Ricker, (1981).

Where more than 16 labels were needed, the author's practice was to double the letters, starting at KK. Letters were then used in order from top to bottom of the diagrams. With rare exceptions, key letters did not correspond with the initial letters of the structures shown. Although it would be helpful if the connection between key letters and initial letters could be consistently achieved, in practice the scatter of initial letters makes this impossible, so it is best to use top-to-bottom key letters with an alphabetical listing. The Braille 'letter symbol' is needed on the key to avoid confusion with contracted Braille, but is not necessary on the actual diagram.

Consistent placing of key letters is important. Letters can be placed on the diagram components themselves when there is room, on the side nearest the margin of the page or alternatively can be placed beside the component. To be consistent, labels should be placed towards the left on the left half of a diagram and towards the right on the right half, and generally slightly above rather than below a structure. However, this is a rule of thumb and each label must be put where it will be most helpful to the students.

Where several small structures are so close together that there is not enough room for individual labels, two or more structures can be described in the key under one key letter. If these combinations are carefully chosen, the search for the structures can be a learning exercise in itself, and there need be no ambiguity for the student.

It is important to minimise all of these distractions in tactile diagrams, and to be aware that quite small tactual defects, virtually invisible to the eye, can be obtrusive to the touch, and can mar and confuse a tactile impression. At the same time in other contexts, the fingers can be aware of interesting features that the eye can overlook. (Hinton, 1984, p 30).

6.5 Distracting elements in tactile pictures

Kennedy (1982, p 314) has warned of possible confusion for blind users from distracting elements in tactual pictures as, for example in collages made from components like shells which already have a strong shape of their own. The writer has met similar problems, and also possible confusion from the use of textured sheet materials with a strong one-way pattern (eg; a wallpaper with a pattern of parallel ridges). Materials like these may have a use in a particular diagram context, but it must be recognised that they impose a strong pattern or trend of their own which may contradict or confuse the

picture. This may not be a problem when a print pattern of a similar kind is used as an element in a visual diagram, because borders of patterned areas and delineating marks can be given greater weight to compensate for the strength of the pattern.

Many of the author's earliest tactile pictures were of biological subjects and were originally given strongly contrasting and sometimes very artificial textures, to ensure that picture components could be discriminated. It was quickly realised that it was desirable for such diagrams to be 'lifelike' as well, so that the blind user could make connections between the picture and the reality. To this end, textures were made less harsh and were chosen for their lifelikeness to the touch. (Hinton, 1988a, p 24).

It was realised that with the relatively strong relief which became a characteristic of the author's designs, natural forms could be used as picture elements. Raised border lines marking the limit of one tissue and the beginning of the next were frequently found to be unnecessary; a slight difference in relief level or texture would suffice. (Ibid, p 10) The omission of such edge lines removed yet one more distracting element from the tactile presentation.

6.6 Braille labels

With a few exceptions (generally diagrams of very simple layout) full Braille labels take up too much room to go directly on the diagrams. The best alternative is to put key letters on or near the structures and to have an alphabetical key on the facing page. (Hinton, 1988a, pp 9 and 10). This also helps with revision and testing of diagram comprehension. Where a series of diagrams share the same key and are bound up into a booklet, it is most helpful to the student if a separate copy of the key is bound to face each diagram.

The arrows which lead from the labels of printed diagrams always cause confusion in their tactile form, so they are best avoided altogether. Directional arrows are needed on flow diagrams of course, and these are satisfactory if they are prominent and carefully drawn. This is also true of the snakeskin-like tactile arrow symbol of Schiff, Kaufer and Mosak.

When using key letters in Braille, it is recommended that only the letters from K to Z are used, because the first to letter symbols are also used to denote figures in Braille. Where more than 16 labels were needed, the author's practice was to double the letters, starting at KK. Letters were then used in order from top to bottom of the diagrams. With rare exceptions, key letters did not correspond with the initial letters of the structures shown. Although it would be helpful if the connection between key letters and initial letters could be consistently achieved, in practice the scatter of initial letters makes this impossible, so it is best to use top-to-bottom key letters with an alphabetical listing. The Braille 'letter symbol' is needed on the key to avoid confusion with contracted Braille, but is not necessary on the actual diagram.

6.7 Microcapsule* diagrams

In recent years the diagrams produced on microcapsule paper by the stereocopier process have come to be widely used in education. In fact one of the principal speakers at the International Cartographic Association symposium held in 1988 at King's College, London produced user trial evidence to back his assertion that they were now the formal of choice for tactile maps. (Dacen and Coulson, 1988).

[*Please note that since this publication was written, the equivalent available technology would be Zychem or an equivalent.]

Their widespread use stems partly from the vigorous salesmanship of the makers of the copying machine, and partly from the speed at which diagrams can be produced. However, experienced diagram makers now find that it can take almost as long to produce a good-quality black and white ink drawing for reproduction in the stereocopier as it does to produce a master diagram of the same subject for thermoforming. It is also likely that the low-technology alternatives to the stereocopier for producing this type of diagram will be used more in future. (Ibid, p 9; Edman, 1989).

An advantage of this type of diagram is that lines, textures and Braille annotation are coloured in black, so that they are easier for a person with residual vision to see.

Disadvantages of this type of diagram include a rubbery surface texture which is found to be unpleasant by some users. These diagrams also smudge and deteriorate in use after a while. From the perceptual point of view the major disadvantage of this type of diagram is that all of the lines, areas and symbols on a diagram or map are raised to a constant height above the surface of the page so that there is no opportunity to provide the variety of levels and three-dimensional shapes which are possible with thermoformed diagrams.

In the opinion of the present writer the use of microcapsule diagrams should be determined by valid perceptual and educational considerations, and not by mere convenience to producers. The factors which would suggest their use in particular contexts would seem to be as follows:

(1) They probably provide the neatest and best option for producing simple, open-textured maps and graphs, particularly where simple geometrical shapes are shown. A comparable thermoform would probably be less tidy, or would take an inordinately long time to produce.

(2) Diagram components can be electronically stored for re-use in other diagrams. (Buultjens. 1988)

(3) They also function effectively as tactile overlays for the Nomad audio-tactile device (Parkes, 1988), where the more elaborate kinds of thermoform are less satisfactory when they interfere with the sensitivity of the touch-pad. In fact it may be that Nomad when developed to its full potential will make up for some of the shortcomings of microcapsule diagrams and allow diagrams of poorer structural quality to be used with greater success.

(4) Because of IT factors, they may be the best alternative for diagrams for use by blind students in Further and Higher Education at the present time, particularly in subjects where the diagram structure is relatively simple, but where the information carried is very varied and detailed.

However it is quite clear from me work of the present project, and from many conversations with experienced specialist teachers and technicians, that in many learning situations microcapsule diagrams are inadequate. There is also clear evidence from the present project and from other tactile diagram collections that the thermoform method will provide a solution to many diagram problems where the microcapsule method would utterly fail. Experience also suggests that the potential of both ways of making tactiles has yet to be fully exploited.

The criticism which is occasionally levelled at thermoforms by a few teachers is that they are bland and bleak in colour, and therefore dull and less helpful to users with some sight. It is interesting that this criticism is not levelled at thermoformed braille text, although admittedly the diagrams can be used by students with more vision than those who would want or need to read braille, and are even helpful to bright students with normal vision.

The writer's experiments with the colouring of thermoformed diagrams for use by people with some sight have so far proved disappointing. The two possible approaches are hand-colouring of the finished thermoform, and screen printing of the sheet before thermoforming, with careful registration of the print with the thermoform. Not only are technical problems found with both of these methods, but the results when apparently achieved are visually disappointing. More appears to be lost than is gained.

Some teachers get their partially sighted pupils to search for diagram components in order to colour them by hand with felt-tip pens. This can be a useful learning experience in its own right. However, in view of the problems noted above, and also me fact that the writer has never received complaints from partially sighted students, despite their readiness to draw attention to other shortcomings in diagrams, thermoformed diagrams in plain PVC appear to be the most useful product of this method of producing diagrams. Future colouring experiments may include rapid airbrush techniques.

6.8 Realism versus ease of interpretation

Anyone who makes biological tactile diagrams has to find an effective path between what appears to be realistic and what is easy to interpret by touch. When a student finds a diagram difficult to interpret the teacher can try the following:

a) Careful thought and questioning of the blind student may reveal obvious defects in the construction of the diagram which can easily be put right.

b) The teacher may need to redesign the diagram completely in order to produce something which is easier to follow. It may be necessary to make the diagram more crude, stylised or 'unreal'. On the other hand it may simply be a matter of putting less information on the page, perhaps by spreading the subject matter over two or more diagrams.

c) The teacher may give the student a more careful briefing, particularly if the student is not used to reading diagrams.

d) A preliminary diagram or series of diagrams may be given to students to prepare them for a more difficult one.

e) An audio file which instructs the student in both the exploration and interpretation of the diagram may be provided, perhaps in the style of those described by Ricker (1981) and summarised in Section 6.4 of this book.

f) Models, living organisms or other teaching materials may be brought in. Diagrams should be part of an overall teaching strategy involving many different media and plenty of concrete experience. It was clear from our classroom trails that most teachers are aware of the need to link the thermoformed diagrams to all sorts of practical experiences in the laboratory and outdoors. Museum services are sometimes a useful supplement to school resources.

We believe that biological diagrams should be as lifelike as possible. When textures and other features are used for labelling purposes. the student should not be given a misleading impression of the living organism or a false idea of its structure and function. This is particularly important when the student is trying to compare a diagram and the real object.

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Chapter 8

Tactile Graphics

CHAPTER SEVEN: The depiction of scenes

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7.1 The information available in pictures

Gibson observed two conflicting theories of what a picture is. The first theory assumes that it consists of a sheaf of light rays coming to a station point or perceiver, each corresponding to a spot of colour on the picture surface. (Reed and Jones, 1982, p 272).

The second theory assumes that it consists of a set of symbols, more or less like words and that a painting is comparable to a written text. (Reed and Jones, 1982, p 274). On the first theory a picture could represent a real object or scene, insofar as the light rays from the picture are the same as the light rays from the original. On the second theory, a picture can stand for a real object or scene, insofar as the language of pictures is understood. It also implies that one has to learn to 'read' a picture, much as the child learns to read written speech, but the first theory suggests that as soon as a child can perceive an object directly, he can perceive it in a picture. (Ibid, p 267). Gibson points out that the point projection theory can only strictly apply to a painting or a photograph and not to a line drawing and in fact does not apply if the viewer's vantage point is changed. There is no point-to-point correspondence of brightness or colour between the optic array from a line drawing and the optic array from the objects represented.

This theory also cannot explain the situation which pertains in cartoons. The cartoonist's drawing of a man is not even a faithful projection of the shape of his features and his body and yet it may be faithful to those features of the man that distinguish him from all other men find thus may truly represent him in the higher sense of the term. It may be uniquely specific to him - more so than a projective drawing or a photographic portrait would be. Even where a political cartoonist deliberately distorts and plays with a representation of a face for humorous reasons, recognisable characteristics of the face are preserved. That is part of the skill of caricature.

This is, as Gibson asserts (loc cit) a compelling objection to the whole theory that pictorial information can be reduced to light rays. A caricature is not a mixture of optical projection and symbolic distortion but something different from either one. Gibson suggests that it is an effort at displaying relevant information.

In considering the symbol theory, Gibson points out that a picture is not simply a matter of symbolic language (Ibid, p 276). Gibson goes on to construct his own theory of pictorial information by whose formal definition, "a picture is a surface so treated that a delimited optic array to a point of observation is made available that contains the same kind of information that is found in the ambient optic arrays of an ordinary environment". (Ibid , p 277).

This definition is broad enough to admit the case of a caricature. An artist can capture

the information about something without replicating its sensations. Indeed, for Gibson having sensations is at most only an accompaniment of perceiving, not a prerequisite of perceiving. (Ibid, p 361). Gibson then goes on to describe the emergence of invariants from the optic array and the way in which these invariants carry information which describes features of the environment. In looking at the world, one begins to see the elements of non-change underlying the changes. Primitive artists, eg; ice-age hunters, did not fully appreciate the changes in appearance of an animal from the from, the side, the rear and above, but they learned these things when they attempted to represent them and they learned from their mistakes.

Through experience it is possible to perceive the real size and distance of one of the objects represented in a picture, as well as the size of the representation; for example, in looking at a picture of a tree the distance and size of the tree and of its picture are not the same, for they are not in the same space, but it is nevertheless possible to perceive and estimate both. In the same fashion a picture of a room contains information for both the perception of the room space and the perception of the picture space.

It is also possible to have pictures of objects which do not exist in fact. There are pictures of mermaids, of buildings not yet constructed and of events that will never happen. (Ibid, p 281) The information provided by a picture is information for perceiving, in the widest sense of the term, not only for remembering something in the past but also for conceiving something in the future.

Displays which are ambiguous or reversible with respect to what is seen, have been interpreted as proving that perceiving depends more on the perceiver than it does on the external stimulus. The fact of two alternative percepts from the same drawing is very puzzling. The light to the eye has not changed when a pair of faces is seen instead of a goblet, but the percept has. If such drawings are analysed as sources of information instead of mere stimulation, the puzzle becomes intelligible. The information in the array is equivocal. There are two incompatible kinds of pictorial information in the light to the eye and the percept changes when the beholder shifts from one kind to the other. (Ibid) Kennedy (1974) has also studied and reported this question of equivocal representation in drawings of the edges and corners of surfaces in the world.

To speak of the information in an optic array does not imply that it consists of conventional symbols or that pictures constitute a language, for they are still subject to some of the basic principals of what Gibson calls ecological optics. The informative structure of ambient light is richer and more inexhaustible than the informative structure of language. Indeed, animals and people could see things long before people began to describe them and we can still see many things that we cannot, as yet, describe.

Picturing becomes a means of communication and a way of storing, accumulating and transmitting knowledge to successive generations of people in much the same way that speaking and hearing and reading and writing are ways of accumulating and transmitting knowledge. The difference is that picturing exploits some of the information in the structure of light. (Reed & Jones, 1982, p 283).

Not only do we perceive in terms of visual information, we can also think in those terms. The present writer would agree with Gibson that visual thinking is freer and less stereotyped than verbal thinking, but it would appear that to state as he does that 'there is no vocabulary of picturing as there is of saying' (Ibid) denies the effect of cultural experience on the viewer of a work of art, and also denies the stylistic conventions of modern advertising.

Gibson used his theory of visual perception as the basis of a theory of picture perception. It was then possible for him to distinguish between the pictorially mediated perception of the features of a world, and the direct perception of the features of the surroundings, and yet to understand there is common information for the features they have in common.

7.2 The perception of works of art

Some artists have expended a great deal of effort in attempting to create pictures which deceive the eye into believing that they really are the objects that they portray. Such paintings are commonly known as *'trompe l'oeil'* and there are examples to be found in architecture and cartography as well. Unfortunately one of the characteristics of solid objects is that they look different from differing viewpoints, and a truly effective *trompe*

l'oeil painting works best if it is mounted in a peepshow box so that one particular viewing point is imposed upon the observer. Thus *trompe l'oeil* paintings are a very special case.

All other paintings attempt to portray the world as seen by the artist, and using various approaches to the task of portrayal which vary through the eras of an history, and also vary according to the individual artist's style and intentions.

In certain works, eg; impressionist painting and caricatures, certain features which the artist takes to be the essence of the subject are emphasised in an uncommon way to portray the subject. Very often the artist's means are difficult to describe in words, and yet the message is understood, although it needs to be emphasised that this may require a measure of stylistic or cultural acclimatisation on the viewer's part.

Indeed, as Gombrich (1960) has pointed out, every artist is limited to the terms of his medium, and not one of the tones of a painting would correspond objectively to what we call the reality of the subject. (Ibid, p 30) The viewer can be conditioned into accepting and interpreting as reality representations which include negative images (Ibid, p 39) and other forms of illusion (Ibid, chapt VII) and can become attuned to transposed relationships between components of pictures, and gradients of colour and brightness and even to distorted viewpoints if necessary. (Ibid , pp 46 & 47)

7.3 Comparison with the tactile mode

The discussion of picture theory in this chapter so far has been confined to visual perception and visual pictures. These have been extensively discussed and written about for centuries and have been the subject of much research and philosophy in recent times. In comparison, tactual perception has been far less thoroughly investigated although JJ Gibson is one of the few writers with an interest in both senses, and his general theories are not incompatible with tactual phenomena. In particular his description of a recognisable invariant emerging from confusing background of sensations describes the touch sense equally well.

In the author's experience this is exactly what seems to happen in tactual exploration of an everyday object or a tactile picture. Recognisable features ('invariants') quickly emerge from an initial hand-scan and these can be identified and used.

In the present writer's experience caricature is of no direct use in tactile pictures for educational use. Present day teaching materials published in snappy cartoon style for 'user appeal' simply have to be depicted 'realistically' (though this term is itself problematic) when in tactile form. Otherwise the subject of the picture can be unidentifiable to the blind reader. The humorous distortions obstruct the message of the picture.

The same is true of any features of visual depiction which create ambiguities when they appear in a tactile picture. Laboratory experiments on figure/ground confusion may be very revealing to the experimental psychologist, but the educational diagram designer needs to take every precaution to avoid or minimise confusion and some of the techniques used have already been described in Chapter Six of this book.

This approach to interpreting visible information and picture information is of relevance to tactile pictures in that it directs attention towards the 'discontinuities' or boundaries of picture components and emphasises their importance to the emerging perception during a hand-scan, and the filtering process by which objects are located applies to touch as well as to vision. This is why questions of scale are important in tactile pictures. If the scale relationships are not clear, the blind user may completely misinterpret the picture. as in the dinner fork/human hand confusion mentioned in Section 6.1 in connection with one of Kennedy′s experiments (Kennedy 1974, p 152)

7.4 Depicting works of art for blind people

One extension of the research described in this book is the production of tactile versions of notable paintings from the National Gallery collection, under the auspices of a charity called the Living Paintings Trust. This trust had its formal development at the beginning of 1988 from a working party set up to explore the feasibility of interpretative materials on tape and in tactile form, designed to communicate the intentions and methods of the great painters to blind people who already had a practical interest in the arts.

It will be apparent that this kind of tactile picture has terms of reference markedly different from most educational diagrams, whose main intention is to describe a structure or process in such a way that the blind person can understand the principles involved. In such diagrams gross simplification or even distortion may be accepted in order that the educational principles may be conveyed to the user.

In rendering a work of art one has to be as faithful as possible to the intentions and methods of the original artist, while making the unusual transformation from a visual to a tactual medium. This is not to say that picture components will not have to be simplified; the smaller size on which one is working generally ensures that, if nothing else does. However, things cannot be modified simply at the will of the tactile artist or his user; there is a responsibility to the artist whose work is being portrayed.

In commencing this portrayal it would be possible simply to 'map' the canvas with stylised textured areas, or to attempt a flat strictly two-dimensional portrayal. Alternatively the task can be accomplished through a raised line drawing which merely marks out the limits of features in the painting, or what Kennedy (1974) calls 'visual discontinuities'. This has been done by other working parties, like the group in Finland known as 'Pictures for Listening' which is run by the Finnish Central Association for the Visually Handicapped and the Art Museum of the Ateneum. This group has confined its presentations to sparse line drawings or map-like presentations reproduced by the microcapsule process. (Personal communication)

It is the contention of the writer however that just as different painters have markedly different ways of using paint and colour to achieve their desired ends, so tactile representations would be doing blind people a great disservice if they did not attempt to convey these artistic differences if at all possible. If it is an impossible task then one might as well leave the project alone entirely; it becomes a sterile operation, and the task of description is better left entirely to the evocative power of words.

7.5 Form and texture

In order to describe some of the problems and challenges involved in this task, this chapter will describe specific examples and discuss their effect on adult blind users of the tactile pictures.

The first such example concerns the depiction of water in oil-paintings. In discussing this, a congenitally blind person said, 'Well, water is just water isn't it? It's wet. Why should it be different from one painting to another?', (White, 1989).

The blind person knows water by its feel. It is uniformly wet. Its temperature may vary, and it may be still, rippled or wavy, but is otherwise very similar from place to place. The blind person thinks mainly of the mass or body of the water. He may have been told and remembered other characteristics such as its transparency, but never experienced them.

It was pointed out in conversation that the artist is generally depicting the surface of the water as it appears from a particular viewing-point. The appearance of this can change not only if it is wavy or still, but if the light falling upon it changes and is reflected differently to the viewer's eye. Reflections of surrounding objects are seen in it as in a mirror, although the mirror may be still and glassy or broken up into tiny independent pieces by ripples and waves. It is therefore the varying appearance of this water surface which the artist generally tries to convey.

This was described by a comparison between three situations in paintings:

(a) An even patch of water with no ripples and no noticeable reflections as in the canals of The Avenue, Middleharnis' by Hobbema. This was conveyed in the tactile picture by a smooth, glossy surface.

(b) A sea inlet with uniform wavelets painted as a regular pattern, as in Claude Ie Lorrain's 'Enchanted Castle'. This was depicted in the tactile version by a sheet of aluminium mesh on the master diagram.

(c) The surface of the river Thames on a misty morning as painted by the impressionist. Monet in his representation of `The Thames below Westminster'. Monet simply picks out the crests of the wavelets as they catch the light in small horizontal splashes of white

paint. These were depicted in the tactile picture by horizontal blobs of cement of similar form to Monet's paint.

In a similar way Monet depicts a tree on the Thames embankment by using an array of blobs of paint of appropriate colour. It is interesting that just as the paint version is rather shapeless when seen at close quarters, but merges into a treelike form from a more distant viewpoint, so the tactile blobs coalesce into a treelike shape under the fingers.

One special problem in reproducing tactile versions of works of art is the need to illustrate features such as clouds, fog, reflections, and sunsets which are not solid but ethereal in nature. They are often essential to the understanding of particular pictures and so inescapable in the tactile portrayal.

Obviously any feature of a thermoformed tactile picture has a degree of solidity which is the property of the medium (a formed polymer sheet). It is, however, possible to minimise one feature in relation to the rest so that the perception appears less solid. This may still need some oral interpretation, but is nevertheless easier to understand than a picture where the inter-relationships are misleading. It was never the belief that these tactile representations of works of art would ever stand alone, however. They were designed to be used with a tape-recorded commentary.

One restriction on the tactile picture maker, particularly when his end-product is made of one material like a PVC thermoform or a capsule-paper print, is that he has at his disposal a relatively small palette of reproducible textures. This is the case even when the master pictures are predominantly modelled in cement as in the Living Paintings Trust pictures. Despite the variety of natural forms which appear on the picture, the surface textures are far less varied than the colour and shade palette of the visual artist . That this constitutes a restraint of the medium used is undeniable, but the effect on the final perception of the blind user is not as restricting as may at first appear. This is because the context in which each picture element finally appears influences the way that feature is perceived.

A simple example from the author's own work is the use of the aluminium mesh commonly sold for reinforcing fibreglass car body repairs in two entirely contrasting picture contexts. In the first the material was used to represent the ripple pattern of the water in Claude Ie Lorrain's 'Enchanted Castle' landscape already discussed. (Hinton, 1989b) In the second example, the same material was used to represent a cloth-of-gold shawl on which the infant Jesus was resting in the right-hand panel of the Wilton Diptych. (Ibid) Because of the completely new context there was no confusion for blind users of the picture. A blind person examining the two pictures in close succession, and questioned about the material used, would probably detect the similarity between the two picture elements, but in normal use the reader would tend to overlook this completely in searching for the wider meaning of the picture as a whole. (Hinton, 1990b)

For this reason all results of laboratory texture discrimination tests (eg; Nolan & Morris, 1971; Armstrong, JD, 1978) need to be considered with caution. Although they contribute useful information to our understanding of tactual perception and can guide the tactile picture designer's work, it is the picture as a whole which is most important in the end. Some elements which appear to work under laboratory conditions fail when incorporated into a diagram or picture; and conversely, some elements which appear to cause difficulty to blind users in laboratory trials are influenced by the context in which they appear in a diagram to the extent that the expected difficulty disappears.

In relation to texture and colour, the 'touch colour' suggestion of Elder and Tonelli (1982) in which colours and shades are indicated on a tactile picture by textured areas according to a code which they devised. The writer's entire experience of designing and making tactiles and of observing their use by people who are blind underlines the restricted 'palette' of textures which are available for effective use in tactiles, as compared with the vast array of tints and shading available to the visual artist.

In the wide range of tactile diagrams with which the writer is involved, the available diagram textures have important uses in describing the form and texture of the objects depicted, and occasionally as textural labels. One must also bear in mind the modifying effect of the medium in which the tactile diagram is made.

In this context, it appears to the writer that Elder and Tonelli's system conveys little of educational value to a blind person. Words would convey more, even in the absence of

prior colour experience. At the same time their elaborate textural coding system appears to lock up textural effects which would be better used in ways which would be more informative to the blind person using the picture.

7.6 Perspective

For the person of normal vision perspective does not have to be understood to be used in the environment. A child learns to pick up visual clues which can allow it to make spatial judgements. To begin to do this it must move through the environment and learn by experience the relationship between the visual image and what will be experienced in reality. A baby learns this gradually, first by discovering its own body space, and then as crawling, and later, walking begin, discovers the relationships between 'other' things at first by relating them to itself. (Bower, 1974, pp 154ff) Phenomena such as the continued presence of an object which disappears from sight by being covered up by a cloth have to be experienced to be understood. (Ibid, p 187) With more experience the ability to interpret a scene in spatial terms becomes more widely developed.

If the visual field has a lot of depth so that occlusions occur, with one object partially covering another, then colouring and shading gradients must be interpreted in order to make depth judgements. In this connection small head movements can yield sufficient difference in the image from parallax and other effects to enrich the available information and thus assist interpretation of the image. (Gibson, 1950, p 29) This is particularly important in dealing with visual ambiguities or anomalies etc.

Perspective doesn't exist in the sensory experience of a totally and congenitally blind person (except by hearsay). It is solely a visual phenomenon. The blind person understands the environment by touch, hearing and smell, and so works mainly at close quarters. Size judgements, for example, are generally made in comparison with a person's own body measurements. Objects which are the same physical size always appear to be so, unlike the experience of vision where more distant objects appear to be smaller by perspective effects.

For this reason there is no need to trouble blind people with academic perspective knowledge during childhood, or even later in most cases. People with academic perspective knowledge during childhood, or even later in most cases. Such depictions as plans, side elevations, and sections of various sorts will supply all necessary information. Even adult blind people can spend their whole lives profitably with no practical or theoretical knowledge of perspective. Just as cavemen began to become aware of perspective only when they began to draw and paint, so blind people encounter perspective for the first time when they begin to meet tactile pictures of scenes (which are not in fact very common). Thus there is no particular reason for approaching perspective academically with blind people; it makes better pedagogic sense to allow them to experience it first through actual examples of visual art transcribed into tactile form. (Hinton, 1990b). It is then possible to discuss the picture in terms of the artist's visual experience.

In this connection it is also important to note the cultural differences in picture perception demonstrated by Hudson and others. Hudson found that many unsophisticated African subjects preferred illustrations of an elephant which depicted the animal from above, but with all of the legs which they knew it to possess shown at the same time (similar to an elephant skin spread out on the floor) rather than a normal orthogonal view preferred by Europeans. (Gregory and Gombrich, 1973, p 183)

This way of resolving the conflict between what is actually seen at one time, and what is known from other experience is understandable in people not schooled in draughtsmanship and artistic convention, and it is also interesting in the light of Kennedy's findings with congenitally blind adults and their modes of representation. (Kennedy, 1982, p 321) They, too, sometimes illustrated several aspects of an object which could not be seen simultaneously by normal vision. Such drawings are sometimes termed 'split representation' or 'chain-drawings' (Derogowski, 1970, p 21), although they also conform very closely to what mathematicians call a 'net' (or sometimes a partial net) of a solid object.

7.7 The work of C N Vincent

From the more practical standpoint of the teacher of technical drawing, C N Vincent developed a special drawing board by the use of which blind people could produce perspective drawings by measuring from the three axes of the specially shaped board

and drawing along the T-squares provided. The T-squares clicked over the special graduations on the edges of the board so that measurements could be made. Vincent's trainees could make measurements of features in a room and from these produce a perspective drawing on the board. When they had once experienced perspective in this way they could interpret perspective drawings presented to them in tactile form, and from these assess and if necessary, measure and calculate real sizes of features of the environment depicted in the drawing (Vincent, 1970). Although in the literature the success of Vincent's subjects in drawing and interpreting perspective drawings was apparent, his idea appears not to have been taken up by the colleges where he did this work, and his drawing board has dropped out of use. (Vincent, 1984,p 17).

That Vincent achieved what he set out to do in the technical sense is undeniable, but as this book emphasises repeatedly (see Section 5.3 above), perspective is a purely visual phenomenon and quite outside the experience of a blind person. Tobin (personal communication) quotes the response of the late Reg Bonham, a blind mathematician who was present when Vincent's techniques were demonstrated and discussed. Bonham rephrased the well known saying thus 'to a blind person a cube is a cube is a cube'. In other words a blind person working by touch always encounters the edges of a cube as being of equal length and the sides as being parallel. The tapering effect of visual perspective is never experienced. So in seeking to do what he did, Vincent was imposing an alien viewpoint on touch experience, and as this chapter has discussed, perspective very rarely has any practical use for a totally blind person.

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Chapter 9

Tactile Graphics

CHAPTER EIGHT: Tactile graphics design

8.1 Tactile graphics and Braille
8.2 Contextual factors
8.3 Use of the graphics software and scanner
8.4 The designer's selection process

[**Please note** the first part of this chapter has been substantially changed since the technology mentioned in the original is now obsolete]

8.1 Tactile graphics and Braille

Because of the great shortage of tactile diagrams and the vast numbers of diagrams which may be required by blind students in formal education, particularly those at university, production methods which are computer based are obviously attractive. The microcapsule process lends itself to computer drawing and also to the use of scanned images as working templates. In this way diagrams can be shared easily.

It is of course be possible for an experienced designer to use any graphics software on any computer to produce designs for tactiles.

8.2 Contextual factors

Microcapsule (Zychem) diagrams have a maximum relief height of 1 mm while faint dotted lines and light, stippled infill patterns are raised lo about half of this height. In order to maximise the effectiveness of the diagram format it is necessary to work within these restrictions in such a way that the user can discriminate the essential components of the diagram. In doing this, the designer has to keep the word 'context' constantly in mind; for context is all-important. Components that can be identified or differentiated in isolation or in one context may behave differently in a different context. To illustrate this, and the way it can be manipulated to good effect, the following series of maps may provide a simple example.

The UK maps

The first illustration (Figure 5) shows a map of the UK as it may appear on the computer screen after scanning in. The visual quality of the image could be enhanced but this is not necessary, because the image shown will only be used as a template to guide the designer.

Figure 5 Scanned image with outline begun

First the designer may draw around the coast line to produce a simple map outline (Figure 6). In tactile form this is not so simple for a blind user because (a) the raised line becomes an 'object' to be identified, and (b) the shape of the enclosed void is difficult to appreciate.

Figure 6 Simple black outline

It is possible to fill this outline with a solid black infill (as in Figure 7 a strategy would give an excellent strong coastline and the shape of the land mass would be easier to appreciate. However, in doing this the designer has lost all chance of adding other features internally.

Figure 7 Solid black map

One alternative would be to infill with a light stippled pattern which would only partially rise under the heat treatment, because the individual dots do not receive enough heat during the normal exposure time. To leave the coastal boundary line on would risk confusion with rivers or internal boundaries (eg; of counties, or river catchment areas). So the coastal boundary can be left out entirely, except that this results in a coastline which is rather difficult to follow. (Fig 8).

Figure 8 Light stipple

A strategy for overcoming this problem is to substitute a narrow strip of a more dense stippled pattern for the original black solid line coastal boundary (Fig 9). This has the

effect of making the edge rather more distinct to the touch and yet still giving good contrast with other features of the map.

Figure 9 Light stipple with denser edge

Thus in Figure 10 the Rivers Thames and Severn have been added to the map as solid black lines, with a selection of cities as small black squares. All of these features are distinct from one another in the tactile version.

Figure 10 Map with rivers and cities

Sometimes quite small differences in diagram components are all that is required to ensure successful discrimination. A relatively thick, meandering line of a river may be

easy to differentiate from a finer, straighter political boundary. The overall context in which these diagram components are used ensures successful reading.

However, in the vast majority of maps and diagrams the totally blind student may need some initial assistance to interpret what he or she feels, although this assistance may simply be a Braille title or note, or the diagram may contain some feature that is already known and which provides the key to the rest. In some cases a taped description may augment the map or the interpretation may be assisted by a tutor in person.

The Loughborough Research Unit has made a vast range of diagrams which all have their own particular challenges to discrimination and interpretation, but it is the kind of approach suggested in the example above which nearly always provides a solution.

One other practical detail that ought to be mentioned at this point is the effect of strong cross-hatching or other unidirectional infill patterns. Any raised line in a tactile diagram may develop a meaning of its own. It may be perceived as a piece of string, a river or a wall (for example) depending on the context. For this reason any raised line must be used with care.

Also in visual diagrams adjacent areas of an illustration are commonly marked off with boundary lines. Where areas of a tactile diagram are in filled with a pattern to produce a perceivable texture the limits of that infill mark the boundary without the necessity for an added line. The author generally avoids tactile boundary lines altogether unless some special circumstance requires their use.

Cross-hatching can lead the finger in a particular direction which may not be congruent with the structure of the diagram component which they are filling, so this style of infill is probably best avoided except in highly stylised diagrams like pie-charts. Safer and more generally useful are the more diffuse. 'non-directional' infill patterns illustrated.

8.3 Use of the graphics software and scanner

Although it is easy to draw diagrams of simple structures freehand, our research unit commonly scanned in the more complex diagrams on a fiat-bed scanner. The presence of a draft image that can be used as a template may save much time when extensive alterations and re-drawing are required. This scanned image can be displayed on screen at will, or hidden and omitted when the final computer drawn diagram is printed.

Educationally speaking, a tactile that is as near as possible to the diagram that sighted students are using is a good thing, provided that the resulting tactile is effective for the blind student. It is also important that teachers and lecturers using such diagrams and encountering difficulties with individual students or groups enquire why this is happening. Is the diagram badly designed or do the students lack some preparatory experience or simple guidance that would equip them to interpret it?

Even visual diagrams differ in their ease of interpretation for the sighted student, and considerable effort may be required to come to terms with them, although that effort may be worthwhile for the understanding gained from the diagram. When working with tactile diagrams blind users must not expect every one to be easy and immediate in its impact. It may demand careful exploration and thoughtful consideration for full understanding.

Of course tactile diagram makers must always consider whether the diagram is the best way of communicating information to a blind student as compared to oral methods, Braille text or type. (The subject of judicious selection by teachers and designers is considered separately below)

Normally the designer's first step with the scanned image is to define the limits of the main structures of the diagram. Even if the boundary lines are going to disappear in the final print they may be required (earlier) for the application of infill patterns. The boundary line can later be replaced by a narrow band of stippled infill or it can be made to disappear.

Fairly early in the designing process the Braille labels and titles are applied, because Braille is a bulky script and to work properly the diagram may have to be designed around the Braille. If the Braille is positioned early there is still an opportunity for adjustment later as the diagram evolves. In particular, the finger which is reading the

Braille must not be obstructed by adjacent diagram components. Braille labels and key letters must be placed in such a way that their presence is obvious to the blind user. In general the rules about Braille label placement are the same as those already described for thermoformed diagrams.

Grade I Braille directly corresponds with normal type, whereas Grade II Braille has many short forms and contractions, which will reduce the bulk of labelling and titles.

Some useful diagram types like flow charts are almost entirely Braille, but laid out with boxes and link lines or arrows. These can easily be designed on-screen by an experienced operator.

This description is deliberately not going into fine detail about the computer package because software writers are continually improving their product and readers may wish to use other software.

8.4 The designer's selection process

Tactile diagrams are generally more expensive to reproduce than their print counterparts. They frequently require more effort from a blind person attempting to read and interpret them for the first time. It seems wise, therefore, to be thoughtful and selective when producing the material so that the result is genuinely useful and worth the effort for designer and user.

Nevertheless it is important to bear the following points in mind when making the selection:

(a) Any selection process denies the blind user access to diagrams which the sighted person has and must be carried out with care and thought and for sound reasons.

(b) Diagrams remaining must add more to the user's understanding than words alone, at least for some users.

(c) Perceived difficulties with diagrams may often be overcome by the use of preparatory material or by breaking the subject matter of the original print diagram down into smaller parcels which are more easily understood.

(d) For many blind users, the diagram may provide the blind users with a conceptual framework which makes the information more easy to understand and often more easy to translate into a new setting. This is often very important for the understanding of the sciences and technical subjects.

It is perhaps worth making the point that every aspect of the transcription of a print diagram into a tactile format entails some form of selection process. So the above comments are just as relevant to diagram components as they are to the whole diagram.

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Tactile Graphics

CHAPTER NINE: The importance of these observations for education

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9.1 Recommendations for the design and use of tactiles

For ease of storage, durability, and freedom from floppiness during use, thermoformed diagrams should have as shallow relief as possible, given the demands of the subject matter. Nevertheless, many diagrams will need a bolder, multi-layer treatment in order to carry the desired picture content.

The diagram formal should be uncluttered. All unnecessary detail should be omitted, but where less important material has an educational or informative value, the possibility of conveying the information through more than one diagram should be considered. For example, in a histological illustration some secondary detail may put the tissue which is the main purpose of the illustration into a more realistic context, and to omit it altogether would be misleading. In such a case a second illustration showing the main subject in bolder detail or more magnification may be advisable.

In all types of diagram the writer has often observed that blind users are helped by the presence of more frequent points of reference than would be necessary for a sighted person. Examples of this would be the scale markings on a graph, or grid markings on a map. If these are too widely separated from the operative part of the diagram it becomes difficult for a blind reader to correlate the two features accurately. On the other hand, it is important that extra information like this should not add to the general clutter or distract the reader from the primary purpose of the diagram.

Applied textures should be natural and appropriate to the subject, since the blind person may need to relate the picture to something experienced in real life.

The spacing of diagram components should be adequate for discrimination unless different textures reinforce this. It is not helpful to lay down hard and fast rules for the spacing of components as some map-makers have been inclined to do, because the resulting perception is shaped by the overall context of the display, and the way the various components interact.

Since Braille is a major limiting factor on any diagrams which are intended to carry Braille annotations, such designs must be worked out with the space required for the Braille and the need for unobstructed Braille reading kept firmly in mind. Whenever complex Braille labelling, supplementary notes or scanning directions are required, the provision of such instructions via supporting audio files should be considered. (Hinton, 1988a, p 13)

For more advanced work, great care should be taken when a tactile diagram or flow chart spreads over to several pages. There is great danger of disjunction of information when this happens, and students using this kind of diagram may find effective study difficult. To counteract this, the related pages should be carefully cooordinated, with all interrelated information being adequately cross-referenced. Particular care should be taken with mathematical information in such circumstances, because this may be misread or overlooked by the student in making calculations.

Microcapsule paper diagrams have a valid educational use, and their effectiveness should not be underrated, but it is vital that they are only used in conditions where educational considerations, and not convenience, dictate their use (as with all diagrams).

Satisfactory microcapsule diagrams can be produced with an ordinary photocopier, followed by radiant heat treatment, for which the author's research unit usually employs a Ricoh fuser which originally, from an off-set lithography installation.

There is clearly the potential for more widespread use of the more pictorial forms of tactile display, and with these any suggestion that can be given of 'the third dimension' will help the blind user to understand the message of the picture, Where scenic types of picture are transcribed into tactile form, perspective phenomena will be encountered, and these are outside the direct experience of congenitally blind people. Where perspective can be avoided in teaching diagrams it is better omitted, but where it is necessary for a blind reader to come to terms with it, this can be accomplished initially within a meaningful picture context. Auditory analogues which the blind person will have experienced are useful in explaining perspective effects. (see Section 5.3) Only at a later stage, depending on the maturity of the student and future study needs, is it wise to embark upon an academic explanation of perspective geometry.

9.2 Educational environments which engender success

It is especially important that blind pupils encountering tactile diagrams should be at ease and should not feel threatened by the experience. Such students often feel that features of their lessons are set up with the intention of testing their intelligence. They may have experienced failure on previous occasions, and do not want to find themselves in any situation where they do not feel entirely in control. Rather than be speculative, they would prefer to wait to be told the 'correct' answer, which they are happy then to remember and reiterate. If the above sentences sound condescending to the pupils concerned, this is unfortunate, because they are intended to criticise the educational environment in which they are often reared, and not the pupils who have to endure it.

Tactile diagrams, maps and pictures do not always have to be presented in this didactic fashion. They can be an important extension of the outside world, waiting to be explored. It is this exploratory attitude to diagrammatic material which needs to be fostered. Wherever possible, the pupil should be encouraged to search for the available information within the diagram or picture. If this is not apparent, the pupil should feel free to ask for help and further information from the teacher, without feeling a sense of failure. Indeed, older pupils should be aware of the possibility of an inadequate diagram. (Hinton, 1988a, p 15) Knowledge gained in this way can generally be remembered, and experience with this way of studying will not only have its immediate reward in terms of what is understood from the diagram under scrutiny, but every diagram experienced in this way helps the pupil's preparation for more advanced material later in life, and lays a good foundation for secure independent study and personal research. The writer has seen ample evidence of this in working with individual children over periods of several months and in some cases for two or three years during research described in this book.

The word 'diagram' in this instance is intended to include the whole integrated package of picture, Braille caption and supplementary text.

9.3 What kind of educational programme is required as a preparation?

This section describes some ways in which the element of the child's educational programme can be developed and the implications of some of its components. These are suggestions which are not intended to be prescriptive, but can be adapted to fit individual learning needs, or the individual teaching styles of teachers. They can also be taken out of order in response to a particular learning need, as long as the general progression of activities is preserved.

Firstly, the blind child needs active exploring and handling experience from infancy. The live experience illuminates the diagram; the diagram may later help to explain the live experience. This activity is particularly important if the child shows a tendency towards undue passivity when young. It may be necessary to provide extra encouragement and stimulus to break out of this state in an environment which feels safe.

Parents and teachers need to communicate some of the excitement and interest of finding out things, and sharing experiences. Most teachers who are trained as visual impairment specialists will do this as a matter of course, but some have greater success than others. It is perhaps another example in education where it is better to drink from a running stream than a stagnant pool; teachers who are prepared to learn and discover for themselves, far from losing face in front of their pupils, often teach best. Their attitude is apparent even to the very young child.

It is important for teachers to make every possible use of analogies meaningful to a blind child in discussing everyday phenomena which are visible to the child with full sight, but outside the blind child's direct experience. To take as an example: A six-year old anophthalmic child in a mainstream primary class had been discussing falling rain and its importance as a source of streams and rivers with the members of her class. The child had, of course, never seen raindrops coalescing on a window-pane to produce a trickle, which was the starting point of the discussion for the other children. In this case the following 'model' was devised from apparatus already in the classroom:

A large bean-bag type cushion was rested partly across the child's knee with the child squatting on the floor. Under one side of the cushion a large plastic tray was placed. The child was then provided with a container of glass marbles which were to be used as 'raindrops'. The child was encouraged to drop the marbles slowly, one by one, onto the nearest half of the cushion. Each marble fell with an audible thump onto the fabric of the cushion.

At first the 'raindrops' were isolated, so no further sound was heard. However, after a while one of the marbles eventually hit another with a glassy click, and this soon became a frequent occurrence. (In fact it was possible for the child to say from the sound whether the marbles bounced apart or remained in contact.) At each stage careful exploration with the fingers would verify the arrangement of the marbles, taking care not to cause a disturbance. The teacher/researcher then suggested that a similar fate would befall a succession of raindrops. Eventually little rows or 'trickles' would be formed.

Sooner or later a long trickle would weigh the filling of the cushion down, forming a tiny valley, and this would eventually cascade off the side of the cushion with a vigorous rattle into the plastic tray.

The marble analogy was reinforced by running water from a beaker into a sloping tray of sand. The blind child could now follow this as well as a sighted child would, but was able to feel damp patches and hollows in the sand and to feel the tiny valleys and meanders created by the water flow. It was necessary for the child to explore this with care and delicacy to avoid destroying the evidence.

Tactile presentations on the page can include both pictorial and map-like formats from an early stage. Pictures should be bold, simple and in fairly deep relief to begin with, so that the comparison with the object portrayed is obvious. With increasing experience the relief can be reduced a little.

Mapwork should begin on a scale which allows the environment depicted to be encompassed by the child's two hands so that there is no abrupt change of scale in moving from environment to map. This has been discussed in more detail in Chapter Four and in the simple introductory strategy described in Yngstrom's writings. (Yngstrom, 1988) From these early beginnings maps can increase in size and complexity, but should always be backed up by on-site experience so that the child builds up an understanding of how things are depicted on a map. The 'site' can of course be a model if this is more convenient. Simple spatial exercises are helpful in developing directional sense and an understanding of the relationships of objects in space. As pupils reach the stage of predicting the environment from a map, Yngstrom's strip method for orienteering maps (Ibid, p 11) seems an appropriate way of providing a clear linear pathway which minimises distractions, and focuses attention on the essentials.

Pupil drawing on German film or Melinex is a helpful way of developing skills with maps, (Ibid, p 2,3, & 5) geometrical diagrams and life drawings. In geometry, finger tracing should be encouraged before pen drawing is attempted. In the absence of visual feed back the blind pupil needs to develop a repertoire of kinaesthetic shape drawing experience to be able to draw fluently. This approach is also important when moving on to solid shapes. In order to understand the idea of drawing a single 'viewpoint' the congenitally blind child needs to outline with a finger the shape which corresponds to a particular sight line. A blind child of average intelligence in Year 2 can understand the aspects of simple shapes like a rectangular box or a cylindrical cocoa tin.

Pupil drawing is also beneficial in dealing with items drawn from life (eg; objects from 'the nature table' and other found objects). Although the teacher may draw for the pupil so as to demonstrate the style of line drawing and its use for illustrations of this kind it is important that the pupil's final drawing is made from the object itself.

With such subjects and with environmental layouts all possible transcriptions of the subject should be experienced. For example: From the explored environment the pupil should try to produce a model in some suitable medium such as Lego bricks, cardboard boxes or clay. From the model a map can be drawn. Later, perhaps, the map can be drawn directly from the environment, initially from general impressions and later from measurements. Conversely a model could be built from the map, or the environment could be predicted and explored with the aid of the map. It should always be the aim of the teacher to offer a stimulating context for the task which is being proposed. For example, the task may be presented in the form of a puzzle which may require the pupil to rearrange components according to a given plan.

It is found that drawing and modelling exercises are not just an end in themselves, but that the pupil is stimulated to explore the real object or environment more carefully and critically in order to produce an accurate model or drawing.

At appropriate stages more and more detailed information can be sought from the maps and diagrams so that the pupil accumulates greater skill. The significance of viewpoint for the sighted person should emerge in a natural way early in the blind child's learning with pictures. It should certainly not be taught in an academic fashion even at the secondary school level except where this information is required for the pupil in a technical subject.

9.4 Measuring and mathematics

Measuring has already been mentioned and should begin in a simple way in year 1, with techniques being gradually extended as understanding grows. It must be noted, though, that tactile measuring devices in some cases have weaknesses and inaccuracies which are built in to the apparatus. These not only create problems for the pupil, but also place restrictions on the tasks which the teacher can prescribe. With blind pupils it is especially important to develop skills of rapid measurement. Pupils must be taught to read along the largest possible units as quickly as possible and only at the end to count the finer graduations for an accurate measurement. For example, when making length measurements with a metre stick, there is a tendency for the blind pupil to count laboriously every centimetre, instead of rapidly scanning the decimetre and 5 cm graduations as far as possible. Failure to use the latter strategy makes a slow task even slower.

There are problems for blind children in dealing with the measuring tasks found in mainstream maths books when the tactile measuring devices available to them may not have the finer graduations. For examples, a tactile protractor commonly measures to the nearest 5 deg and a tactile ruler to the nearest 5 mm and not to 1mm. This means that a lesson development that may seek to integrate the pupils knowledge of units of length with developing knowledge of decimal place may be impossible. Individual millimetres are not available to the pupil and metres are so large as to be difficult to manage.

The writer has taught the beginnings of decimal place notation to 6-7 year-olds by using an invented unit of length (named after one of the children). Not only could several of the 'whole units' be kept within the span of two hands, but the 1/10 unit tactile division was large enough to be detectable. This kind of strategy may sometimes be necessary to overcome some of the practical manipulative problems. At the same time much of the standard apparatus for practical maths at Primary level can also be used by blind children.

In mathematics and in dealing with all quantitative information, pupils should experience all the usual forms of graphic display such as histograms, line graphs and pie charts, and should learn how to read quantities and coordinates from these. As has been mentioned before, blind users often need more points of reference than a fully sighted person would, in order to orientate themselves. Some information will be better presented in a model or a microcapsule diagram.

With all types of tactile diagrams and pictures it is important that users learn scanning techniques, beginning with a light, cursory sweep before more detailed examination. When diagrams fail for a blind student it is important that the diagram itself should be examined critically to see if it is deficient in any respect, but it is also vital to consider whether the student's preparatory experiences were lacking in any detail.

9.5 Educational provision for advanced study

In secondary and further education it is important that blind students have tactile versions of anything shown on the blackboard or overhead projector. This needs to be provided at least when the visual presentation is made, and preferably before the lesson to give the student an opportunity to preview the tactile presentation so that the lesson points can be followed with reasonable fluency.

At this educational level there must be very close cooperation between course lecturers and those responsible for the provision of tactile resources, or the resource staff must have an intimate knowledge of the content and intentions of the course.

The provision of tactile resources is never adequate if the resource staff are relegated to the role of 'jobbing printer', merely transcribing into strict tactile copy every feature of print handouts without question.

9.6 Introductory material for older students

One of the problems with adult blind students is that their educational experiences will have been very varied and particularly where tactile diagrams are concerned, their previous experience may be very limited or non-existent. However adequate it may have seemed at the time it may have happened before recent developments of relevant technology and its application.

Because of this, adult blind students may be offered tactile presentations which they find impossible to understand. The conclusions most frequently drawn in these circumstances are either (a) the diagram is no good, or (b) the student is incapable of using such material. In fact, the most likely explanation is that the student has not had the benefit of appropriate introductory material to develop skills of exploration and interpretation.

In these circumstances, students may be inclined to 'switch off' mentally when first presented with tactile diagrams. It is therefore important that an appropriate introductory study pack is provided when required. This would cover the various kinds of mathematical representation which may be important (eg; line graphs, histograms, pie-charts etc) and common map and diagram types in simple form. It should also present simple exercises in obtaining information from such displays.

The student also needs experience of the likely position of Braille titles, labels and other instructions, and practice in the use of Braille and textural keys.

9.7 Scenic presentations

Tactile depictions of scenes, as distinct from isolated objects, arc still comparatively rare, and greater use of these could be made in the future. Congenitally blind users will not have had prior experience of any of the phenomena of visual perspective. They will not have experienced the occlusion of one object by another standing in front of it. They will not have experienced the apparent upward movement of an object in the visual field with increasing distance, and the way this affects groupings of people and objects in pictures. They can learn to understand these phenomena, but not usually in the vivid way in which the TVSS subjects experienced them in controlling their own camera. (Guarnerio, 1974, p 103) An older user of scenic tactiles can go on to understand perspective phenomena in a more precise way, and begin to appreciate them as a source of absorbing interest and challenge to many visual artists.

When attempts are made to transcribe visual art into tactile form for the enjoyment and education of interested blind users, it is the writer's strongly held belief that the tactile pictures should at least hint at style differences between one artist and another.

The blind person would get a very false impression if human figures by, say, Gainsborough, Monet and Stanley Spencer appeared to have the same solidity. This intention is undeniably problematic, but if it cannot be attempted, then the tactile page remains as a very superficial kind of map, and it would perhaps be preferable to rely on the evocative power of words instead.

9.8 The overall picture

Tactile diagrams and pictures are still sorely underused in the education and leisure pursuits of blind people. It is true that first hand experiences are vitally important wherever they can be provided, but tactile pictures fill in many unattainable gaps. Many things are too large, too small, too fragile, or too dangerous to be touched and it is in situations like these that models and tactile pictures come into their own. Tactiles provided in early life also prepare the user for later, more detailed material. There is a need for home-based activities which contribute to the developing corpus of understanding.

Media like German films need to be more generously provided for the child to experiment with, for 'practice makes perfect' and only by experimenting and making mistakes in solitude will the blind child acquire fluency in reading and drawing tactile pictures.

It is also possible to create diagrams and pictures which have a game or puzzle element and can be used as the starling-point for practical activity. There are many possible uses for such things as tracking and discrimination tasks, counting and shape matching games, and so on.

One congenitally blind six-year old in a mainstream class needed some kind of apparatus to give her some idea of snow-crystal forms when her sighted peers were looking at photographs etc. She was provided with a six-fold star-like shape of thin rods spaced at 60 deg intervals. This was then thermoformed in heavy grade pvc and used as the basis of a snow crystal shape which she built for herself out of small rod-shaped or v-shaped sub-units of white plasticine. She was told that any unit which she added to the first rod (generally the top one) should be matched by identical additions to the other five arms as in the diagram opposite. She in fact prepared six identical pieces of plasticine which she rolled and shaped before laying them in position on the matrix provided. The finished model exhibited the six-fold symmetry which is characteristic of snow crystals, and formed an acceptable alternative to the visual experiences and drawings of her peers.

9.9 The future for tactile illustrations

With present knowledge and equipment it has to be admitted that the available tactile illustrations fall woefully short of the capabilities and variety of visual illustrations. Despite this, the various sorts of tactile presentation have advanced greatly in the past two decades, and teachers and others working with visually impaired children and adults are learning how to make better use of them.

In an era when the world of technology becomes more and more complex, and where communication, whether for education, information or entertainment, becomes more visual, it is vital that the means are found to make as much of this material available to visually impaired people as possible. This is particularly so where visually impaired people are supported in a setting where they are integrated with sighted people. A failure to do this would further handicap them in education and career opportunities and in leisure and entertainment. Fortunately for the future, even the present methods of provision have not yet been fully exploited, and some present work gives hope of imminent advance

The research of the present writer has made it clear that even congenitally blind people can learn to use tactile graphics, and that their responses can be quicker and more complete than some teachers have suggested. Their enthusiasm and enjoyment in doing so is likewise heartening.

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