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ORIGINAL ARTICLE

**Andrew J. May · Tracy Ross · Steven H. Bayer
Mikko J. Tarkiainen**

Pedestrian navigation aids: information requirements and design implications

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Abstract Recent years have seen an increased interest in navigational services for pedestrians. To ensure that these services are successful, it is necessary to understand the information requirements of pedestrians when navigating, and in particular, what information they need and how it is used. A requirements study was undertaken to identify these information requirements within an urban navigation context. Results show that landmarks were by far the most predominant navigation cue, that distance information and street names were infrequently used, and that information is used to enable navigation decisions, but also to enhance the pedestrian's confidence and trust. The implications for the design of pedestrian navigation aids are highlighted.

Keywords Design · Navigation · Pedestrian · Requirements · Wayfinding

1 Introduction

1.1 Background

Recent years has seen an increased interest in the design of navigation aids for pedestrians, within the broader remit of location-based services or context-aware computing. Although the business case for navigational and related services remains to be proven, technological advances such as Internet-capable mobile devices with high resolution colour screens, increased accuracy and miniaturisation of positioning technologies, more widespread and detailed digital mapping coverage and enhanced mobile data transfer rates have resulted in the technological feasibility of mobile navigation aids for pedestrians.

Recent research has addressed a range of issues concerning pedestrian navigation. Much empirical work has focussed on the design of navigation aids for users who have a visual or cognitive impairment (e.g., [1, 2, 3, 4, 5]). Other research has focussed explicitly on the provision of turn-by-turn instructions for pedestrians over mobile phones [6], the multimodal nature of journeys [7] or the incorporation of route guidance information with points of interest for tourists [8] or business users [9]. A trend in much of the recent research is the provision of turn-by-turn rather than map-based guidance. This mirrors the automotive market where navigation systems have been available as original or after-market options for over a decade and well designed turn-by-turn route guidance, incorporating information that supports basic human navigation strategies, has been shown to be the most effective design of a navigation aid for a driver [10].

A key prerequisite to designing successful pedestrian services, and delivering these over mobile devices, is to understand the nature of the navigation task, and the information requirements of the pedestrian. This paper assumes that a pedestrian is undertaking a journey specifically focussed on reaching a destination, with information being required that supports an effective turn-by-turn navigation strategy. (Specific groups such as tourists may require additonal information such as points of interest). In addition, it is assumed that information is delivered via a mobile device, although of course future services may be based on concepts such as interactive environments or augmented reality.

A. J. May (✉) · T. Ross · S. H. Bayer
Ergonomics and Safety Research Institute,
Loughborough University,
Holywell Building, Holywell Way,
Loughborough,
Leicestershire, LE11 3UZ, UK
E-mail: a.j.may@lboro.ac.uk

M. J. Tarkiainen
VTT Industrial Systems,
P.O Box 1302, 33101 Tampere,
Finland

1.2 The nature of navigation

Much of the most relevant theory-driven (as opposed to device-centred) research on navigation has focussed on how individuals think about and process geographical information. People make wayfinding decisions based on a previously acquired spatial understanding of their world; this spatial representation of the environment is termed a "cognitive map". Recent work, such as that by Kitchen and Blades [11] has integrated cognitive theories from geography and psychology to enable a better understanding of environment-behaviour interactions.

Baker [12] describes navigation as the "method of determining the direction of a familiar goal across unfamiliar terrain" and, based on a series of empirical studies, describes how navigation involves both route-based and location-based mechanisms. Route-based mechanisms involve monitoring the direction of travel and the relative distances during the different stages of a journey; the location-based mechanism involves checking position and direction in relation to distant, recognisable landmarks.

Hirtle and Jonides [13] state how people use landmarks, route knowledge and survey knowledge when navigating. Landmarks are defined as conceptually and perceptually distinct locations. Route knowledge is an understanding of the environment described in terms of paths between locations, and relative to locations along those paths. Survey knowledge describes the relationships amongst locations, e.g., in the form of maps. Where studies have empirically investigated the information used by a pedestrian for navigation purposes they have shown that the main elements include: geometric and spatial relations, compass directions, distance units, place names, descriptions of the nature of the route and landmarks. In addition, authors such as Hill [14] have highlighted the importance of personalisation of information and non-verbal communication (e.g., pointing).

1.3 Research objectives

This paper investigates the extent to which different types of information such as those mentioned above are used within a turn-by-turn navigation strategy in a complex and varied town centre environment, and to identify design implications for a mobile navigation device. Specifically, there were four research questions posed at the beginning of the study:

1. What information is needed by pedestrians for navigation purposes?
2. What terminology is used to describe this information?
3. How is information used at, and between, key navigation decision points?
4. How important is particular information in enabling key navigation objectives, and to what extent is information redundancy employed in navigation instructions?

2 The experimental approach

The results described in this paper are from an empirical requirements study, where participants were presented with a series of complex pedestrian routes, and asked to identify in detail the information that they felt a pedestrian unfamiliar with the area would need in order to navigate those routes successfully. These navigation instructions were elicited from two separate participant groups: either from participants' memories (the cognitive map group), or based on the participants physically walking through the routes (the walkthrough group).

A basic assumption underlying the methodology employed in the study was that the best environmental cues were those which were pertinent in participants' cognitive maps (reflecting the recognised importance of mental representations of spatial environments [11, 15]), and/or those which were visually prominent (i.e., which would depend highly on their perceptual-visual characteristics and so would support an information processing perspective). In order to identify relevant navigation cues, the cognitive map group used route schematics which were designed to provide just enough information to enable the participants to recognise the routes, without incorporating any potential navigation information such as road names, buildings, other landmarks or any indication of distance. The walkthrough group based their navigation instructions on being physically led through each of the chosen routes, i.e., the information identified by this group was based on direct observation and experience, rather than the recall of these cues from memory. These different approaches had associated advantages and disadvantages, as shown in Table 1.

Trial participants were chosen based on them being current users of mobile phones and potential early adopters of future handheld navigation devices. A group of undergraduate students was recruited, and 20 were

Table 1 A comparison of different information sources for direction-giving studies

Information based on:	Advantages:	Disadvantages:
Long-term memory (a cognitive map)	Based on repeated exposure to cues—information used by "expert" navigators	Individual's memory for navigation cues prone to subjective biases
Direct experience (walkthrough)	Based on direct observation: the view of an unfamiliar traveller	Potential inconsistencies between the experience of routes: limited by the specific views available, the time of day, etc.

then selected and randomly allocated to either the cognitive map or the walkthrough participant groups. Both groups comprised 50% males and 50% females, and were balanced as far as possible for age (the cognitive map group: mean 23, s.d. 3.4; the walkthrough group: mean 22, s.d. 1.4). In addition, all participants were required to have extensive local knowledge, having spent at least three years living and/or working in the local area.

The route employed within the study was chosen based on findings [16] that recommend that requirements studies of this nature employ complex, diverse routes in order to (1) impose a significant navigation task demand on participants (increasing the need for accurate navigation information), and (2) promote the generalisation of the results that are obtained. A circular route was selected based around the centre of Loughborough, a town in the East Midlands region of the UK. The route was 2.4 km length in total, took approximately 30 minutes to walk, and was comprised of an indoor shopping centre, main shopping streets, pedestrianised areas and a large park.

2.1 The experimental procedure

Participants were informed that the study was investigating the information pedestrians use when navigating within a range of environments, with a view to improving the design of pedestrian navigation systems. Both participant groups (the cognitive map and the walkthrough) were told that they were required to give directions to a pedestrian to enable them to navigate the route in question, and that the pedestrian was totally unfamiliar with the area. The cognitive map group was based in an office, and were given a schematic map of the route. A total of 30 minutes was allocated, and participants were encouraged to use a pen and paper to make notes before using a dictaphone to record the navigation instructions necessary to enable a pedestrian to navigate the route successfully. The walkthrough group was also given a schematic to ensure that they understood the intended route and then walked the route (accompanied by the experimenter) using the dictaphone to record the navigation instructions. If any mistakes were made, the participants could either state that an error had been made, or could rewind the dictaphone and re-record the instructions.

After having completed the direction-giving task, both participant groups completed a questionnaire covering demographic details, pedestrian navigational habits and questions relating to the adoption of IT innovations. The participants were then debriefed and paid.

3 The data analysis and coding

The dictated navigation instructions generated by the 20 participants were transcribed in full, and each individual reference to a navigation information item was identified. A categorisation and coding schema was used to investigate the research questions in Section 1.3; this schema is outlined in Sections 3.1 to 3.4 below.

3.1 The information category

The chief aim of the study was to identify the type of information required for pedestrian navigation, i.e., that which could be presented by mobile navigation devices. A three-tier coding categorisation was used, incorporating five top level categories comprising the following categories:

1. distance
2. junction
3. road type
4. street name/number
5. landmarks.

This was based on a pilot trial and cross-checked against other navigation information taxonomies, such as that used by Burnett [10].

Following the approach taken in much of the literature, the definition of a landmark included buildings (e.g., post offices), street furniture (e.g., traffic lights) and built aspects of the environment (e.g., bridges), but excluded geographical features such as hills and bends in the road, and also street signs (these were coded under different categories). The junction, road type and landmark categories were then split further as shown in Table 2. (Note that there were nearly 40 landmark

Table 2 Main information categories

General category	Specific category	Example
Distance (qualitative or quantitative)	N/A	"Turn left in 100m" "Continue for some way"
Junction	Road junction Pedestrian "junction"	"Turn right at the T junction" "Go left where the path forks"
Landmark	40 sub-categories including: bank, bridge, car park, library, steps, tree	"Go past the NatWest bank"
Road type	Road/street Path (pedestrian) Pedestrianised area	"Follow the main road" "Go down the path..."
Street name/number	N/A	"Turn left down Market Place"

sub-categories; only a selection is shown). A third level of coding was used to identify each instance of a particular type of landmark (for example, one sub-category within landmarks was bridges; references to particular bridges were then coded as BR1, BR2, etc.).

3.2 The terminology used by participants

For each participant reference to a piece of navigation information, the actual wording used by the participant to refer to that information was recorded.

3.3 The use of information at, and between, key navigation decision points

Two coding taxonomies were used to identify *when* and *how* information was used. The pedestrian route was described in terms of a path-node network [17] such as that shown in Fig. 1. A *node* is a point where there are several directions that may be taken and navigational uncertainty may be high; the nodes are joined by *paths* where there is less navigational uncertainty.

In practice, a *node* was where a pedestrian would expect navigation information to be provided to enable a navigation decision to be made. Information was coded according to whether it was given at a node or a path, but it was recognised that a degree of judgment was needed for this path-node categorisation; for example, where the pedestrian was continuing past minor turnings off a major road, these were potential navigation decision points. However, these were not coded as nodes as the participants would normally walk straight past these turnings without a perceived need for any navigational information.

As well as information being needed at particular points along a route, it could also be used for different purposes in relation to any of these route points. A simple navigation model [10] was used to describe how information was used: this model categorises information as being used in a *preview*, *identify* or *confirm* capacity, and enables a direct mapping between the temporal nature of navigation cues along a route and the task-based information requirements of a pedestrian using turn-by-turn navigation instructions.

For each reference to a navigation cue (as shown in Table 2), its context of use was assessed and categorised as follows: *preview* information was that used to give the pedestrian advance warning that a navigation decision (at a node) or confidence point (along a path) is coming up: it is preparatory information. Examples would be "turn left in 100m when you see the pub". Information coded as *identify* is used to pinpoint an exact point on route, for example, "turn left at Sainsburys". *Confirm* information is used to confirm that the pedestrian has accomplished that aspect of the task successfully (e.g., has taken the correct turning). An example would be "turn left, the Lunn Poly [travel agents] is then on your right hand side".

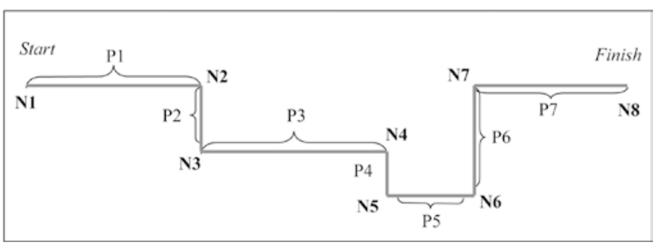

Fig. 1 A path-node based description of a pedestrian route

3.4 Information importance

All information items were coded according to whether they were being used as primary or secondary information. *Primary* information was defined as that which the pedestrian *must* receive in order for him to navigate successfully or to identify a particular point on the route. If primary information was removed from the navigation instructions, it would make it impossible to complete, or create substantial uncertainty about, the navigation task. Examples would be "turn left past *Sainsburys",* or "turn right at the *mini roundabout".* *Secondary* information was defined as information that the pedestrian does not necessarily *need* in order for him to navigate, but that which aids the navigation task. This is information that is partially redundant and whilst it may help the pedestrian at a point of navigational uncertainty, it could be removed whilst still enabling a destination to be reached. An example would be a visual or auditory instruction representing "turn left at the next set of lights, with the *pub* on the corner".

4 Results

4.1 Information categories

It was expected that a wide range of different navigation cues would be generated by the participants, given the information diversity present in a town centre environment. Figure 2 shows the total number of references to different categories of information, coded according to Table 2, and split according to whether information was identified by the walkthrough group or cognitive map group participants.

Table 3 shows the frequency of reference to the top twelve landmarks, split by the cognitive map group and walkthrough group participants. Those shown in Table 3 represent 79% of the landmark information, and 56% of all information used.

4.2 The terminology used by participants

A wide range of descriptions were used; in particular, a combination of specific names (e.g., "Ashby Cars") and generic descriptions (e.g., "car garage") were used.

Fig. 2 The total frequency of reference to general information categories by the walkthrough group and cognitive map group participants

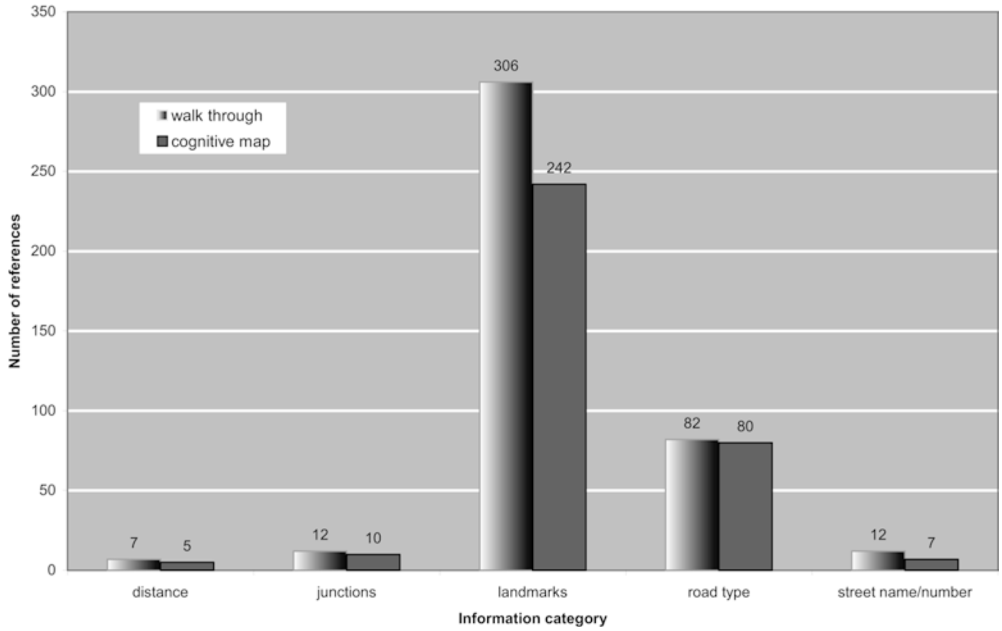

Table 3 References to the most frequent landmark categories

	Landmark category & frequency ranking	No. of different items referenced	Walkthrough: no. of references to that information category	Cog. Map: no. of references to that information category	All participants: no. of references to that information category
1.	Shops (general)	16	26	34	60
2.	Pubs	9	37	18	55
3.	Supermarkets	5	26	26	52
4.	Traffic lights	3	18	27	45
5.	Parks	1	20	19	39
6.	War memorial	1	17	17	34
7.	Pelican crossings	4	17	17	34
8.	Car parks	4	19	10	29
9.	Shopping centre	1	13	10	23
10=	Restaurants	4	13	7	20
10=	Shopping precinct	1	10	10	20
10=	Town hall	1	10	10	20

Detailed results cannot be presented here due to space limitations; however, the approximate proportions of the three most used landmarks that were referred to by specific name were: pubs: 90%, supermarkets: 70% and shops: 50%.

4.3 The use of information at, and between, key navigation decision points

It was assumed that the majority of navigation information would be given at *nodes*, i.e., main navigation decision points on the route. 68% of all references to the information categories shown in Table 2 were given at nodes; the remaining 32% were given along paths, i.e., between nodes. Figure 3 shows *how* the information is used, at all nodes and paths, in either a preview, identify or confirm capacity.

4.4 The importance/redundancy of information

It was expected that a considerable degree of redundancy would be employed within the navigation instructions generated, i.e., that some information would be vital in terms of enabling a pedestrian to navigate the routes successfully, whilst other information would be redundant to some extent. This redundant information is helpful to a pedestrian, but not necessarily required. Figure 4 shows the frequency with which information categories were used by all participants as primary (required) or secondary (redundant) information.

5 Discussion

The two main aims of this study were to (1) understand the information needed by a pedestrian to navigate

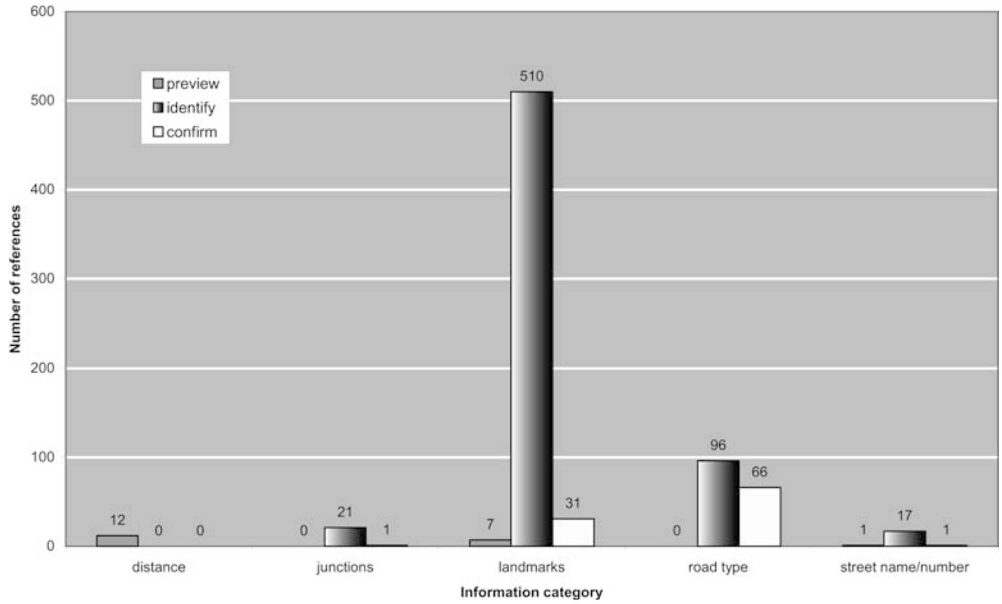

Fig. 3 The use of information for preview, identify or confirm purposes (all participants)

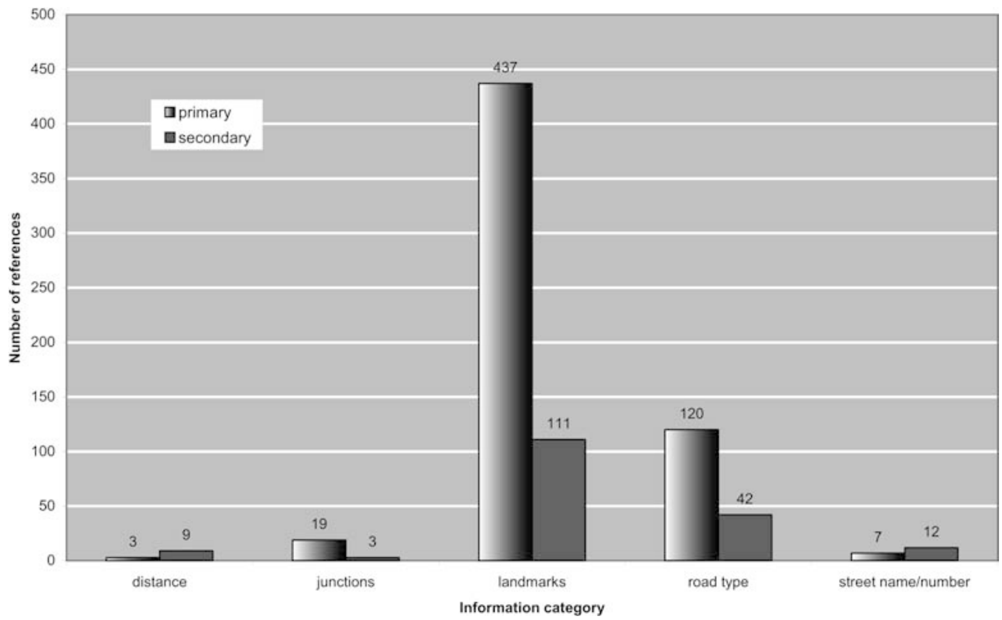

Fig. 4 The use of general information categories such as primary (required) or secondary (redundant) information (all participants)

successfully through a complex town centre environment, and (2) identify the implications for the design of mobile navigation devices.

Figure 2 shows that landmarks were by far the most frequently used category of navigation information identified by both the cognitive map group and walk-through group participants, comprising 72% of all cues identified. These results are consistent with recommendations concerning the design of pedestrian navigation systems [6], (and also the information valued by *drivers* [18]). The frequent use of landmarks is due to a number of factors—the landmarks category included a wide range of different types of information, and therefore the availability of information within this category was high. (Landmark categories included traffic lights, bridges, pedestrian lights, petrol stations, public houses, parks, restaurants, post boxes, phone boxes, plus a wide range of other buildings including shops; there were a total of 83 different landmarks referred to). In addition, landmarks are traditionally used (at least within the UK) to help provide navigation directions: navigation directions given by a passer-by would invariably incorporate instructions of the form ‘‘turn left past the supermarket’’ or ‘‘go up to the lights and turn right’’, with the choice of landmark having a crucial impact on wayfinding ability [19]. (Note that where other road layouts such as grid structures predominate, landmarks may comprise a smaller proportion of the navigation cues employed.)

Further analysis of the ‘‘landmarks’’ category (Table 3) indicates that a wide range of different landmarks were used as navigation cues with surprisingly few differences between the walkthrough group and cognitive group map participants. It can be seen that the landmarks in Table 3 have the characteristics of "good" landmarks [20], i.e., they are visually prominent and familiar objects, may have recognisable logos and are located on the pedestrian route. Where landmarks were used, they were often referred to by name rather than function, this being particularly the case for pubs, and to a lesser extent, supermarkets (there were a total of nine pubs and five supermarkets on the route). This result is not surprising as both of these categories are generally referred to by name in general conversation, e.g., "I will be in the Jolly Farmer [pub]" or "I am going to Tesco" (a supermarket)". Research into the incorporation of landmark information into *vehicle* navigation systems has shown a preference for specific (e.g., a brand name or a logo) representations of landmarks where these objects are familiar to the user [21]; it is likely that these results will translate to a pedestrian navigation context.

After landmarks, the next most frequently used navigation cues were references to roads, pathways, streets or tarmac areas, i.e., information that described the form or visual appearance of the pathway that the pedestrian was on, or was required to turn into (i.e., the "route" distinction of Hirtle and Jonides [13]). All other categories of information were little used as navigation cues. Of particular interest is that distance information and street names were used infrequently by both sets of participants. This information does have the advantages of being easily obtainable, stable over time and relatively easy to present to a user; however, it does not support basic human navigation strategies. The infrequent use of distance information underlines the general difficulty that humans have in judging distances, and particularly the difficulties of mapping actual experience, or visual representations of routes onto distance judgements. The results of this study highlight the potential danger of relying on distance information within pedestrian navigation devices.

Intuitively, you would expect that the vast majority of information contained within navigation instructions would relate to points where an explicit navigation decision is needed, i.e., that there would be a predominance of information associated with *nodes* on a route. However, the results from this study shows that this is not the case, with approximately one third of all information cues being given along *paths* (i.e., between nodes). This result highlights that a pedestrian is not simply directed from one navigation decision point to another: he also requires information between those decision points in order to maintain his trust in the information source and his confidence and orientation throughout the route (underlining the continuous dynamic nature of the navigation task [11]).

Figure 3 shows *how* different information categories were used throughout the route; it can be seen that the vast majority of information cues were landmarks being used to *identify* a point on route (either a navigational decision or where information is needed to maintain confidence). Information was also used to enable a pedestrian to *confirm* that a correct navigation decision had been made; road names were used for this purpose more frequently than landmarks. There was very little use of information to *preview* forthcoming decisions, presumably because the rate of progress of a pedestrian is such that he does not need this information, in contrast to the information needed by drivers where there is a requirement to manage vehicle speed and ensure correct lane positioning [22].

Figure 4 shows *how important* different categories of navigation information were, based on information being used as primary or secondary navigation cues, and the extent of redundancy built into the navigation instructions. Where landmarks (the largest category) were used, in only 20% of the cases were they used as secondary (i.e., at least partially redundant) information. Road type (the next largest category) was used as secondary information in about 25% of the cases. In contrast, distance and street name/number (infrequently used) were used more often as secondary information, i.e., used in addition to other information. Overall, Figure 4 shows that little redundancy was built into the navigation instructions—participants felt that effective navigation instructions could be provided that usually used only one main navigation cue (e.g., "turn left at the *bank*", or "turn left onto the *main road*").

6 Summary and design implications

This study has investigated the information requirements for a pedestrian following a route within a complex town centre environment. The detailed results themselves are only a "snapshot" of user behaviour in relation to a specific context (the specific route at a particular point in time). However, the trends in using particular information categories, and the way in which this information was used, should have an applicability to pedestrian navigation in general due to: (1) the varied and representative nature of the routes chosen, (2) the dual requirements elicitation method, (3) the diverse participant pool and (4) the generalised data coding schemas used.

In general, since there was little redundancy built into the navigation instructions identified within the study, there is a potential for navigation services to present concise, but effective instructions to pedestrians. The results of this study enable some initial design recommendations to be made regarding mobile navigation systems for pedestrians:

- Landmarks should be used as the primary means of providing directions to pedestrians. Suitable navigation cues include pubs, specific shops (plus restaurants and fast-food outlets), supermarkets, petrol stations, traffic lights and parks.
- Where a name is visible, landmarks should be referred to by that specific name, rather than general category

(e.g., a NatWest bank should be referred to as such, rather than just "a bank"). If the landmark incorporates a familiar logo, this should be used in any graphical representation of the landmark.

– The design of pedestrian navigation devices should not rely on the provision of distance or road name information to the user.
– Information is needed at key navigation decision points (i.e., nodes) to help identify the next manoeuvre, but also between these nodes (i.e., along paths) in order to promote user orientation and trust. The identification of prominent landmarks en-route will maintain user confidence and trust that (1) he is following the correct route, and (2) that the navigation aid is working correctly.
– It is useful to provide information that confirms that a correct navigation decision has been made; this information could be a suitable landmark, or a street name (although as stated above, a street name should not be used as the primary means of identifying a potential turning).

There are undoubtedly considerable challenges involved in designing effective pedestrian navigation services, particularly where these are based around the concepts of using landmarks rather than distances and street names. The most obvious implication is the need for navigable databases that contain the types of objects referred to within the "landmarks" category, shown in Table 3. These objects must be accurately located and correctly named, but should only be included within navigation instructions if they are readily visible from the pedestrian's direction of approach, and easily recognisable.

A dilemma facing the service designer is that geographic distances are relatively easily calculable (at least outdoors) using locating technologies, and street names are (1) readily available via existing map databases, and (2) relatively stable, i.e., the information quality associated with these will have a relatively slow decay rate over time. In contrast, public houses and other buildings frequently change name or even function, and there will be considerable effort required to keep this information up to date on a navigable database. Other types of information (e.g., built features, pedestrian crossings, traffic lights) present different challenges due to the diversity of this data and the current lack of standardised and centralised data sources.

It is recognised that there are considerable commercial, technological and logistical challenges in implementing new concepts for pedestrian navigation aids, either as individual services, or integrated within other location-based services. This study has shown how navigation aids could be developed that are congruent with basic human navigation strategies, and it is hoped that these results will aid the future development of effective and acceptable navigation aids for pedestrians.

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