Travel and Information Processing by Blind People: A New Three-Component Model

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Abstract

This paper presents a three-component model of the travel processes of blind and partially sighted people. Significant features of the model include the fact that it is based on a process involving information processing and route and spatial learning rather than one-off journeys. The model has the following three components: (1) the travel process i.e. the activities which take place on a particular trip; (2) information processing to obtain or update the cognitive or mental map; and (3) the cognitive or mental map of a route or space. The model is validated using data from 100 interviews with blind and partially sighted people in France, Italy, Poland, Spain and the UK. The use of the model in developing new travel aids was discussed and the validation data was used to investigate the impact of different types of aid use on the travel process, as well as the differences between the travel behaviours of participants based on gender, visual status and country.

Index terms: blind, travel process, three-part model, validation, travel aid, route learning

I. INTRODUCTION

The ability to travel (independently) is very important for participation in education, work and leisure activities, as well as all other aspects of modern life. Successful travel involves signal processing using information from the senses and possibly also technology, and awareness of the position (proprioception) and movement (kinaesthetics) of all or part of the body. Despite the tendency to consider the representation of space a purely visual activity, there is evidence that vision is neither necessary nor sufficient on its own for spatial coding [1]. Hearing, touch and movement can provide spatially relevant information to be used in spatial coding. In addition, many blind and partially sighted people are very successful (independent) travellers, though others rarely go out on their own. There is still very limited understanding of how blind and partially sighted people process spatial information. There has been little progress beyond the inefficiency and difference theories according to which they are able to understand and manipulate spatial information, but do so less efficiently [2] or differently and possibly more slowly [3] and the formerly considered deficiency theory has been discredited [4]. There also seems to be a total lack of literature on the relationship between the spatial understanding of blind and partially sighted people and the design of travel aids for them.

This raises the following questions: (1) how blind and partially sighted people in general and successful travellers in particular solve the signal processing problems involved in travel; (2) the implications of the responses to this question and how they can be used to increase understanding of current use of travel aids and the differences in travel and information processing with different aids; and (3) how this information can best be used to support the design of new travel aids. This paper is the first in a series that examines these issues.

A The Use of Sensory Information to Support Independent Travel

The comparison of information from the different senses [5] in table 1 indicates that visually impaired people generally do not have a preview of objects or obstacles. However, there is limited, if any, research on the impacts of training and/or visual impairment on the ability to locate and identify objects with the senses other than vision.

Property	Vision	Hearing	Touch	Smell
Spatial field	Large	Large	Small	Large
Overview information	Yes	No, different signals interfere	No	No
Object location	Good	Less precise than vision	Very precise within small field	Very imprecise
Object identification	Good	Less precise than vision	Less easy than vision	Very imprecise

Table 1: information from the different senses

II. MODELS OF THE TRAVEL PROCESS

Work dealing specifically with the travel processes of blind and partially sighted people is very sparse. Therefore, this section also considers models developed for sighted people, but which may also be relevant, possibly with some modifications, to blind and partially sighted people. The discussion is organised into the following types of models: (i) cognitive maps; (ii) types of space and environmental descriptions; (iii) the development of cognitive maps; and (iv) the process of locomotion.

A Features and Types of Cognitive Maps

The best known attempt to propose a generic structure for cognitive maps is due to Lynch [6]. It draws on the cognitive maps of cities obtained from a qualitative study of people interviewed in three US cities to propose a city image based on elements divided into the five categories of path, edge, district, node and landmark. Paths are the channels along which people travel; edges are other linear elements; districts are medium-to-large sections of the city with a common, identifying character; nodes are strategic points, foci and junctions; and landmarks are local or distant point references [6]. However, the evidence on the use of these elements in structuring the mental representations of cities seems somewhat contrived and the approach and terminology have a visual bias, so some modifications would probably be required to adapt the model to blind and partially sighted people.

Appleyard [7] has derived a de-facto model of the different types of organisation of cognitive maps based on studies of the spatial descriptions of 75 sighted people. The model has two levels, with each of the two first level categories having four second-level categories. The first level categories of sequentially and spatially dominant are very useful. However, the second level categories were derived from the organisation of a specific city and cannot necessarily be usefully generalised to other cities or spaces.

B Types of Space and Environmental Descriptions

Many of these models are de-facto models, which are implicit in the literature rather than being presented explicitly. There are three main sub-categories: (i) generally de-facto models of the categorisation of space, based on ‘size’ and distance from the observer; (ii) de-facto models which link frames of reference to environmental descriptions or spatial representations; and (iii) formal, possibly abstract, classifications of space, including Couclelis and Gale's [8] formal model which will not be discussed further here.

The simplest (de facto) model of the categorisation of space has the two categories: small-scale or near space which can be seen from one vantage point; and large-scale or far space which requires movement to be experienced [5, 6, 9]. Later models include small, medium and large-scale spaces, [10-12] with the possible addition of the further category of maps [12]. The primary perceptual space [13] or spatial framework model [14, 15] consists of the three up-down, left-right and front-back axes, which have been used to model the physical space close to the body. Several studies show that it is used in practice [14, 15]. De-facto models which relate frames of reference to styles or perspectives of environmental description or spatial representation include the relationship between three styles or perspectives of environmental description and three frames of reference, with an additional category based on reference landmarks [16]. Another de-facto model links two different frames of references to spatial representations: (i) body-centred or egocentric frames of reference, which may be based on the body axes [17] are linked to route based spatial representations [18]; and (ii) exocentric frames of reference, which may be based on external reference axes, including compass directions, are linked to survey or map-like representations [18].

C Learning Spatial Information and the Development of Cognitive Maps

There are two models in this category, one of the information used to form spatial representations and the other of the development of cognitive maps. The information used to form spatial representations of the environment has been categorised into three classes [19]; (i) route information, which can be used to subsequently travel along the route, but not to find shortcuts and detours; (ii) path integration, which is the process of using sensed displacements and turns [20] to update the current position, but which stores minimal information in memory; and (iii) landmarks, with bearing and distance information from distant landmarks used to form a coherent global representation that integrates different parts of the environment.

The so-called 'dominant framework' [21] is the main theoretical framework for the development of cognitive maps or spatial representations of new environments. It has the following three non-overlapping stages: (i) landmark knowledge about the identities of recognisable discrete objects or scenes; (ii) route knowledge of sequences of landmarks and associated decisions, such as 'take the first left' and (iii) survey knowledge of two-dimensional, maplike, scaled representations of the environmental layout, including the distance and directional relationships between landmarks. However, despite its popularity until the 1980s, there is no convincing empirical evidence to support this framework and some empirical evidence against it [22]. The current view is that landmarks, routes and configurations are all learnt together, with accuracy and precision refined over time [23, 24].

D The Process of Locomotion

Both the two main models of the process of locomotion of blind and partially sighted people focus on individual journeys and do not consider the (route) learningwhich results from making a journey or the way this knowledge affects subsequent journeys. They also do not consider the factors which motivate and/or enable blind people to travel and determine whether they are able to make the trip on their own or require an accompanying person, and there seems to be an unstated assumption that the whole journey will take place on foot, whereas many journey by blind people involve public (and private) transport.

Brambring's [25] two-level model has two first level components, 'perception of objects' and 'process of orientation', leading to the second level 'detection of obstacles' and 'identification of landmarks', and 'spatial orientation' and 'geographical orientation' respectively with various links between the different components. Spatial and geographic orientation are defined respectively as the abilities to estimate or determine position relative to the immediate surroundings and topographic (distant) space. Brambring recognises that the distinction between obstacles and landmarks is not well defined and that objects can be both or become landmarks with familiarity.

Harper and Green's [26] 'flow of travel' model comprises eight main stages, supplemented by a graphical commentary. It organises navigation and orientation objects as memories, obstacles and cues with a set of associated actions linked to a method with several associated properties. The stages are not totally independent of each other and some looping back to previous stages occurs. They consider orientation to require knowledge of the basic spatial relationships in the environment and navigation the ability to move in the local environment. The stages are: (1) aim or aimlessness; (2) pre-plan journey; (3) decide on start and end points; (4) journey; (5) keep to track, with looping back to stage 4; (6) in-route guidance; (7) move to next point with looping back to stage (5) keep to track; and (8) achieve next point with looping back to stage (4) journey.

Brambring's model has the advantages of simplicity and clearly indicating the main activities involved in travelling on foot. It also has the disadvantages of not considering all aspects. The greater complexity of Harper et al's model is both a disadvantage and allows a more detailed consideration of the processes involved in travel, including modelling the interaction between the different travel tasks and the repetitive nature of the process.

E Model Categorisation

The models and model approaches presented in the previous sections can be categorised using the following structured two-level classification:

1. Cognitive maps:
   - 1.1 Lynch's [6] five component model of the cognitive maps of cities
   - 1.2 Appleyard's [7] two-level model of the organisation of cognitive maps of cities
2. Types of space
   - 2.1 Generally de-facto models of the categorisation of space, based on 'size' and distance from the observer e.g. [5, 6, 9, 12-15, 17].
   - 2.2 De-facto models which link frames of reference to environmental descriptions or spatial representations e.g. [10, 16, 18].
   - 2.3 Formal, possibly abstract classifications of space e.g. [8].
3. Learning space and environmental descriptions:
   - 3.1 Péruch et al's [19] model of the type of information used in deriving cognitive maps.
   - 3.2 Siegel and White's [21] three-stage framework of the development of cognitive maps of space.
4. Process of locomotion
   - 4.1 Brambring's [25] two level hierarchical model.
   - 4.2 Harper and Green's [26] eight-stage travel flow model with looping back to previous stages.

III THREE-STAGE TRAVEL MODEL

A Methodology

The model presented here was developed from the author's research on travel issues for blind, partially sighted and deafblind people funded by the Leverhulme Trust [27]. This involved in-depth semi-structured interviews with over 300 blind and visually impaired people in ten different countries, as well as visits to academic and industrial researchers developing travel aids for blind people and in-depth interviews with orientation and mobility instructors and the parents of young blind people in several different countries.

Contacts for interviews were obtained through organisations of blind, partially sighted and deafblind people, and via researchers working with them. Issues related to sampling disabled people are discussed in [28, 29] and will not be considered here. The majority of interviews took place in the office of an organisation of blind or deafblind people, and the remainder either in another convenient location chosen by the interviewee, or by telephone. Interviews lasted between 30 minutes and nearly fours hours, depending on the issues that arose and the amount of time the interviewee had available. With a small number of exceptions, all the interviews took place in the participants' language without an interpreter, thereby reducing the likelihood of misunderstandings and distortion. The interviews were transcribed by a native speaker in the original language without translation.

The blind and visually impaired people interviewed were approximately gender balanced (44% female: 56% male) and had a wide distribution of both age (1% under 16, 10% 16-25, 16% 26-40, 40% 41-60, 17% 61-70 and 7% over 71) and age of onset of impairment (48% birth, 22% childhood, 17% adulthood, 11% middle age and 2% over 60), though this distribution is somewhat different from that in the population. 70% were blind and 30% visually impaired. 10% additionally had some degree of hearing impairment or were deafblind and another 10% required the use of a cane for support. There were also two deafblind wheelchair users.

B Three-Stage Travel Model

The main preliminary findings of this research of relevance to modelling the travel process include [27, 30]: (1) the importance of the difference between familiar and unfamiliar routes and places and the processes by which unfamiliar places and routes become familiar; and (2) the role of accessible information from all the senses in making travel possible, leading to great difficulties in travelling in areas in which no useable information is available. The concept of a mental or cognitive map of space is already familiar from the literature [5, 31], though this is at least to some extent a theoretical construct rather than fully representing the real cognitive processes that take place. The simplest mode based on the research findings is a process of learning which transforms 'unknown' into 'known ' routes and spaces through processing the sensory and other information obtained during the travel process, and the retention and possible codification of this information in some sort of 'mental map', with the term used in its widest meaning.

Formulating these conclusions as a model leads to the following three main components: (1) the travel process i.e. the activities, including information gathering, which take place on a particular journey or trip; (2) information processing to obtain or update the mental map of a particular route or space as a result of undertaking a journey; and (3) the representation of a route or space, frequently referred to as a cognitive or mental map. There is a cyclical relationship between the three components, which reflects the process by which routes and areas are learnt and go from being unfamiliar to becoming familiar. In particular, as shown in Fig. 1, the activities on a particular journey feed into the process of learning or updating the cognitive or mental map. This then leads to updated knowledge of the particular route and/or the surrounding space. This updated knowledge (modified mental map) then affects and facilitates subsequent travel on this route and may also affect other journeys. Models of each of the three components can then be developed and will be discussed in subsequent papers. There is again a cyclical relationship between the three component models.

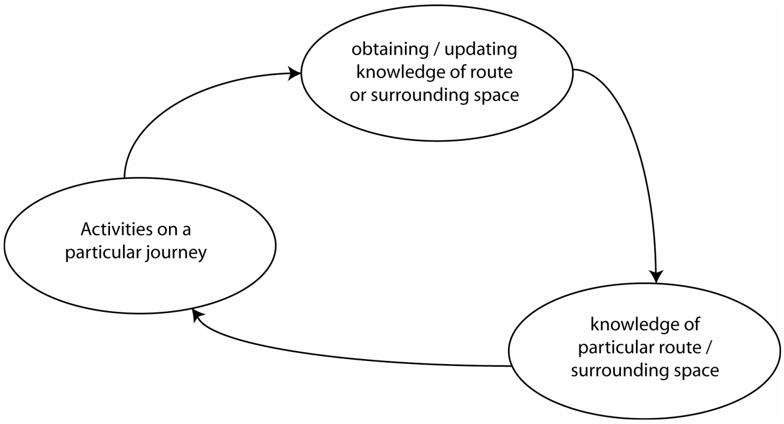

Figure 1, Process of route learning by which unfamiliar routes become familiar

IV VALIDATION

A Validation of methodology

It is now necessary to validate the model or compare it to empirical reality in order to corroborate, refute [32] or modify it to obtain corroboration. In this case empirical reality is based on the interview data obtained from participants and validation involves evaluation of the consistency of the travel behaviour predicted by the model and the experiences reported by research participants. Since the number of research participants was very large, a sample of 100 was selected, 20 each from France, Italy, Poland, Spain and the UK and chosen to be gender balanced and to cover a wide range of variation on demographic variables, such as age, age of onset of visual impairment, aid use and type of location, as shown in tables 2 and 3. It should be noted that the data represents both total numbers and percentages. The sample included significantly greater numbers of cane than guide dog users, as is the case in the blind population. Only a small number of non-aid users was included, since they are less likely to experience barriers to mobility. A higher proportion of blind than partially sighted people was included for the same reason. People who only or mainly travel accompanied were excluded, since they have less need to learn routes and areas than people who travel on their own and are therefore less likely to have opportunities to experience the confirming behaviours.

Gender		Age					Where live				Additional		
Male	Female	16-25	26-40	41-60	61-70	71+	Big City	City	Town	Village	EM	DB	PD
50	50	9	28	43	17	3	36	37	20	7	5	9	6

EM = ethnic minority, DB = dual sensory impairment/deafblindness, PD = physically disabled
Table 2: Demographic information

Visual status		Age of onset of visual impairment					Travel aid use		
Blind	Partially sighted	Birth	Childhood	Adult	Middle aged	60+	No aid	Cane	Guide dog
77	23	54	27	12	7	0	9	68	23

Table 3, Visual impairment profile

Model validation was carried out using sections of the interviews relevant to the themes of the model. They were obtained by searching the transcripts for relevant keywords in the appropriate languages, such as ‘familiar’, ‘know(n); ‘learn’, ‘route’, ‘map’, 'representation', ‘mental’ and ‘cognitive’. Model validation involved checking and tabulating the presence of predicted behaviours consistent with the model and the absence of behaviours inconsistent with the model for each of the 100 interview transcript sections. The 15 predicted consistent behaviours which were tested for are stated below organised into three groups. To avoid repetition the term routes is used to cover routes, areas and spaces.

The difference between known and unknown routes:
i) making distinctions between known and unknown routes; (ii) mainly or solely travelling (unaccompanied) on unknown routes; (iii) greater use of travel aids or the use of different travel aids on unknown routes; (iv) only or mainly travelling accompanied on unfamiliar routes; (v) asking for information more frequently on unfamiliar routes;

Route learning and mental maps:
(vi) memorising landmarks and other route information; (vii) the use of a mental map or representation; (viii) the need to be shown or taught new routes; (ix) preparing for travelling on unknown routes by seeking information in advance; (x) route learning;

Easier, more effective and less stressful travel on known routes:
(xi) more anxiety or stress on unknown routes; (xii) using familiar landmarks to determine position on known routes; (xiii) walking faster on known routes; (xiv) using the familiarity of known routes; (xv) using the preknowledge of landmarks on known routes to anticipate.

In addition, the validation process involved checking for the presence of the following behaviours inconsistent with the travel model, such as (i) mainly or solely travelling on unfamiliar routes; (ii) evidence of a lack of memorisation or attempting to remember route information (for reasons other than a poor memory); (iii) evidence of finding it easier to travel on an unfamiliar than a known route and (iv) evidence of lack of a cognitive representation or mental model.

It should be noted that some of the consistent behaviours are complementary, whereas others are generally mutually exclusive. In addition, the fairly large number of behaviours listed and the fact that validation is based on data from semi-structured interviews where these questions were not posed explicitly means that participants are unlikely to exhibit all the behaviours. A trip is often a means of getting somewhere with a particular aim in mind rather than an aim in itself. Therefore, as FM indicates, whether or not learning takes place on a particular trip or over several trips, may be dependent on other factors. ‘Also there are places were I am so stressed because I am late, I have something complicated to do or a difficult meeting, that I will arrive where I need to, but without really exploring, I will have asked for assistance, … but I won’t have learnt anything of the route, as I was too preoccupied to pay attention … there are also times when I learn well because I feel relaxed.’ Therefore, rather than a particular threshold of percentage of individuals exhibiting particular behaviours or number of behaviours exhibited by individuals being required to establish validity, this will be discussed when the results are presented.

The presence of the consistent behaviours and absence of confounding behaviours was also verified for different groups of participants, based on gender, visual status and aid use to ensure that it was valid across the spectrum of blind and partially sighted people with mobility difficulties. In addition, to increase understanding of the travel processes and use of aids the differences in behaviours between different groups of respondents were investigated. The Fisher exact test with software developed by Langsrud [33] was used to determine statistical significance at the 0.05 level.

B Validation Results and Discussion

The numbers (also equal to the percentages) of respondents showing the consistent behaviours listed above are presented in tables 4 to 6.

Distinction known & unknown routes	Mainly travel on known routes	Greater use of aids on unfamiliar routes	Mainly accompanied on unfamiliar routes	More frequently ask on unknown routes
96	27	29	45	50

Table 4: The difference between known and unknown routes

Memorising route information	Mental map or representation	Need to be taught or shown new routes	Preparing travel on unknown routes	Route learning
42	54	24	56	48

Table 5: Route learning and mental maps

More anxiety on unknown routes	Familiar landmarks to determine position	Walking faster on known routes	Using familiarity of known routes	Using preknowledge of landmarks
19	20	9	44	22

Table 6: Easier, more effective and less stressful travel on known routes

Examination of the data shows significant evidence of consistent behaviours. Behaviours per person ranged from 2 to 11, with an average of 5.9. The percentage of participants showing each behaviour ranged from 9 (walking faster on known routes) to 96 (distinction between known and unknown routes), with an average of 39. No participants showed any evidence of three of the four confounding behaviours: mainly travelling on unfamiliar routes, not (trying to) remember route information and finding it easier to travel on an unfamiliar than a known route. Although three participants gave indications that they were uncertain whether they had a mental map, subsequent responses indicated that they did encode and mentally store information, in two cases in the form of lists and in one case automatically rather than consciously.

While considerable evidence was found for all the behaviours, significantly higher proportions of respondents had behaviours in the first two categories, difference between known and unknown routes (table 4, average 49.2,) and route learning and mental maps (table 5, average, 44.8) than the third category, easier, more effective and less stressful travel on known routes (table 6, average 22.8), with $p=3 \times 10^{-18}$ and $2 \times p=10^{-13}$ for the differences between the averages over tables 4 and 6, and tables 5 and 6 respectively. However, the lower value for easier, more effective and less stressful travel on known routes may have been due to the fact that the participants who would experience the greatest stress and difficulties on unknown routes never travelled on them.

The most popular behaviours reported by at least 50% of participants included making distinctions between known and unknown routes, spaces and areas (96%); preparing for travel on unknown routes (56%); the use of a mental map or representation (54%); and asking for information more frequently on unknown routes (50%). This shows that the overwhelming majority of participants made a distinction between known and unknown routes and the majority of participants formed mental maps and exhibited behaviours illustrating the greater difficulty of travelling on unknown routes and the need to obtain additional information in advance and/or while travelling to overcome this.

The behaviours of different groups of participants will now be considered and are presented in tables 8a and 8b. These tables do not include all the behaviours in tables 4-6 and the focus is on the more 'popular' behaviours. To facilitate comparisons the number of behaviours in each category has been scaled up to that of 100 participants. Values for particular behaviours are stated to the nearest integer and for the average number of behaviours to one decimal place.

Since only 12 participants were GPS users, a non-GPS group consisting of 12 people matched as far as possible to the GPS group on gender, type of visual impairment, age, age of onset of visual impairment, country and aid use was chosen for comparison purposes. This was not done for other cases, such as blind and partially sighted and cane and dog users, with significant differences between the numbers in the different categories, as, though large, the differences were not nearly as great. In the case of non aid users it would have been difficult to find a comparable sample, particularly with regard to visual profile.

Category	Difference known & unknown	Mainly known routes	Accomp-anied on unfamiliar	Ask on un-known	Mental map	Preparing unknown routes	Route learning	Using familiarity	Familiar land-marks	Average number behaviours
All	96	26	45	50	54	56	48	44	20	5.9
Blind	95	27	44	51	61	57	49	43	21	5.9
Part sight	100	26	48	48	30	52	43	48	17	5.5
Male	94	30	42	46	58	50	50	40	20	5.6
Female	98	24	48	54	50	62	46	48	20	6.1
No aid	100	11	33	56	11	44	22	67	22	4.2
Cane	97	35	54	43	54	56	50	44	19	6.1
Dog	91	9	22	70	70	61	52	35	22	5.7
GPS	100	25	33	58	50	50	50	42	25	5.8
No GPS	92	42	33	50	58	50	42	50	17	5.9

Table 7a The consistent behaviours of different groups of participants

Category	Difference known & unknown	Mainly known routes	Accomp-anied on unfamiliar	Ask on un-known	Mental map	Preparing unknown routes	Route learning	Using familiarity	Familiar land-marks	Average number behaviours
France	100	10	50	65	60	75	50	30	20	6.1
Italy	100	20	45	55	75	70	65	55	20	6.6
Poland	100	25	45	50	50	65	40	50	20	6.0
Spain	96	35	50	55	45	35	50	25	15	5.4
UK	85	45	35	25	40	35	50	60	25	5.2

Table 7b The consistent behaviours of participants from different countries

Tables 7a and b show that the different groups of participants all show significant numbers of consistent behaviours. As previously discussed, the participants overall show significant evidence of the consistent behaviours, no evidence of the confounding behaviours and there are several important behaviours exhibited by a majority of participants. Therefore the model has been validated.

C Differences between Different Groups of Participants & the Impacts of Travel Aids

The data in tables 7 will now be used to investigate the differences between the travel behaviours of different groups of participants and the impacts of the use of travel aids on travel behaviour. In particular, the data (and associated comments) indicate that the increased difficulty in travelling on unfamiliar routes, spaces and areas requires additional information to compensate and that this information can be obtained from a variety of sources, including the internet or other people in advance, asking passers-by and the use of travel aids. This implies that there is a need for the development of travel aids to (better) overcome the gap between known and unknown routes, spaces and areas, for instance by providing the equivalent of preview information and information about the actual location, thereby reducing the need to be accompanied or to ask for information, as well as stress while travelling.

In the case of GPS and non-GPS users, the main difference was in the extent participants mainly travelled on known routes, with just under twice as many non-GPS as GPS users doing this. However, this difference was not statistically significant (p = 0.77), probably due to the small sample size. However, the result was in line with comments by GPS users that, for instance, 'You can mark the points from where you are to where you are going on a route you do not know. Thus GPS allows me to go on holiday in places that I do not know.' [CC] and 'You can see the route in advance. it also helps me to feel calmer. If I already have some information when I get to a new route I am much less stressed.' [IB] This indicates that one of the main (potential) and highly significant advantages of GPS use for blind and partially sighted people is to enable them to travel on their own in places they would not otherwise be able to visit without a sighted guide. However, comments by some of the non-GPS users (not necessarily those in the comparative sample), indicated barriers to GPS use of cost and insufficient precision of the technology. Other smaller (and non statistically significant) differences included greater route learning (50 compared to 42%) greater use of familiar landmarks to determine position (25 compared to 17%) and more asking on unfamiliar routes (58 compared to 50%) by GPS than non-GPS users, but greater use of familiarity by non-GPS users (50 compared to 42%). Further research involving larger sample sizes is required to determine whether these differences still hold at a statistically significant level. The more frequent asking on unknown routes by GPS users may be due to GPS use enabling them to travel more widely, but not resolving all travel information issues, possibly due to lack of precision.

The tabulated data also indicated a different pattern of travel between cane and guide dog users, with cane users being nearly four times as likely as dog users to travel mainly on known routes (35 compared to 9%, p = 0.016), nearly two and a half times as likely to be accompanied on unfamiliar routes (54 compared to 22%, p=0.008), but asking for information in unknown areas only three fifths as often (43 compared to 70%, p=0.03). As indicated by the p values, all these differences are significant. They parallel the situation of GPS and non-GPS users (where the differences were not found to be significant, probably due to the small sample size), with dog use reducing the need to be accompanied and increasing travel in unknown areas, but also increasing the need to ask for information. Comments by participants indicated how dog use enabled them to travel more widely with the dog overcoming the lack of preview information and generally reducing stress compared to cane travel. 'Very less stressful. I think it's much easier.' [RS] 'You can let the dog guide you, you do not need to look for landmarks' [SD] and 'my dog has an incredible memory, so if she goes there once, the next time she remembers the route, as though she had always known it' [RB].

Dog users were found to use mental maps more frequently than cane users (70 compared to 54%), though this difference was not statistically significant (p=0.23). Some dog users indicated that they preferred to learn routes using a cane and then presumably used their mental maps to travel on them. However, participants who had used both a dog and a cane indicated that they generally had less information about obstacles when using a guide dog than a cane as the dog avoided the obstacles. 'It is much easier to get around with a dog ... with a white cane I bumped into things ... with a dog I avoid all the obstacles .... I missed the building ... because my dog took me round the dip [in the road], because it was an obstacle for him, ... and this landmark wasn't any use with the dog' [DN].

Non-aid users made considerably less use of mental maps than either cane (11 compared to 54%, p=0.029) or dog users (70%, p=0.005), prepared unknown routes (44 compared to 56 and 61%); and learnt routes (22 compared to 50, p=0.16; and 52%, p=0.23). However, they were accompanied on unknown routes to about the same extent as cane users (56 compared to 54%) and their frequency of asking on unknown routes was between that of cane and dog users (56 compared to 43 and 70%), whereas they used familiarity more than either cane or dog users (67 compared to 44, p=0.29; and 35%, p=0.13). Further research will be required to determine whether the non-statistically significant differences become significant for larger samples of non-aid users. Non-aid users are generally partially sighted rather than blind. Comments from non-aid using participants (not all in this sample) indicate that they can be divided into those who have sufficient vision to travel safely without an aid and those who do not, but are experiencing psychological or other barriers to using one. Thus the reduced mental mapping may be due to a combination of obtaining too little information to do it effectively and having less of a need for mental maps, since more visual information is available, but further research would be required to confirm or disprove this.

The most significant difference between blind and partially sighted respondents was in the twice as frequent mental map use by blind participants (61 compared to 30%, p=0.016). This may be a consequence of the fact that partially sighted participants are able to use visual information to some extent and therefore are less dependent on memorising and storing route (and spatial) information. There were also some differences between male and female participants, with women both being accompanied (48 compared to 42%, p=0.69) and asking more frequently on unknown routes (54 compared to 46%, p=0.59). Women both prepared unknown routes (62 compared to 50%, p=0.31) and used familiarity more frequently (48 compared to 40%, p=0.55), whereas men more frequently used mental maps (58 compared to 50%, p=0.55). Although the differences were not statistically significant, the presence of several differences in the same direction is indicative. They may be due to the greater confidence of men than women both in general and in the specific situation of blind travel, as well as greater awareness of the processes involved in using mental maps. Although the gender samples were not particularly small, it is possible that investigation using a larger sample would give significance.

Considerable differences were also found between participants in different countries. In particular, the average number of consistent behaviours ranged from 5.2 in the UK to 6.6 (p=0.02) in Italy, with Spain (5.4) also at the lower end and Poland (6.0) and France (6.1. p=0.18) at the higher end. There was also considerable variation on the specific properties. As might be expected from the totals, participants from the UK had lower values on most behaviours, in particular they were less frequently accompanied (35 compared to 45, p=0.75; or 50%, p=0.52), asked less frequently (25 compared to 50, p=0.19; 55, p=0.11; or 65%, p=0.02) and prepared unknown routes less frequently (35 compared to 65, p=0.11; 70%, p=0.056; or 75 p=0.025). However, they used familiarity considerably more frequently (60 compared to 25, p=0.054; 30, 50 or 55%) and more frequently travelled mainly on known routes (45 compared to 10, p=0.03; 20, p=0.18; 25 or 35%).

Participants from France, Italy and Poland had similar patterns for many of the behaviours, with high values for being accompanied (45 and 50%) and asking on unknown routes (50, 55 and 65%), forming mental maps (50, 60 and 75%) and preparing unknown routes (65, 70 and 75%) and low values for mainly travelling on known routes (10, 20 and 25%). The values for participants in Spain were similar to those of participants from France, Italy and

Poland for being accompanied (50%) and asking on unknown routes (55%) and closer to the UK values for making mental maps (45%) and preparing unknown routes (35%). Further research will be necessary to determine whether some of the non statistically significant differences become significant for larger samples and investigate the reasons for the differences. However, possible explanations include (some combination of) cultural factors, differences in the availability of orientation and mobility training and/or the approaches used in it, and differences in attitudes to independent mobility by blind people.

V CONCLUSIONS

The paper has presented a new three-component model of the travel processes of blind and partially sighted people, comprising models of (1) the travel process i.e. the activities, including information gathering, which take place on a particular trip; (2) information processing to obtain or update the mental map of a particular route or space as a result of undertaking a journey; and (3) the representation or cognitive map of a route or space. The significant aspect of this model is the treatment of travel as a process involving obtaining and processing information to produce a mental map and transform unknown to known routes rather than isolated trips. The model was validated by demonstrating the presence of 15 predicted consistent behaviours and the absence of four confounding behaviours in relevant sections of a sample of 100 gender balanced interviews from France, Italy, Poland, Spain and the UK.

The model indicates the importance of the difference between known and unknown routes (spaces and areas) and the need for information from technology and/or people to bridge this gap and enable travel by blind and partially sighted people. This indicates a need for the development of travel support technology which is able to provide this information more effectively and completely. A number of differences between the behaviours of different groups of participants were found, based on gender, the extent of visual impairment, country, and the type of travel aid used. In particular, guide dog use enabled more frequent travel on unknown routes and less need to be accompanied, but led to more frequent asking information on unknown routes than cane use and these differences were statistically significant. GPS use also increased travel on unknown routes, but not to a statistically significant extent, possibly due to the small sample size.

A secondary contribution of the paper was the development of a structured two-level categorisation of existing models and modelling approaches, However, these models have the disadvantages of not modelling travel as a process, being based on single journeys, lacking empirical valuation and, with a view exceptions, having been developed for sighted people without consideration of possible extensions to blind and partially sighted people.

Further work is required in several areas, including the development and validation of models for the three components of the model and determining whether it can be extended to partially sighted people who do not experience significant mobility barriers. There is also a need for investigatation and development of the model's applications in furthering understanding of the travel processes of blind and partially sighted people, predicting behaviour and supporting the development of travel aids. Further investigation of the differences in behaviours between different groups of participants is required both to determine whether some of the currently non-significant differences become significant for larger samples and investigate differences, such as age, not considered in this paper.

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