CARTOGRAPHY CROSSING SENSORY BORDERS

Dr Andrew Tatham
Royal Geographical Society
London, SW7 2AR, UK
Fax 44-171-584-4447

For nearly ten thousand years, cartography has been a very successful visual mode of communication. Although examples of mapping which may be sensed tactually as well as visually do exist, until the present time there have been few which have been specifically designed to encourage the use of the sense of touch. Indeed, it could be argued that it is only with the coming of campaigns for universal literacy that the case of those people who are visually impaired has been even considered.

However while few countries have legislation as inclusive as the United States "Americans with Disability Act", it is now widely accepted that people with sensory impairments are as entitled as any other citizen to have access to information, whether textual or graphical. In the attempt to provide people with visual impairments this access to information, cartographers are crossing traditional sensory borders and adding the senses of sound and touch to that of sight. In doing so, they often go beyond the traditional role of communicating information to one of enabling an enhanced quality of life.

One example of this has been the development of the NOMAD* Audio-Tactile pad and software system. The paper outlines the characteristics of the system and then demonstrates its application in the context of a specific project, that of mapping the transport networks of Britain. Transport networks can be mapped or portrayed as a cartogram. The relationship between a cartogram and geographical reality is often very complex with a multiplicity of scalar and orientational variations. To demonstrate this, the project includes audio-tactile representations of the major road network of Britain as a map and of the major rail network as a cartogram. The two are displayed side by side so that comparisons can be made in, for example, the relative positions of nearby towns in the two styles of presentation. The benefits to the user, especially in reducing clutter, of this form of multi-sensory presentation are also demonstrated in the paper.

The final part of the paper examines the extent to which mainstream cartographic design can, or should, be influenced by the specialist applications of audio-tactile mapping as cartographic design approaches the multi-media era.

* Registered name: TOUCHBLASTER NOMAD™

Introduction

It seems generally accepted that the oldest known example of cartography is the plan of the settlement at Çatal Hüyük in Anatolia. This is dated to c. 6,200 BCE [1], although it is a work of considerable sophistication which, I believe, presupposes a significant period of development of both the principles and practice of cartography prior to the construction of this 'first map'. It does not seem unreasonable to assert, therefore, that cartography has been a recognisable graphic form for nearly 10,000 years.

During this period, it must also be asserted, it has been a successful graphic form. Indeed, were this not so, it would not have survived, since the considerable effort involved in data collection, analysis and display would hardly have been pursued had it been worthless.

Furthermore, during these ten millennia the cartographic product has been predominantly solely designed for visual appreciation. Indeed, the only exceptions to this rule have occurred when the normal medium for communication or display has been three dimensional. Examples of this are the clay tablets bearing incised markings such as the Nuzi tablets (c. 2300 BCE) [2], the Gudea statue (c. 2,100 BCE) [3], or the marble celestial globe carried on the shoulder of the Farnese Atlas (c.200 AD) [4]. In none of these cases, however, is there any evidence of an intention that the image should be interpreted through the sense of touch rather than vision.

The earliest cartographic information deliberately designed for use by blind people is believed to date from c.1819, when staff at schools in Weissenbourg and Paris prepared tactile maps from layers of wood to assist in teaching geography to the pupils [5]. Although nothing has survived from this early period, the same technique is still in use today, with the products of the 'Cathedrals through touch and hearing project' [6] providing a fine example in the appreciation of architectural rather than cartographical spatial relationships. Until comparatively recently however such work was very unusual. There were, essentially, two constraints. The first was economic, as it was, and is, extremely costly in terms of time if not money, to prepare such maps. Almost invariably, only single copies were ever produced and even the limited economies of the present day longer run production methods could not be realised. The second constraint was social, for, in many societies, people with handicaps like deafness or blindness were shunned as having been cursed by the gods. Even in the philanthropic climate of nineteenth century Europe, the intention was often simply to enable an individual to contribute to his or her upkeep by providing training in some useful, if tedious, task.

This approach has changed since the Second World War and particularly in the last twenty years. Campaigns for universal literacy and for minority rights, while not usually originally focused on the needs of blind and visually impaired people, have been extended to them as their needs have been brought into stark contrast with their abilities. Thus, at least in the so-called first world, it is widely accepted that people with visual impairments are just as entitled to have access to information as any other citizen. Consequently, considerable efforts are made within either the legal or moral framework to provide such access to graphical and textual information. Maps can only ever be part of this process, but it is certain that those cartographers who are involved in this work find it both challenging and rewarding. They are crossing the traditional sensory borders of their craft, which have, as noted above, largely confined cartography to the visual mode of communication. To the mode of sight, cartographers are now adding the modes of both touch and hearing to aid perception and communication. (Smell and taste are still available for exploration and use by future generations of cross-sensory-border cartographers).

Transport mapping

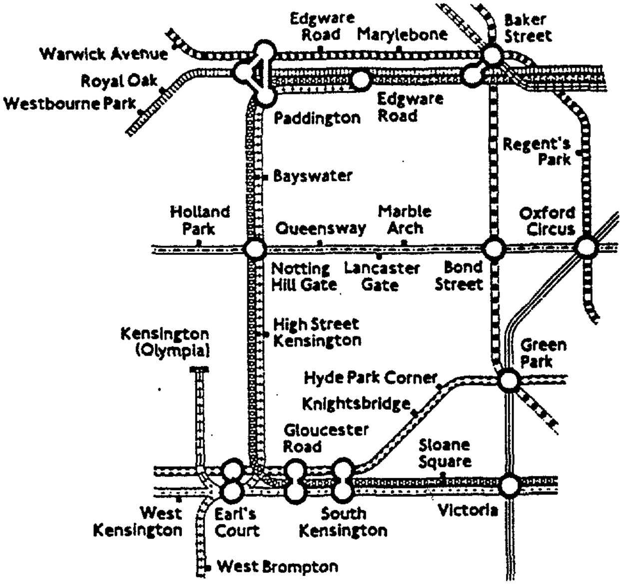
While it is true that any competent tactile mapping is likely to assist a visually handicapped person better to understand his or her environment, one class of mapping, it has been argued, has a disproportionately greater liberating effect. This class of mapping is that of transport routes, systems or networks. Being able to travel independently to and from work, or for social and recreational purposes, is a significant achievement for a visually-handicapped person. It depends on the possession of confidence in one's ability to travel safely to a chosen destination and knowledge of the route needed to reach the destination. Indeed the possession of this knowledge is likely to increase the level of confidence, especially as the visually handicapped traveller does not have the continuous reinforcement of visual cues to his or her position on the chosen route, such as station or street names, for example.

Transport mapping forms an important source of route knowledge, complementing verbal instructions from experienced travellers, timetables and on-route assistance. Transport mapping is very widely available, typically being provided free of charge by operators to their customers, as well as appearing on tourist brochures, on the verso or as an inset of street maps, and on posters at stations, bus stops and on-board locations. It may portray a single route, a simple combination of related routes, the services available from a single location or adjacent group of locations, a part or the whole of a network, which may itself be less or more complex. However complex the subject of the transport mapping it may be depicted by a variety of conventions ranging from topographical, that is at a constant scale with planimetric location respected, to topological, where both scale and planimetry are variable. The topological transport network map is perhaps typified by the pioneering product of Henry Beck and by his successors, for London Transport, and by his imitators world-wide. [7]

The essential feature of this type of graphic is that the relationship between adjacent features (stations) on the same route is maintained at the expense of scalar or positional consistency across the graphic. Thus using Figure 1a as an example, a person on a westbound Central Line train will travel successively through Bond Street, Marble Arch, Lancaster Gate, Queensway, Notting Hill Gate and Holland Park stations. Furthermore, the traveller will know that by changing trains at Notting Hill Gate, access may be gained to High Street Kensington or Bayswater. As a route-finding tool between starting point and destination, the diagram is clear and easily used. It is, however, largely limited to that function because of its scalar and positional distortions. The former mean that it cannot be used to estimate time or distance, either along routes or between them, while the effects of the latter can be seen in Figure 1b, which shows the true positions of the stations shown in Figure 1a. The combined effect of scalar and positional distortions can be illustrated by considering the relationship between Bayswater and Queensway stations. Separated at street level by some 90 metres, the apparent shortest underground route between them, *via* Notting Hill Gate, has a track distance to be covered of 1.2 kilometres [8], as well as approximately 55 m of connecting foot tunnels (excluding escalators or stairs) between the District/Circle and Central Lines at Notting Hill Gate[1].

While this example clearly does not lessen the value of either the topological approach, since Notting Hill Gate *is* the next station westbound from Queensway on the Central Line and Bayswater *is* the next station northbound on the District and Circle Lines from Notting Hill Gate, or the topographical approach, since Queensway station *is* to be found where Bayswater Road and Queensway intersect and Bayswater station *is* at the intersection of Queensway and Moscow Road, but it does illustrate that different visualisations of the mapped data are required.

[1] The connection is described as "Stairs 20,9 dn., subway, escalator (or stairs 3x17,10) dn., escalator (or stairs 16,13,3)dn." [9]



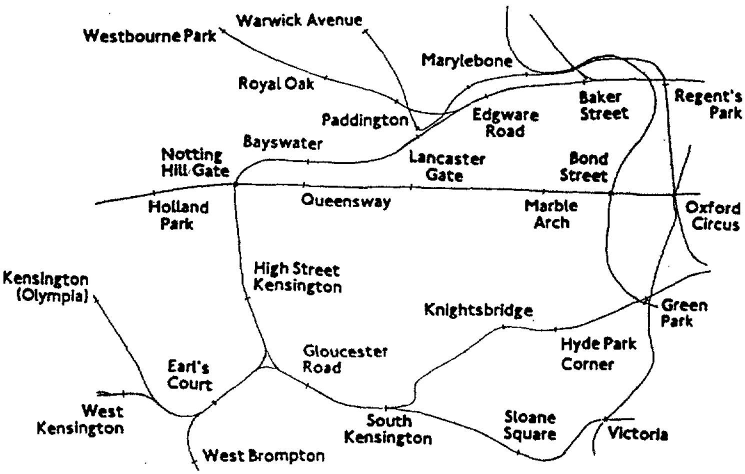


Figure 1: Topological and topographical arrangement of the same part of the London underground system

It is this need for users to learn to operate different systems for visualising different graphic products which suggested that there would be value in developing an educational package, using the Nomad system, to assist people with a variety of handicaps to understand and use the different systems. While this educational package, like the Nomad system itself, was originally developed for visually handicapped people, it could equally assist autistic people, or indeed, anyone who, for whatever reason, finds the acquisition of basic spatial concepts and relationships, or their interpretation from maps or diagrams, to be difficult. The use of the Nomad system, in addition to its designed capabilities, has an intrinsic advantage in this context because of its interactive nature, providing a learning environment which is not only rewarding but also fun.

Touchblaster Nomad ™

Touchblaster Nomad ™ is the official name for the 'Nomad' system which has been developed over the last eight years by Prof. Don Parkes[2], and his colleagues in New South Wales and California [10] It has become an extremely sophisticated package of software and hardware, but it is based on a simple idea. This is that information which is stored in a computer can be related to an 'address' on a touch-sensitive pad. Thus, by touching a point on the pad, the stored information specific to that point is released. If this output is through a speech synthesiser, the user hears the stored information relating to the touched point.

The A3-size 'Nomad' pad has a grid of such addressable points at five millimetre intervals. This spacing is related to the size of a standard Braille letter cell (6mm x 4mm) which is itself related to the ability of the finger-tip nerve-endings to discriminate adjacent stimuli. While a 5mm grid may seem rather course by comparison with the sub-millimetre recognition capabilities of sighted people, it is a considerable advance over most tactile mapping. That this can be achieved is a result of two concurrent improvements to the process of the acquisition of information by the user.

The first improvement is the use of auditory, as well as tactile stimuli, thus effectively allowing the amount of information being passed to the brain to be doubled. The second is that, by removing the need for textual information to be derived from the tactile image since it can be derived directly via the auditory signal, the tactile image is rendered considerably less cluttered. Furthermore, much finer lines and other symbols can be used since they do not need to be distinguished purely by touch. Consequently the amount of non-textual detail on the map or other graphic can actually be increased significantly.

Such a learning environment allows a number of different concepts to provide points of access to the notion that any given spatial relationship can be expressed in a variety of ways. Of these, perhaps the most useful are topographical, temporal and topological. Taking the road network between the three northern English places, Leeds, Liverpool and Kendal as an example (Figure 2), it will be seen that while they are topographically equidistant, temporally, Kendal and Leeds are further apart by about a third than either Kendal and Liverpool or Liverpool and Leeds. Topologically, Kendal and Leeds are adjacent, with but one link between them, while the journeys from Liverpool to Kendal and Liverpool to Leeds are both composed of five links and four nodes.

[2] Currently Associate of the University of California, Santa Barbara

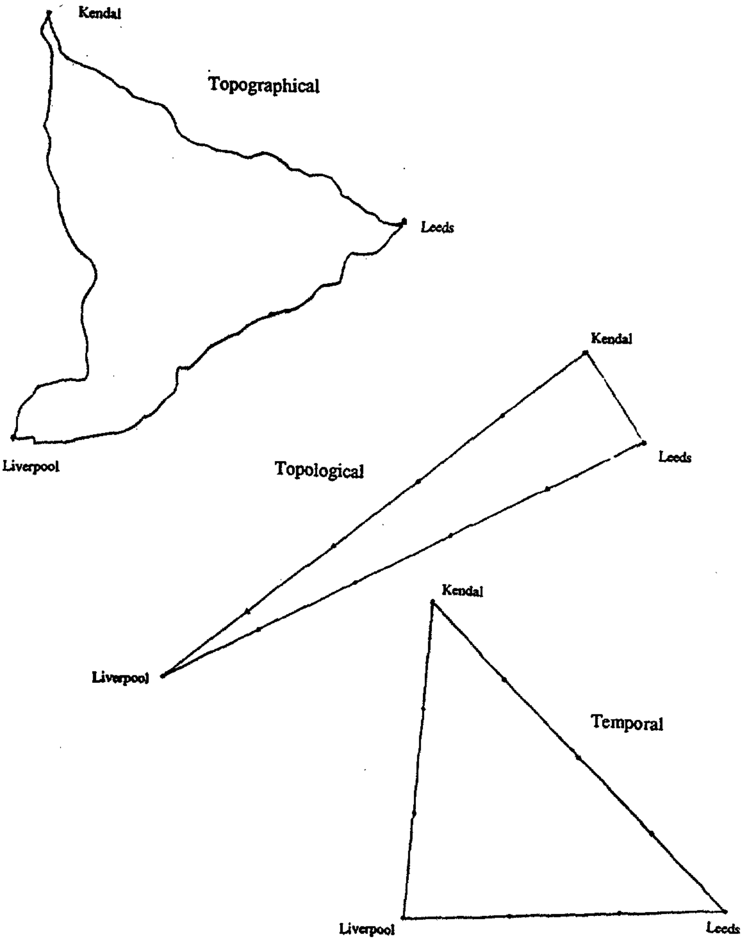


Figure 2: Topographical, topological and temporal connections between Kendal, Leeds and Liverpool

Road - Rail GB

In developing the educational package to allow users to explore the concepts discussed above, it was decided to display the main road and intercity rail networks of Great Britain on separate but adjacent graphics. This has a number of benefits. Firstly, the user can discover both networks from one Nomad file, while the separation of the two systems allows a greater clarity to each. Furthermore, since the Nomad pad is arranged to be used with a landscape format graphic, two adjacent outlines of Great Britain can be shown at the same scale as a single outline.

Secondly, the graphic is designed to convey information, which has as intrinsic value, about the two networks. The location of roads, their numbers and the places linked by them, or the connections possible at different rail intersections can, for example, be discovered from this graphic. Further information can be linked to this graphic, either as separate tabulations or texts, or, using the embedded layers of the Nomad system, actually entered into the file. Thus, if at the surface layer the audio response is "Paddington", the second layer could be "London terminus for Great Western services to South-west England, South and Mid Wales, the South and West Midlands and for Thames Trains services to Windsor, Reading and Oxford. The station is served by the Hammersmith and City Line to Hammersmith and Baker Street, Euston Square, Farringdon, Moorgate, Liverpool Street and Whitechapel; by the Circle Line to Notting Hill Gate, South Kensington, Victoria, Embankment, Blackfriars, Cannon Street and Tower Hill;...(etc)". The third layer could include information about the facilities on Paddington Station, its architecture and history, tourist information about that part of London, and other matters of interest.

Thirdly, since the rail network is displayed topologically and the road network topographically, the two types of presentation can be compared. It may be noted that in such a comparison, the scale of the two graphics is too small for any differences between major railways stations and city centre road intersections in the same urban area to be significant. Furthermore, while minor variations between road and rail routes from one town to another are similarly not significant, major differences can be due to differences of history and economics., which can themselves lead to a valuable educational discussion.

Fourthly, as with any Nomad graphic, the many features of the software can be explored and used to improve the user's dexterity, including line following and finger-pressure control, keyboard skills and ability to respond to instruction. For example, using the 'find' feature, the map reader enters a place-name on the keyboard and is guided to the location on the map by successive 'left', 'right', 'up', or 'down' responses by Nomad to finger-pressure on the pad.

Cartographic Design

As noted above, Touchblaster Nomad ™ enables the cartographer who chooses to cross this particular sensory frontier to use both touch and hearing to replace sight (or to complement residual sight). On the graphic itself, this results in the cartographer being able to move all text from the visual to the auditory channel. In addition, a considerable part of the symbology, for example texture or colour, can be transferred to the auditory channel. To demonstrate the value of this, as well as its effect on cartographic design it is necessary to mention some parameters of traditional tactile map design (see [11] for a fuller discussion of these parameters).

The most significant parameter is the constraint imposed by the tactile sensor itself. In an average adult, the finger tip nerves, which are used to sense tactile information, cannot distinguish stimuli that are closer than 2.0-2.5 millimetres. In order to accommodate this constraint the centres of the

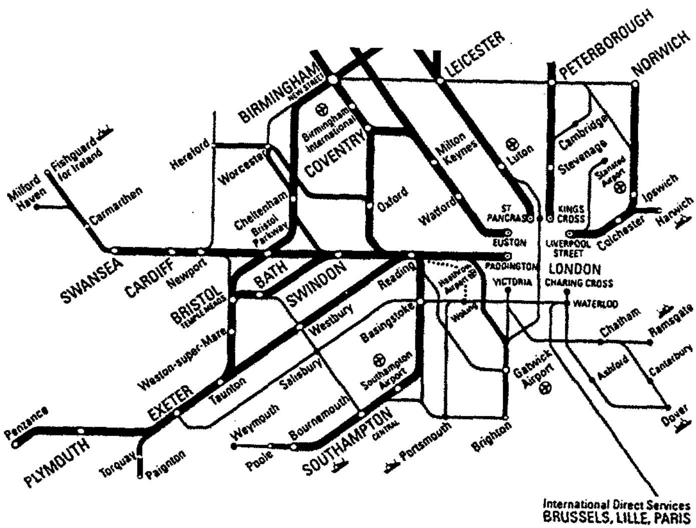


Figure 3: Part of the Intercity rail network

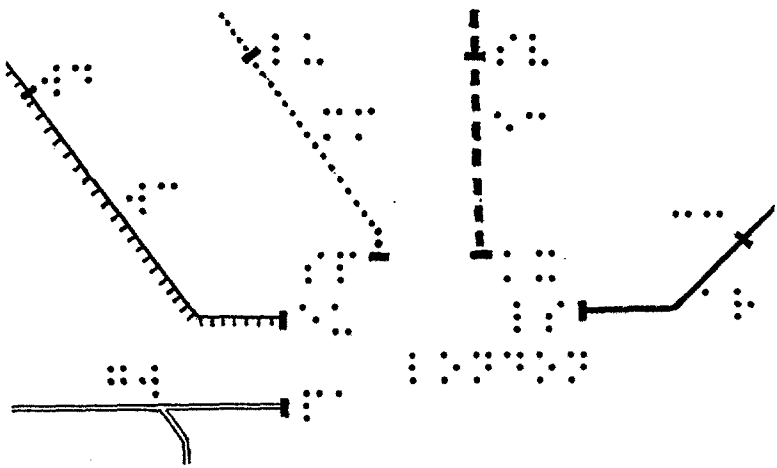


Figure 4: The 'master' for a tactile version of part of Figure 3 (full-size)

dots that form Braille character cells are approximately 2.3 mm apart and this represents a minimum spacing between any tactile features. The standard Braille cell is approximately 6mm high and 4mm wide overall, and there is a gap of c. 2mm between each cell. Thus, even if place-names are reduced to a two-character code, as in Figure 4, complex or crowded parts of the original diagram (Figure 3) have had to be enlarged by a factor of three or four. Each station must be unambiguously named by a two-character code, as must each line, which is also identified by a different, tactually-discriminable line symbol. It is unlikely that more than eight to ten line symbols can be categorised as tactually-discriminable on any single graphic. Similar constraints apply to point and area symbols, although these do not affect the present example. However, Figure 4, even with only five line symbols, fourteen two-character codes, nine point symbols and one name in full, is approaching the limits of tactual discriminability.

By contrast, Figure 5, which is suitable as a basis for a 'Nomad' graphic, is able to contain a considerably larger area. Furthermore, all the station names and railway operating companies can be named in the audio channel, together with relevant additional information stored at lower levels (see above). There is no need for different symbols, as simply by pressing the features of interest elicits an audible response, eg. "InterCity West Coast" or "Milton Keynes", is obtained. It is good practice to leave a separation between features, as suggested in [11]. However, it will be seen that the scale of this diagram, although considerably smaller that that of Figure 4,could have been reduced even further by only a very limited re-design of the London area.

Conclusion

Changing understandings of our obligations, as cartographers, to cross the traditional sensory borders of our discipline and include all potential users of spatial data,have prompted an important growth of interest in tactile mapping. Amongst the enormous range of cartographic products which could be transformed into tactile media, transport mapping is arguably the most beneficial as it significantly increases confidence and hence independent mobility.

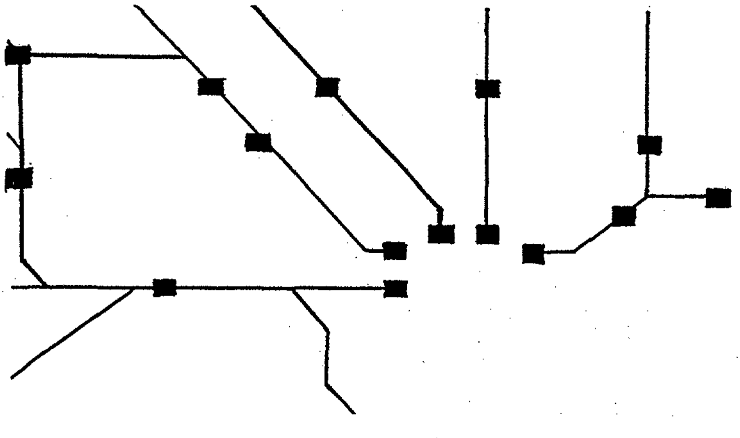


Figure 5: The 'master' for the tactile graphic
of a Nomad version of part of Figure 3 (full-size)

Transport mapping is not a homogeneous category of mapping, but itself crosses the borders of at least three conceptual systems. Topography, topology and, indeed, time are all valid descriptions of spatial relationships and all are commonly used.

All the varieties of transport mapping are readily available for sighted users. The availability of large-print versions for partially-sighted users, or tactile versions is very restricted. However, many transport authorities are now accepting that their moral responsibility extends to all potential users rather than only to those who happen to be sighted and are encouraging, assisting and even commissioning the production of tactile transport mapping.

While transport mapping is often relatively simple and is usually transformed with relatively little adjustment to any of the tactile media, since the original mapping may use topographical or topological conventions, these will be reproduced in the tactile format. It is therefore important to ensure that the user is familiar with the differences between these conventions and can use the appropriate map reading strategies.

Using the audio-tactile system, Touchblaster Nomad™, an educational package is being developed. This will assist in the development of appropriate map reading strategies and of both map use and physical skills. It will also provide information, allowing the user to acquire knowledge in an effective and enjoyable manner. There is no doubt that cartographers will, by crossing the sensory borders of our discipline, allow the discipline itself to develop. More importantly, cartographers will be assisting in improving the independence and confidence of our fellow-citizens.

References

[1] Harley, J.B. and Woodward D,. (eds.), 1987. The History of Cartography, Vol.1 Cartography in prehistoric, ancient and medieval Europe and the Mediterranean. Chicago, University of Chicago Press, pp. 73-74.

[2] ibid., pp. 113-114.

[3] ibid., pp. 109.

[4] ibid., pp. 142-143.

[5] Wallis, H.M. and Robinson A.H., (eds.), 1988. Cartographical innovations: an international handbook of mapping terms to 1900. Tring, Map Collector Publications, pp. 70-71.

[6] Tatham, A.F., 1989. Tactile Mapping in the United Kingdom, in Ishido, Y., (ed.), Proceedings of the Third International Symposium on maps and graphics for visually handicapped people. Yokohama, p.24.

[7] Garland, K., 1994. Mr Beck's Underground Map. Harrow Weald, Capital Transport Publishing, 80pp.

[8] Yonge, J., 1994. Railway Track Diagrams, Vol. 5, England South and London Underground. Exeter, Quail Map Co., pp. 37 and 44.

[9] London Regional Transport, 1989. Access to the Underground. London, London Regional Transport, p.113.

[10] Parkes, D., 1988. "Nomad": an audio-tactile tool for the acquisition, use and management of spatially distributed information by partially sighted and blind persons, in Tatham, A.F. and Dodds, A.G., (eds.), Proceedings of the Second International Symposium on Maps and Graphics. London, pp.24-29.

[11] Tatham, A.F., 1991. The design of tactile maps, theoretical and practical considerations in Rybaczuk, K. and Blakemore, M., (eds.), Mapping the Nations, Proceedings, Vol. 1. London, ICA 1991 Ltd, pp. 157-166.