TACTILE CAMPUS MAPPING: EVALUATING DESIGNS AND PRODUCTION TECHNOLOGIES

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This paper reports on ongoing research into the design of tactile maps. Its focus is upon the potential significance of production technology for tactile map design, and upon methodologies for map design evaluation. Experiments have been carried out contrasting microcapsule with thermoform-based map production. The same campus area was mapped by sighted students using these technologies. Designs were based upon established reported best practice elsewhere and upon user evaluation. Completed designs were subsequently evaluated.

Meanwhile an ongoing programme of thermoform-based production of a wide variety of tactile maps has explored ways in which mapping might be evaluated. Maps have been tested in the lab. and field by blind and sighted subjects and by designers. Evaluation has involved analysis of video evidence of map use, in depth interviews with map users and more theoretical ground truthing of designs. Participants talked about their map use and results were contrasted with systematic analysis of videoed finger movement. The emphasis on complex maps of real environments contrasted strongly with the more usual simplified and laboratory-based evaluation of pilot products. Triangulation between evaluation methods was central to the research.

Results suggest the need for more complex iterative processes of map design and the need for active involvement of users in the tactile map design process. They demonstrate the potential of using video evidence in map user studies, particularly if carried out in a multi-method framework. In contrast to other studies this research suggests that well designed thermoformed tactile maps may have significant advantages over other production technologies. Above all else results suggest that the context and ethnography of map use should be central in any map evaluation.

1. Introduction

Since 1997 we have been developing a range of tactile maps to cover the campus of the University of Manchester. These have been produced by sighted students for visually impaired members of staff [Perkins 1999]. In the last five years we have also investigated the potential of tactile mapping in environmental education and recreation in countryside areas [Gardiner 1997; Gardiner and Perkins 1996a 1996b 1996c; Gardiner 2001].

During the first three years of an ongoing project students produced microcapsule maps of routes across the campus. These maps were part of a guidance package incorporating a taped voice overlay, and were an outcome of an extended group learning experience for sighted students taking a Third Year mapping course [Perkins 1998]. Students surveyed a route, investigated possible symbol and map designs, based upon literature and critique of existing maps, and created a working guidance package. Part of their assessment was derived from a self-critique of method and outcome. The aims of the mapping exercise were to:

- allow students to survey, design and produce tactile mapping packages for totally blind staff and students
- offer real world learning with a demonstrable benefit to a disadvantaged group in the university
- encourage group evaluation of skills
- test a model of good practice for map compilation
- incorporate team, self and peer evaluation
- incorporate user feedback into product designs
- be a pilot for an extending programme of student involvement with tactile map production
- actively link students' learning experience with university equal opportunity policies
- contribute to improved access to the campus
- set up an integrated module in a third year mapping course [Perkins 1999].

Underpinning this research were a number of critical educational factors:
Tactile mapping as a model for sighted map design. A tactual map ought to be much simpler than its visual equivalent and should be aimed at individual needs [Tatham 1991]. The tactile image should therefore help undergraduate students to get to grips with map design, by focusing upon relatively simple decisions.
Real world application. From the outset it was intended that maps would be of *actual* routes across the campus, designed to be used by visually impaired staff and students. Whenever possible we tried to incorporate their views into designs. Lab.-based testing of artificially simple symbols was not an option.
Group work and active learning. Educational research in geography suggests that group-based learning offered a number of benefits [Gold et. al. 1993]. Carefully designed team-based activities can lead to more active learning, with deeper insights, but also allow more students to develop and apply skills [Haigh and Gold 1993]. There is also a growing body of evidence that suggests that *better* maps result from group discussion and evaluation [Monmonier and Gluck 1994].
Iteration and problem solving. A design can always be improved. Students were strongly encouraged to reflect critically upon design quality and to change in the light of evidence. This involved sharing skills and incorporating customer views into a form of problem-based learning [Boud and Felati 1999].

In the first three years a total of 28 maps of routes across the campus area were produced. Advice prior to the mapping comprised formal lectures and surgery sessions in which more interactive exploration of design possibilities were explored. Practice varied from year to year. In the first year we actively involved visually impaired users in the design process. In the second year part of the teaching support was offered by a visit to an exhibition explaining what it means to be blind. In 1999 we organised visits from a mobility officer and visually impaired people, to talk about their experiences of mobility issues. The emphasis of our research altered in 2000. We were interested investigating the role of map design and production technology, and so shifted from route to area-based mapping.

Research questions addressed in this paper flow from the last two years of our experience in this ongoing programme, but are also critically informed by Ann Gardiner's work for her PhD into the role of the tactile map in environmental education [Gardiner 2001]. The focus of the paper is therefore twofold:

- What difference does production technology make to tactile map reading?
- How might evaluation of designs best be carried out?

2. Production technologies

Two principal technologies continue to dominate in the mass production of raised diagrams: vacuum forming and microcapsule. Vacuum forming is the shaping of sheet materials by techniques which employ reduced air pressure to draw a heat-softened sheet into or over a mould. The first vacuum-formed maps were produced in Slovenia in 1957 [Rener 1996], and the technique has been widely used across the developed world, notably by Wiedel and Groves [1969], James and Armstrong [1976] Nolan and Morris [1971] and Salmon [1977]. The main advantages of vacuum forming are the possibilities of multiple raised surfaces, consistent symbol design, possible incorporation of information for sighted helpers as underlays beneath transparent PVC, and an affordable mass production system with cheap media and widespread commercially viable and supported vacuum forming equipment [Gardiner 2001]. On the other hand results depend upon the availability of an appropriate gauge of PVC sheeting, creating masters for map construction may be time consuming and a skilled job, and map masters may degrade after multiple use.

Possible problems over cost effectiveness have led to microcapsule paper becoming increasingly popular as a production technology. It was first used for generating raised graphics in Japan in 1981, with design principles being described by Andrews [1985] and Edman [1992]. This system uses paper coated with an emulsion including microcapsules of alcohol, encased in acrylic resin shells and suspended in a water-based acrylic binder. When heat is applied the microcapsules expand: normally this takes place at 110 degrees centigrade, but carbon black pigment reduces the key temperature to 95 degrees. Black symbols may be transferred to microcapsule using a photocopying machine, these may then be raised when a precisely regulated heat source is applied. The advantages of microcapsule paper lie in the simplicity of reproduction. Graphics can be computer-generated, and paper and fusing machines are readily available. Black raised lines, areas and point symbols may be read by sighted helpers without recourse to an underlay. However only a single symbol height is possible using this method, a much more limited range of discriminable symbols is possible and microcapsule maps degrade rapidly with use.

In February 2000 groups of students in Manchester were asked to produce two maps of a part of the campus of the university, one using vacuum forming and the other based on microcapsule paper. The exercise remained group-based, and sighted students were asked to evaluate the successes and failures of their pair of maps, in order to assess whether the theoretical differences between production technologies were borne out by a real world production exercise. As the course convenor I was worried that vacuum-form-based mapping would prove too difficult for students to master in the time span available, so a paired comparison with microcapsule mapping was included as a means of ensuring equity between groups of students. The outcomes were very surprising, with vacuum form mapping being consistently better than microcapsule equivalents, according to well established marking criteria. As a consequence in the current year's exercise we have moved entirely across to vacuum forming. Why did these maps seem to be so much better designed? To what extent are more complex methods of map evaluation be needed to explain findings?

3. How to evaluate tactile map performance?

Almost all the reported research on tactile map design focuses upon the performance of maps made using a single technology. For example Andrews [1985] evaluated the potential of microcapsule-based techniques, whereas Wiedel and Groves [1969] focused on vacuum-forming. Most evaluation of tactile mapping assesses the value of individual symbols, rather than complete maps e.g. Nolan and Morris [1971]. Almost all of the limited number of studies that test complete maps use artificially constructed maps and test performance in the simplified context of the laboratory. In the real world the use of environmental cues strongly influences map use and probably significantly affects how a map functions, but the desire to produce 'hard' factual evidence about design has led to complexities being filtered out of most evaluations. Only limited comparisons of the performance of production technologies have been made, notably by Pike, Blades and Spencer [1992] and Nagel and Coulson [1990]. Their studies nevertheless form an essential starting point for any critical review of map performance.

Nagel and Coulson [1990] constructed a series of test maps of a hypothetical college campus, designed at four levels of relative complexity. The maps were made with four different production technologies and tested in the laboratory by a sample of 20 legally blind people, ten of whom had partial sight. The testers were given a separate legend and map and asked to respond to three route-finding and three locational questions. Each subject responded to five of the 20 test maps and results were quantified according to the time taken to reach an answer. Subjects were also interviewed about their feelings over the different map types. Their results suggested a strong preference for microcapsule paper as offering both clear visual images and tactual clarity. Vacuum formed maps in their sample took longer to read, and were least liked.

In contrast Pike, Blades and Spencer [1992] found no significant difference in their comparative study of microcapsule and vacuum forming. Their subjects were all visually impaired children, and test mapping was artificially simple, in order to allow results to be quantified across a number of tasks.

Any map reading task depends fundamentally on the map design, the context of use, and the users' experience. None of these are examined in sufficient detail by Nagel and Coulson, so sweeping conclusions about the value of technologies should not be made. We are not given sufficient information about the test map designs. Symbol separation and dimensions are not specified and it is unclear how many levels are used on the vacuum formed maps. Basic misconceptions about durability of microcapsule mapping also cast doubt over the validity of the findings. Despite their use of a mix of objective and subjective assessments their results are almost certainly a function of their experimental design. Poorly designed thermoform maps are likely to be hard to read – their results do not mean that *all* vacuum-formed maps are disliked and hard to read.

4. Principles of map evaluation

What principles might govern how we evaluate quality? The following list illustrates our approach in Manchester and has been applied to a wide variety of contexts and kinds of tactile map products. Underlying these principles is the assumption that evaluation should be integral to design, rather than tacked on after to completed map.

Use best practice in symbol and map design

Properly designed maps are essential if meaningful evaluations of design quality are to be carried out. Gardiner [2001] has listed a number of principles that ought to be followed. These best practice guidelines recognise that the context of map use influences design, stress the importance of base mapping and sensory surveys in collecting information and discuss the need to relate scale to page layout. Symbol choice should reflect production technology and the reproduction material. Different grades of PVC foil require different symbol design and establishing the relative height of features in multilevel designs is an important part of this process. The form of any key should be considered, and links established to interpretation guides. Underlay design may be important, if the map is being produced in a transparent medium and if sighted helpers or partially sighted users are to be involved. It is interesting to note that these guidelines imply very different design outcomes when different production technologies are used and that simple translation of the same symbols into a different technology will not result in the best designed symbols.

Be very clear about the kind of use that the map is being designed for

Tactile maps may be needed to support independent travel around a site along specified routes, or they may be designed for a more general orientation and relate to the whole site. They may however also relate to places that will never be experienced by visually impaired users, and depict spatial relationships and configurations to inform rather than support navigation. Mobility support differs significantly from less focused uses. The context of use will also affect design. Independent use without a sighted guide differs significantly from guided use. Portable use in the field differs greatly from use prior to, or after, a real world experience.

Evolve designs in consultation with users

There are significant differences amongst visually impaired people, that have a greater bearing upon map use than is the case with maps designed for those with sight. A cane user will have different needs from a guide dog user; an experienced braille reader is likely to want different maps from someone more used to audio transcription. The implication is that users should be more involved in the design and evaluation process than is the case with maps for sighted people. Evidence from piloting tactile map designs suggests these are better if there is two-way consultation between users and producers [Gardiner and Perkins 1996a; 1996b; and 1996c; Gardiner 1997).] There are also ethical arguments why visually impaired people ought to be involved in this process [Perkins and Gardiner 1997].

Incorporate real world with lab-based assessment

Different kinds of map information are needed in different contexts. Simplified mapping tested in a laboratory can yield useful results that can be replicated, for example in paired comparisons of symbols, or testing of discrimination of symbol separation. Field-based research is likely to be more subjective, but evaluation that involves a number of data collection methods and many respondents can introduce elements of objectivity into testing [Robson 1993].

Use multi-method evaluation techniques and triangulate

Multi-method approaches should be central to map evaluation. Field observation, extensive overview and intensive interview data can be incorporated and triangulation between these can lead to better designs [Monmonier and Johnsson 1991]. Interviews with visually impaired map users have been central in much of our research. The exact form of the interview depends upon the context. In our research semi-structured and open ended interviews have been most frequently used, but more closed quantitative interviews may be appropriate if aggregation of multiple viewpoints amongst a larger number of users is needed. Informal conversations allowing freedom of expression by map users have also added depth. Interview data have been recorded for subsequent transcription, and then coded to reveal any systematic trends. Interview data have been supplemented by participatory observation of map use in the field. Body language and hand movements may contradict views expressed in interview. These observation studies have been recorded using photography and video-recording. Video in particular has considerable potential for the analysis of tactile map reading [Gardiner 2001].

Incorporate objective testing with more subjective qualitative criteria
Quantitative evaluation criteria such as speed, accuracy and precision may allow informed evaluation of the performance of aspects of a map design. However they are unlikely to be sufficient as indices of quality – the unstated and broader contexts of real world map use are more suited to in depth and qualitative observational studies.

5. Conclusions

Results from campus mapping in Manchester show that relative novices with little experience of tactile mapping can produce effective designs, using both microcapsule paper and vacuum form-based production technologies. Iterative processes of design can lead to effective products. When users are involved in this process a more useful design emerges. Multi-method evaluation of tactile map designs produced using vacuum forming shows that a focus upon design quality and incorporation of user feedback can lead to a more informed and critical approach to mapping. Above all else results suggest that the context and ethnography of map use should be central in any map evaluation.

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