Effects of Urban Form and Navigational Aids on Visitors’ Spatial Cognition and Wayfinding Behaviour

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Abstract

Wayfinding is a cognitive activity that is embedded in a complex social and spatial environment. People use their cognitive ability to gather spatial information from their surrounding environment while navigating and finding their way through space. Lynch (1960) argued that there is a relationship between physical perceivable urban elements and urban legibility, and that a strong legible city would help form a strong mental image of the city. In turn, a very imageable city would facilitate urban orientation and wayfinding performance. However, in addition to spatial information other external information like navigational aids and social environment could assist navigators to reach their desired destinations easier. With the ubiquity of “wayshowing” tools such as paper maps, digital maps, smart phone navigators, and local signage, pedestrians are able to locate themselves in an unfamiliar environment and find their desired destinations. Each of these tools provides specific spatial information in particular ways, with a range of limitations in their use. The way visitors to a new city wayfind in the digital era and their social and spatial interaction with their surrounding environment has been given less research attention than might be expected. In addition, physical urban elements are not the only characteristics that shape urban form. Spatial configuration of urban layout and land use are other influential factors that influence people’s route choice behaviour.

This study aims to explore: a) the effects of different wayfinding tools, such as paper maps, GPS and non-mapping on an individual’s spatial cognition; b) the effects of urban form and navigational aids on people’s wayfinding performance; c) the effects of urban form and navigational tools on navigators’ social and spatial interaction with space; and, d) how people make sense of an unfamiliar urban environment and find their ways within it while using different types of navigational aids.

38 participants who had never visited Brisbane, Australia, were recruited and placed in one of the three groups, given different wayfinding tools, and asked to find seven pre-determined tourist destinations. A wide set of qualitative and quantitative methods were used including GPS tracking, think-aloud recordings, sketch mapping, other cognitive tests and post-test interviews, combined with built environment analysis using space syntax.

The results showed clear differences in the cognitive tests across the three groups of participants who navigated using different wayfinding tools (GPS, maps, paper maps, signage only). The GPS group neither were the best nor the worst compared with the two other groups. However, this is not seemingly because they were looking more at their devices and not looking...
around, as think-aloud utterances showed no significant difference in mentions of landmarks between the groups. But passively following the suggested route shown by GPS reduced their reliance on the environmental information to wayfind. Multivariate regression models revealed that digital navigation is fundamentally altering first-time visitors’ use of the city and affecting our natural movement and urban experience. In addition, the analysis of social interaction of navigators with space revealed that GPS navigators are becoming “anti-social”.

The analysis of the think-aloud utterances by three groups of participants showed clear differences in wayfinding performance, in terms of strategies and using spatial information, across three groups of participants who navigated using different wayfinding tools.

There is a modest methodological contribution of the study is in using the think-aloud methodology along with GPS tracking and cognitive mapping, space syntax techniques, and post-test interview in combination, to observe and analyze human wayfinding behavior.

The outcomes of the thesis could be used to improve the effectiveness of the navigational aids and legibility of urban environments. Designers should consider routes that will likely be suggested by GPS navigation in how they design, manage and operate street and pathway networks. Designers will need to experiment on the best methods to discourage digital navigators from taking less desirable routes, for instance encouraging them onto street segments with greater commercial and recreational activity.
Statement of Originality

This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

The research reported upon this dissertation was conducted with ethical clearance for human research as approved by the Griffith University Human Research Ethics Committee (GU Protocol Number 900/2016) under the supervision of Associate Professor Matthew Burke, Dr Rongrong Yu.

(15/03/2019)

Sima Vaez
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Section 9.1 of the Griffith University Code for the Responsible Conduct of Research (“Criteria for Authorship”), in accordance with Section 5 of the Australian Code for the Responsible Conduct of Research, states:

To be named as an author, a researcher must have made a substantial scholarly contribution to the creative or scholarly work that constitutes the research output, and be able to take public responsibility for at least that part of the work they contributed. Attribution of authorship depends to some extent on the discipline and publisher policies, but in all cases, authorship must be based on substantial contributions in a combination of one or more of:

- conception and design of the research project
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- Offer authorship to all people, including research trainees, who meet the criteria for authorship listed above, but only those people.
- accept or decline offers of authorship promptly in writing.
- Include in the list of authors only those who have accepted authorship
- Appoint one author to be the executive author to record authorship and manage correspondence about the work with the publisher and other interested parties.
- Acknowledge all those who have contributed to the research, facilities or materials but who do not qualify as authors, such as research assistants, technical staff, and advisors on cultural or community knowledge. Obtain written consent to name individuals.
Included in this thesis are papers in Chapters 4, 5, 6 and 7 which are co-authored with other researchers. My contribution to each co-authored paper is outlined at the front of the relevant chapter. Appropriate acknowledgements of those who contributed to the research but did not qualify as authors are included in each paper.

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1. Introduction

1.1 Research Overview

The term wayfinding describes a person’s ability, both cognitive and behavioural, to travel from an origin to an out-of-sight destination, by following the paths and routes between them (Blades, 1991; Garling et al., 1984; Gluck, 1991; Golledge, 1992). Different disciplines such as social geography, architecture, urban design and planning have sought to understand how people make sense of an unfamiliar urban environment and to navigate.

Urban form and environmental cues, such as landmarks, edges and paths, are the primary information available to individuals to orient themselves within the built environment. In addition, spatial configurational of urban layout is another characteristic of urban form which has significant influence on route choice decision-making of visitors. To complete a successful wayfinding task, people use different strategies to navigate themselves, including route following, track following, screening, map reading, or just learning from other people, called social navigation. People also get assistance from navigational aids, such as local signs, maps and Global Positioning Systems (GPS) (Chang, 2015). These navigational aids provide specific spatial information in different ways, with most users using this information whilst also scanning and trying to make sense of their immediate surrounding environment.

Wayfinding includes several key tasks, such as destination decision making, route planning, moving towards out-of-sight locations, and cognitive mapping (Tenbrink & Wiener, 2006). Cognitive mapping refers to the process of perceiving and storing environmental knowledge while navigating from place to place (Lynch, 1960). People rely on their generated mental maps to recall routes and find the correct way to their destinations in a familiar urban environment (Mondschein, Blumenberg, & Taylor, 2013). Using these mental images, people build a personal urban model that helps them make sense of an unfamiliar built environment and navigate through (Appleyard, 1973, p. 97).

The layout of an urban environment is also known to influence wayfinding, and this needs to be considered in any meaningful study of the effects of navigational tools on visitor's wayfinding. Space syntax refers to quantitative analysis of spatial configuration of urban form. Research methods using space syntax have been developed and applied to similar questions showing syntactic measures of urban layout, such as integration, connectivity, visibility and choice could predict individuals’ movement patterns. The ways in which one can track real-world wayfinding have improved dramatically since the rise of ubiquitous smartphones and the
ready availability of GPS tracking apps. These have revolutionised wayfinding research in urban environments, allowing us to know where visitors are travelling, and their exact route choices.

This research seeks to understand the effects of urban form, in terms of environmental cues and spatial configuration of urban layout, and different types of navigational tools on visitors’ wayfinding behaviour and spatial cognition; using a set of methods, including think-aloud, sketch mapping, space syntax, GPS tracking and post-test interviews. Using the combination of these methods allows us to gain a deeper insight into how people make sense of an unfamiliar urban environment to wayfind, their social interaction while navigating, and how urban form in terms of spatial configuration and various environmental cues including land use could affect visitors’ wayfinding behaviour. Only a mixed-method approach, with this combination of methods, allows us to isolate the effects of navigational tools from the effects of other factors. The sketch mapping technique provides understandings of urban form characteristics that remain in long term memory and create urban mental image. Think-aloud analysis discerns what aspects of urban space draw visitors’ attention while walking along a city street. Space syntax reveals the effects of spatial configuration of urban layout on wayfinding behaviour. Only when used in combination though, will these methods effectively reveal differences between groups who are provided different navigational tools.

Three groups of participants were asked to find seven predetermined tourist destinations in the Brisbane central business district (CBD) with either paper maps (n=12), the Google Maps app (n=12), or the local signage system only (n=14). They were asked to think aloud, in English, about the wayfinding process, the buildings, streets, the signs, the maps, their feelings and whatever came to their minds. Smart voice recorder and GeoTracker apps on the given smart phones recorded their voices as well as their route. At the end of the experiment all three groups of participants were asked to draw their mental maps of their observed environment and answer some questions related to their wayfinding task. Using the think-aloud, sketch mapping and GPS tracking techniques in combination, allowed us to gain better understandings of the cognitive process and wayfinding behaviour of the three groups of navigators during and after the wayfinding task, as well as their social and spatial interaction with the environment. No other study using these methods in combination has yet been identified. Though past studies have advanced our understandings of how navigational aids, and the built environment, shape wayfinding and travel behaviour, and influence spatial knowledge acquisition, the think-aloud method allows one to explore further why we obtain such results. For instance, think-aloud
provided further insight into how landmark knowledge was generated, or, more importantly, wasn’t generated, across the three groups. In addition, the effect of urban form and navigational aids in combination on the navigators’ route choice behaviour and their interaction with the city has not yet investigated by any previous studies. Though previous studies have considered the influence of syntactic properties, land use or navigational aids on wayfinding behaviour in isolation, we are not certain that any previous study has as yet tested their joint contribution.

The research consists of five main tasks that has led to four published or submitted peer-review papers that flow from an integrated set of research methods. This is a modular Ph.D. that lends itself to a PhD-by-publications.

This study is grounded in the conceptual framework of Environment and Behaviour (E.B), which aims to understand the effects of urban form as an object on subjective spatial behaviour of people. Better understanding the role of urban form and navigational aids on visitors’ wayfinding behaviour and spatial cognition may assist urban designers and wayfinding practitioners to develop better wayfinding systems, and could also assist urban planners to create more legible urban environments.

1.2 Structure of the Thesis

This document consists of eight chapters covering the Introduction, Literature review, Research Methodology, four results chapters and a discussion. The first chapter outlines the overarching aim and research questions, expected outcomes and contribution of this study. To keep the consistency of the thesis format the result chapters are not in the form of published and in review manuscripts. There are also literature review materials contained in each results chapter in accordance with the requirements of conference and journal manuscripts. There is therefore some repetition among the result chapters, including the description of the study area, data collection process and reference lists. Aims stated in papers for publication may differ slightly from those stated in the Research Methodology, again, due to the needs of a particular publication outlet. A separate reference list for each chapter is included at the end of each chapter. The thesis was prepared in accordance with Griffith University’s policy of including research papers in a thesis. For reference, this policy is provided in Appendix A.

1.3 Research Question

To achieve the research aims mentioned above, following key question and some sub-questions need to be addressed:
1. How do different approaches to wayfinding, such as paper maps, GPS and local signage only, affect navigators’ wayfinding behaviour and spatial cognition?

2. What is the relationship between urban form and wayfinding behaviour? How does digital wayfinding influence route choice behaviour in combination with urban form?

3. How do different navigational aids, including paper maps, GPS and local signage influence navigators’ interactions with their surrounding social and spatial environments?

4. How do different approaches to wayfinding, such as paper maps, GPS and local signage, affect navigators’ wayfinding strategies in unfamiliar urban environments?

1.4 Contributions and Implications of the Study

There is a modest methodological contribution by this research that has provided an innovative application of the think-aloud methodology in combination with GPS tracking, cognitive mapping and space syntax techniques in combination, in order to observe and analyse human wayfinding behaviour. This study is the first to consider the cognitive mapping technique in combination with the think-aloud method to give a better understanding of the wayfinding behaviour and spatial knowledge generated by the three methods of wayfinding (GPS, paper map, and signage system) discussed in Chapter 4/Task 2. In addition, a combination of the use of the think-aloud technique and the post-test interview to investigate the influential urban features in wayfinding behaviour and acquired spatial knowledge has not been used before.

Secondly, Chapters 5/Task 3 and Chapter 6/Task 4 are the first studies to consider the role of navigational aids (GPS, paper maps, and signage systems) in wayfinding behaviour, in combination with the syntactical properties of an urban layout.

Thirdly, the use of the space syntax and think-aloud techniques in combination (Chapter 6) is another methodological contribution of this research, allowing a comparison of the social and spatial interaction of the three groups of participants in their surrounding environments during a wayfinding task.

Confirming others’ findings (i.e. Chang, 2015; Ishikawa et al., 2008, Bakdash et al. 2008) and also the identification of some results that are at odds with those of others using similar approaches, albeit in quite different settings are another contribution of this study. In addition, the thesis has some applied contributions in terms of being the first such examination in an Australian city, the issues identified for wayfinding in the CBD of Brisbane; and also maybe,
in terms of finding how the GPS navigators ‘locked-in’ to becoming GPS navigators throughout the task (even when they weren’t forced to).

The key applied contributions of this study could be the identification of new conceptual ideas, such as:

- How urban designers could design more memorable landmarks and paths (urban imageability).
- How urban designers and wayfinding practitioners could design more effective navigational aids.
- Urban planners and designers need to consider the routes that will likely be suggested by GPS navigation in how they design, manage and operate street and pathway networks.
- Mobile app. designers could experiment on the best methods to discourage digital navigators from taking less desirable routes and encourage them onto street segments with greater commercial and recreational activity.
2. Literature Review

This section provides a review of recent progress in research into spatial cognition and wayfinding behaviour. The aim is to provide an up-to-date understanding of how theory drawn from different fields of research may explain how people make sense of urban environments, and find their way in and through such spaces. The first step will be to explain what spatial cognition is, and how spatial features in an urban environment affect people’s spatial knowledge. Following this, the cognitive mapping process and different wayfinding methods to examine these will be explained. Then the definition of wayfinding and different wayfinding strategies found in the literature will be explained. The next step will clarify how spatial cognition could assist individual’s wayfinding behaviour. Then theory of space syntax and its role in prediction of people’s route choice and wayfinding behaviour will be explained. The role of new technologies and their implications for human navigation provides additional concerns. Numerous research gaps are identified, including a lack of studies on how visitors make sense of an urban environment, how they create mental imagery, and how they then use that imagery to navigate through that urban space. There is little research into how ubiquitous smart phone technology and global positioning systems (GPS) are complementing or disrupting these processes. In the following sections, different gaps and research questions that have been raised through the review will be identified. The research concludes with suggestions for new research methods and techniques which may help fill these gaps in knowledge, and in turn help planners assist visitors with urban navigation and wayfinding.

2.1 Spatial Cognition

The basic meaning of cognition is “the mental action or process of acquiring knowledge and understanding through experience, and the senses” (Angus, & Oxford University Press, 2010). Broadly speaking, the cognitive system can be considered to be common among humans, animals and intelligent machines. Particularly in humans, the cognitive system includes skills such as thought, perception, imagination, sense making and problem solving. The human brain and internal nervous system have the ability to process and make sense of the surrounding social and physical world (Montello, 2001, p. 14771). In cognitive studies, different pioneers use the two terms ‘cognition’ and ‘perception’ to describe a human’s ability to acquire knowledge of the physical environment surrounding them. Although the distinction between these
The term "cognition" has a much broader meaning than simply describing perception. Regarding the spatial cognition process, first, environmental information is encoded by the human mind (that is, it is perceived) and then the information is processed using different cognitive resources, stored in the long-term memory, and eventually retrieved and applied for a particular purpose, for example, wayfinding (Vandenberg, 2016, p. 17).

Cognition involves different experiences such as observing, feeling, memorizing, perceiving, deciding and any other mental actions (Gold, 1980, p. 20). Cognition is dependent on personal and cultural aspects because it is the result of mental action and processes of knowledge acquisition. As a result, different people might make different judgments of, and have different perceptions about, the same object (Rapoport, 1977, pp. 31-36).

Since the early 20th century, cognition and perception of space in the human mind were a major focus of many geographers for three reasons; first, they believe that the cognition of space or place represents the relationship between humans and the environment. Second, transport geographers expected that spatial cognition would assist them in better understanding individuals’ interests; for example, where people choose to shop depends on what spatial characteristics they prefer. Finally, an understanding of the cognition processes that assist people in their comprehension of spatial relations would be helpful in improving the design and use of wayfinding tools such as maps and other geographic information products. Maps, images, 3D models and language are indirect ways of knowledge acquisition which people may use to get information about their surrounding environments. Therefore, transport geographers may be interested in understanding the effects of different way-showing tools on acquired spatial knowledge (Montello, 2001, p. 14772). We turn now to look at a particular issue of spatial memory and cognitive mapping that is an essential component of human wayfinding.

2.2 Cognitive Maps

2.2.1 Process and development

The process of using stored spatial knowledge to form a mental map, and the use of this map in wayfinding and route selection or other spatial behaviours, is called “cognitive mapping”
(Golledge, 1987, p. 143). Tolman (1948) identified this term in his experiment which suggested that rats were able to create a mental map of their surrounding environments indicating routes and paths and spatial relationships. Since Tolman’s experiment, many other researchers have worked on the nature of the cognitive representation of the environment. Stea (1969) indicated that different points of space are arranged hierarchically in cognitive maps, with respect to relative distance and size. In addition, Stea (1969) indicated that the degree of interconnection among points in the geographic environment could be represented in cognitive maps.

Kuipers (1978) identified three principle attributes for cognitive maps: a) *maps in head*, which more or less have the properties of physical maps; b) *a network* consists of routes and nodes and almost always includes errors; and, c) *a catalogue of routes*, representing procedural knowledge that can be used to get from A to B. On the other hand, O’Keefe and Nadel (1978), believed that cognitive maps are networks of stimulus-response-stimulus connections, for example, go straight on until you see the city tower and then turn left. Evans (1980) argued that cognitive maps are the representation of relative distance, orientation, and cardinal directions of different parts in the real environment (Evans, 1980). Denis (1991) identified cognitive maps as internal representations of the metric properties in space, and topological relationships among landmarks in the environment.

Most studies in the development of cognitive maps are based on the work by Piaget and Inhelder (1967) who found that cognitive maps are developed through acting in space, not only by perceptions in space. In other words, while urban users travel from one point to another they gain and store spatial knowledge kinesthetically (Hegarty et al., 2006, p. 155). Through this exploration within the urban environment, we can gain spatial knowledge, which is distinct from perceiving objects in the urban environment as an external observer (Ishikawa, 2016; Piaget and Inhelder, 1967). People conceptualize the properties of space through three kinds of spatial relations: topological, projective and Euclidian (Piaget and Inhelder, 1967). Topological relations are simple qualitative relations between different places in the environment (e.g., open and closed). Projective relations are the spatial relations of objects that depend on a particular perspective or point of view (e.g., parallel lines) (Down and Stea, 1974, pp. 263-264). Euclidian or metric relations mean that “spatial objects are represented with precise coordinates along objects’ edges or outlines” (Blanchard and Volchenkov, 2008, p.19).
In summary, a cognitive map is the result of a set of psychological processes through which individuals will code, store, remember and decode their acquired knowledge about elements, locations, distances and directions, or the general pattern of their surrounding environment (Rapoport, 2013, p. 120). This cognitive map provides navigators with an internal tool for wayfinding (Vandenberg, 2016, p. 17).

### 2.2.2 Urban form and cognitive maps

The urban form characteristics of the built environment play an important role in cognitive mapping, and, as will be shown, certain aspects of urban form can improve ability and performance in spatial cognition.

Urban designer and planner Kevin Lynch, in his seminal study *Image of the city* (1960), showed that while people move through an urban environment they interpret spatial knowledge obtained through observation, and convert this knowledge into mental images. He argued that these mental maps consist of five urban elements: landmarks, paths, nodes, edges and districts. These urban elements play an important role in the interaction between the urban environment and urban navigators. A legible city is one that has these elements grouped into a coherent overall pattern (Lynch, 1960, p.3). He believed that such a well-planned city is more memorable and imaginable for urban users, simplifying the wayfinding process. “It is that quality in a physical object which gives it a higher probability of evoking a strong image in any given observer” (Lynch, 1960, p. 9).

Lynch (1960, p. 96) defined ‘paths’, including sidewalks and streets, as providing directional movement through urban environments for navigators. He defined ‘edges’ as certain boundaries surrounding a particular district with a continuous, certain form, such as rivers or highways (Lynch, 1960, p. 99). The junction of paths forms ‘nodes’ that tend to be more identifiable if they have sharp and closed boundaries and can be used as public spaces (1960, p. 102). Districts are large areas that have homogeneous characteristics, including physical characteristics such as colour, texture, façades of buildings, materials and patterns of pavement, that consciously can be observed in one district area (Lynch, 1960, p. 103). Landmarks are distinctive features that by their uniqueness makes them memorable in urban users’ minds. If they are observable from near and far, they play the role of reference points during navigation through an urban environment (De Jonge, 1962; Gulick, 1963; Heft, 1997; Jones, 1972; Lindberg, 1984; Lynch, 1960). In this regard, Beattie (1990, p. 113) suggested that: a “comprehensible environment [is] one which has a
discernible structure and the structure is based on a network of paths punctuated with orientating devices in the form of nodes and landmarks and discriminated into districts which are clearly defined by boundaries and edges”.

Generally, these visual elements in a city can make images in visitors’ minds, which helps individuals’ navigation behaviour and sense making of that city. In Lynch’s later work, he argued that the role of spatial structure, such as location of landmarks and arrangement of pathways in a strong hierarchical pattern, makes for a recognizable image of a city (Lynch, 1984).

Researchers have followed this approach seeking to explore how people make images of their surrounding environment, using studies of urban perception to understand different methods of mental image generation (Yadav, 1987, p. 3). To obtain a comprehensive understanding of how images of the urban environment can be generated, Appleyard (1973, p. 97) defined three coherent classifications:

1. **Operational**: in this method citizens become familiar with various city elements through using them repetitively, such as key buildings, landmarks, bus stops, signs, etc. These elements play the role of reference points in their everyday lives. People remember them and their role within urban form and build a mental image of them.

2. **Responsive**: in this method, unique and unusual buildings become more memorable to observers, more so than buildings with ordinary features. Distinct and unusual elements catch the eyes of travelers. Some buildings have memorable features that create responses beyond the mere operational.

3. **Inferential**: in this method people develop a coding system to relate and understand the concepts of urban elements as they experience them repeatedly in cities. This means that people have a unique personal urban model, which helps them understand concepts and the relationship of urban elements. When people move to a new city, the personal urban model that is created through their experiences helps them make sense of their new environment.

This process of generating mental imagery is generally accompanied with simplifications and errors.
2.2.3 Errors in cognitive maps

Cognitive maps are simplified mental images of the environment, and such simplification can result in some errors, making them different from real-world geographies in various forms, such as distance and direction (Downs and Stea, 1973; Tversky, 1981), alignment and rotation, turns and angles, and the way people ignore some streets and buildings (Tversky, 1981). Tversky (1981) argued that mental maps generated by individuals have some alignment errors because people try to remember the location of one object relative to the locations of several other objects in a particular environment. Therefore, mental maps represent the relative location of objects, which is different from the absolute location of existing objects in that environment. On the other hand, individuals’ minds tend to simplify existing locations in the real world; meaning that the misaligned figures which are perceived as a group in the real environment tend to be remembered as being horizontally or vertically aligned in mental maps, because people tend to simplify the real image of an environment in their minds. That is why in individuals’ mental maps, Europe is often represented as being precisely to the east of the lower 48 states of the USA rather than slightly to the north. A common error observed in mental maps is the error of rotation. People tend to remember the spatial location of objects relative to a frame of reference. Even when the natural axes of objects are not aligned vertically or horizontally, people’s minds tend to remember them as being upright (Tversky, 1993, p. 17). Another common error is related to remembering existing distance among spatial objects within a large environment. Real distances may seem lengthier if there are barriers, detours, turns, nodes, and clutter on the routes (Tversky, 1993, p. 17). In this regard, studies have shown that landmarks play an important role in distance misjudgement. For people, “landmarks draw buildings closer to them, but ordinary buildings do not” (Tversky, 1992, p. 134).

Previous studies have shown that increased familiarity leads to the development of more accurate cognitive maps. A higher frequency of visits to an urban environment leads to more spatial knowledge being acquired (Kalakoski and Saariluoma, 2001; Lynch, 1960; Pearce, 1977; Tolman, 1948; Wang and Schwering, 2015), and people use their cognitive maps to navigate themselves through the environment (Schwering et al., 2017).
2.2.4 Cognitive mapping techniques

There are different ways of studying mental maps, such as sketch mapping tasks (Lynch, 1960), verbal interviews (Lynch, 1960), recognition tasks (Piaget and Inhelder, 1956), making models to represent the environment (Piaget and Inhelder, 1967), pointing to unseen objects (Kozlowski and Bryant, 1977), estimations of the lengths of streets and their angles of intersection (Byrne, 1979), and estimations of Euclidean distances and angles (Golledge et al., 1987).

The sketch mapping task, as a tool, requires people to draw their mental image of the area under study. The mental images drawn can be analysed qualitatively or quantitatively. Some early studies analysed the sketch maps by calculating the frequency of physical elements appearing in humans’ sketch maps, and then synthesized them into a single citizen map (Lynch, 1960; Appleyard, 1969). From the 1980s onwards, researchers began to incorporate statistical methods into the analysis of sketch maps, including T-tests or correlations. For example, Chang (2015) counted the frequency of environmental information drawn by participants who navigated by different way-showing tools, and conducted a one-way ANOVA analysis to compare their sketch maps.Billinghurst and Weghorst (1995) suggested scoring sketch maps based on three criteria; map goodness, object classes, and relative object positioning. All sketch maps were rated by two independent raters who were familiar with the study area but who were unaware of the participants’ identities. Using statistical analysis they found a high positive correlation between subjective ratings of orientation, world knowledge and sketch-map accuracy. On the contrary, Willis et al. (2009) analysed sketch maps only focusing on their qualitative characteristics, such as orientation of the maps, or whether the maps were a ‘survey’ or a ‘route’ sketch map. However, using the sketch mapping method as a tool for examining mental maps has some limitations, because the drawing is greatly influenced by individuals’ graphical abilities. In addition, the interpretation of sketched maps is vulnerable to subjectivity (Blades, 1990). To cover such limitations, other tasks can be used in conjunction with the sketch mapping technique, such as the recognition task and the estimation of distances. The recognition method asks people to see pictures of some of the places in the area of study and indicate whether they have seen those places during their wayfinding task. This task does not require any graphical ability and can be analysed more objectively. On the other hand, the estimation of distances and angles allows researchers to reveal the navigators’ acquired configurational knowledge (Kitchin, 1993).
The other key limitation is that sketch-mapping tells a researcher what a person’s cognitive map looks like, but it doesn’t explain why they produced that result. Additional methods are required to help understand how images and other information are coded.

2.3 Wayfinding: Definition and Strategies

Wayfinding is a cognitive activity which is embedded within a complex social and spatial environment (Willis, 2009). The term wayfinding describes a person’s ability, both cognitive and behavioural, to travel from an origin to an out-of-sight destination by following the paths and routes between them (Blades, 1991; Garling et al., 1984; Gluck, 1991; Golledge, 1992). Therefore, to reach their destinations, navigators make sequences of wayfinding decisions, upon which local decisions are driven by newly obtained visual information (Passini, 1992). Wayfinding and navigation is an area of spatial behaviour in individuals’ everyday lives, so it can be understood as spatial problem solving, in which various disciplines including transport, tourism, urban and architectural design, are incorporated. But perhaps most prominent is the field of environmental psychology, which seeks to understand how people interact with their surrounding environment and make sense of it, for example, while performing a wayfinding task.

A wayfinding task can be broken into three interrelated processes: decision making (development of an action plan based on environmental information), decision execution (transformation of the action plan into an appropriate behavioural action), and information processing (spatial knowledge acquisition and cognitive mapping) (Passini, 1984, p.154). Wayfinding behaviour may be conceptualized as an interaction between navigators and their surrounding environment whilst moving from an origin to a destination, and it is a combination of cognition and motion in space (Hunter et al., 2016, p. 6). In this regard, Hillier (2003) identified wayfinding as an interaction between ‘seeing’ and ‘going’.

Vandenberg (2016, p. 17) identified the four main components of a wayfinding task, which begins with orientation and route planning, or, where am I now? After orientation and considering the nearby landmarks, the desired destination can be chosen based on different reasons, such as distance to the destination, ease of accessibility and so on. Then the navigator comes to the second component which is route selection. In any given trip navigators need to choose a route that eventually will allow them to reach the desired destination. While following the selected route, navigators need to make sure they are on the right track, which is the third component of
wayfinding, called route control. Two types of orientation mechanisms help navigators to orient themselves in the environment: piloting (Etienne, 1992) and path integration, sometimes called dead reckoning (Denny, 2012; Trumble et al., 2016). Through a piloting strategy, the navigator uses a visible landmark to determine the location of a nonvisible target (Foo et al., 2005). Path integration is the ability of navigators to orient themselves, while considering the distance and direction change from the starting point.

The last phase is recognition of destination or closure (for example, is this the hotel that I am looking for?); navigators need to make sure they have found their desired destination (Downs and Stea, 1973). In the past, landmarks had an especially important role in navigators’ spatial knowledge acquisition and wayfinding behaviour (Caduff and Timpf, 2008; De Condappa, 2016; Presson and Montello, 1988). In a wayfinding task navigators can use visible landmarks as reference points to orient themselves (Foo et al., 2005; Siegel and White, 1975); this is sometimes referred to as position-based navigation (Loomis et al., 1993). A second strategy, route-based navigation, is slightly more complex and relies on remembering the sequence of paths between landmarks, including turns, intersections, vistas and so on (Foo et al., 2005; Siegel and White, 1975). A third and more complex strategy consists of using survey knowledge, as acquired from the individual’s cognitive map of the environmental layout (Allen, 1999; Foo et al., 2005; Golledge, 1999; Siegel and White, 1975). Using survey knowledge enables navigators to have a bird’s-eye view of the urban layout and to know the location of urban elements, routes and landmarks as they relate to one another. Landmark, route and survey knowledge are the three main approaches to wayfinding which individuals can use as a preferred style of spatial information learning (Vandenberg, 2016, p. 17).

More recently, Mollerup (2013) expanded wayfinding strategies to nine main strategies, including track following (following an edge without stopping), route following (using knowledge of a route provided before or during the task to follow the correct route), educated seeking (using wayfinding knowledge gained through previous experiences), inference (following the logical pattern of numbers, names, etc.), aiming (moving toward a visible target), screening (systematic observation of an area until the destination is found), map reading (planning the best route based on route knowledge gained from a map) compassing (using cardinal direction), and social navigation (learning from others, for example, following the crowd). To complete a wayfinding task, navigators might use a combination of some or all of these nine methods (Dieleman, 2014, p.28).
2.4 Spatial Cognition and Wayfinding

The following section discusses the issue of how urban form, including the five key urban components, could facilitate the wayfinding process.

Siegel and White (1975), and Hart and Moor (1973) defined three types of spatial knowledge that people use to navigate through the urban environment: landmarks – point-like elements; routes – line-like elements; and survey knowledge, which unifies landmarks and routes with metric survey information. Landmarks play an important role in wayfinding. If they are observable from near and far, they play the role of reference points during navigation through a spatial environment (Heft, 1979; Lindberg, 1984; Wehner, 2003; Zhao and Warren, 2015). Specifically, in an unfamiliar space in which, due to lack of detailed environmental knowledge, navigators need to keep themselves oriented (Wiener & Meilinger, 2018), they are able to use landmarks to ensure they do not become lost. For example, when a woman arrives in an unfamiliar city she may decide to have dinner in a restaurant on her way from the airport to the hotel. In order to recall the location of this restaurant, she would memorize the fact that it was after the park and around the corner from a particular statue. After using this method several times to search for and find the restaurant, she will begin to use route knowledge (Dillon and Vaughan, 1997). Route knowledge refers to the spatial knowledge that is acquired by travelling from an origin to a destination, using existing paths that connect the landmarks. It is based on the knowledge acquired by travelling from A to B through paths that connect landmarks and places (Siegel et al., 1978; Thorndyke and Hayes-Roth, 1982), and consequently developing a network. In humans, this urban network will be developed in a hierarchical order using such landmarks as freeways, highways, roads, streets, lanes and eventually down to alleyways. The most often used path segment will be represented by lines in cognitive maps (Golledge, 1978b). Now, our abovementioned woman begins to make sense of the location of her hotel. She knows that the hotel is almost located on the corner and up that particular road. After visiting her chosen restaurant several times, she will begin to make sense of existing environmental features – in two or three dimensional layouts – in her way from the restaurant to the hotel. In other words, she begins using her previously observed/survey knowledge to generate a mental map of that environment (Dillon and Vaughan, 1997; Golledge, 1999). Survey knowledge is based on coordinating different routes between landmarks and the estimation of the Euclidean distance between them, while creating a cognitive map (Siegel et al., 1978; Thorndyke and Hayes-Roth, 1982). Survey knowledge gives an allocentric view, through which we locate spatial objects.
in relation to each other, independent of ourselves (Vandenberg, 2016, p. 21). To solve a wayfinding task, navigators might switch between different forms of spatial knowledge (Iglói et al., 2009).

Regarding the influence of urban form on wayfinding behaviour, Weisman (1981) identified four influential environmental variables: 1) visual access; 2) differentiation; 3) layout configuration, and; 4) signage. Visual access refers to the degree to which an observer is able to see different parts of a place from various view-points. The second factor, differentiation, is the degree to which different parts of a built environment are similar or different. Well-differentiated urban elements make wayfinding performance easier because the unique characteristics of differentiated parts of the city make them memorable and distinct in individuals’ minds. Weisman and others (Gärling, Böök, and Lindberg, 1986; O’Neill, 1991) note the particularly influential role of layout on improvement or deterioration of wayfinding behaviour. Navigation and wayfinding in areas where layouts are complicated, as found in pre-modern cities, is both more difficult and confusing.

Kuipers (2001) proposed a hypothesis that people create a mental skeleton of existing major paths and places and their relationships. He believed that, when a wayfinder wants to travel from an origin to a destination, at first he recalls the route from his location to the nearest point on the skeleton, then finds the correct path from that point to the nearest point to the destination. Paths which are used frequently will become even more popular over time, therefore popular paths become dominant in cognitive maps of urban users, and the skeleton emerges. Some cities have more obvious skeletons than others.

To help make sense of how cities compare, a science-based theory called space syntax has been developed to investigate the relationship between what is termed the syntactic properties of streets and their potential to be used more frequently. We now turn to examine space syntax methodology.

2.5 Spatial Configuration and Wayfinding Behaviour

Space syntax is a graph-based method for analysing spatial configuration on an urban design scale. It has allowed researchers to measure topological relationships between a specific node on an urban network with any other existing nodes (Penn, 2003). It has been used to analyse the urban morphology of organic cities (Karimi and Motamed, 2003) or cities with grid-like urban patterns (Haq and Berhie, 2018). The space syntax technique has enabled researchers to investigate the influence of the urban environment as an object on the subjective spatial behaviour of urban users.
Spatial Configuration

Space syntax seeks to find out the causes of people’s social behaviour through spatial configuration analysis. Configuration is an important notion of space syntax, and as defined in Hillier’s book, space is the machine, “a set of interdependent relations in which each is determined by its relation to all the others” (Hiller, 1996, p. 24). Use of the graph-based technique of space syntax would help researchers to analyse spatial spaces quantitatively. A justified graph represents the typological relationships among various spaces in a spatial system, in such a way that a specific space is placed at the bottom and all other spaces are arranged in rows above, representing the number of syntactic steps away from that specific space. Consequently, dependent on which space on the whole system is considered as the main one, there is a different graph representation of the same system (Figure 2-1).

Figure 2-1: The basic concept of the node network analysis: (a) A floor layout and its functional spaces with their connections; (b) The justified graph of space-1 shows that in order to get to all other spaces from this space at least four steps are needed; (c) The justified graph of space-5 shows that in order to get to all other spaces from this space only three steps are needed. (Rashid et al., 2014, p. 495)
Each urban space is composed of set of urban elements such as alleys, roads, streets, boulevards, parks, etc. Spatial configuration refers to the complex relationship among these urban elements. In the graph representation of an urban network, termed a justified graph, the intersection of each linear feature is considered as a node and the connections between pairs of nodes are regarded as edges (Miller and Shaw, 2001). An axial map is the basis map enabling the analysis of an urban network representing the longest distance that a person can see while moving through an urban space. The connectivity of an axial line measures the number of lines that directly intersect that given axial line (Figure 2-2).

![Figure 2-2: (a) A fictive urban system, (b) its axial map, and (c) connectivity graph. (Jiang & Claramunt, 2002, p. 2)](image)

The value of integration is the first and most important variable for calculation. The quantitative calculations are usually made by space syntax software applications, of which DepthMap and Axwoman are the most well-known ones.

-Angular segment-based analysis

As described, the basis for space syntax analysis in urban studies is the axial map. Each road and street in an urban network is represented by the longest and fewest lines of sight. In other words, an axial map represents the degree of visibility and directional change within an urban area. Any turn from one axial line to another one is called a syntactic step, and the number of syntactic steps from one specific axial line to all other existing lines measures the value of topological depth.

Integration is the main concept of space syntax methodology and refers to the mean number of turns needed to be taken to go from one specific point to all other points in the network system.
When a place in a network system is well integrated, it means that people do not need to take many turns to travel from that point to any other point in the system (Turner, 2004). Therefore, it is supposed that the integration value of streets correlates with people’s natural movement patterns. It is possible to calculate the integration value of an urban area in different radii. Global radii could measure the relation of a single urban element to any other existing element in the whole urban system. The local integration value represents the topological distance between one existing node on the system to other nodes within several steps (radius 3, for example). Several previous studies have found that people’s movement could be predicted by local integration within two steps (Hillier et al., 1993; Penn at al., 1998).

Syntactic analysis of an axial map can be analysed based on three different methods: metric distance, topological relationships, and angular changes. The basic difference among the abovementioned models of syntactic analysis is the definition of distance when calculating the shortest path between a pair of street segments (Xia, 2013, p. 17). In topological analysis, the concept of short distance refers to the minimum number of turns between a starting street and an ending one. Angular analysis refers to the least angle between street segments; and in metric analysis, a short distance means the shortest street length. According to a comparative study by Hillier and Iida (2005) angular and topological analysis is more advanced than metric analysis. The most powerful tool for measuring accessibility is angular segment-based analysis using metric radius (Hillier, Yang, and Turner, 2012, p. 73). As the basis of all syntactical examinations, in order to analyse the syntactic characteristics of an urban area based on angular segment analysis, the axial map would be imported into the Depth Map program. At first, axial lines need to be divided into segments.

The main movement indicators measured by angular segment-based analysis are called ‘through-movement’ and ‘to-movement’. Through-movement (choice) indicates the potential of a street segment to be chosen by pedestrians or vehicles as the shortest path for urban navigation. To-movement (integration) refers to the possibility for a street segment to be chosen as a desired destination for urban users (Hillier et al., 2012).

The normalized value of integration (NAIN) and choice (NACH) is measured by these formulas where XXX is the metric radius for each measure:
NAIN

value(“T1024 Node Count RXXX metric”)\(^{1.2} / (\text{value(“T1024 Total Depth RXXX metric”)})+2\)

NACH

\[ \log(\text{value(“T1024 Choice RXXX metric”)})+1)/\log(\text{value(“T1024 Total Depth RXXX metric”)})+3 \]

It is also possible to combine the integration and choice measures using this formula:

\[(\text{NC}/\text{MD})*(\log(\text{CH}+2))\]

-Theory of natural movement

The theory of natural movement is one of the basic notions which was developed in the late 1970s. According to this theory, the way that people use a public space depends on its spatial configuration (Hillier and Hanson, 1984). The term natural movement describes the potential power of the street network to automatically attract urban users’ movements (Griffiths, 2014; Hiller, 1996; Hillier, 2012). In an urban network, people’s natural movement refers to ‘going-to’ and ‘going-through’ (Seamon, 2015, p. 24). According to Hiller (1996), in spatial configuration analysis and in terms of people’s wayfinding behaviour, those urban streets with high value of integration have powerful potential to be chosen as a destination; and those with higher choice value will have powerful potential to be chosen as a desired route. In recent years, the space syntax technique has been used in many urban studies to analyse and predict the interaction between a spatial layout and people’s spatial behaviour.

-Space syntax, spatial cognition and wayfinding behaviour

A key focus of such studies has been trying to understand the influence spatial configuration has on spatial cognition and individuals’ wayfinding behaviour. Hillier (1985) made a comparison of syntactic values of spatial configuration and the number of pedestrian movements along street lines, finding a strong positive correlation between integration value and density of movement. The first study into the influence of spatial configuration of a building on wayfinding behaviour was done by Peponis et al. (1990), who investigated the relationship between the inherent intelligibility of a building to people’s wayfinding behaviour, finding that intelligibility might improve the wayfinding process. In addition, they reported that in a wayfinding process if people
become lost, they return to the more integrated spaces of the space, although those spaces are not located on the shortest path between their location and their destination. In later studies, Haq (1999a, 1999b, 2003) and Haq and Zimring (2003) found how important the role of connectivity was in choosing routes during wayfinding processes and cognitive map formation. Kim (2001) concluded that cognitive maps drawn by people living in areas with what the analysis suggests is a high value of intelligibility better represents their surrounding environment, in comparison to cognitive maps produced by residents in areas with low intelligibility value. Tzeng and Huang (2009) used space syntax to choose the best locations in which to put hospital signage to guide people through healthcare facilities. Their research confirmed the results of previous studies which found that the most segregated areas in the plan are the most difficult places for people to find their way to, therefore directional signage is needed in order for people to be able to solve their wayfinding problems in these locations. Another study by Kubat et al. (2012) reconsidered the relationship between built environment and wayfinding performance. Their findings implied that while navigating within an urban network, people prefer to choose road segments with higher values of visual connectivity and spatial accessibility.

However, in addition to spatial information other external information could assist navigators to reach their desired destinations easier, such as navigational tools.

2.6 Navigational Aids, Wayfinding, and Spatial Cognition

People need to use some external information in addition to their surrounding environmental knowledge in order to perform a successful wayfinding task. Direct experience (which does not involve physical-mapping) is probably the most common approach to gaining spatial knowledge, whether this be through walking, bicycling or driving through an environment. Signage systems help navigators to create an image of their surrounding environment. Following the local signs help navigators to find their ways towards their desired destinations (Chang, 2015, p. 352).

Maps are also common sources of spatial information, which are available in various formats, such as printed on paper or in books, digital, photographs and three-dimensional (3-D) views. Language, and vocal instructions are a further source of spatial knowledge that people use often, such as when someone is told to “go straight two blocks and the hotel is on your right” (Ishikawa. 2016, p. 118). These navigational aids provide specific spatial information in different ways, with most people using this information whilst also scanning and trying to make sense of their immediate surrounding environment.
Several studies have compared the spatial knowledge acquisition produced when using different types of navigational aids (Aslan et al., 2006; Chang, 2015; Ishikawa and Montello, 2006; Siegel and White, 1975; Ishikawa et al., 2008; Münzer et al., 2006; Willis et al., 2009). It was found that people who navigated by GPS were slower in wayfinding tasks and drew poorer cognitive maps compared with those who used paper maps or local signage only (Ishikawa et al., 2008). Chang (2015) conducted a study in Taipei and found that first-time visitors who used local signage could remember more details, including landmarks, street names and routes; paper map users performed worst in recognizing landmarks and in route knowledge. Several early studies have shown that passively following the turn-by-turn guidance provided by navigational tools will result in poor spatial cognition (Bakdash et al. 2008; Burnett and Lee 2005; Farrell et al., 2003; Gaunet et al., 2001; Parush et al., 2007; Péruch et al., 1995). In addition, neuroscientists have shown that navigation by GPS can damage cognitive function of brain as people age (Neyfakh and So, 2013).

One possible reason could be that navigators do not purposely plan and control their route choice decisions in order to remember the spatial information. In other words, they only observe and perceive the urban environment instead of exploring and conceiving it. On the other hand, the navigator’s attention, specially while navigating by using the small screen of smartphones, could be distracted from the surrounding environment by looking at the way-showing tool (Dillemuth, 2009; Gardony et al., 2013; Gartner and Hiller, 2010; Leshed et al., 2008; Willis et al., 2009).

Other similar studies have shown that maps had an influential role in experiencing a large public building more efficiently, however there was no significant difference between wayfinding efficiency accomplished by using either a paper map or a digital map (Schnitzler and Hölscher, 2015). Map users and non-map users did not differ in their general wayfinding strategy preferences while navigating in a multi-building ensemble (Hölscher, Büchner, Meilinger, and Strube, 2009). GPS users felt more lost and made more mistakes compared with paper map and signage-only users (Chang, 2015). GPS users had more tendency to use an orientation (survey) wayfinding strategy, while hand drawn map users preferred to use route strategy (Chang, 2013). People who navigated using paper maps tended to be quicker at completing wayfinding tasks than those using GPS or local-signage only users (Chang, 2015; Ishikawa et al., 2008). Table 2-1 shows different measures used in similar previous studies.
Table 2-1   Measures used in similar previous studies

<table>
<thead>
<tr>
<th>Measure</th>
<th>Previous studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total trip distance to reach destination</td>
<td>Ishikawa et al, 2008; Chang, 2015; Hölscher et al., 2009</td>
</tr>
<tr>
<td>Time taken to reach destination</td>
<td>Ishikawa et al, 2008; Chang, 2015; Hölscher et al., 2009; Schnitzler &amp; Hölscher, 2015;</td>
</tr>
<tr>
<td>Number of stops made</td>
<td>Ishikawa et al, 2008; Hölscher et al., 2009</td>
</tr>
<tr>
<td>No. of correct routes in cognitive maps</td>
<td>Ishikawa et al, 2008; Chang, 2015; Kato &amp; Takeuchi, 2003;</td>
</tr>
<tr>
<td>No. of Landmarks</td>
<td>Chang, 2015; Ahmadpour &amp; Heath, 2018</td>
</tr>
<tr>
<td>Travel speed</td>
<td>Ishikawa et al, 2008; Chang, 2015; Hölscher et al., 2009</td>
</tr>
<tr>
<td>Stop time</td>
<td>Hölscher et al., 2009</td>
</tr>
</tbody>
</table>

2.7 Conceptual Framework

Based on the literature review, it is possible to represent the relationships among the environmental information, spatial cognition and the use of navigation tools in a general conceptual framework (Figure 2-3). The figure shows the influential factors of urban form, including perceptual urban elements and syntactical properties of urban layout on wayfinding behaviour and spatial cognition. In addition, the crucial role of navigation tools on spatial cognition and people’s social and spatial behaviour needs to be taken into consideration.
2.8 Research Gaps

The literature review in this thesis has helped this emerging field of research start to make sense of spatial knowledge acquisition, and the role of different wayfinding tools. But the small number of studies undertaken, the limited set of urban environments where these studies have been conducted, and the particular limitations of the methods used by the research teams, all creates uncertainties and leaves gaps that need to be filled. Building on this literature, this study aims to explore: a) the effects of different wayfinding tools, such as paper maps, GPS and non-mapping on an individual’s spatial cognition; b) the effects of urban form and navigational aids on people’s wayfinding performance; c) the effects of urban form and navigational tools on navigators’ social and spatial interaction with space; and, d) how people make sense of an unfamiliar urban environment and find their ways within it while using different types of navigational aids. A set of qualitative and quantitative methods, including think-aloud, space syntax, cognitive mapping, interview and GPS tracking are used.

Though previous studies have considered the influence of syntactic properties, land use or navigational aids on wayfinding behaviour in isolation, we are not certain that any previous study has as yet tested their joint contribution.

A few studies have compared the acquired spatial knowledge of three groups of navigators who used GPS, paper map and no-map to wayfind in an urban environment. Ishikawa et al. (2008) conducted their research in a small residential area in Chiba, Japan. The study area in their research was limited to six predetermined routes. Later Chang (2015) conducted a similar study in Taipei, Taiwan. There is a need to confirm the findings of these researchers in terms of issues such as the influence of navigational aids on navigators’ spatial knowledge acquisition and wayfinding behaviour. There is also a need to see if these findings hold if the research is conducted in different urban environments.

The present study therefore aims to fill the gap by providing empirical data on how pedestrians use current smart phone map apps. Moreover, by comparing the effects of different navigation aids on navigators’ spatial cognition, new insights may be revealed by the observation and findings of this study.

Cities and societies change, and it may well be time for continuing to add to our knowledge, and making use of newer technologies and additional methods, to further our understandings of how
mental images of cities are created in a world replete with ubiquitous information systems technologies. Way-showing aids such as digital maps, signs, GPS tracking devices and smartphone apps are all available to help people navigate and find their way. Each of these tools provides specific spatial information to wayfinders in particular ways. One of the remaining gaps in spatial cognition and wayfinding behaviour literature is the role of what we might term navigational aids in the creation of cognitive maps in individuals’ minds. Though researchers such as Chang (2015) and Ishikawa et al. (2008) have established much of our base knowledge, we do not know quite how the mental images created through using these tools (paper maps, GPS, no-mapping) may differ from each other; whether smart phone technology and global positioning systems (GPS) are complementing or disrupting processes of spatial knowledge acquisition.

Further, no previous study has investigated the influence of different navigational aids on navigators’ social and spatial interaction with their surrounding environments, considering the syntactic properties of urban layouts. This matters as designers need to experiment on the best methods to discourage digital navigators from taking less crowded streets that could be unsafe, and encourage them onto more crowded street segments with greater safety.

To answer such questions a range of research approaches may be considered. This study has prepared a research framework using research methodologies like the think-aloud method, in conjunction with GPS tracking and smartphone recording, space syntax analysis, and post-test interviews, to observe and analyse the wayfinding behaviour of different people in different parts of a city. That is, a research program developed on a sound theoretical basis that may help overcome the limitations of previous work, allow for the conceptual as well as the perceptual issues to be considered, and help us understand what wayfinders are actually doing in today’s world. An early part of this program will be to compare cognitive maps drawn by three groups of wayfinders who used specific way-showing tools (paper maps vs. GPS and smart phone apps vs. local signage only) to find their way. This should help clarify a number of outstanding issues in helping understand human navigation and wayfinding in our more urbanized world.
3. Research Approach & Methodology

This chapter discusses key aspects of the research approach and methodology, including the research paradigm, the case study selection, and the research methods and design. The strategy for publishing the findings and the description of research ethics requirements follows at the end of this chapter.

3.1 Research Paradigm

Researchers need to be certain about the worldview assumptions upon which their research is based (Creswell & Clark, 2007). Guba and Lincoln define paradigms as one’s “basic belief system or worldview” (1994, p. 107) which influence not only the researcher’s choice of methodology but also the epistemology and the ontology of his/her research. Regarding research in social science, four paradigms are recommended; post-positivism, constructivism, critical theory and pragmatism (Creswell, 2013; Guba & Lincoln, 1994). Each of these paradigms can be led by a set of assumptions which could be ontological, axiological or epistemological. Many researchers try to understand these philosophical worldviews in the context of quantitative and qualitative methods of inquiry and analysis (Bryman, 1992; Creswell, 1994; Saunders, Lewis, & Thornhill, 2009). These research methods are associated with the research philosophies (ontology, epistemology, axiology and pragmatic) and attitudes of the researchers (Ihuah & Eaton, 2013). Identifying a suitable paradigm for this study was crucial, as it influenced the research design.

Identification of the effects of built environment characteristics, such as wayfinding and movement behaviour, on social behaviour was the main focus of this inquiry. Rorty (1999, p. xxvi) suggested a pragmatic paradigm that suits such a research focus, given it emphasises solving practical problems in the “real world”. In this paradigm, research should aim at ‘utility for us’ rather than fully mirroring the reality. In other words pragmatism is an “anti-representational view of knowledge” (Rorty, 1999, p. xxvi).

Pragmatism offers an alternative worldview to those of positivism/post-positivism and constructivism and focuses on the problem to be researched and the consequences of the research (Creswell & Clark, 2007). For this research, pragmatism allows for aspects of the other paradigms to be called on at appropriate moments.

This research followed a mixed methods approach in addressing all aspects of the study. The inquiry required that explanations were found for qualitative behaviour (wayfinding behaviour and spatial cognition) by using quantitative and qualitative methods (space syntax analysis,
think-aloud, cognitive maps and questionnaires). For the more quantitative elements of this thesis, (such as the space syntax work, to be discussed at length shortly) a relatively positivist paradigm was selected. For the more qualitative work, a constructivism paradigm was selected.

Methodologically, pragmatism provides an ideal opportunity for researchers to use mixed methods. Pragmatists have the ability to use different techniques to collect and analyze data, enabling them to consider the existing phenomenon subjectively, objectively, and in combination.

A pragmatic *ontological* position regarding the existing truth is “what works at the time”, and in this position there is no segregation between the truth which is socially constructed and “a reality completely independent of the mind” (Creswell, 2013, p. 11). From this point of view of philosophical assumption, existing truth is the result of actions and experiences that could change over time and space. The focus of this study is to understand how people make sense of an unfamiliar environment, and the existing relationship between built environment characteristics and people’s wayfinding behaviour. Such an understanding will be useful for urban planners in creating more legible urban environments.

A pragmatist believes that existing knowledge in a continuum is *epistemically* objective and subjective (Tashakkori & Teddlie, 2010). In other words, during a research process, the relationship between researcher and participants may change from subjectivity to objectivity and vice versa. In order to understand how people make sense of an unfamiliar environment and wayfind within it, we need to reassess and redefine the existing knowledge we already have in this area, and gain new information from different sources.

### 3.2 Research Approach

Chapter 2 discussed how individuals use environmental cues to navigate through space and make mental images of it. Navigational tools provide a type of external information, assisting navigators to reach their desired destinations with ease. To respond to key gaps in knowledge identified in Chapter 2, this study aims to explore: a) the effects of different wayfinding tools, such as paper maps, GPS and non-mapping on an individual’s spatial cognition; b) the effects of urban form and navigational aids on people’s wayfinding performance; c) the effects of urban form and navigational tools on navigators’ social and spatial interaction with space; and, d) how people make sense of an unfamiliar urban environment and find their ways within it while using different types of navigational aids. To address the research objectives, a set of qualitative and quantitative methods were used, including cognitive mapping, think-aloud,
space syntax, questionnaires and GPS tracking. Many previous studies have investigated navigators’ wayfinding behaviour and spatial cognition similar methods and techniques, but never in full combination. For example, Cheng (2015) investigated the influence of different navigational tools on tourists’ wayfinding behaviour and spatial cognition using the cognitive mapping method. Kubat et al. (2012) examined the effects of spatial layout configuration and land use on visitors’ wayfinding behaviour using a space syntax technique. Other studies used the think-aloud method to investigate the wayfinding strategies people use to make sense and navigate through a complex multi-story building (Passini, 1984a; Tenbrink et al., 2015). Using think-aloud, Kato and Takeuchi (2003) examined differences in wayfinding strategies between participants with a good sense of direction and those with a poor sense of direction. Using think-aloud method, Schnitzler et al. (2015) compared the wayfinding strategy choices of navigators who used different navigational aids to wayfind through a complex building. Each of these methods can be used to answer a specific research question regarding wayfinding behaviour. For example, sketch mapping technique allows us to measure the acquired spatial cognition of visitors. Think-aloud enables us to understand how people make sense of an unfamiliar urban environment to navigate through it and what aspects of an urban space, including paths, landmarks and other environmental cues, may influence their wayfinding behaviour; as well as their social interaction with their surroundings. In addition the comparison between drawn sketch maps and think-aloud utterances allows us to gain better understanding of urban legibility (imageability) factors. In addition, spatial configuration of urban layout, or syntactical properties, are other aspects of urban form that play an influential role in wayfinding behaviour. Using space syntax and GPS tracking techniques enables us to investigate the role of spatial configuration in navigators’ wayfinding behaviour.

It is believed that this thesis is the first study to use a fuller set of qualitative and quantitative methods, including cognitive mapping, think-aloud, and space syntax, all in combination to examine how urban form and navigational aids affect wayfinding behaviour and acquired spatial cognition, as well as navigator’s social interaction with their surrounding environments.

3.3 Research Design

3.3.1 Research tasks

The research was conducted through several key activities to address the associated research questions.


**Task 1: Literature review and conceptual framework**

This task commenced with a literature review of recent progress in spatial cognition and wayfinding behaviour research, most of which is presented in Chapter 2. The aim was to provide an up-to-date understanding of how theory drawn from different fields of research may explain how people perceive the urban environment and find their way in and through it. Google Scholar, TRID, Scopus and other datasets were searched using prescribed terms, identifying studies of human spatial cognition and wayfinding from 1960 until the present. In this task, a set of key relationships between urban form, navigational aids, and wayfinding behaviour were identified. Also provided are explanations of the theory of urban image and its role in wayfinding, and the theory of space syntax and its role in prediction of people’s route choice and wayfinding behaviour. An assessment of the current state of research on urban form, spatial cognition and wayfinding behaviour has determined that there are gaps in this area of study, and a dearth of investigation into how visitors make sense of an urban environment, create a mental image and then use that image to navigate through the city. The role of new technologies and its implications for human navigation provide additional concerns. It is assumed that different navigational aids represent various images of an environment. While a signage system may convey an urban image based on landmarks and individual routes, maps might provide a more birds-eye image for wayfinders (Siegel & White, 1975). There remains little research on how ubiquitous smart phone technology and GPS are complementing or disrupting those processes.

Following the literature review, work commenced on developing the conceptual framework for the study, most of which is also provided in Chapter 2. Built environments are both socially and physically constructed, and there is a permanent interaction between people and the built environment (Herbert & Thomas, 2013, p. 252). Multiple variables can affect this interaction, therefore in this study, data collection methods are combined; this approach is often called triangulation. Using the think-aloud method, participants were asked to verbalize their thoughts, and this assisted the investigation into how visitors interact with their surrounding environment. The inclusion of think-aloud also provided an understanding of what visual aspects of the environment might affect the spatial cognition and wayfinding performance of visitors. Space syntax and regression analysis enabled the researcher to investigate the relationship between urban form and people’s wayfinding behaviour. Cognitive mapping techniques allowed the researcher to determine the spatial knowledge people had of their surrounding environment. The conceptual framework of the literature review shown in Figure
2-3 pointed out the effects of the physical aspects of the environment, including perceptual urban elements and syntactical properties, and the effects of navigational tools on people’s spatial cognition and social and spatial (wayfinding) behaviour.

**Participants and study area for Tasks 2, 3, 4 & 5**

Tasks 2, 3, 4 and 5 all use an identical sample of participants, who undertook a wayfinding task in the same study area. For convenience, these issues are described first, prior to discussion of each individual task. Thirty-eight students from Griffith University’s Gold Coast campus, 15 men and 23 women, were recruited through sending emails (Appendix B) and hanging posters (Appendix C) around Gold Coast campus (the posters did not allow us to establish a response rate). The respondents’ ages ranged from 18 to 56, with a mean of 26.8 years (Appendix D). All the participants were unfamiliar with the area of study and came by train from the Gold Coast to Roma Street Station in Brisbane. The list of destinations that they were asked to find were given them on the same day before starting their journey. The travel costs from the Gold Coast to Brisbane were reimbursed; in addition they received $50 incentive payment. Participants were briefed on the purpose of the study and were given the Informed Consent Form (Appendix E) for their agreement and signature. They were then given written instructions on how the study should be conducted (Appendix F).

Brisbane’s CBD and South Bank, the most popular sightseeing areas in the city, were chosen as the study area (Figure 3-1). To obtain the required data for this study, students were asked to find seven destinations in the study area. The predetermined destinations were as follows: Brisbane City Hall, Queen Street Mall, The Cathedral of St Stephen, Cultural Centre Station, South Bank Beach, South Bank Railway Station, and the COWCH Café Bar at South Bank. The data collection process was completed from June to October 2017.
Partly taking into consideration their own preferences (an element of self-selection) the participants were assigned to one of three groups: a group using the Google Maps application \((n=12)\), a group using a conventional 2D paper map for the CBD \((n=12)\) and a group with no aids other than the local signage that is already in place in the built environment \((n=14)\). The starting point was Roma Street Station and the final meeting point was at a designated café in Southbank where debriefing occurred (Figure 3.1).

A Samsung Galaxy J5 mobile phone equipped with 3G service and the Google Maps App was given to participants in the GPS-based navigation group. The map of the surrounding area was shown on a screen, sized 14 cm x7cm, and the location of the user on the screen was dynamically updated as users moved in the area. The participants were asked not to use the voice navigation option.

Participants in the paper map group were given an A4-size tourist map of Brisbane, provided by tourist information centres in the city. There was no suggested route or other annotation on the map and they had to find the destinations and plan their preferred routes by themselves.

Participants in the local signage only group were provided with an A4 size conceptual non-representational map, showing only vague locations of each destination to help them set off in the correct direction. All participants were allowed to ask others only if they were unable to navigate via the built environment without assistance. Participants were asked to think aloud.
and verbalize their thoughts, in English, about the wayfinding process, the buildings, streets, the signs, the maps, their feelings and whatever came to their minds. The route tracker application (Geotracker) installed on the same smartphone recorded the length of time for all participants, as well as the route they travelled.

**Task 2: Investigating how different methods of wayfinding affect people’s spatial cognition and wayfinding behaviour**

The main aim of this task was to examine differences in spatial knowledge acquisition and wayfinding behaviour between the three groups of participants who used different navigational aids: a group with a paper map, a group with the Google Maps app, and a group relying on local signage only (see Section 3.2.1). A sub-set of the full set of research methods was used to address the task, including think-aloud, cognitive mapping, and post-test questionnaire methods.

The think-aloud method (Ericsson & Simon, 1980) asks participants to vocalize their decision-making processes. A voice recorder application on the smart phones recorded their voices and all recordings were transcribed later. It provided rich verbal data about reasoning during wayfinding, and the strategies being employed by the navigators. The method is well-used in wayfinding research (see Hölscher et al., 2009; Hölscher et al., 2006; Kato & Takeuchi, 2003; Passini, 1984; Schnitzler & Hölscher, 2015), but not previously been used for to explore the objectives of this study, nor at this urban scale.

Use of the cognitive mapping technique enabled the researcher to determine people’s spatial knowledge of their surrounding environment (see Section 2.2.4). In this task we used a sketch mapping technique in conjunction with recognition and estimation of distance methods. Before beginning the experiment, participants were informed about the post-test questionnaire and that they would be sketching their cognitive maps. After the wayfinding task, they were given an A4 paper and a pencil to draw their mental maps of the study area (Appendix G). All participants tried to draw and write as much information as they could remember, such as streets, buildings, landmarks, parks, transport stations, etc., without using a paper/digital map (Appendix H).

Through another landmark recognition test, photos of five buildings and landmarks in the study area were shown to participants and they were asked if they could recognise them (Appendix I).
In the distance estimation task, participants were given a pair of landmarks on the list of those they had to find, and they were asked to score the Euclidean distance between each pair from 0 to 9; where 0 meant next to each other (no distance) and 9 meant the longest distance. As a unit of measurement, the participants were given the distance between South Bank Station and COWCH, as equal to 1 (Appendix J).

In the Brisbane CBD, streets facing north-east have female names, each street named after a past or present member of the British royal family. Going in the opposite direction, the street names are of male members of the royal family, making navigation easier. So to find out how visitors learned Brisbane’s street names, participants were given a plain map of the study area and were asked to write down the street names they remembered (Appendix K).

Finally, to gain more insight into how visitors developed a mental image of space and the role of navigational aids in that process, participants were asked to write their answers to the following questions:

- Why did you remember and draw certain streets on the sketch map (i.e., what were the features that made them memorable?)
- Why did you remember and draw certain landmarks on the sketch map (i.e., what were the features that made them memorable?)
- How did your way-showing tool (digital map, paper map, signage only) influence the cognitive map you drew?

All think-aloud protocols were transcribed (Appendix L), and analysed using NVIVO 11 Pro software. Participants’ reasons for choosing a street segment or any side of the street during the navigation were extracted from the think-aloud protocols, as were the names of landmarks. Then, using SPSS software, the Kruskal-Wallis H test was conducted to statistically compare the route choice preferences of the three groups of participants based on the extracted data from NVIVO. Further information regarding the analysis and results is discussed in Chapter 4.

The analysis of the sketch mapping task was adopted from the methods of Lynch (1960), landmark recognition test (Piaget and Inhelder, 1956), and the map goodness method (Billinghurst and Weghorst, 1995). The frequency of landmarks remembered by participants’ was calculated, and by conducting a one-way ANOVA test, their acquired landmark knowledge was compared. Then, in order to analyse the acquired route knowledge of participants, all the sketch maps were rated by two independent raters who were familiar with the study area but were unaware of the participants’ identities. The ratings were based on three criteria: map
goodness, route accuracy, and relative object positioning. To rate the map goodness of sketch maps, raters were asked to score the maps using this question “how good the drawn routes are to help you navigate toward the destinations?” (Beime, 2007; Billinghurst & Weghorst, 1995; Lukas et al., 2014). For all ratings, a Likert scale from one to seven was used, where 1 represented “completely bad”, 7 represented “completely good” and 4 represented “neither bad nor good”. Route accuracy refers to any added routes in terms of “correct relations of the routes drawn in the sketch maps, turns and directions” (Lukas et al., 2014, p. 134). Relative object positioning was the last criteria defined according to the number of different objects included as landmarks added on the drawn routes (Lukas et al., 2014; Parente, 2016). Using the Kendall’s tao test, good agreement for rating all the three criteria was achieved. Then the Kruskal-Wallis H test was used to compare the acquired route knowledge between the three groups of participants. Further information can be found in Chapter 4.

Task 3: Investigating the effects of urban form and navigational aids on wayfinding behaviour

To understand the influence of urban form, or the syntactical characteristics of the urban network and land use, on route choice decision-making processes, the morphological and syntactic characteristics of the centre of Brisbane were analysed using space syntax methodology and Depthmap software.

The syntactical properties of the study area were obtained by first creating an axial map using AutoCAD software and then analysing it using Depthmap, in terms of choice value (through-movement) and integration value (to-movement). The frequency of use of each road segment by each participant group was calculated. As some street segments were at locations participants were told to visit, these segments were only counted if participants had chosen to pass them en route to another destination (through-movement). If they used a street segment twice due to wrong route selection and backtracking, it was counted only once.

Land use data was obtained from Google Maps and its Street View function where necessary. Parcel-based data was categorized into commercial (shopping malls, retail, cafes, bars, restaurants, public car parks) recreational (museums, amusement and gathering spaces, parks, art centres, libraries) and ‘river’, which attracts walking, cycling and more static activities in central Brisbane. In order to estimate the proportion of different land uses, including buildings, space or water, along each street segment, the frontage percent for each land use was calculated.
All participants were provided with devices that captured their route choice behaviour via GPS tracking. A regression analysis enabled us to estimate the relationships among variables like land use, syntactical measurements and people’s route choice behaviour. Bivariate and multivariate regression models were used to reveal whether the urban form, in terms of the spatial configuration of the urban layout and land use, shapes route choice behaviour. Further information about the analysis and results can be found in Chapter 5.

**Task 4: Investigating the effects of urban form and navigational aids on navigators’ social and spatial interactions with space**

This task was an attempt to understand how much influence different navigational aids exert in shaping navigators’ social and spatial interactions with their surrounding environments, using space syntax and think-aloud techniques. The think-aloud recordings were used in combination with some of the urban form variables.

Bivariate regressions between the configurational variables (to/through movement potential of street segments) and the frequency of segment use (as described in Task 3) allowed an estimation of the relationships among syntactical measurements and route choice behaviour of the three groups of participants (spatial interaction).

All think-aloud protocols were analysed using NVIVO 11 Pro software. To investigate the interaction between participants and their surrounding social environments in relation to wayfinding behaviour, the verbal utterance of each participant was analysed. Three types of situations related to social interaction were found, based on the literature and on participants’ think-aloud utterances: 1) *asking for assistance*, e.g., “I need to ask someone”. 2) *Following others*, e.g., “I assume I should follow people to where the mall is”. 3) *Avoiding the crowd*, e.g., “I think I will go to a less crowded place because I have to look at my GPS while I am walking”.

Any utterances related to asking others, including asking for correct directions or asking others to make sure they had found the right destination, were counted. Any comments related to following others, including choosing a street or a particular side of the street, were counted.

Then, using SPSS software, the Kruskal-Wallis H test was conducted to statistically compare the social interaction of the three groups of participants based on the extracted data from NVIVO. Further information regarding the analysis and results can be found in Chapter 6.
**Task 5: Investigating the effects of using different navigational aids on pedestrians’ wayfinding strategy**

During the wayfinding task, all participants were asked to think aloud. This included describing freely what was going through their minds at any time, and they were supposed to indicate what information in their surrounding environment would help them make their decisions. After transcription, the participants’ statements were segmented; with one segment of utterance defined as the continuous statement which occurs between two pauses (Kato & Takeuchi, 2003). Two rounds of coding were then conducted by a single researcher with a time interval of two weeks (following the approach of Yu & Gero, 2015). All the task-related statements were coded based on the literature and on participants’ utterances, and were classified into four main categories regarding the components of wayfinding behaviour, including decision making, wayfinding strategy, route control and closure. Each category consisted of several subcategories. All the statements were then classified into eight categories found in the descriptive statements participants made during their navigation. Krippendorff’s α (alpha) statistics suggested that the two rounds of coding had good agreement, so then a statistical analysis (Kruskal-Wallis H and Mann-Whitney tests) was conducted to compare the differences between the three groups of participants in terms of wayfinding strategies and other related factors. More information on these methods can be found in Chapter 7.

**3.4 Research Methodology**

A summary of the key tasks, the research questions being addressed, the methods and related result chapters are presented in Table 3-1.
**Table 3-1** Research questions, research activities and associated publications

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Research Tasks/Activities</th>
<th>Methods</th>
<th>Chapter/Publication</th>
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</thead>
</table>
| RQ1: How do different approaches to wayfinding, such as paper maps, GPS and local signage only, affect visitors’ spatial cognition? | **Task 2:** Investigating how urban form and different methods of wayfinding affect people’s spatial cognition. -Three groups of participants were asked to draw their mental images of the observed environments. -Produced mental images were compared. -The results of think aloud process of three groups of participants were compared. | • GPS tracking  
• Think aloud  
• Post-test interview | **Chapter 4** Comparing the Effects of Different Navigational Aids on Acquired Spatial Knowledge Submitted to *Environment and Behavior* for journal publication |
| Sub-questions:  
-How do different approaches to wayfinding, such as paper maps, GPS and local signage only, affect visitors’ wayfinding performance?  
-How do different approaches to wayfinding, such as paper maps, GPS and local signage only, affect the use of environmental knowledge by navigators?  
-How do urban elements affect visitors’ route choice behaviour?  
-How do urban elements affect visitors’ spatial memory? |                                                                                                               |                             |                                                                                   |
| RQ2: How do urban form and different approaches to wayfinding, such as paper maps, GPS and local signage only, affect visitors’ wayfinding behaviour? | **Task 3:** Investigating the effects of urban form and navigational aids on wayfinding behaviour. -Urban pattern of the study area was analysed by space syntax technique. -Participants’ route choice behaviour was captured by GPS tracking. -The relationship between urban form and wayfinding behaviour was investigated using statistical analysis. | • GPS tracking  
• Space syntax | **Chapter 5** Effects of Urban Form and Navigational Aids on Wayfinding Behaviour Submitted to *Urban Design International* for journal publication |
| RQ3: How do different approaches to wayfinding, such as paper maps, GPS and local signage only, affect visitors’ social and spatial interaction with space? | **Task 4:** Investigating the effects of on visitors’ social and spatial interaction. -Urban pattern of the study area wasanalysed by space syntax technique. | • GPS tracking  
• Think aloud  
• Space syntax | **Chapter 6** Effects of Urban Form and Navigational Aids on Navigators’ Social and Spatial Interaction with Space |
| Sub-question:                                                                 |                                                                                                               |                             |                                                                                   |
| How do urban form (syntactical properties) and navigational aids (GPS, paper map and local signage only) affect navigators’ wayfinding behaviour? | analysed by space syntax technique - Participants route choice behaviour was captured by GPS tracking - The results of think aloud process of three groups of participants were compared | Submitted to *Travel Behaviour and Society* for journal publication |

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<tr>
<th>Research Questions</th>
<th>Research Tasks/Activities</th>
<th>Methods</th>
<th>Chapter/Publication</th>
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<tr>
<td>RQ4: How do navigators who use different methods of wayfinding, such as paper maps, GPS and local signage only, make sense of an unfamiliar urban environment to navigate? Sub-question: - How do navigational aids (GPS, paper map and local signage) affect navigators’ wayfinding performance?</td>
<td>Task 5: Investigating how visitors make sense of an unfamiliar urban environment while using different navigational aids - Participants route choice behaviour was captured by GPS tracking - The results of think aloud process of three groups of participants were compared</td>
<td>• GPS tracking • Think aloud</td>
<td><strong>Chapter 7</strong> Pedestrian Wayfinding Strategies and Navigational Aids in an Unfamiliar Urban Environment Submitted to <em>Environment and Behavior</em> for journal publication</td>
</tr>
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</table>

3.5 Research Reliability

In term of the overall set of methods we laid out a very consistent approach to data collection towards analysis and interpretation. In that sense we believe this has reasonable internal reliability and in that any independent researcher if try to analyse the same data would come to similar conclusion.

The study has performed strong reproducibility that is by having set up quite strong protocols for how various elements of the work conducted and any new independent research tries to replicate the study using the same approach and methods will produce similar results and conclusions (external reliability).

There is a little bit of triangulations in my method, the set of methods in this research are not trying to score the same measure. So there is not that kind of overt triangulation. But there is some reflection that allows us to measure different but related aspects that we assume there is
some level of cross-confirmation. That gives us some confidence that the result are due to the different way-showing tools provided.

The sample was useful and convenient but cannot reflect the general population or all tourists visiting Brisbane (we cannot generalise the outcome). So there are some issues with external validity.

3.6 Ethics
The collection of the data required for this research complies with the National Statement for Ethical Conduct in Research Involving Humans (National Statement on Ethical Conduct in Human Research 2007) and Griffith University Ethical regulations as laid out in the Griffith University Code for the Responsible Conduct of Research (2007). As think-aloud and questionnaire methods were used in this research, ethical approval for the research was submitted and approved by the Human Research Ethics Committee (HREC) of Griffith University under protocol number 2016/900. All participants in the study were informed about research aims and data usage. All participants were required to sign informed conse
4. Comparing the Effects of Different Navigational Aids on Acquired Spatial Knowledge

The work presented here in Chapter 4 has been submitted to the journal *Environment and Behavior* as:

- Vaez, S., Burke, M., and Yu, R., “Differences in acquired spatial knowledge from different navigational aids”
- First Submission on 06/03/2019

This chapter summarises the results of Task 2. The main aim of this study is to examine differences in spatial knowledge acquisition between three groups of participants who used different navigational aids: a group with a paper map, a group with the *Google Maps* app, and a group relying on local signage only. A set of methods were used to address the objectives of this study, including think-aloud, cognitive mapping, GPS tracking and post-test interview. Similar studies have compared the effects of navigational aids on spatial cognition using cognitive mapping technique (Chang, 2015; Ishikawa et al., 2008). In another study, Schnitzler and Hölscher (2015) used think-aloud method to examine the effects of different navigational aids on individuals’ cognitive process (orientation strategy) while navigating in a complex building. Using the think-aloud method in combination with cognitive mapping and post-test interview techniques allowed us to gain a better comparison between groups in terms of their spatial knowledge acquisition process, during and after the wayfinding task. In addition, the GPS tracking method provided more details about the wayfinding behaviour of the three groups in terms of route choice behaviour, travelled distance, travel duration, and walking speed.

The overall outcome showed that those who used paper maps performed best in route accuracy and street naming tests. Participants who had no navigational aids other than exiting signage systems were more successful in landmark recognition than map users, while, there was no significant difference between groups in terms of the number of perceived landmarks mentioned in their utterances. As suggested by the literature (Bakdash et al. 2008; Burnett and Lee 2005; Farrell et al., 2003; Gaunet et al., 2001; Parush et al., 2007), passively following the navigational tools will result in poor spatial cognition, and we have confirmed this result through a different method (think-aloud).
Research questions addressed in this paper and contributions

Primary Question:

RQ1: How do different approaches to wayfinding, such as paper maps, GPS and local signage only, affect navigators’ wayfinding behaviour and spatial cognition?

Sub-questions:

- How do different approaches to wayfinding, such as paper maps, GPS and local signage only, affect navigators’ wayfinding performance?
- How do different approaches to wayfinding, such as paper maps, GPS and local signage only, affect the use of environmental knowledge by navigators?
- How do urban elements affect navigators’ route choice behaviour?
- How do urban elements affect navigators’ spatial memory?

Summary of contributions:

1. The methodological contributions of this study:

- The study is the first to consider the cognitive mapping technique in combination with the think-aloud, GPS tracking and interview methods to give a better understanding of the wayfinding behaviour and spatial knowledge generated by three methods of wayfinding (GPS, paper map, and signage system only).

2. Practical and applied contributions of the study:

- The outcomes can be used to improve the effectiveness of the navigational aids and legibility and walkability of urban environments.
- GPS navigators in this particular urban environment were more efficient than those relying solely on local signage, but GPS offered fewer advantages over traditional paper maps (confirming results found in the few similar studies conducted thus far).
- The GPS group used the environmental information in their surroundings significantly less than the two other groups.
- The paper map group were the most likely to remember the name of the streets they travelled; a finding inconsistent with Chang’s (2015) results.
- The study produce new understandings of why landmarks and paths were memorable
- The study produced new understandings of the role of different wayfinding tools in spatial knowledge acquisition

This chapter is an exact copy of the paper referred to above.
4.1 Statement of contribution to the co-authored published paper

This chapter includes a co-authored paper that summarises the results of Task 2. The bibliographic details of the co-authored paper, including all authors, are:

- Vaez, S., Burke, M., and Yu, R., Comparing the Effects of Different Navigational Aids on Acquired Spatial Knowledge

The authors listed below have certified that:

1. They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
2. They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
3. There are no other authors of the publication according to these criteria;
4. They agree to the use of the publication in the student’s thesis and its publication on the Griffith University database consistent with any limitations set by publisher requirements.

<table>
<thead>
<tr>
<th>Contributors</th>
<th>Statement of contribution</th>
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<tbody>
<tr>
<td>Sima Vaez</td>
<td>• Designed the data collection process, including the site selection, participant recruitment, and questionnaires.</td>
</tr>
<tr>
<td></td>
<td>• Attended in the study area to conduct the wayfinding task and managed and trained the participants</td>
</tr>
<tr>
<td></td>
<td>• Complied, cleaned and analysed the data</td>
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<tr>
<td></td>
<td>• Conceived, planned and wrote the first draft of manuscripts</td>
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<td></td>
<td>• Managed the academic editorial process for the manuscript</td>
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<tr>
<td></td>
<td>• Submitted and revised the manuscript at the suggestion of the conference reviewers.</td>
</tr>
<tr>
<td></td>
<td>• Prepared presentation slides and presented the paper at the conference.</td>
</tr>
<tr>
<td></td>
<td>• Managed journal submission as corresponding author.</td>
</tr>
<tr>
<td></td>
<td>• Responsible for revisions made at the suggestion of the journal reviewers and resubmitting the paper.</td>
</tr>
</tbody>
</table>
| Matthew Burke | • Provided assistance in the theoretical framing of the research.  
|              | • Provided suggestions in response to journal reviewers.  
|              | • Provided editing revisions in the initial and the reviewed manuscript.  |
| Rongrong Yu | • Provided assistance in the theoretical framing of the research.  
|              | • Provided suggestions in response to journal reviewers.  
|              | • Provided editing revisions in the initial and the reviewed manuscript.  
|              | • Provided the methodological advice as an expert in the think-aloud method.  |

(Signed) _________________________________ (Date) _____15/03/2019_________  

Student and Corresponding Author: Sima Vaez  

Supervisor Confirmation: I have obtained an email or other correspondence from all co-authors confirming their certifying authorship.  

(Signed) _________________________________ (Date) ___________  

Principal Supervisor: A/Prof Matthew Burke
Comparing the Effects of Different Navigational Aids on Acquired Spatial Knowledge

Abstract
Navigators often need to use navigational aids, in addition to their surrounding environmental knowledge, in order to successfully wayfind. Few studies have as yet examined the effects of different navigational aids on acquired spatial knowledge. To explore this, the aim of this study was to examine differences between three groups of participants who used: i) a paper map only; ii) smartphones with the Google Maps app; and, iii) no navigational aids (local signage only). Research methods included use of think-aloud, sketch mapping, global-positioning system (GPS) tracking and post-test interviews and tests. 38 participants who had never visited central Brisbane, Australia, were recruited and placed into one of the three groups and asked to find seven pre-determined tourist destinations. Participants’ reasons for choosing a particular street segment and remembering key spatial information was then investigated in-depth. Post-task tests showed that participants in the group without personal navigational aids were more successful in landmark recognition than map users. Those who used paper maps performed best in route accuracy and street naming tests. However, across all the spatial recognition tests, the GPS group were systematically neither the best, nor the worst, in terms of acquired spatial knowledge. The findings have potential to assist navigational mapping producers to design more effective way-showing tools.
Keywords: Wayfinding, Spatial Cognition, Navigational Aids, Urban Legibility, Think-aloud

1. Introduction
Wayfinding is a spatial-solving behaviour that people experience in their daily lives (Arthur & Passini, 1992, p.25). Lynch (1960, p6) argued that observation of environmental cues, while navigating in an urban environment, creates a mental image in an individual’s mind, which he called an “urban image”. During wayfinding activities, navigators use this stored spatial information to assist their decision-making process (Li, 2007; Wiener & Meilinger, 2018). However, in an unfamiliar urban environment, where people have no stored spatial information of their surrounding environment, they have to rely on navigational aids, and other clues in the built environment or asking others for help (Chang, 2015). Digital navigational aids have made the wayfinding process much easier for today’s urban navigators. GPS on smartphones and geographic information systems (GIS) have been combined to provide positional information in space as well as audible and textual directions that people can navigate with, turn-by-turn.
Several previous studies have compared the use of different navigational tools with acquired spatial knowledge (Aslan et al., 2006; Chang, 2015; Hou, 2014; Ishikawa et al., 2008; Münzer et al., 2006; Willis et al., 2009). For example, Ishikawa et al. (2008) examined the effectiveness of a Global Positioning System (GPS)-based mobile navigation system in comparison to paper maps and direct experience of routes, by focusing on the user's wayfinding behaviour and acquired spatial knowledge. The results showed that mobile map users drew less accurate sketch maps in terms of topological accuracy than did the direct-experience navigators.

Later Chang (2015) conducted a similar study comparing wayfinding efficiency and behaviours of international tourists when using a mobile navigation aid, as compared with a paper map and local directional signs. The study found that sketch maps drawn by participants who used the local signs for wayfinding provided more detailed information/landmarks, and their drawn walking routes were more accurate than those of the two other groups. But these studies had some limitations in explaining why. Confirming these results in other settings and better understanding these psycho-cognitive effects is necessary to move the field forward. There are also research needs to explore how urban elements, such as certain streets and buildings, evoke a strong image in visitors’ minds, and what other features of the urban environment contribute to legibility/imageability.

The main methodological advance of this study is to use the think-aloud (Ericsson & Simon, 1980) GPS tracking, and sketch mapping (Lynch, 1960), in combination, to obtain deeper insights into navigators’ cognitive processes. The think-aloud method, described at length later, asks participants to vocalise their navigational decision-making. Three groups of participants were asked to find seven predetermined tourist destinations in Brisbane city with either paper maps (n=12), the Google Maps navigation app (n=12) or use local signage only (n=14). At the end of this paper we will compare our results with those of the Chang (2015) and Ishikawa et al. (2008) findings.

Better understanding the role of navigational aids and how real-world navigators acquire spatial knowledge with them may assist urban designers and wayfinding practitioners to develop better wayfinding signage approaches and systems, and could also assist app-developers produce improved navigational aids, particularly for GPS-based devices.
2. Cognitive Maps

2.1 Acquisition of environmental knowledge

The process of using stored environmental information in any spatial behaviour, such as in route selection and navigation, is called ‘cognitive mapping’ (Golledge, 1987, p. 143). It is not possible to perceive a complex, large-scale 3D environment from a single vantage point; navigators need to repeatedly move from one “nested” subspace to another (Wiener & Meilinger, 2018). As urban users travel from one point to another they gain and store spatial knowledge kinesthetically (Hegarty et al., 2006, p. 155). Through their exploration of the urban environment, they gain spatial knowledge that is distinct to perceiving the urban elements in which we only observe an object as an external observer (Ishikawa, 2016, p. 115).

Lynch (1960) suggested that one’s mental image of an urban environment can be conceived as consisting of five key elements: landmarks, paths, nodes, edges and districts. A legible city is one that has these elements grouped into a somewhat coherent overall pattern. Lynch (1960, p. 96) defined ‘paths’ as providing directional movement through urban environments for navigators, including sidewalks and streets. ‘Edges’ are certain boundaries surrounding a particular district, such as rivers or highways (ibid, p. 99). The junction of paths will form ‘nodes’ that tend to be more identifiable if they have a sharp and closed boundary and can be used as a public space (ibid, p. 102). ‘Districts’ are large areas that have homogeneous characteristics, including physical characteristics such as colour, texture, façades of buildings, materials and pavement (ibid, p. 103). Siegel and White (1975), and Hart and Moor (1973) drew on these ideas and defined three types of spatial knowledge that humans use to create cognitive maps: landmark knowledge – using point-like elements of the environment; route knowledge – using line-like elements; and survey knowledge, which encodes the metric information about the layout of space (Golledge, 1997, p.166). To solve a wayfinding task, navigators may switch between these different forms of spatial knowledge (Iglói et al., 2009).

- Landmarks are distinctive features that by their uniqueness are made memorable in one’s mind (Couclelis et al., 1987, p. 102). If they are observable from near and far, they play the role of reference points during navigation to help navigators avoid getting lost (Hubbard & Ruppel, 1999, p. 242)
- Route knowledge is acquired when one travels from an origin to a destination, using paths that connect points and landmarks together. The route itself, as a linear element,
is remembered, though for many this can take multiple trips to be successfully memorised.

- Survey knowledge is the most complex. It’s based on coordinating different routes between landmarks and estimating the Euclidean distance between them, all while creating a cognitive map (Siegel et al., 1978; Thorndyke & Hayes-Roth, 1982). Survey knowledge provides an allocentric view through in that we locate spatial objects in relation to each other, independent of ourselves (Vandenberg, 2016, p. 21).

One’s cognitive map, which is a simplified mental image of the environment, will often contain errors, being different from real-world geographies in terms of, say, distance or direction, alignment or rotation, turns and angles, or through omission of key streets or buildings (Downs & Stea, 1973; Tversky, 1981). Increased familiarity leads to one developing a more accurate cognitive map and the higher frequency of visits to an urban environment leads to more spatial knowledge being acquired (Kalakoski & Saariluoma, 2001; Lynch, 1960; Tolman, 1948; Wang & Schwering, 2015). People then use their cognitive maps to orient themselves and navigate an environment (Schwering et al., 2017). However, navigators increasingly rely on navigational aids, including smartphone apps, as secondary information sources.

2.2 Cognitive maps and navigational aids

People need to use some external information in addition to their stored spatial knowledge, in order to perform a successful wayfinding task. This external knowledge is often in the form of what they can sense in their given location at a point in time, and what they can gather from a navigational aid such as a map or smartphone app. The classic study of Thorndyke & Hayes-Roth (1982) showed that acquired spatial knowledge of map users is qualitatively different to those who navigate without such aids. With the increase in use of GPS-based navigation systems, several studies have compared the spatial knowledge acquisition with mobile maps and paper maps (Aslan et al., 2006; Hou, 2014; Münzer et al., 2006; Willis et al., 2009). There are two key studies that compared the acquired spatial knowledge of three groups of navigators who used GPS, paper map and no-map to wayfind in an urban environment. Ishikawa et al. (2008) examined the wayfinding behaviour and acquired spatial knowledge of navigators who used GPS-based mobile navigation system compared with those navigated by paper maps and direct experience of routes. The study area in their research was limited to six predetermined routes. They found that the distance travelled and the number of stops for the GPS group were significantly larger than two other groups. In addition, the GPS users walked more slowly and made more direction mistakes, and drew less accurate sketch maps in terms of topological
Later, Chang (2015) conducted similar research in Taipei to investigate the influence of three different navigational aids (GPS, paper map and signage only) on users’ mental image and wayfinding behaviour in an unfamiliar large scale urban environment. In her study participants needed to complete two wayfinding tasks started from a Mass Rapid Transit train station and arrived at two attraction sites. In addition, participants’ level of anxiety or feeling lost were examined. In consistent with Ishikawa et al. (2008) she found that participants in the GPS/3G mobile phone user group felt lost more often than two other groups. In addition, navigators using smartphone apps or paper maps provided less detailed information and fewer landmarks than those who had to rely solely on the local signage and other elements of the existing built environment. But GPS users remembered more information regarding transportation and route/road items, as well as road names and the entire travel route. The GPS group made less direction error than paper map users. This result differed from that of Ishikawa et al. (2008), and Chang suggested that at the time of her study people got more familiar with the use of digital devices for navigation. But these studies had some limitations in explaining why.

Several other studies have shown that passively following the turn-by-turn guidance provided by navigational tools will result in poor spatial cognition (Bakdash et al. 2008; Burnett and Lee 2005; Farrell et al. 2003; Gaunet et al. 2001; Parush et al. 2007; Péruch et al. 1995). One possible reason could be that navigators do not porously plan and control their route choice decisions to remember key spatial information. In other words, they only observe and perceive the urban environment, switching off key cognitive processes, instead of exploring and conceiving it. It is believed that navigators’ using the small screen of smartphones place their attention on the device and take it away from the surrounding environment (Dillemuth 2009; Gardony et al. 2013; Gartner and Hiller 2010; Leshed et al. 2008; Willis et al. 2009).

Remaining research gaps include: a need to confirm the findings of Chang and Ishikawa et al. in terms of the differences in acquired spatial knowledge that occur from use of three different navigational aids in an outdoor setting; a need to understand why these differences occur; and, building further on our understandings of how key features of the urban environment contribute to legibility/imageability. The present study tries to explain these issues by using think-aloud method, and slightly improved method of cognitive mapping tests.
Research Design

3.1 Participants

Following Chang’s (2015) approach, thirty-eight students from Griffith University’s Gold Coast Campus, 15 men and 23 women, were recruited through emails and through posters on campus (the posters prevent us from establishing an accurate response rate). Their age ranged from 18 to 56 years old, with a mean of 26.8 years. All participants were unfamiliar with the study area and travelled at least 70km from the Gold Coast to central Brisbane by train to undertake the wayfinding tasks.

3.2 Study Area

The Brisbane central business district (CBD) and the South Bank precinct, being the two most popular sightseeing areas in Brisbane, were chosen as the study area (see Figure 1). The participants were asked to find seven pre-determined destinations in the study area, in any order, being: the Brisbane City Hall, the Queen Street Mall, St Stephen’s Cathedral, the Cultural Centre Station, South Bank Beach, South Bank Railway Station, and the COWCH Café Bar in South Bank. The data collection process was completed from June to October 2017.

![Figure 1: The map of the study area](image-url)
3.3 Data Collection Procedure

3.3.1 Wayfinding task

Partly taking into consideration their own preferences (there was an element of self-selection) the participants were assigned to one of three groups: i) a group using Google Maps (n=12); ii) a group using a conventional 2D paper map (n=12); and, iii) a group with no aids other than the local signage that is already in place in the built environment (n=14). The starting point was the Roma Street Station where their train arrived. The final meeting point was at COWCH café, where debriefing occurred.

A Samsung Galaxy J5 cellphone equipped with 3G service and the Google Maps app, was given to the first group. The map of the surrounding area was shown on the screen size of 14cm x 7cm. The app shows the location of the user on the screen, dynamically updated as they move in the area. Participants were asked not to use the voice navigation option.

Participants in the paper map and local-signage only groups were also given smartphones, but only to record audio of their speech, and to capture a GPS tracks of their movement, and they were instructed not to use them as a navigational aid. The route tracker application Geotracker installed on the same smartphone recorded the length of time for all participants, as well as their travelled route. Participants in the paper map group were given an A4-size tourist map of Brisbane, as provided by tourist information centres in the city. There was no suggested route or other annotation on the map and they had to find the destinations and plan their preferred routes by themselves. Participants in the local-signage-only group were provided an A4 size conceptual non-representational map, showing only vague locations of each destination, to help them know the approximate direction/location (see Figure 2).

![Figure 2: The plain map given to the local-signage-only group](image-url)
All groups were instructed to only ask other people for help if they were unable to navigate via their navigational aid, or the built environment, without assistance. All groups were asked to think aloud and verbalize their thoughts, in English, about the wayfinding process, the buildings, streets, the signs, the maps, their feelings and whatever else they see or came to their minds.

3.3.2 Think-aloud

A voice recorder application on the given smart phones recorded participants’ voices and all recordings were transcribed. Participants’ reasons for choosing a street segment or any side of the street during the navigation were extracted from the think-aloud protocols, as well as the names of landmarks perceived by them.

3.3.3 Post-test Interviews

After the completion of the wayfinding task, a post-test interview was conducted at COWCH café. All participants were asked to fill in a questionnaire consisting of different tasks to test their acquired spatial knowledge, and interviewed about their experiences.

I. Sketch mapping and recognition test

Using a Lynch-ian (1960) approach the participants were asked to draw and write as much information as they could remember, such as streets, buildings, landmarks, parks, transport stations, etc., solely from memory and without referring to any other paper or digital map. In order to overcome the problems of individuals’ drawing ability, a spatial recognition test (Piaget and Inhelder, 1956) was also taken after collecting their cognitive map sheets. The photos of five buildings and landmarks in the study area were shown to the participants and they were asked if they could recognize them.

In the Brisbane CBD, streets facing north-east have female names, each street named after a past or present member of the British royal family. Going in the opposite direction, the street names are of male members of the royal family, making navigation easier. So to find out how visitors learned Brisbane’s street names, participants were given a plain map of the study area and were asked to write the street names.

II. Sketch mapping follow-up interview

To gain more insight into how visitors developed a mental image of space and the role of navigational aids in that process, participants were asked to write their answers to the following questions:
• Why did you remember and draw certain streets on the sketch map (i.e. what were the features that made them memorable?)
• Why did you remember and draw certain landmarks on the sketch map (i.e. what were the features that made them memorable?)
• How did your way-showing tool (Digital map, paper map, signage only) influence the cognitive map you drew?

III. Distance estimation task

To assess participants’ survey knowledge, they were given a set of pairs of landmarks, all were on the list of those they had to find. They were asked to score the Euclidean distance between each pair from 0 to 9; where 0 meant next to each other (no distance) and 9 meant the longest distance. The participants received a unit of measure, as the distance between South Bank Station and COWCH (which they had all just been to) as equal to 1.

3. Results

4.1 Wayfinding performance

The average distance travelled to find all destinations helps indicate the effectiveness of the navigation aid on performance. Table 1 lists the average travel time, the average distance travelled, and the average walking speeds across each group of navigators. Average travel time is a less reliable indicator of performance, due to variability in breaks taken by the navigators. A one-way, between-subjects ANOVA was conducted which showed the difference in the average travel times across the groups were not statistically significant at the 95% confidence level. But the average distance travelled was significantly different between groups (F (2, 35) = 3.71, p < 0.05), as was their average walking speed (F (2, 35) = 3.5, p < 0.05).

Table 1: Wayfinding performance of the three groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>Average distance travelled (km)</th>
<th>Average travel time (h)</th>
<th>Average walking speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS</td>
<td>5.47</td>
<td>1:46</td>
<td>3.1</td>
</tr>
<tr>
<td>Paper map</td>
<td>6.03</td>
<td>1:47</td>
<td>3.3</td>
</tr>
<tr>
<td>Local-signage-only</td>
<td>6.47</td>
<td>1:52</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Post-hoc paired comparisons showed that the average distance travelled as well as walking speed of the local-signage-only group was significantly greater than that of the GPS group (p
< 0.05). However, statistically there was no significant differences in the average distance travelled and walking speed between the paper map group and the two other groups.

4.2 Sketch maps

All 38 sketch maps of the participants were collected and analysed based on Lynch’s five urban image elements. 32 of the cognitive maps were drawn from a top-down view (i.e. see Figure 3a); only two of them were drawn from a side perspective (see Figure 3b). Four maps used a combination of both (see Figure 3c). One participant’s sketch map was too simple to be analyzable as a cognitive map; so her map was excluded from the cognitive map analysis.

Figure 3a: Top-dawn view  
Figure 3b: Side perspective  
Figure 3c: A combination of top-dawn and side view

Figure 3: Examples of different views in drawing the sketch maps

4.2.1 Proportion of urban elements

In this regard, the number of landmarks, paths, nodes, edges and districts, for each participant, were all counted. In this study, a ‘landmark’ refers to any building such as a shop, cafe, restaurant, museum, hotel, etc. Although a river is considered as an edge in Lynch’s study (1960), here participants also vocalized how the Brisbane River was a benchmark or landmark
to orient themselves during the wayfinding task, rather than just as an edge to follow; e.g. “I know where exactly I am by looking at the curve of the river” or “I should go to the left because the river is in front of me”. Therefore, in this particular study, the river was considered a landmark as well as an edge. ‘Paths’ refer to any route such as a street or bridge. ‘Nodes’ are considered to be transport stations, intersection of streets, and public gathering places. All blocks along streets were considered an ‘edge’. ‘District’ refers to any large area in the study area with homogenous urban characteristics.

For all participants, landmarks, with 40% of the total urban elements, were the most drawn element in participants’ cognitive maps. Paths and nodes were the second and third most common, at 29% and 25% respectively. Edges were only 6% of all the elements included. There was no immediately discernible district represented on any of the participants’ cognitive maps, even including the large South Bank area.

4.2.2 Analysis of landmark knowledge by group

The number of remembered landmarks was considered a measure of landmark knowledge across the groups (see Table 2, first row). A one-way, between-subjects ANOVA was conducted to compare the effect of navigation aid on the landmark knowledge acquisition of participants. There was a significant difference in the number of remembered landmarks across the groups \[F (2, 34) = 6.50, p < 0.01\]. Post-hoc paired comparisons showed that participants in the local-signage-only group remembered a significantly larger number of landmarks compared with the two other groups (p < 0.05). However, there was no significant difference between the numbers of landmarks mentioned by participants across the two other groups.

Table 2: Means (and standard deviation) for each variable by participants in the three groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>GPS Group (n=12)</th>
<th>Paper map Group (n=12)</th>
<th>Local-signage-only Group (n=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landmark Knowledge</td>
<td>7.4 (3.5)</td>
<td>8.6 (3.4)</td>
<td>10.1 (7.9)</td>
</tr>
<tr>
<td>Distance Estimation</td>
<td>2.0(1.4)</td>
<td>2.5(0.7)</td>
<td>2.8(1.3)</td>
</tr>
<tr>
<td>Street Name</td>
<td>2.7 (1.5)</td>
<td>4.5 (2.1)</td>
<td>2.1 (2.2)</td>
</tr>
</tbody>
</table>

4.2.3 Analysis of route knowledge by group

To assess the route knowledge gained by participants, we adapted the method of Billinghurst and Weghorst (1995) who suggested scoring the sketch maps based on three criteria: map
goodness; object classes; and, relative object positioning. All sketch maps were rated by two independent raters who were familiar with the study area but unaware of the participants’ identity. They first rated the map goodness by using the question “how good the drawn routes are to help you navigate toward the destinations?” (Beime, 2007; Billinghurst & Weghorst, 1995; Lukas et al., 2014).

As we were particularly interested in route knowledge we used route accuracy as the second rating criterion to represent object classes (Lukas et al., 2014). Route accuracy refers to any added routes in terms of “correct relations of the routes drawn in the sketch maps, turns and directions” (Lukas et al., 2014, p. 134). Relative object positioning, was determined by the positioning of any landmarks added on the drawn routes (Lukas et al., 2014; Parente, 2016). The inter-rater-reliability, Kendall’s tao, for rating of map goodness, route accuracy and relative object positioning was 0.70, 0.65, and 0.72 respectively, suggesting good inter-rater agreement/reliability. The scores given to the maps were of ordinal value, so the Kruskal-Wallis H test was used. There was a difference among the ranking of map goodness drawn by each group that was approaching but not quite reaching statistical significance [H (2) =5.42, p<0.1]. The results of Mann-Whitney U-tests (Table 3, first row) showed that the map goodness of routes drawn by the paper map group was significantly higher than the GPS group, but there was no significant difference between the local-signage-only group and the two other groups.

There was a significant difference among the three groups in case of route accuracy [H (2)= 7.37, P<0.05]. The results of the Mann-Whitney U-test showed that the paper map group significantly outperformed the two other groups, while there was no significant difference between the local-signage-only and GPS groups (Table 3, second row).

Table 3: The results of the Mann-Whitney U-test for the analysis of route knowledge between groups

<table>
<thead>
<tr>
<th>Category</th>
<th>Groups</th>
<th>Mean ranks</th>
<th>Mann-Whitney U Test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map goodness</td>
<td>GPS, paper map</td>
<td>9.29, 15.71</td>
<td>33.5</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>10.58, 15.23</td>
<td>49</td>
<td>.1</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage- only</td>
<td>14, 12</td>
<td>66</td>
<td>.5</td>
</tr>
<tr>
<td>Route accuracy</td>
<td>GPS, paper map</td>
<td>7.92, 17.08</td>
<td>17</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>11.33, 14.54</td>
<td>58</td>
<td>.2</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage- only</td>
<td>16.79, 9.50</td>
<td>32</td>
<td>.006</td>
</tr>
<tr>
<td>Relative object</td>
<td>GPS, paper map</td>
<td>10.88, 14.13</td>
<td>52.5</td>
<td>.2</td>
</tr>
<tr>
<td>positioning</td>
<td>GPS, local-signage-only</td>
<td>9.21, 16.5</td>
<td>32.5</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage- only</td>
<td>12.38, 13.58</td>
<td>70.5</td>
<td>.6</td>
</tr>
</tbody>
</table>
There was a difference approaching significance between groups in terms of relative object positioning \([H (2) = 5.17, p<0.1]\). According to the Mann-Whitney U-tests, the local-signage-only group significantly performed better than the GPS group, while there was no significant difference between the paper map group and two other groups (Table 3, third row).

4.1.4 Analysis of distance estimation (survey knowledge) by group

As noted earlier, all participants were asked to score the Euclidean distance between some pairs of destinations, using a score between 0 to 9. The mean number of correct distance estimations for participants was slightly higher in the local-signage-only group and lowest in the GPS group (Table 2, second row). But the result of an ANOVA test did not show a statistically significant difference among the three groups of participants (p>0.1).

4.1.5 Analysis of street naming task by group

The descriptive statistical analysis showed that participants in the paper-map group mentioned more street names than the other groups (Table 2, third row), confirmed by ANOVA \([F (2, 34) = 4.48, p<0.05]\). The Post-hoc analysis showed that using a paper-map had an influential role in assisting participants with the street naming task.

4.2 Results of the sketch mapping follow-up interview

- Why some paths are more memorable?

Each group of participants was asked why some streets were memorable in their mental maps and drawn in their sketch maps, with results shown in Table 4.

The most frequently mentioned reason for streets to be memorable for paper map and local-signage-only groups were attractions along the streets (for example, the existence of shops, cafes and bars along Queen Street and Grey Street), and for the GPS group was noticeable building along the street. This result shows the importance of landmarks and buildings in making a memorable path for navigators.

- Why some buildings/landmarks are more memorable?

Each group of participants was asked why some buildings/landmarks were memorable with the results shown in Table 5. The most frequently mentioned reason for landmarks to be memorable for all groups was being an eye-catching building.
**Table 4:** Frequency of reasons for remembering paths in route knowledge task by participants in the three groups

<table>
<thead>
<tr>
<th>Reasons for remembering streets drawn in sketch maps</th>
<th>Total frequency of reasons mentioned by all participants</th>
<th>Paper Map Group</th>
<th>GPS Group</th>
<th>Local-signage-only Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attractions (shops, cafes, bars,...) along the street</td>
<td>18</td>
<td>6</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Noticeable building along the street</td>
<td>17</td>
<td>3</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Locating next to the river</td>
<td>12</td>
<td>3</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Noticeable signage</td>
<td>11</td>
<td>3</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Getting lost in it</td>
<td>10</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Crowded with people</td>
<td>7</td>
<td>3</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Having vast view to its surrounding (like bridge)</td>
<td>7</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>appealing</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Length</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Width</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Major Street</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Easy to memorize the street name</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 5:** Frequency of reasons for remembering landmarks in landmark knowledge task by participants in the three groups

<table>
<thead>
<tr>
<th>Reasons for remembering landmarks drawn in sketch maps</th>
<th>Total frequency of reasons mentioned by all participants</th>
<th>Paper sap Group</th>
<th>GPS Group</th>
<th>Local-signage-only Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye-catching (color, mass, height)</td>
<td>33</td>
<td>6</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Beautiful Design</td>
<td>13</td>
<td>6</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Historical Building</td>
<td>10</td>
<td>1</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Locating next to the river</td>
<td>8</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Having big open space in front</td>
<td>7</td>
<td>0</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Crowded with people</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Having noticeable signage</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Well written on the map</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>Hard to find</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
How did your way-showing tool influence the cognitive map you drew?

Table 6 shows how different navigational aids helped participants create a mental map. For the paper map group the most frequently mentioned influence was in helping them realise the overall shape of the city centre, as a peninsular, followed by locating the position of streets in relation to the river. For the local-signage-only group, being without a proper map was more confusing, preventing them from creating an accurate mental image. Compared with the paper mapping group, participants in the GPS group found their wayfinding tool more confusing and less helpful in helping them create a cognitive map; however a few of them found it influential in estimating distance and remembering street names.

Table 6: Different roles of navigational aids in spatial knowledge acquisition mentioned by participants in the three groups

<table>
<thead>
<tr>
<th>Different roles of navigational aids in creating mental image</th>
<th>Paper Map Group</th>
<th>GPS Group</th>
<th>Local-Signage-only Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overviewing the shape of the city</td>
<td>12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Locating the position of streets in relation to the river</td>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Locating the position of buildings in relation to each other</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Remembering orientation of the streets</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Remembering the street names</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Distinguishing the land types</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Estimation of distance</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Identification of landmarks</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Not helpful</td>
<td>0</td>
<td>4</td>
<td>9</td>
</tr>
</tbody>
</table>

4.3 Analysis of the think-aloud data

4.3.1 Using environmental cues in wayfinding performance

All groups were asked to think aloud and verbalize their thoughts about the wayfinding process, the buildings, streets, the signs, the maps, their feelings and whatever else came to their minds.

To get more insight into the influence of environmental features on people’s wayfinding behaviour, participants’ reasons for choosing a street segment or any side of the street during the navigation were extracted from the think-aloud protocols.

Table 7 shows the participants’ preferences for taking a street segment or even a side of the street, based on their utterances. A diversity of route selection criteria were mentioned by the
three groups of participants, including: a) physical characteristics of the road, such as being straight, short, highway or major road; for example “I take this street because it is wide.” (Group: local-signage-only) / “I take North Quay because I see it directly goes to the city hall.” (Group: Paper map) / “I think this way is the shortest one.” (Group: Paper map). b) Being comfortable for pedestrian due to having shade, pedestrian roads; for example “I will go on the left side because it is shady.” (Group: GPS) / “I stay in this side because it has wide pedestrian road.” (Group: Local-signage-only). c) Type of space along the street, such as green areas, river, or shops and cafes or any attraction; for example “I take the right one because I think I can pass through the parkland as well.” (Group: GPS) / “I am going to the right side because of those stores and cafes.” (Group: Paper map) / “I choose the left because it looks nice.” (Group: Local-signage-only). d) number of cars e.g. “there is busy with cars, so I go there” (Group: Local-signage-only). e) The crowd on the street; e.g. “I will continue here because here is less people.” (Group: GPS) / “I am fine with the left side of the street because I see a lot of people” (Group: Paper map). f) green light; e.g. “I prefer to turn right, the light is green, it is better than waiting for front cross.” (Group: Paper map). The results of a Kruskal-Wallis H test showed that the three groups differed significantly in using environmental cues during the navigation [H (2) = 6.69, p= 0.035].

**Table 7:** The participants’ environmental preferences for taking a street. The percentage within condition are shown in parentheses.
A Mann-Whitney U-test (see Table 8) shows the GPS group used the environmental cues significantly less than the local-signage-only group (p=.01), and there was a difference approaching significance between the GPS and paper map groups (p=.05); while there was no significant difference between the paper map and local-signage-only groups (p=.5).

Table 8: The results of the Mann-Whitney U-test for the analysis of total environmental cues mentioned by participants for choosing a street segments

<table>
<thead>
<tr>
<th>Category</th>
<th>Groups</th>
<th>Mean rank</th>
<th>Mann-Whitney Test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total environmental cues</td>
<td>GPS, paper map</td>
<td>9.83, 15.17</td>
<td>40</td>
<td>.05</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>9.54, 16.89</td>
<td>36</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>12.54, 14.32</td>
<td>72</td>
<td>.5</td>
</tr>
</tbody>
</table>

Comparing the participants’ reasons for remembering streets with that for choosing a route segments (Table 4 and Table 7) represents some similarities, such as attractions and locating next to the river. On the other hand, some influential factors in route choice behaviour was not mentioned in the mental image generation reasons, such as major roads and crowd for the local-signage-only group. On the contrary, some reasons were only mentioned for mental image generation but not for their route choice behaviour, like major roads for the GPS group. Although the GPS group followed the crowd during their navigation considerably less than two other groups, the crowded streets that they passed through remained in their minds. The influence of the crowd on the wayfinding behaviour of the groups was interesting. The GPS group mentioned avoiding the crowd six times in their think-aloud utterances, while it was never mentioned by the two other groups as a route choice reason. This result shows how GPS is changing our social interaction with the surrounding environment, and further research is needed to be done on the safety of the routes that GPS users take.

4.3.2 Perceived landmarks

From the think-aloud recordings, a count of names of landmarks was extracted from transcripts for each group; e.g. “I see a big wheel”. There proved to be no significant difference in the number of landmarks mentioned across the groups (p> 0.1).

4. Discussion

The findings provide significant further confirmation on key psycho-cognitive effects of navigational aids, and especially the use of GPS-based smartphone apps in real-world, outdoor
situations. They also provide a set of methodological and applied contributions that are likely of value to researchers and practitioners.

Firstly, the GPS navigators in this particular urban environment were more efficient than those relying solely on local signage, but GPS offered fewer advantages over traditional paper maps. This result is inconsistent with the findings of Ishikawa et al. (2008). One possible reason for that could be that individuals are more familiar with a GPS-based navigation system at our study that conducted in 2016 and they followed the shortest routes offered by their devices. However, the local-signage-only group were not excessively inefficient in their wayfinding compared with the paper map group. Brisbane, with its useful CBD wayfinding signage system and its relatively logical orthogonal grid in the downtown area, proved not too difficult for them to navigate.

With respect to the acquisition of spatial knowledge, there were significant differences among the three groups broadly in line with the previous literature, again confirming more of what we know in this emerging field. For landmark recognition, the local-signage-only group performed better than the two other groups, in line with Chang (2015). The navigational assistance provided to the two other groups reduced their dependence on landmark knowledge to navigate. They still observed landmarks, in that there was no significant difference in the number of mentioned (perceived) landmarks across the three groups. But the local-signage only group had to rely on this landmark knowledge more, and inscribed it in their spatial memory. In other words, the GPS and paper map groups were, as seen in previous studies, more often only observing and perceiving the urban environment, instead of exploring and conceiving it (Bakdash et al. 2008 ; Burnett and Lee 2005 ; Farrell et al. 2003; Gaunet et al. 2001 ; Parush et al. 2007 ; Péruch et al. 1995). There was no significant difference in terms of map goodness between the local-signage-only and the two other groups. Moreover, the paper map group in our study performed better in terms of route accuracy than the two other groups. This was somewhat different from two previous studies’ findings (Ishikawa et al, 2008; Chang, 2015), who found the group without any navigational aid performed better than the GPS group in terms of route knowledge. However, all these findings confirm that navigation by GPS has no privilege in route knowledge acquisition. The GPS group could rely on simple turn-by-turn directions, and did not have to think as much about their route choices, and looking down at their devices made it more difficult to view both their location and destination at the same time. The map image on their devices (radius 2 km) helped the GPS group understand and memorise
“an overall shape of the city”, as one respondent called it, but not so much the routes taken within it.

In line with Chang’s findings the local-signage-only group more accurately located landmarks on drawn routes than the GPS group.

The paper map group were the most likely to remember the name of the streets they travelled, than the two other groups, presumably as the paper map users needed to look for the names on the map to locate themselves in the actual environment, and needed to see and understand the street names to know where to turn. It is cognitively more demanding. This result differed from that of Chang (2015), one possible reason for that could be the difference in methods used in two studies. In our study we separately defined a street naming task by asking participants to name the street names on the plain maps of the study area. But, in Chang’s study street naming performance were assessed through counting the road names provided in drawn sketch maps. This method could be a bit misleading as it is affected by participants’ drawing ability. In addition, In Chang (2015) study, majority of study participants were foreigners. They might have difficulties remembering the street names which are presented in Roman spelling. Another reason could be, differences in study areas used in the two studies. The grid street pattern of Brisbane city and its street naming strategy might have made it easier for participants to remember the street names.

The think-aloud data showed that the GPS group used the environmental information in their surroundings significantly less than the two other groups. They only focussed on their devices to update their spatial information, and just followed it.

The importance of attractions and buildings in path and landmark recognition demonstrated in this study confirms previous work. This response suggest that map designers, whether digital or paper, should pay more attention to showing tourist attractions in an accurate way, in order to catch navigators’ attention and make them more memorable. Firms like Google are producing mapping with increasing sophistication in terms of displaying building and landmark information. But with 3D models of cities now commonplace, more could be provided to the wayfinder. Augmented reality may offer significant advantages here, if systems are carefully designed to maximize not just immediate navigation needs but also spatial learning.

There are many limitations of our research. As in similar studies, and due to a lack of budget, we were unable to continually observed participants and some may have strayed from protocol.
The quality of the sketch maps can be influenced by the drawing ability of participants. We used the tourist map provided by tourist information centres in Brisbane, and alternative mapping may have shifted the results for the paper map group.

Methodologically, the study showed the value of including the think-aloud model in such research designs. It provided useful insights into landmark knowledge and route knowledge formation, but (along with the geotracking) helped us confirm that the participants were indeed following the instructions. In addition, to answer the research question we used slightly improved cognitive mapping methods compared with previous studies, such as distance estimation and street naming tasks.

As GPS-based smartphone apps and similar technology improves, we need to continue to develop methods that help us observe behaviour, capture acquired spatial memory, and understand how and why such memories are created. A number of issues remain unresolved. There are many options for spatial memory testing, but, as we found, respondent burden and costs are high if one includes most of them. If one had to reduce the set of tests conducted, which are the “best” to help us understand particular issues of wayfinding effectiveness, spatial cognition and memory?

For practitioners, there remains a need to continue to improve urban wayfinding systems, regardless of the increasing use of digital navigation. The landmark features of central Brisbane lent themselves to landmark knowledge in ways that the more uniform blocks of centres in, say, some newer Chinese cities, also proved itself helpful to the wayfinders, across all groups. But there might also be ways in which the wayfinding systems cities are installing in the built environment can better interact with digital wayfinding. There are also ways in which practitioners may wish to disrupt GPS-navigators and encourage them to make other route choices. How this might best be achieved has been little explored as yet.

References


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5. Effects of Urban Form and Navigational Aids on Wayfinding Behaviour

An earlier version of the paper presented in Chapter 5 was first presented as:


A revised version was then submitted to the journal *Urban Design International* as:
- Vaez, S., Burke, M., and Yu, R., “Effects of Urban Form and Navigational Aids on Wayfinding Behaviour”.
- First Submission on 19/02/2019

The previous chapter focused on the effects of perceivable urban elements and navigational aids on people's spatial cognition and wayfinding behaviour. However, it is known that syntactical properties of an urban network, such as integration, choice, and visibility play an important role in shaping people’s movement patterns and their wayfinding behaviour. This chapter summarises the results of Task 3. The main aim of this task is to examine effects of urban form, in terms of spatial configuration and land use, in wayfinding behaviour of three groups of participants who used different navigational aids: a group with a paper map, a group with the *Google Maps* app, and a group relying on local signage only. Two main methods were used to address the objectives of this study, including GPS tracking and space syntax. Similar studies have compared the effects syntactical properties of urban network on individuals’ movement pattern (Kubat et al., 2012; Ozbil et al., 2011; Peponis, 2016). No published space syntax study has as yet considered the role of navigational aids in wayfinding behaviour, and how digital wayfinding may influence wayfinding behaviour in combination with urban form.

It is believed that the paper presented in this chapter is the first to examine the effects of spatial configuration of urban layout and navigational aids in combination on navigators’ wayfinding behaviour. Using space syntax and GPS tracking methods allowed us to gain more insight into the influence of different methods of wayfinding (*Google Maps* app, paper map and signage only) on individuals’ natural movement behaviour. Bivariate and multivariate regression analysis were conducted to find out the relationship between urban form characteristics (land use and syntactical properties) and the participants’ wayfinding behaviour.

The outcomes confirm that the spatial configuration of urban layout has significant influence on wayfinding decision-making of visitors, but only for the paper-map and local-signage-only
groups. These two groups behaved much as we expected, following routes with strong choice (through-movement) and integration (to-movement) values, in line with past studies (i.e. Hillier & Iida 2005). The GPS navigators behaved very differently. They were unaffected by (or, emancipated from) the theory of natural movement.

Research questions addressed in this paper and contributions

Primary Question:

**RQ2:** How do urban form and different approaches to wayfinding, such as paper maps, GPS and local signage only, affect navigators’ wayfinding behaviour?

Summary of contributions:

1. The theoretical/conceptual contributions of this study:
   - Ubiquitous navigational apps like Apple Maps and Google Maps are creating a set of first-time visitors who become rigid digital navigators. These GPS navigators are unaffected by (or, emancipated from) the theory of natural movement. As heard repeatedly in their voice recordings, the digital device overpowers the effect of the city and its built form on their wayfinding behaviour. We need to rethink the application of space syntax and the theory of natural movement in terms of such visitors.

2. The methodological contributions of this study:
   - The study is the first to consider the effects of syntactical properties and land use in wayfinding behaviour of three groups of participants who used different navigational aids

3. Practical and applied contributions of the study:
   - We confirm that the spatial configuration of urban layout has significant influence on wayfinding decision-making of visitors, but only for the paper map and local-signage-only groups.
   - Urban planners and designers now need to consider the routes that will likely be suggested by GPS navigation in how they design, manage and operate street and pathway networks.
Designers will need to experiment on the best methods to discourage digital navigators from taking less desirable routes and encourage them onto street segments with greater commercial and recreational activity.

This chapter is an exact copy of the paper referred to above.
5.1 Statement of contribution to the co-authored published paper

This chapter includes a co-authored paper that summarises the results of Task 3. The bibliographic details of the co-authored paper, including all authors, are:

- Vaez, S., Burke, M., and Yu, R., Effects of Urban Form and Navigational Aids on Wayfinding Behaviour
- First Submission on 19/02/2019

The authors listed below have certified that:

1. They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
2. They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
3. There are no other authors of the publication according to these criteria;
4. They agree to the use of the publication in the student’s thesis and its publication on the Griffith University database consistent with any limitations set by publisher requirements.

<table>
<thead>
<tr>
<th>Contributors</th>
<th>Statement of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sima Vaez</td>
<td>• Designed the data collection process, including the site selection, participant recruitment, and questionnaires.</td>
</tr>
<tr>
<td></td>
<td>• Attended in the study area to conduct the wayfinding task and managed and trained the participants</td>
</tr>
<tr>
<td></td>
<td>• Complied, cleaned and analysed the data</td>
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<tr>
<td></td>
<td>• Conceived, planned and wrote the first draft of manuscripts</td>
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<td></td>
<td>• Managed the academic editorial process for the manuscript</td>
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<tr>
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<td>• Submitted and revised the manuscript at the suggestion of the conference reviewers.</td>
</tr>
<tr>
<td></td>
<td>• Prepared presentation slides and presented the paper at the conference.</td>
</tr>
<tr>
<td>Name</td>
<td>Contributions</td>
</tr>
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<td>---------------------------</td>
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</tr>
<tr>
<td>Matthew Burke</td>
<td>• Provided assistance in the theoretical framing of the research.</td>
</tr>
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<td></td>
<td>• Provided suggestions in response to journal reviewers.</td>
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<tr>
<td></td>
<td>• Provided editing revisions in the initial and the reviewed manuscript.</td>
</tr>
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<td>Rongrong Yu</td>
<td>• Provided assistance in the theoretical framing of the research.</td>
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<tr>
<td></td>
<td>• Provided suggestions in response to journal reviewers.</td>
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<tr>
<td></td>
<td>• Provided editing revisions in the initial and the reviewed manuscript.</td>
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<tr>
<td></td>
<td>• Provided the methodological advice as an expert in the space syntax method.</td>
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(Signed) _______________________________ (Date) 15/03/2019________

Student and Corresponding Author: Sima Vaez

Supervisor Confirmation: I have obtained an email or other correspondence from all co-authors confirming their certifying authorship.

(Signed) ___________________________ (Date) ______________

Principal Supervisor: A/Prof Matthew Burke
EFFECTS OF URBAN FORM AND NAVIGATIONAL AIDS ON VISITORS’ WAYFINDING BEHAVIOR

Abstract

Space syntax studies have previously revealed relationships between syntactical features of urban space and pedestrian walking behaviour. But few studies to date have focused on the role of urban form and street network pattern in pedestrian wayfinding behaviour. No published space syntax study has as yet considered the role of navigational aids in wayfinding behaviour, and how digital wayfinding may influence wayfinding behaviour in combination with urban form. 38 student participants were recruited to undertake a wayfinding task in the centre of Brisbane, Australia. The participants were assigned into one of three groups: i) those provided with the city’s main tourist paper map; ii) those provided with smart phones with Google Maps and GPS navigation; and, iii) those who had to rely on local signage only within the existing built environment. Bivariate and multivariate regression models were used to reveal the role of urban form, in terms of spatial configuration of urban layout and land use, is shaping wayfinding behaviour. The implications are that, given its take up in recent years, digital navigation is fundamentally altering first-time visitors’ use of the city and affecting our natural movement and urban experience.

Keywords: Wayfinding, Space Syntax, Navigational Aids, Urban Configuration, Land use

1. Introduction

The term wayfinding describes a person’s ability, both cognitive and behaviourally, to travel from an origin to an out-of-sight destination, by following the paths and routes between them (Blades, 1991; Garling et al., 1984; Gluck, 1991; Golledge, 1992). Environmental cues, such as landmarks and paths, are the primary information available to individuals to orient themselves within the built environment. For instance, when a destination is located along an edge, such as a river, people with little knowledge about the environment tend to follow that edge towards their destination (Hutchins, 1995). People also get assistance from navigational aids, such as local signs, maps and Global Positioning Systems (GPS) (Chang, 2015). Successful wayfinding matters. It helps travellers gain a sense of safety and well-being (Lu, 2016, p. 11). Good wayfinding can more efficiently bring visitors to tourist assets, and is
essential to linking first-time visitors to public transport systems. The so-called ‘static’ wayfinding design industry, including firms like Maynard and DotDash, draws on disciplines such as urban design, transport, sociolinguistics and social geography to install signage and other clues into the built environment to help people find their way through cities, institutions, transport systems or special events. At the same time, the rise of ‘digital’ wayfinding, through global-positioning-system (GPS) apps such as Apple Maps and Google Maps, has forever changed how first-time visitors to cities navigate, allowing them to follow turn-by-turn instructions delivered on-screen or via audio.

People are of course able to orient themselves in cities and wayfind, even without elaborate signage or digital assistance. A known influence on route choices are the syntactical properties of urban layouts. For instance, syntactic measures of integration and connectivity predict individuals’ movement patterns (Kubat et al., 2012; Ozbil et al., 2011; Peponis, 2016). People prefer to minimize their angle toward their destinations (Dalton, 2003). They choose spaces and links with higher visibility measures (Kubat et al. 2012, Hölscher, 2007). The static wayfinding systems put in place by urban designers improve route accuracy significantly and relieve the stress of navigators (Carpman & Grant, 2002). Early studies suggested digital way-finders using GPS mobile devices walked slower and made larger direction errors than those relying on the built environment and local-signage-only (Ishikawa et al., 2008). Though the technology has improved and familiarity with it is much increased, this phenomena is still believed to happen as users “switch off” part of their brain that undertakes wayfinding and immerse themselves in the virtual screen world of their device (Javadi et al., 2017; Konkol et al., 2017; McCullough & Collins, 2018).

The interplay between the syntactical properties of the built environment, static wayfinding systems, and digital wayfinding, and how visitors choose to navigate when given multiple options, is unfortunately little understood. This leaves the urban design industry unsure how to deal with digital wayfinding, and city or asset managers uncertain as to whether static built environment wayfinding systems are even worth investing in.

This paper continues a line of investigations by researchers in locations such as Britain (McCullough & Collins 2018) and Germany (Willis et al., 2009) comparing the wayfinding behaviour of similar groups of first-time visitors given different wayfinding tools and asked to undertake a wayfinding task. We know that people who navigate using GPS devices or local-signage-only tend to be slower at undertaking wayfinding tasks than paper map users (Chang, 2015; Ishikawa et al., 2008). GPS navigators draw poorer cognitive maps compared with those
who use paper maps or local-signage-only (Ishikawa et al., 2008). Those using local-signage-only can remember more local landmarks and buildings; paper map users perform worse in recognizing landmarks later and in their route knowledge; mobile phone users provide more information on street names and road items (Chang, 2015). But the aim of this paper is to explore the role of navigational aids in wayfinding behaviour, and especially how digital wayfinding may influence wayfinding behaviour in combination with urban form.

The paper is arranged as follows. Background material on the influence of spatial arrangement on wayfinding behaviour, and the theory of space syntax is provided. Next, the study’s methods are outlined. The results follow, focusing on key bivariate and multivariate analyses, as well as the striking divergence in route choices made by each group of participants in the Southbank Parklands precinct. A discussion draws out the implications of this work, its limitations, and the avenues for further research.

2. Background

Whether we look at indoor space (Carlson et al., 2010; Hölscher & Brösamle, 2007), virtual space (Dalton, 2003; Natapov et al., 2014) or outdoors in the real-world (Kubat et al., 2012; Ozbil et al., 2011; Peponis, 2016) study after study has shown that spatial arrangement is related to route choice. Underpinning much of this research is the theory of natural movement, which contends that the way people use a public space depends on its spatial configuration (Hillier & Hanson, 1984). The term natural movement describes the potential power of the street network to automatically attract and influence a traveller’s movements (Griffiths, 2014; Hiller, 1996). This relates to two key measures: integration and choice. To obtain these measures we need to create an axial map. Each road and street in an urban network is represented by the longest and fewest sight-lines. The axial map then represents the degree of visibility and direction change of an urban area. Any turn from one axial line to another is called a syntactic step. The number of syntactic steps from one specific axial line to all other existing lines measures the value of topological depth. From the axial map we can calculate a connectivity graph, as shown in Figure 1. These processes can be performed efficiently using UCL’s Depthmap program. To calculate syntactic measures like integration and choice, the axial lines need to be divided into segments. Integration (closeness centrality) measures how close each segment is to all others within a given radius, based on the least angle measure of distance; or, in simple terms, how accessible that segment is from all other segments.
This relates to how much potential that segment has to be chosen as a destination, so it measures *to-movement*. By contrast, *Choice* (between-ness centrality) estimates all shortest paths between all possible origin-destination pairs in the urban grid and then calculates this possibility for each street segment, which is a segment’s *through-movement* potential (Hillier, 2007, p. 4). According to Hillier et al. (2005, p 556-557) in spatial configuration analysis those urban streets with high value of integration have greater potential to be chosen as a destination; those with higher choice value have greater potential to be chosen as a route.

Syntactic analysis of an axial map could be analysed based on three different methods: Metric distance, topological relationships, and angular changes. Angular and topological analyses are more advanced than metric analysis; indeed, the most powerful tool for measuring accessibility is angular segment-based analysis with metric radius (Hillier et al., 2012, p. 73; Hillier and Iida 2005). To analyse the syntactic characteristics of an urban area based on angular segment analysis, at first, axial lines need to be divided into segments. The normalized value of integration (NAIN) and choice (NACH) is measured by these formulas where XXX is the metric radius for each measure:

**NAIN**

\[
\text{Value ("T1024 Node Count RXXX metric")}^{1.2}/(\text{value ("T1024 Total Depth RXXX metric")} + 2)
\]

**NACH**

\[
\text{Log (value ("T1024 Choice RXXX metric") + 1)/ log (value ("T1024 Total Depth RXXX metric") + 3)}
\]
It is also possible to combine the integration and choice measures using this formula:

\[(NC/MD) \ast (\log (CH+2))\]

It should be noted that these space syntax studies have limitations, particularly as street layout does not necessarily determine the land uses that attract travellers. The locations of various land uses, such as offices, transport hubs and retail, influence the density of pedestrian volumes around them, and commercial street-fronts have the highest correlation to pedestrian movement (Chu, 2005). Including for land uses, such as commercial activity, in multivariate analysis, can provide a more refined assessment.

3. **Approach and Methods**

38 university students who were first-time visitors to Brisbane were recruited via targeted emails and posters placed in key buildings on a campus in the nearby City of Gold Coast. The use of posters for recruitment means we cannot establish a response rate. The sample comprised 15 men and 23 women. Their ages ranged from 18 to 56, with a mean of 26.8 years. They received AU$50 as an incentive and were reimbursed for local travel. All participants travelled from the Gold Coast to Brisbane’s Roma Street Station by train. Partly taking into consideration their own preferences (an element of self-selection) the participants were assigned to one of three groups: i) a “GPS Group” using GPS enabled mobile phones with a digital navigator (n=12); ii) a “Paper-Map Group” using a conventional 2D paper map for the CBD in the form of the main tourist map for central Brisbane (n=12); and, iii) a “Local-Signage-Only” group with no aids other than the local signage that is already in place in the built environment and who were provided a conceptual map/list of destinations only (n=14). The starting point was at Roma Street Station and the final meeting point was at a designated café in Southbank where debriefing was to occur (Figure 2). Participants walked alone and were asked to find seven predetermined tourist destinations. There was no assigned order to the destinations; the participants were free to put together their own itinerary, with significant variation as to how

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1 The GPS group were provided with a Samsung Galaxy J5 cellphone equipped with 4G service and the Google Maps, GeoTracker and Audio Recorder apps installed. Google Maps provided participants with a map of the surrounding area on a screen size of 14cm x 7cm with the user’s location dynamically updated as they walked. Participants in the paper-map group were given an A4-size tourist map of Brisbane as provided by tourist information centres across the city. There was no suggested route or other annotation on the map and they had to find the destinations and plan their preferred routes by themselves. Participants in the local-signage-only group were provided with an A4 size conceptual non-representational map, showing no street layouts and only vague locations of each destination to suggest an approximate direction/location. Participants in the paper-map and the local-signage-only groups were also asked to carry a Samsung Galaxy J5 cellphone with the GeoTracker and Audio Recorder apps installed but could not use of Google Maps. The GeoTracker app recorded all participants’ travel routes and travel time. The Audio Recorder app recorded their speech throughout the walk and participants were encouraged to “Think Aloud” when they made key navigational decisions. All participants were allowed to ask people on the street for navigational assistance only if they were unable to navigate via their navigational aids. A risk (health and safety) briefing also indicated they were to avoid any alleyway or other locations that made them at all feel unsafe.
they walked from the start to end points.

All participants were provided with devices that both recorded their movements via GPS and captured their voice through a microphone in a set of discrete in-ear headphones. Participants were asked to “Think Aloud” while making their route choices and finding their way, though we do not report at length on this aspect in this particular paper. The end destination of their walk was a café in the Southbank Parklands area, which offered a particular set of route choices, and challenges to wayfinding, for pedestrians crossing Brisbane’s Victoria Bridge.

The frequency with which each street or path segment was chosen by the participants was compared with those segment’s integration (to-movement), and choice (through-movement) values, and whether they had commercial land uses, recreational land uses and/or river frontage. The syntactical properties for the study area were obtained by first creating an axial map for the study area using AutoCAD software and then analysing it using Depthmap.

Land use data was obtained from Google Map and its Streetview function where necessary. Parcel-based data was categorized into commercial (shopping malls, retails, cafes, bars, restaurants, public carparks) recreational (museums, amusement and gathering spaces, parks, art centres, libraries) and “river”, which is an attractor for walking, cycling and more static activities in central Brisbane. To estimate the proportion of different land use along each street segment the length of front façade per 100m of street length were calculated (street frontage of each land use per 100m of street length).
4. Data Analysis

The syntactic characteristics of the study area are illustrated by thematic mapping in Figures 3, and Figure 4. The more the value of integration (to-movement) or choice (through-movement) the redder the colour of the line; the lower the value of integration/choice the bluer the line. Figure 3 shows the to-movement values of street segments in the Brisbane CBD. Streets with higher integration values include Queen Street (the city’s most important pedestrian mall), the Victoria Bridge, Grey Street, Melbourne Street, Merivale Street, and Vulture Street. This suggests these streets would be best suited for land uses requiring significant footfall (shops, cafes & restaurants, public transport interchanges and the like).

Figure 3: Axial analysis of Brisbane CBD weighted by Integration (r250)

Figure 4 shows the graph measured for choice value (r250). This indicates that Queen Street, Victoria Bridge, Grey Street, Vulture Street and Main Street have greater potential to be selected as segments when navigating from any origin point on the urban network to any destination within the specified radius (250m).
5. Results

The frequency of use of each road segment by each participant group was calculated, as shown in Figure 5. As some street segments were at locations participants were told to visit, these segments were only counted if participants had chosen them to pass by towards another destination (through-movement). If they used a street segment twice due to wrong route selection and backtracking it was counted only once.

Figure 5 shows that the route choice pattern differed across the three groups. For example, from starting point most of the people in the local-signage-only group (n=9) walked directly towards the Brisbane River and followed the river’s edges (Figure 5a). But, the majority of the participants in the paper map group (n=10), and all of the participants in the GPS group (n=12) started down from Roma Street which is the straightest route from the starting point to all other destinations (Figure 5b&5c). In the Southbank area, the differences across the three groups were even more pronounced. Most of the participants in the GPS group (n=8) followed the Arbour path in Southbank, a beautiful bougainvillea-lined walk that cuts directly through the parklands (Figure 5c). Most of the participants in the paper map group (n=8) chose Grey Street, which is a straight route with high to-movement and through-movement potentials (Figure 5b).
Figure 5: Heat map for travelled route by type of navigational aid

a: Local-signage-only group

b: Paper map group

c: GPS group

Frequency of segment use

- High
- Low

Starting Point
End Point
Half of the local-signage-only group ignored both those options (Grey Street and Arbour Path) and preferred to walk along the river’s edge (Figure 5a), which is a common strategy for unfamiliar visitors in such locations (Hutchins 1995). As confirmed by the voice recordings, the type of navigational aid available to participants strongly influenced their route choice decisions, especially as they exited the Victoria Bridge. The GPS group were effectively directed down the Arbour Path by their devices. The Arbour is a direct, yet winding route through the parklands, without good sightlines towards an end-destination, and therefore confusing for a visitor without GPS navigation. New visitors would be unaware this architectural feature travels the entire length of the parklands. Only the GPS navigators took up the option.

The integration (r250) and choice (r250) values for each segment were correlated against the total frequency of use for that segment, for each group (Table 1).

**Table 1:** Correlation between choice, integration and frequency of segment use, by group
(Numbers shown in bold = significance correlation; p<0.01)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Local-signage-only</th>
<th>Paper-map</th>
<th>GPS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Choice (r250)</td>
<td>Integration (r250)</td>
<td>Choice (r250)</td>
</tr>
<tr>
<td>Frequency of segment use</td>
<td>0.20</td>
<td>0.18</td>
<td>0.33</td>
</tr>
<tr>
<td>Choice (r250)</td>
<td>1</td>
<td>0.81</td>
<td>1</td>
</tr>
<tr>
<td>Integration (r250)</td>
<td>0.81</td>
<td>1</td>
<td>0.76</td>
</tr>
</tbody>
</table>

The paper map group and the local-signage-only group have frequencies of use that are as expected, showing strong positive relationships with both integration and choice. There seems little difference between the powers of the effect of choice vs. integration on the route choices of these two groups. Strikingly, the GPS group’s frequency of segment use had no discernible relationship with either integration or choice values. The multiple-interaction effects of the syntactical variables in combination with the land use variables (commercial land use, recreational land use and river edge), as the independent variables, on segment frequency of use (the dependant variable) was next explored. Preliminary analysis revealed the partial correlation between choice and integration was high, such that integration had to be removed from the following multivariate regression modelling. Table 2 provides outputs of the resulting multivariate regression analysis. Each column shows, first, the predictability of the model with
only the choice variable, and then in turn, the effect of adding the land use variables to the model (a similar approach to that of Kubat et al., 2012).

The results show that initially only around 12% of the total effect on the paper map group’s frequency of segment use can be explained by the choice variable ($R^2 = 0.12; p = 0.000$). After adding the land use variables to the model, this increased to 25% ($R^2 = 0.25; p = 0.000$). A similar shift can be seen with the local-signage-only group in how the effect of the choice value on frequency of segment use was very small in the initial model ($R^2=0.04, p=0.001$) but increased substantially with the addition of the land use variables ($R^2 = 0.19, p=0.000$). The choice variable had no meaningful effect on frequency of segment use for the GPS group, with or without the land use variables.

Table 2: Results of the multivariate regressions between the urban form measures and the frequency of segment use (Numbers shown in bold = significance correlation; $p<0.01$)

<table>
<thead>
<tr>
<th></th>
<th>Local-signage-only (N=243)</th>
<th>Paper map (N=163)</th>
<th>GPS (N=112)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Syntactical measure + Land use measures</td>
<td>Syntactical measure + Land use measures</td>
<td>Land use measures</td>
</tr>
<tr>
<td></td>
<td>$\beta$ $t$ $td \beta$</td>
<td>$\beta$ $t$ $td \beta$</td>
<td>$\beta$ $t$ $td \beta$</td>
</tr>
<tr>
<td>Constant</td>
<td>.81</td>
<td>.9</td>
<td>3.0</td>
</tr>
<tr>
<td>Choice</td>
<td>1.8 3.26 .2 2.2 4.07 .25 3.35 4.71 .34 4.11 5.58 .42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>River</td>
<td>.03 5.01 .30</td>
<td>.02 1.77 .12</td>
<td>.02 1.2 .12</td>
</tr>
<tr>
<td>Recreational</td>
<td>.01 3.33 .22</td>
<td>.02 4.07 .37</td>
<td>.01 1.7 .2</td>
</tr>
<tr>
<td>Commercial</td>
<td>.02 5.53 .37</td>
<td>.03 5.04 .43</td>
<td>.24 2.1 .29</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.04</td>
<td>0.12</td>
<td>0.25</td>
</tr>
</tbody>
</table>

There are subtle differences between the groups. As one might expect, the river-edge variable had no influence on either the paper map group or the GPS group, but was significant for the local-signage-only group. The highest standardized coefficients were mostly for the commercial land use variable for the paper map group and the local-signage only group, suggesting that these land use variables have a stronger influence on wayfinding behaviour in study area, as compared with the syntactic measure of choice.

6. Discussion

The paper’s contributions are mostly in demonstrating the ways in which GPS navigation is changing visitor’s route choice behaviour and their use of and interaction with the city. Though previous studies have considered the influence of syntactic properties, land use or navigational aids on wayfinding behaviour in isolation, we are not certain that any previous study has as yet tested their joint contribution. Our research confirms that the spatial configuration of urban layout has significant influence on route choice decision-making of visitors, but only for the paper map and local-signage-only groups. These two groups behaved much as we expected,
following routes with strong choice (through-movement) and integration (to-movement) values, in line with past studies (i.e. Hillier & Iida 2005). These groups continue to prefer to minimize their angle toward their destinations (Dalton, 2003; Kubat et al., 2012). But the paper map and local-signage-only groups were much more diffuse in their travels compared to the GPS group, collectively walking a much greater set of street and path segments and wandering much further. The GPS navigators behaved very differently. The results suggest that ubiquitous apps like Apple Maps and Google Maps are creating a set of first-time visitors who become rigid digital navigators. Once locked into this mode of wayfinding, they stick pretty closely to the turn-by-turn instructions provided them and generally walk along the shortest metric routes. There was great uniformity in the routes they choose to walk. These GPS navigators are unaffected by (or, emancipated from) the theory of natural movement. As heard repeatedly in their voice recordings, the digital device overpowers the effect of the city and its built form on their route choices.

Whether this is positive or negative is context dependent. Being on a shortest path can be beneficial to the navigator, at least in terms of reducing travel time and effort. And at times it can also mean experiencing parts of the city that would otherwise be avoided, as was the case of the beautiful Arbour bougainvillea pathway in South Bank Parklands. But it is a lottery as to what level of pedestrian amenity will be offered along a shortest path. There were numerous instances in our study where members of the GPS group eschewed more pleasant pedestrian environments for a shorter route.

The first and most obvious implication of all this is that urban planners and designers now need to consider the routes that will likely be suggested by GPS navigation in how they design, manage and operate street and pathway networks. A town’s high streets may not necessarily be on the shortest path between, say, a central public transport node and a major tourist attraction, especially when that public transport is retrofitted into an older urban fabric. Designers may need to use cues and signage to deliberately disrupt digital navigation. They may need to find new ways to help digital navigators to ignore the blue arrows and voice commands of their devices. Designers will need to experiment on the best methods to discourage digital navigators from taking less desirable routes and encourage them onto street segments with greater commercial and recreational activity. Maximising both positive tourist experience, and economic return from tourist visitors, may well rely on it.

One way forward may be in increasing the options available to GPS navigators within the digital apps themselves. At present the Google Maps app has few options for pedestrian route
directional guidance. Indeed in Brisbane, at the time of writing, one can really only select to “avoid ferries” (which strangely get coded incorrectly as pedestrian links) and to choose the unit of measurement (miles vs. km). Yet for public transport way-showing Google already offer such options as “less walking”, “fewer transfers” and something labelled “best route”2. Google’s driving and public transport algorithms have been built up from historical traffic data and information feeds from transport agencies. In the era of the Smart Cities movement and Big Data, where the internet giants obtain data daily from millions of iOS and Android users as they go about their daily travel, there must be opportunity to develop a richer set of options for pedestrian digital navigation. Others have already called for or started developing navigation settings to support communities with special mobility needs by minimizing barriers, limiting road crossings, and/or choosing routes with known curb ramps (Karimi et al. 2013). For the broader public some useful alternatives to shortest-path algorithms could be based on space syntax. Identifying these options, programming them into an app and testing them with real-world users is an avenue for future research.

Second, the findings emphasize the importance of considering land use in wayfinding studies. Table 2 suggested that, at least in the central Brisbane case, some land use variables were more powerful than syntactical measures in predicting route choice behaviour. This outcome is contrary to the findings of Kubat et al. (2012), who found no relationship between land use and visitors’ wayfinding behaviour in their study area, albeit in an environment that likely had a more homogenous set of land uses compared to central Brisbane. Future syntactical studies should look at the interplay between the two.

Third, the study showed how ‘locked in’ to digital wayfinding the GPS navigators became. We know from past research this can affect our urban experience, but it is not yet known quite how much they are changing us. Are pedestrian visitors guided by digital apps capable of the same acts of resistance to planning and design that de Certeau (1984, p93) identified. Do those who navigate their way by GPS on the Camino de Santiago pilgrimage, or other key cultural and recreational walking routes, have a different experience to those who try to read the landscape and follow the local signage? Are they more or less ‘present’ as they walk? These are questions for others to explore.

The limitations of this paper include the effects of having all participants start from the same origin point. Though this was necessary for us to obtain other metrics in our broader study, this

2 No further information is provided on this setting, but it may well involve known road traffic delays that will affect bus services
decision concentrated pedestrian trip-making on street segments close to the origin and destination of the wayfinding task. There are alternative research designs involving multiple origins to one destination across the city centre that might have revealed more about wayfinding behaviour. Our methods also trusted that participants followed the instructions provided to them throughout their wayfinding task. Voice recordings give us confidence that they did so, but without direct observation throughout we cannot be fully certain. The study is also placed in one Australian CBD only. Understanding how wayfinding is influenced by different navigational aids in cities with a distinctively pre-modern pedestrian street layout (i.e. Venice) would help further our understandings.

References


6. Effects of Urban Form and Navigational Aids on Navigators’ Social and Spatial Interaction with Space

- The work presented here in Chapter 6 has been submitted to the journal *Travel Behaviour and Society* as: Vaez, S., Burke, M., and Yu, R., Effects of urban form and navigational aids on navigators’ social and spatial interaction with space.

- First Submission on 20/02/2019

Previous chapter focused on the effects of urban form in terms of syntactical properties and land use, on wayfinding behaviour of navigators who used three different navigational aids. In line with previous chapter this paper summarizes the results of Task 3 and focuses on the social and spatial interaction of navigators who used three different navigational aids: a group with a paper map, a group with the Google Maps app, and a group relying on local signage only. Three methods were used to address the objectives of this study, including GPS tracking, space syntax, and think-aloud. All participants were asked to think aloud while walking, their voices were recorded and later transcribed. To find out the interaction between participants and their surrounding social environment in relation to wayfinding behaviour, the verbal utterance of each participant were analysed based on three types of situation related to social navigation: 1) *asking for assistance*, 2) *Following others* 3) *Avoiding the crowd*. Any situation related to asking for assistance, whether for the correct direction or to ensure they had found the correct destination were counted. In addition, any comment regarding following other people, whether for choosing a street or even a side of the street were counted. Using statistical analysis (Kruskal-Wallis H test) the social interaction of the three groups of participants were compared.

To examine the participants’ spatial interaction with space bivariate regression analysis were conducted to find out the relationship between urban form characteristics (syntactical properties) and the participants’ route choice decision making. This paper is the first study to compare the influence of navigational aids in shaping spatial and social behaviour in a real urban environment, considering its syntactic characteristics.

The outcome of study showed that the paper map and local-signage-only groups behaved much as expected, either following routes with strong choice (through-movement) and/or integration (to-movement) values, or using social navigation. While the GPS group were unaffected by the theory of natural movement and not only had less social interaction with their surrounding
environment, but also preferred to avoid the crowd.

Research questions addressed in this paper and contributions:

Primary Question:

**RQ3**: How do different navigational aids, including paper maps, GPS and local signage influence navigators’ interactions with their surrounding social and spatial environments?

Sub-question:

- How do urban form (syntactical properties) and navigational aids (GPS, paper map and local signage only) affect navigators’ wayfinding behaviour?

Summary of contributions:

1. The methodological contributions of this study:

   - The study is the first to use three methods of GPS tracking, space syntax and think-aloud in combination.

2. Practical and applied contributions of the study:

   - The study is the first to consider the effects of syntactical properties in route choice behaviour of three groups of participants who used different navigational aids.
   - This paper is the first study to compare the influence of navigational aids in shaping spatial and social behaviour, considering its syntactic characteristics.
   - Urban planners and designers now need to consider the routes that will likely be suggested by GPS navigation in how they design, manage and operate street and pathway networks.
   - Designers will need to experiment on the best methods to discourage digital navigators from taking less crowded streets that could be unsafe, and encourage them onto more crowded street segments with greater safety.

This chapter is an exact copy of the paper referred to above.
6.1 Statement of contribution to the co-authored published paper

This chapter includes a co-authored paper that summarises the results of Task 3. The bibliographic details of the co-authored paper, including all authors, are:

- Vaez, S., Burke, M., and Yu, R., Effects of urban form and navigational aids on navigators’ social and spatial interaction with space

<table>
<thead>
<tr>
<th>Contributors</th>
<th>Statement of contribution</th>
</tr>
</thead>
</table>
| Sima Vaez     | • Designed the data collection process, including the site selection, participant recruitment, and questionnaires.  
• Attended in the study area to conduct the wayfinding task and managed and trained the participants  
• Complied, cleaned and analysed the data  
• Conceived, planned and wrote the first draft of manuscripts  
• Managed the academic editorial process for the manuscript  
• Submitted and revised the manuscript at the suggestion of the conference reviewers.  
• Prepared presentation slides and presented the paper at the conference.  
• Managed journal submission as corresponding author.  
• Responsible for revisions made at the suggestion of the journal reviewers and resubmitting the paper. |
| Matthew Burke | • Provided assistance in the theoretical framing of the research.  
• Provided suggestions in response to journal reviewers.  
• Provided editing revisions in the initial and the reviewed manuscript. |
| Rongrong Yu   | • Provided assistance in the theoretical framing of the research.  
• Provided suggestions in response to journal reviewers.  
• Provided editing revisions in the initial and the reviewed manuscript.  
• Provided the methodological advice as an expert in the space syntax and think-aloud methods. |
The authors listed below have certified that:

1. They meet the criteria for authorship in that they have participated in the conception, execution n, or interpretation, of at least that part of the publication in their field of expertise;

2. They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;

3. There are no other authors of the publication according to these criteria;

4. They agree to the use of the publication in the student’s thesis and its publication on the Griffith University database consistent with any limitations set by publisher requirements.

(Signed) _________________________________ (Date) _____15/03/2019_________

Student and Corresponding Author: Sima Vaez

Supervisor Confirmation: I have obtained an email or other correspondence from all co-authors confirming their certifying authorship.

(Signed) ___________________________ (Date) ______________

Principal Supervisor: A/Prof Matthew Burke
EFFECTS OF URBAN FORM AND NAVIGATIONAL AIDS ON NAVIGATORS’ SOCIAL AND SPATIAL INTERACTION WITH SPACE

Abstract
This paper is an attempt to understand the influence of different navigational aids on shaping the navigators’ social and spatial interactions with their surrounding environment, using space syntax and think-aloud techniques. Previous space syntax studies have shown a strong relationship between syntactical features of urban space and pedestrian walking behaviour. However, few studies have focused on the role of street network pattern in pedestrians’ route choice behaviour. No study has as yet compared the influence of navigational aids in shaping spatial and social wayfinding behaviour in a real urban environment, considering its syntactic characteristics. 38 participants undertook a wayfinding task while they were thinking aloud in the city centre of Brisbane, Australia. The participants were assigned into one of three groups: i) those provided with the city’s main tourist paper map; ii) those provided with smart phones with Google Maps navigation; and, iii) those who had to rely on local signage only within the existing built environment. The paper map and local-signage-only groups behaved much as expected, either following routes with strong choice (through-movement) and/or integration (to-movement) values, or using social navigation. While the GPS group were unaffected by the theory of natural movement and had less social interaction with their surrounding environment.

Keywords: Wayfinding, Space Syntax, Navigational Aids, Urban Configuration, Social Navigation

1. Introduction
Wayfinding is a cognitive activity which is embedded in a complex social and spatial environment (Willis, 2009). The term describes a person’s ability, both cognitive and behavioural, to travel from an origin to an out-of-sight destination, by following the paths and routes between them (Blades, 1991; Garling et al., 1984; Gluck, 1991; Golledge, 1992). People use different strategies to navigate themselves, including route following, track following, screening, map reading, or just learning from other people, called social navigation. These are unknown knowns for navigators and they might not even be aware which strategy they use while navigating (Mollerup, 2016). In addition, asking others for direction could be considered as a direct social tool for navigation (Dieberger, 2003); and, navigators wayfind in a social dynamic environment. People as social actors have influence on each other’s route choice.
Environmental cues are the main available information that individuals can use to orient themselves in a local environment. For instance, when the destination is along an edge people prefer to follow that edge, such as a river side (Hutchins, 1995). Syntactical properties of street network, including integration and choice, is an influential factor is shaping navigators’ movement pattern. Street segments that have high integration or choice value have more potential to be chosen as a destination or passing route, respectively (Hillier et al., 2005).

Successful wayfinding to a desired destination can help navigators to gain a sense of safety and well-being (Lu, 2016, p 11). So different disciplines such as social geography, architecture, urban design and planning are interested in how people make sense of an unfamiliar urban environment to wayfind. It helps the signage design firms, such as Maynard and DotDash, to design effective way-showing systems to bring visitors to tourist attractions, or direct them towards public transport stations. On the other hand, the wide use of ‘digital’ wayfinding, through global-positioning-system (GPS) apps such as Apple Maps and Google Maps, has significantly changed the first-time visitors’ wayfinding behaviour, allowing them to follow turn-by-turn instructions delivered on-screen or via audio.

This paper seeks to understand how different navigational aids including local signage only, paper map and Google Maps application could influence navigators’ interaction with their surrounding social and spatial environment, using space syntax (Hillier et al., 1970) and think-aloud (Ericsson & Simon, 1980) methods. To find out the spatial relation between navigators and their surrounding urban environment the frequency with which each street segment was chosen by the participants was compared with those segment’s integration-r250 (to-movement), and choice-r250 (through-movement) values; and their social interaction was analysed through coding the think-aloud protocol based on social navigation related statements.

2. Background

People’s wayfinding behaviour and strategies have been analysed through various techniques, such as sketch map drawing (Lynch, 1960; Tversky, 1981), think-aloud (Passini, 1984) point out to invisible landmarks (Haq, 2001; Montello, 1991) eye-tracking (Kiefer et al., 2014). In an attempt to explain wayfinding behaviour several studies used space syntax to understand the interrelationship between space and individuals’ route choice behaviour. Many previous
space syntax studies focused on indoor space (Carlson et al., 2010; Hölscher & Brösamle, 2007), virtual space (Dalton, 2003; Natapov et al., 2016), some looked at the real urban environment (Kubat et al., 2012; Ozbil et al., 2011; Peponis et al., 2016). They have revealed that spatial arrangement is strongly connected to human movement pattern. Syntactic variables of spatial layout, such as measures of integration and connectivity, can predict individuals’ movement patterns (Peponis et al., 2016, Ozbil et al., 2011, Kubat et al., 2012). People prefer to minimize their angle toward their destinations (Dalton, 2003). During a navigation task individuals prefer to choose spaces with higher visibility measures (Kubat et al. 2012).

Wayfinding behaviour is assisted by navigational aids. With the ubiquity of “way-showing” tools such as paper maps, digital maps, smart phone navigators, and local signage, pedestrians are able to locate themselves in an unfamiliar environment and find their desired destinations. Each of these tools provides specific spatial information in particular ways, with a range of limitations in their use. Several studies have compared the wayfinding behaviour of persons using different navigational aids as well as spatial mental imagery generated from the use of different navigational tools. People who navigated using GPS devices or local signage only tended to be slower at undertaking wayfinding tasks than paper map users (Chang, 2015; Ishikawa et al., 2008). GPS navigators also drew poorer cognitive maps compared with those who used paper map or local signage only (Ishikawa et al., 2008). Those using local signage only can remember more details on landmarks; paper map users perform worse in recognizing spatial knowledge; GPS/3G-based mobile phone users can remember more information on route items and street names than paper map and local signage users (Chang, 2015). However, young adults who navigated by GNSS navigational aids had less social and sensory interaction with their surrounding environment (McCullough & Collins, 2018).

Building on this literature, this paper seeks to answer the question: How do navigational aids shape the navigators’ spatial and social interaction with their surrounding environment? Three groups of participants using different navigational aids were asked to find seven predetermined tourist destinations in the Brisbane CBD. To analyse the spatial characteristics of the study area the syntactic values of all the paths used by each group in terms of integration-r250 (to-movement), and choice-r250 (through-movement) values were compared with the frequency of route choice. The social interaction of participants with their surrounding environment was analysed through coding the think-aloud protocol based on the numbers of times they asked others for direction, followed the crowd, or avoided the crowd. The last code was identified based through the participants’ verbalized thoughts.
By undertaking this experiment in a real urban environment, the study offers better understandings of the role of navigational aids in shaping navigators’ social and spatial interaction with space.

3. **How the spatial structure is measured?**

Space syntax is a graph-based method for analysing spatial configuration at an urban design scale. It has allowed researchers to measure topological relationships between a specific node on an urban network to any other existing nodes (Penn, 2003). It has been used to analyse the urban morphology of organic cities (Karimi & Motamed, 2003) or cities with grid-like urban pattern (Haq & Berhie, 2018). The space syntax technique has mostly enabled researchers to investigate the influence of the urban environment as an object on the subjective spatial behaviour of urban users. In this regard Hillier (2012), in his theory of natural movement, suggested that the movement pattern of pedestrians and vehicles is influenced by spatial configuration of urban space. The term natural movement describes the potential power of the street network to automatically attract urban users’ movements (Griffiths, 2014; Hiller, 1996). In an urban network people’s natural movement refers to “going-to” and “going-through” (Seamon, 2015, p. 24), which can be quantitatively analysed.

The basis for space syntax analysis in urban studies is an axial map. Each road and street in an urban network would be represented by the longest and fewest sight-lines. In other words, an axial map represents the degree of visibility and direction change of an urban area. Any turn from one axial line to another is called a syntactic step. The number of syntactic steps from one specific axial line to all other existing lines measures the value of topological depth (Figure 1).

Syntactic analysis of an axial map could be analysed based on three different methods: Metric distance, topological relationships, and angular changes. The most powerful tool for measuring accessibility is the angular segment based analysis with metric radius (Hillier et al., 2012, p. 73). First the drawn axial map needs be analysed using UCL’s Depthmap program. To calculate syntactic measures like connectivity, integration and choice at first, axial lines need to be divided into segments. Integration (closeness centrality) means how close each segment is to all others within the given radius, based on the least angle measure of distance, in other words how accessible that segments is from all other segments, therefore how much potential it has to be chosen as a destination, so it measures *to-movement*. Choice (betweeness centrality) measures the degree to which each segment lies on least angle routes between all other pairs of segments within the given radius, which means *through-movement* potential (Hillier, 2007,
According to Hiller et al. (2005, p 556-557) in spatial configuration analysis those urban streets with high value of integration have greater potential to be chosen as a destination; those with higher choice value have greater potential to be chosen as a route.

4. Approach and methods

38 students from Griffith University’s Gold Coast Campus who had never previously travelled to the Brisbane CBD were recruited via targeted emails and posters placed in key buildings on campus. The use of posters for recruitment means we cannot establish a response rate. The sample comprised 15 men and 23 women. Their ages ranged from 18 to 56, with a mean of 26.8 years. They received AU$50 as an incentive and were reimbursed for local travel. All participants travelled from the Gold Coast to Brisbane’s Roma Street Station by train. Partly taking into consideration their own preferences (an element of self-selection) the participants were assigned to one of three groups: a group using GPS enabled mobile phones with a digital navigator (n=12), a group using a conventional 2D paper map for the CBD (n=12) and a group with no aids other than the local signage that is already in place in the built environment (n=14), they were provided by an abstract map showing the exact location of the destinations but excluding any street network. The starting point was at Roma Street Station and the final meeting point was at a designated café in Southbank where the post-test interview was to occur (Figure 2). Participants walked alone and were asked to find seven predetermined tourist destinations while they were thinking aloud. They were asked to verbalize their thoughts and feelings about the wayfinding task and their navigation choices. There was no assigned order to the destinations; the participants were free to put together their own itinerary, with significant

Figure 1: (a) A fictive urban system, its (b) axial map, and (c) connectivity graph (After Jiang & Claramunt, 2002, p. 2)
variation as to how they walked from the start to end points. All participants were asked to carry a Samsung Galaxy J5 device to record their movements via GPS tracker and their voices via voice recorder apps.

5. Data analysis

5.1 Space Syntax Analysis

The axial line map for the study area was drawn using AutoCAD software. The syntactic characteristic of each street segment of the study area is illustrated by thematic mapping (see Figures 3 & 4). The more the value of integration (to-movement) and choice (through-movement) the redder the colour of the line; and the lower the value of integration/choice the bluer the line. Figure 3 shows the hierarchy of to-movement capacities of street segments in the Brisbane CBD. Streets marked in red on the thematic axial map have more integration value in comparison to other streets; such as, Queen Street, Victoria Bridge, Grey Street, Melbourne Street, Merivale Street, and Vulture Street. This suggests these streets are best suited for land uses requiring significant footfall such as shops, cafes & restaurants, public transport interchanges and the like.
Figure 3: Axial analysis of Brisbane CBD weighted by Integration (r250)

Figure 4 shows the graph measured for choice value (r250). This indicates that Queen Street, the Victoria Bridge, Grey Street, Vulture Street and Main Street have greater potential to be selected when navigating from any origin point on the urban network to any destination within the specified radius (250m).

Figure 4: Axial analysis of Brisbane CBD weighted by Choice (r250)
5.2 Think-aloud Analysis

All participants were asked to think aloud while walking, their voices were recorded and later transcribed. To find out the interaction between participants and their surrounding social environment in relation to wayfinding behaviour, the verbal utterance of each participant were analysed and three types of situation related to social navigation was found based on both literature and participants’ think-aloud utterances: 1) asking for assistance *, e.g., “I need to ask someone”. 2) Following others**, e.g., “I assume I should follow the people where the mall is”. 3) Avoiding the crowd, e.g. “I think I will go to less crowded place because I have to look at my GPS while I am walking”.

6. Results

6.1 Spatial navigation behaviour

The frequency of use of each road segment by each participant group was calculated, (Figure 5). As some street segments were at locations participants were told to visit, these segments were only counted if participants had chosen them to pass by towards another destination (through-movement). If they used a street segment twice due to wrong route selection and backtracking it was counted only once.

Figure 5: Frequency of use for street segments by type of navigational aid

Figure 5 shows that the route choice pattern did differ across the three groups. Within the city area, nine of the fourteen participants in the local signage only group preferred to choose Makeston Street, which connects the starting point at Roma Street Station to the Brisbane

* Any comments related to asking others for correct direction or recognition of destination
** Any comments related to following others for choosing a street or side of the street
River, and then followed the river’s edge towards the other destinations. However, from the same starting point, most of the participants in the GPS group chose either George or Roma Streets, which are the two straight routes towards the other destinations, and have high value of choice-\(r_{250}\) (Figure 4).

In the Southbank area, the route choice behaviour differences across the three groups of participants were even stronger. Seven of fourteen participants in the local signage only group followed the river’s edge, which is a common wayfinding strategy for navigators with lack of knowledge about the surrounding environment (Hutchins, 1995). While, more than half of the participants in the GPS group followed the Arbour path in Southbank parkland, which is a pedestrian walkway covered in the beautiful, although it has low to-movement and through-movement potentials. Eight participants in the paper map group chose Grey Street, which is a straight route with high to-movement and through-movement potentials (Figures 3& 4).

The integration (\(r_{250}\)) and choice (\(r_{250}\)) values for each segment were correlated against the total frequency of use for that segment, for each group (Table 1). The paper map and local-signage-only groups have frequencies of use that are as expected, showing strong positive relationships with both integration (\(r_{250}\)) and choice (\(r_{250}\)). There seems little difference between the powers of the effect of choice (\(r_{250}\)) vs. integration (\(r_{250}\)) on the route choices of these two groups. Strikingly, the GPS group’s frequency of segment use had no significant relationship with either integration (\(r_{250}\)) or choice (\(r_{250}\)) values.

Table 1: Results of the bivariate regressions between the configurational variables and the

<table>
<thead>
<tr>
<th>Variables</th>
<th>Local-signage-only group (N=243)</th>
<th>Paper map group (N=163)</th>
<th>GPS group (N=112)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Choice ((r_{250}))</td>
<td>Integration ((r_{250}))</td>
<td>Choice ((r_{250}))</td>
</tr>
<tr>
<td>Frequency of segment use</td>
<td>0.20</td>
<td>0.18</td>
<td>0.33</td>
</tr>
<tr>
<td>Choice ((r_{250}))</td>
<td>1</td>
<td>0.81</td>
<td>1</td>
</tr>
<tr>
<td>Integration ((r_{250}))</td>
<td>0.81</td>
<td>1</td>
<td>0.76</td>
</tr>
</tbody>
</table>

frequency of segment use (numbers shown in bold = significance correlation; \(p<0.01\))

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6.2 Social navigation

Any utterances related to social navigation for choosing any segment or side of the street were extracted from the think-aloud protocols, including 1) asking for assistance, 2) Following others, 3) Avoiding the crowd.

The local-signage-only group gave more comments than the two other groups, and the GPS group gave fewer comments.

Table 2: Frequencies of comments per group and category. The percentage within condition are shown in parentheses.

<table>
<thead>
<tr>
<th>Commenting on</th>
<th>Local-signage-only group</th>
<th>Paper map group</th>
<th>GPS group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking for assistance</td>
<td>31 (1.9)</td>
<td>9 (0.6)</td>
<td>3 (0.2)</td>
</tr>
<tr>
<td>Following others</td>
<td>31 (1.9)</td>
<td>21 (1.4)</td>
<td>2 (0.1)</td>
</tr>
<tr>
<td>Avoiding the crowd</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>6 (0.4)</td>
</tr>
<tr>
<td>Total</td>
<td>62 (3.8)</td>
<td>30 (2.1)</td>
<td>11 (0.7)</td>
</tr>
</tbody>
</table>

There was a significant association between groups and how likely people were to ask for assistance in finding the correct direction or recognition of destination (H (2) = 19.3, p<.000). With a mean rank of 28.11 for local-signage-only group, 18.46 for paper map group and 10.5 for GPS group; the local-signage-only group asked for assistance significantly more than other groups. The Mann-Whitney Test showed that the frequency of asking for assistance for the GPS group was significantly less than two other groups, while the local-signage-only group significantly asked for assistance more than two other groups (Table 3).

There was a significant difference in the frequency of following others across the three groups, H(2)=6.1, p<0.05, with a mean rank of 23.3 for the paper map group, 21.5 for the local-signage-only group and 13.2 for the GPS group. The Mann-Whitney Test showed that the frequency of following others for the paper map group was not significantly different from the local-signage-only group .The GPS group significantly followed others less than two other groups (Table 2).

There was a significant difference between groups and the frequency of avoiding the crowd during the navigation (H (2) = 9.40, p<0.01), with a mean rank of 23.83 for the GPS group, 17.50 for the paper map and local-signage-only groups. The Mann-Whitney Test indicated that the frequency of avoiding the crowd for the paper map group was not significantly different from the local-signage-only group .The GPS group significantly followed others less than two other groups (Table 3).
Table 3: The results of the Mann-Whitney U-test for all pairs of groups

<table>
<thead>
<tr>
<th>Category</th>
<th>Groups</th>
<th>Mean Rank</th>
<th>Mann-Whitney U</th>
<th>Asymp. Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking for assistance</td>
<td>GPS, Paper map GPS, local-signage-only Paper map, local-signage-only</td>
<td>9.50, 15.50 7.50, 18.60 9.46, 16.96</td>
<td>36.00 12.00 35.50</td>
<td>.006 .000 .01</td>
</tr>
<tr>
<td>Following others</td>
<td>GPS, Paper map GPS, Local-signage-only Paper map, Local-signage-only</td>
<td>8.71, 16.29 9.25, 17.14 14.08, 13.00</td>
<td>26.50 33.00 77.00</td>
<td>.006 .006 .7</td>
</tr>
<tr>
<td>Avoiding the crowd</td>
<td>GPS, Paper map GPS, Local-signage-only Paper map, Local-signage-only</td>
<td>14.50, 10.50 15.80, 13.50 13.50, 13.50</td>
<td>48.00 56.00 84.00</td>
<td>.03 .02 1</td>
</tr>
</tbody>
</table>

7. Discussion and Conclusion
The paper’s contributions are mostly in demonstrating the ways in which GPS navigation is changing visitor’s spatial and social interaction with their surrounding environment, using space syntax and think-aloud methods. Though previous studies have considered the influence of navigational aids on the navigators’ social interaction, or the interrelation of syntactical properties of urban space on their route choice behaviour (Dalton, 2003; Hillier & Iida, 2005; Kubat et al., 2012) we are not certain that any previous study has as yet tested their joint contribution. The study also has a methodological contribution by using the combination of the space syntax and think-aloud methods.

The study findings confirmed that there is an interrelation between the type of navigational aid, and the navigators’ spatial interaction. The paper map and local-signage-only groups behaved much as we expected, either following routes with strong choice (through-movement) and integration (to-movement) values, which is in line with previous studies (Hillier & Iida 2005); or, in the case of the local-signage-only group, choosing routes with lower values, but that were a natural edge, along the Brisbane River (Hutchins, 1995). But the results also suggest that modern GPS navigation systems appear to overpower syntactic variables, such that digital navigators given turn-by-turn instructions by their hand-held devices are unaffected by (or emancipated from) the theory of natural movement, and they preferred to follow the offered routes by GPS which was generally the shortest metric paths. Therefore, it is necessary to
consider this new movement pattern in urban planning, such as designing suitable land use or public spaces in streets offered by the GPS based devices.

In the present study, the three different routes that the different groups chose in the Southbank area are particularly instructive. The GPS group were directed down the Arbour (see Figure 5) which is a direct, yet winding route through the parklands, without good sightlines towards an end-destination. New visitors would be unaware this architectural feature travels the entire length of the parklands. The results show that digital navigation, like paper maps and other navigational aids before them, are fundamentally altering our use of the city. While the GPS group were much more confined in their route choice behaviour, the paper map and local-signage-only groups walked a much greater set of streets and path segments and wandering much further.

On the other hand, the rise of GPS devices is changing visitors’ social engagement with space. Whether positive or negative, relying on GPS has reduced using social navigation strategy among navigators, including asking others for assistance and following others, and new types of wayfinding strategies, such as “avoiding the crowd” is arising. According to the participants’ think-aloud utterance, on the contrary to the paper map and local-signage-only groups, who preferred to follow others and direct themselves towards more crowded areas to benefit from social interaction, some people in the GPS group preferred to walk in the less crowded areas in order not to interrupt pedestrians’ walking and have time to find the right route in their smart phones with more comfort. Although GPS might allow the navigators to independently navigate in unfamiliar environments, at the same time, it is making them “anti-social”. In an unfamiliar environment, this “anti-social” behaviour can also directs them towards “anti-social paths”, which are less crowded and could be unsafe to walk in. As, the Brisbane CBD is a safe place for visitors and offered route by GPS are well-designed and planned for tourists, further studies are required to have clear understanding about all these.

Similar to previous studies (McCullough & Collins, 2018), local-signage-only group significantly had more social interaction, in terms of asking for assistance, than two other groups. However, there was no significant difference between paper map and local-signage-only groups for following the crowd. Crowded streets influenced route planning of some participants in the paper map group (e.g. I changed my mind, there is more people in this street, or, there is no one in this street so I take another one), however, it seems the wide use of GPS navigation has negatively influenced the map literacy among young adults. Consequently, some participants in paper map group preferred to rely on others rather than their navigational aid
(e.g. I am not sure which street I should take, I go that way it looks like a street mall it is too busy).

Limitations of this study include the effects of having all participants start from the same origin point. Though this was necessary for us to obtain other metrics in our broader study, this decision concentrated pedestrian trip-making on street segments close to the origin and destination of the wayfinding task. There are alternative research designs involving multiple origins and destinations across the city centre that might have revealed more about route choice behaviour. Our methods also trusted that participants followed the instructions provided to them throughout their wayfinding task. We also have only undertaken this study in only one Australian CBD. Understanding how social and spatial interaction is influenced by different navigational aids in cities with different social and spatial structure would help further our understandings.

References:


7. Pedestrian Wayfinding Strategies and Navigational Aids in an Unfamiliar Urban Environment

The work presented here in Chapter 7 has been submitted to the journal *Environment and Behavior* as:

- Vaez, S., Burke, M., and Yu, R., Pedestrian Wayfinding Strategies and Navigational Aids in an Unfamiliar Urban Environment
- First Submission on 10/03/2019

In line with previous chapters that examined the relationship between environment and wayfinding behaviour of navigators who used different navigational aids, this paper summarises the results of Task 4 and focuses on the differences of wayfinding strategies used by three groups of navigators used three different methods of wayfinding: *google maps* app, paper map, and signage only. Two main methods were used: think-aloud and GPS tracking. Using GPS tracking method allowed us to compare the wayfinding performance of the three groups of the participants in terms of their route choice behaviour, travelled distance, and travel duration. Key studies have investigated people’s wayfinding behaviour and strategies in the complex buildings (Schnitzler & Hölscher, 2015), using think-aloud method. But it is still unclear how digital navigation is changing how visitors make sense of an unfamiliar outdoor environment and navigate through it, and how digital navigation affects their wayfinding and route planning strategies. This study seeks to obtain deeper insights into navigators’ orientation strategies, using different navigational aids, during a wayfinding task in an unfamiliar urban environment. All the three groups of participants were asked to think aloud while navigating and finding the predetermined destinations. All the utterances were transcribed and, using NVIVO 11, were coded into four main categories regarding the components of wayfinding behaviour (based on the literature), including: *decision making, wayfinding strategy, route control* and *closure*. In addition, participants’ statements were classified into eight categories found in the descriptive statements participants made during their navigation. Participants’ utterances were also analysed based on the frequency of asking others for direction and using the local signage.

The statistical analysis (Kruskal-Wallis H test) revealed significant differences between the three groups of navigators in terms of the strategies of wayfinding they used, as well as their strategies for route control and closure. There were also differences between the groups as to
how likely participants were to use asking others for direction and their overt local signage usage.

Type of navigational aid had significant influence on mentioning anticipatory and recognition statements. ANOVA analysis showed significant difference across groups in terms of their wayfinding performance.

Research questions addressed in this paper and contributions:

Primary Question:

RQ4: How do different approaches to wayfinding, such as paper maps, GPS and local signage, affect navigators’ wayfinding strategies in unfamiliar urban environments?

Sub-question:

- How do navigational aids (GPS, paper map and local signage) affect navigators’ wayfinding performance?
- How do navigational aids (GPS, paper map and local signage) affect navigators’ wayfinding experience, in terms of feelings, emotions, …?

Summary of contributions:

1. The methodological contributions of this study:

   - The study is the first to use three methods of GPS tracking, think-aloud and post-test interview in combination, at this scale of urban space.

2. Practical and applied contributions of the study:

   - The study is the first to consider the effects of navigational aids on wayfinding strategy of navigators in an urban space
   - Urban planners and designers now need to consider the routes that will likely be suggested by GPS navigation in how they design, manage and operate street and pathway networks.
   - The outcome of this study could improve the effectiveness of navigational aids
   - We can bring much of what we have found out about wayfinding strategies from studies inside buildings across to the urban neighbourhood scale.

This chapter is an exact copy of the paper referred to above.
7.1 Statement of contribution to the co-authored published paper

This chapter includes a co-authored paper that summarises the results of Task 4. The bibliographic details of the co-authored paper, including all authors, are:

- Vaez, S., Burke, M., and Yu, R., Pedestrian Wayfinding Strategies and Navigational Aids in an Unfamiliar Urban Environment

The authors listed below have certified that:

1. They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
2. They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
3. There are no other authors of the publication according to these criteria;
4. They agree to the use of the publication in the student’s thesis and its publication on the Griffith University database consistent with any limitations set by publisher requirements.

<table>
<thead>
<tr>
<th>Contributors</th>
<th>Statement of contribution</th>
</tr>
</thead>
</table>
| Sima Vaez    | • Designed the data collection process, including the site selection, participant recruitment, and questionnaires.  
|              | • Attended in the study area to conduct the wayfinding task and managed and trained the participants  
|              | • Conceived, planned and wrote the first draft of manuscripts  
|              | • Managed the academic editorial process for the manuscript  
|              | • Submitted and revised the manuscript at the suggestion of the conference reviewers.  
|              | • Prepared presentation slides and presented the paper at the conference.  
<p>|              | • Managed journal submission as corresponding author. |</p>
<table>
<thead>
<tr>
<th>Name</th>
<th>Contributions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matthew Burke</td>
<td>• Responsible for revisions made at the suggestion of the journal reviewers and resubmitting the paper.</td>
</tr>
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<td></td>
<td>• Provided assistance in the theoretical framing of the research.</td>
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<td>• Provided suggestions in response to journal reviewers.</td>
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<td>• Provided editing revisions in the initial and the reviewed manuscript.</td>
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<tr>
<td>Rongrong Yu</td>
<td>• Provided assistance in the theoretical framing of the research.</td>
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<tr>
<td></td>
<td>• Provided the methodological advice as an expert in think-aloud method.</td>
</tr>
</tbody>
</table>

(Signed) _________________________________ (Date) ______15/03/2019_______

Student and Corresponding Author: Sima Vaez

Supervisor Confirmation: I have obtained an email or other correspondence from all co-authors confirming their certifying authorship.

(Signed) ___________________________ (Date) ______________

Principal Supervisor: A/Prof Matthew Burke
PEDESTRIAN WAYFINDING STRATEGIES AND NAVIGATIONAL AIDS IN AN UNFAMILIAR URBAN ENVIRONMENT

Abstract

Digital navigation apps on smart phones are changing how people find their way through cities. However, digital navigators do not have to solely rely on their app; they may also be influenced by local signage and the properties of the built environment. The way visitors to a new city wayfind in the digital era has been given less research attention than might be expected. The main aim of this study is to examine differences in wayfinding strategies between three groups of participants who used different navigational aids: a group with a paper map, a group with the Google Maps app, and a group relying on local signage only. Methods included GPS tracking, and voice recording of decision-making using the think-aloud method. 38 participants who had never visited Brisbane, Australia, were recruited and placed in one of the three groups. They undertook a two-hour pedestrian wayfinding task and other research activities in the city centre. The results show there are significant differences in wayfinding strategies used by the three groups of participants. The GPS group preferred to follow the suggested route by their navigator, most of them ‘locking in’ as digital navigators throughout the task. By contrast, the local-signage-only group used a diverse range of strategies to wayfind. Local-signage-only and paper map users tried to locate their position in the city by using piloting or path integration strategies, the GPS group just passively followed the guidance line showed by their device. On completion of the task the digital navigators recognized less spatial information. Surprisingly, the digital navigators did not feel less anxious compared with the two other groups. Urban planners and designers may need to re-think their design strategies to interrupt digital navigation. The provision of a more diverse set of digital navigation options, rather than just shortest-path route identification, is likely desirable to assist navigators who wish to experience more on their pedestrian journeys.

1. Introduction

Wayfinding is an essential part of people’s everyday life; it enables them to experience their local neighbourhood and explore new places (Hunter, Anderson, & Belza, 2016, p. 4). Successful wayfinding can contribute to a sense of safety and well-being for navigators (Lu, 2016, p. 11). Different disciplines such as social geography, architecture, urban design and planning have sought to understand how people make sense of an unfamiliar urban environment.
environment and to navigate. Wayfinding includes several key tasks, such as destination decision making, route planning, moving towards out-of-sight locations, and cognitive mapping (Tenbrink & Wiener, 2006). Cognitive mapping refers to the process of perceiving and storing environmental knowledge while navigating from place to place (Lynch, 1960). People rely on their generated mental maps to recall routes and find the correct way to their destinations in a familiar urban environment (Mondschein, Blumenberg, & Taylor, 2013). Using these mental images, people build a personal urban model that helps them make sense of an unfamiliar built environment and navigate through (Appleyard, 1973, p. 97). However, to successfully wayfind in an unfamiliar environment, people often have to rely on navigational aids or ask others to assist them (Chang, 2015). The ubiquity of navigational aids, such as signage systems, paper maps, and global positioning systems (GPS) and digital maps, allow people to orient themselves in an unfamiliar environment and find their desired destinations. These navigational aids provide specific spatial information in different ways, with most users using this information whilst also scanning and trying to make sense of their immediate surrounding environment.

Research on the role of navigational aids in mental image generation has proliferated in recent decades (Aslan et al., 2006; Chang, 2015; Ishikawa et al., 2008; Ishikawa & Montello, 2006; Siegel & White, 1975; Willis et al., 2009). Key studies have investigated people’s wayfinding behaviour and strategies in the complex buildings (Schnitzler & Hölscher, 2015). But it is still unclear how digital navigation is changing how visitors make sense of an unfamiliar outdoor environment and navigate through it, and how digital navigation affects their wayfinding and route planning strategies.

This study seeks to obtain deeper insights into navigators’ orientation strategies during a wayfinding task in an unfamiliar urban environment. The main method used is the think-aloud technique (Ericsson & Simon, 1985) that provides better understanding about the significance of wayfinders’ decision making process and orientation strategies. The focus of this paper is on the influence of different navigational aids on wayfinding behaviour in a larger-scale urban environment, not inside a building or small precinct. This is believed to be the first study using think-aloud in combination with other research methods, at this scale. Three groups of participants were asked to find seven predetermined tourist destinations in Brisbane’s city centre using either: i) paper maps, ii) GPS navigation, or iii) local signage systems only.

The paper follows a conventional structure. The next section provides key theoretical and conceptual understandings of wayfinding. This is followed by the approach and methods of the
study and then the results, which focus on such issues as differences in route control behaviours, use of local signage and asking for directions from others.

2. Wayfinding Behaviour and Strategies

Wayfinding is the process of finding and following the correct routes between an origin and a desired destination using environmental cues (Farr, et al., 2012, p. 715). It can be broken into three interrelated processes: decision making (development of an action plan, based on the environmental information), decision execution (transformation of the action plan into an appropriate behavioural action), and information processing (spatial knowledge acquisition and cognitive mapping) (Passini, 1984). So, wayfinding behaviour could be conceptualized as an interaction between navigators and their surrounding environment whilst moving from an origin to a destination. Therefore, wayfinding behaviour is a combination of cognition and motion in space (Hunter et al., 2016, p. 6).

Wayfinding consists of four main component starts with orientation and route planning, where am I now? After orientation and considering the nearby landmarks, the desired destination can be chosen based on different reasons, such as distance to the destination, ease of accessibility, and so on. Then the navigator comes to the second component which is route selection. In any given trip navigators need to choose a route that eventually will reach the desired destination. While, following the selected route, the navigators need to make sure they are on the right track, which is the third component of wayfinding called route control. Two types of orientation mechanisms help the navigators to orient themselves in the environment: piloting (Etienne, 1992) and path integration; sometimes called dead reckoning (Denny, 2012; Trumble, et al., 2016). Through the piloting strategy, the navigator uses a visible landmark to determine the location of a nonvisible target. Path integration is the ability of the navigators to orient themselves considering the distance and direction change to the starting point (Foo et al., 2005, p.195).

The last phase is recognition of destination or closure (e.g. is this the hotel that I am after?); navigators need to make sure they have found their desired destination (Downs & Stea, 1973, Vandenberg, 2016).

Individuals choose different strategies to be successful. Lynch (1960, p.3) proposed five basic urban elements that can help urban navigators create a mental image of the city and consequently facilitate their wayfinding: edges, paths, landmarks, districts and nodes. In the past, landmarks have played an especially important role in navigators’ spatial knowledge...
acquisition and wayfinding behaviour (Caduff & Timpf, 2008; De Condappa, 2016). In a wayfinding task navigators can use visible landmarks as a reference point to orient themselves (Foo et al., 2005; Siegel & White, 1975). A second strategy, route-based navigation, is slightly more complex and relies on remembering the sequence of paths between landmarks, including turns, intersections, vistas and so on (Foo et al., 2005, p.195). A third and more complex strategy is using survey knowledge, as acquired from the individuals’ cognitive map of the environmental layout (Allen, 1999; Foo et al., 2005; Golledge, 1999). Using survey knowledge enables navigators to have a birds-eye view of the urban layout and to know the location of urban elements, routes and landmarks as they relate to one another. Landmark, route and survey knowledge are the three main approaches to wayfinding that individuals can use as a preferred style of spatial information learning (Vandenberg, 2016, p. 17). Lawnton (1996) showed how people may switch from one strategy to another during a wayfinding task.

Mollerup (2005, pp-45-67) provided a more expansive typology of nine main strategies including track following (following an edge without stopping), route-following (using a route knowledge provided before or during the task to follow the correct route), educated seeking (using wayfinding knowledge gained through previous experiences), inference (following the logical pattern of numbers, names,…), aiming (moving toward a visible target), screening (systematically observation of an area till finding the destination), map reading (planning the best route based on the route knowledge gained by map) compassing (using cardinal direction), and social navigation (learning from others e.g. following the crowd). To complete a wayfinding task, navigators might use a combination of some or all of these nine methods (Dieleman, 2014). There is a question then of where the new forms of digital navigation sit within this typology. In our view, digital navigation using GPS tracking presented on a smart phone mapping app, is a particular form of route-following.

2.1 Navigational aids and wayfinding

Previous studies have investigated different influential factors on wayfinding strategies, including gender (Bangel, 2009; Chang, 2013; Lawton & Kallai, 2002), sense of direction (Kato & Takeuchi, 2003), culture (Bangel, 2009), building structure (Hölscher et al., 2006), urban network (Dalton, 2003; Hillier & Iida, 2005; Kubat et al., 2012) and navigational aids (Schnitzler & Hölscher, 2015). Navigational aids the maps, directional signage and GPS systems people use are an external representation of the environment (Golledge, 1999; Montello & Sas, 2006). Each of these aids provides specific spatial information in particular ways, with a range of limitations in their use. Maps have been shown to allow more efficient
navigation of urban spaces (Chang, 2015); and a key study found no significant difference between wayfinding efficiency accomplished by using either a paper or digital map while navigating a complex building (Schnitzler & Hölscher, 2015). Map users and non-map users have both been found to have the same general wayfinding strategy preferences for navigation in a building (Hölscher et al., 2009). Somewhat contrary to expectations, GPS navigators can feel more lost and make more mistakes compared with paper map and signage-only-users (Chang, 2015). GPS users have more tendency to use a survey-based wayfinding strategy, while hand drawn map users prefer to use the route-based strategy (Chang, 2013). People who navigated using paper maps have been found to be quicker at completing wayfinding tasks than GPS, or local-signage-only users (Chang, 2015; Ishikawa et al., 2008). But the overall research base is limited, with few studies of GPS navigation, compared to other approaches, in the real world. We found no previous research that has compared GPS navigation, paper maps and map-free navigation, and used methods that reveal individual’s wayfinding strategies, outside of buildings.

3. Approach and methods

3.1 Data Collection

This paper seeks to understand the effect of navigational aids, including GPS, paper map and signage-only, on individual wayfinding strategies in a large scale urban environment. 38 students from Griffith University’s Gold Coast Campus [15 men and 23 women] were recruited via email and from posters placed strategically on campus (the use of posters prevents us from establishing a response rate). Participants were from 18 to 56 years-of-age, with a mean of 27 years. The area covering the Brisbane central business district (CBD) including South Bank was chosen as the study area (Figure 1). Only participants who had not travelled to this area previously were selected, to ensure unfamiliarity. Participants travelled from the Gold Coast to Roma Street railway station by train. Participants were asked to walk out of the station and find seven predetermined destinations in the study area: the Brisbane City Hall, Queen Street Mall, St Stephen’s Cathedral, the Cultural Centre Busway Station, South Bank Beach, South Bank Railway Station, and eventually a specific cafe in South Bank where final debriefing occurred. Participants were assigned to one of three groups, taking into account their own preferences: a group using GPS enabled mobile phones with a digital navigator (n=12), a group using a conventional 2D paper map for the CBD (n=12) and a group with no aids other than the local signage system that is already in place in the built environment (n=14). Participants in the paper map group were provided an A4-size tourist map of Brisbane, supplied by tourist information
centres in the city. There was no suggested route or other annotation on the map and they had to find the destinations and plan their preferred routes by themselves.

![Figure 1: Map of the study area](image)

Participants in the GPS group were given a Samsung Galaxy J5 mobile phone equipped with 3G service and the Google Maps app. This displayed a map of the local area on a screen size of 14 cm x 7 cm with the location of the user on the map dynamically updated. These participants were asked not to use the voice navigation option, but a suggested route and turning information was provided by the app.

The local-signage-only group received only a conceptual non-representational map on A4 paper, showing only vague locations of each destination to help them know the approximate direction of travel, without street or other landmark information.

All participants were allowed to take rest breaks during the wayfinding task. All of the groups were allowed to get assistance for directions from others only if they were unable to navigate via the built environment and their navigational aids alone. Participants were asked to “think aloud” and verbalize their thoughts, in English, about the wayfinding process, the buildings, streets, the signs, the maps, their feelings and whatever came to their minds. Voice recorder and GeoTracker apps on the provided smart phones recorded participant’s voices and routes travelled. Voice recordings were transcribed and coded based on the frequency of getting lost, getting confused, making mistakes and asking other people. Geotracking provided the length of time taken by the participant, as well as their travelled route. The data collection process was completed from June to October 2017.
3.2 Verbal Data

The think-aloud method (Ericsson & Simon, 1980) was employed to help identify differences in wayfinding strategies between the three groups of participants who used different navigational aids. Think-aloud asks participant’s to vocalize their decision-making processes, with this speech recorded and analysed by the research team. It provides rich verbal data about reasoning during wayfinding, and the strategies being employed by navigators.

The method is well-used in wayfinding research (see Hölscher et al., 2009; Hölscher et al., 2006; Kato & Takeuchi, 2003; Passini, 1984; Schnitzler & Hölscher, 2015). Using the think-aloud method, Kato and Takeuchi (2003), examined differences in wayfinding strategies between participants with a good sense of direction and those with a poor sense of direction. Schnitzler et al. (2015), compared the wayfinding strategy choices of navigators who used different navigational aids to wayfind through a complex building. It is believed that this paper is the first study to consider the influence of different navigational aids on people’s wayfinding strategies in a large urban layout by using the think-aloud method.

After transcription, the participants’ statements were segmented; with one segment of utterance defined as the continuous statement which occurs between two pauses (Kato & Takeuchi, 2003). Two rounds of coding were then conducted by a single researcher with a time interval of two weeks (Yu & Gero, 2015). All the task related statements were coded based on the literature and participants’ utterances, and classified into four main categories regarding the components of wayfinding behaviour, including: decision making, wayfinding strategy, route control and closure. Each category consists of several sub-categories, as shown in Table 2. All the statements were classified into eight categories found in the descriptive statements participants made during their navigation, as shown in Table 2. Krippendorff’s α (alpha) statistics suggested that two rounds of coding had a good agreement in all categories (all α’s between 0.72 and 1).

4. Results

4.1 Wayfinding performance

The average distance travelled to find all destinations helps indicate the effectiveness of the navigation aid on performance. Table 1 lists the average travel time, the average distance travelled, and the average walking speeds across each group of navigators. Average travel time is a less reliable indicator of performance, due to variability in breaks taken by the navigators. The local-signage-only group had the longest average distance travelled, the longest average
travel time, and (possibly due to the greater distances covered) the fastest average walking speed. A one-way, between-subjects ANOVA was conducted which showed the difference in the average travel times across the groups were not statistically significant at the 95% confidence level. But the average distance travelled was significantly different between groups \( F(2, 35) = 3.71, p < 0.05 \), as was their average walking speed \( F(2, 35) = 3.5, p < 0.05 \). Post-hoc paired comparisons showed that the average distance travelled as well as walking speed of the local-signage-only group was significantly greater than that of the GPS group \( p < 0.05 \). However, statistically there was no significant differences in the average distance travelled and walking speed between the paper map group and the two other groups.

**Table 1: Wayfinding performance of the three groups**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Average distance travelled (km)</th>
<th>Average travel time (h)</th>
<th>Average walking speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS</td>
<td>5.47</td>
<td>1:46</td>
<td>3.1</td>
</tr>
<tr>
<td>Paper map</td>
<td>6.03</td>
<td>1:47</td>
<td>3.3</td>
</tr>
<tr>
<td>Signage-only</td>
<td>6.47</td>
<td>1:52</td>
<td>3.4</td>
</tr>
</tbody>
</table>

4.2 Analysis of verbal data

The verbal utterances of each participant during the wayfinding task were analysed for any comments about: 1) wayfinding behaviour (decision making, strategy, route control, closure); 2) local-signage usage; and, 3) descriptive statements (anxious, uncertain, anticipatory, positive, negative, recognition, rehearsal, and mistake making). A set of categories were generated based on utterances and the literature (Hunter et al., 2016; Kato & Takeuchi, 2003; Siegel & White, 1975). Table 2 shows examples of participants’ utterances in each category.

**Table 2: Categories and exemplar utterances made during the wayfinding task**

<table>
<thead>
<tr>
<th>Wayfinding Behaviour</th>
<th>Destination decision making</th>
<th>Wayfinding strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shortest distance</strong></td>
<td>“I first go to the City Hall because it is the nearest one”</td>
<td></td>
</tr>
<tr>
<td><strong>Clockwise</strong></td>
<td>“I prefer to start from left and see the cathedral and go towards the other destination in the right”</td>
<td></td>
</tr>
<tr>
<td><strong>Route following</strong></td>
<td>“I see the signage point to the city hall so I follow this route.”</td>
<td>“I prefer to walk along the highway, I assume it will reach somewhere important”</td>
</tr>
<tr>
<td><strong>Edge Following</strong></td>
<td></td>
<td>“I go towards North where the cathedral is located”</td>
</tr>
<tr>
<td><strong>Compassing</strong></td>
<td></td>
<td>“Streets beach is located behind these buildings, so I go to the right” or “Cultural Centre is on the other side of the river, so I go towards the river”</td>
</tr>
<tr>
<td><strong>Aiming</strong></td>
<td></td>
<td>“I see many cafes on this street I go and have a look to find the Cowch café”</td>
</tr>
</tbody>
</table>

**Screening**
Educated seeking “I assume the Streets beach should be located near the river, so I go to there”

Social navigation “I see a group of tourists over there so maybe Queen street mall is there”

Chance “Oh I accidently found the Cowch café that I need to come to at the end”

Route control

Piloting “City Hall is near the conservatorium, so I am close to it”

Dead reckoning “Roma street station is behind me now and I should go a bit further to reach the City Hall”

Cardinal direction “The church is located in the North and I walking to North, so I am on the right track”

Closure

Asking others for confirmation “Is this City Hall?”

Semiotic “I see a white building with a clock tower so I assume I found the City Hall”

Name of place “I am looking for a sign to make sure it is City Hall, yes it is”

Descriptive statements

1. Anxious: Expression of unpleasant and stressful emotions related to wayfinding, e.g. “I am so confused”, or “I feel lost”, “I feel so nervous now”

2. Uncertain: Expression of uncertainty in wayfinding decisions, e.g. “I am not sure if I am on the right direction”.

3. Anticipatory: Prediction of what will be seen or happen related to wayfinding, e.g. “I should see the cathedral at the next intersection”.

4. Positive: Expression of any positive emotion about the environment, e.g. “Such a beautiful place”

5. Negative: Expression of any negative comment about the environment, e.g. “bad smell, smoke is everywhere”

6. Recognition: Remembering any urban element that had seen before, e.g. “I was on this street before”

7. Rehearsal: Route planning before beginning the journey, e.g. “I should go straight after two blocks turn left then turn right on Ann street”

8. Mistake making: Expression of making mistakes in wayfinding e.g. “I am going the wrong direction” or, “I am making a loop”.

4.2.1 Wayfinding behaviour

Participants’ utterances showed there were two main approaches to initial destination decision making in the wayfinding task. 36 participants decided to begin by walking to the closest destination. Two participants (one in the GPS group; one in the paper map group) decided to follow a clockwise route, presumably in an attempt to minimize travel distance. There was no significant association between group and participants’ destination decision making.

Wayfinding strategies used differed across the groups, including in the categories route-following (H (2) = 19.96, p=.000), edge-following [H (2) = 12.5, p=.002], compassing [H (2) = 14.34, p=.001], aiming [H (2)= 12.29, p=.000], screening [H(2) = 16.66, p=.000], educated seeking [H(2) = 6.7, p=.03], social navigation [H(2)= 12.05, p=.002], and chance [H(2)= 6.09, p=.04]. Table 3 shows the Mann-Whitney tests between pairs of groups. Importantly, Table 3 shows no significant difference between the paper map navigators and the GPS navigators in using route-following, edge-following, compassing, aiming, screening, educated seeking, or

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1. Categories 1, 2, 3, 6, 7 are driven from Kato & Takeuchi (2003, p177).
social navigation strategies. As would be expected, the local-signage-only group used the route following strategy less than these other two groups. But the local-signage-only group used edge-following, compassing, aiming and screening strategies significantly more than the other two groups. The local-signage-only group also used educated seeking and social navigation strategies significantly more than the GPS group. As expected, the GPS group found their destinations by chance significantly less than the two other groups. But, somewhat unexpectedly, the paper map and the local-signage-only groups did not differ in the proportion of wayfinding by chance.

**Table 3:** The Mann-Whitney test results between pairs of groups for wayfinding strategies

<table>
<thead>
<tr>
<th>Category</th>
<th>Groups</th>
<th>Mean rank</th>
<th>Mann-Whitney U</th>
<th>Asymp. Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route-following</td>
<td>GPS, Paper map</td>
<td>12.08, 12.92</td>
<td>67</td>
<td>.7</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>19.08, 8.7</td>
<td>17</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>19.08, 8.07</td>
<td>8</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>GPS, Paper map</td>
<td>12, 13</td>
<td>66</td>
<td>.3</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>9.5, 16.93</td>
<td>36</td>
<td>.002</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>10.33, 16.21</td>
<td>46</td>
<td>.02</td>
</tr>
<tr>
<td>Compassing</td>
<td>GPS, Paper map</td>
<td>11.5, 13.5</td>
<td>60</td>
<td>.1</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>9, 17.3</td>
<td>30</td>
<td>.004</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>9.83, 16.64</td>
<td>40</td>
<td>.01</td>
</tr>
<tr>
<td>Aiming</td>
<td>GPS, Paper map</td>
<td>12.5,12.5</td>
<td>72</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>6.5,19.5</td>
<td>.00</td>
<td>.00</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>6.5,19.4</td>
<td>1</td>
<td>.00</td>
</tr>
<tr>
<td>Screening</td>
<td>GPS, Paper map</td>
<td>11.2, 13.7</td>
<td>57</td>
<td>.2</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>7.8,18.3</td>
<td>16.5</td>
<td>.00</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>8.7,17.5</td>
<td>27</td>
<td>.003</td>
</tr>
<tr>
<td>Educated seeking</td>
<td>GPS, Paper map</td>
<td>12.4, 12.5</td>
<td>71</td>
<td>.9</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>10.8,15.7</td>
<td>52.5</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>11, 15.5</td>
<td>54.5</td>
<td>.05</td>
</tr>
<tr>
<td>Social navigation</td>
<td>GPS, Paper map</td>
<td>9.88,15.13</td>
<td>40.5</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>8.92, 17.43</td>
<td>24</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>12.2,14.61</td>
<td>63.5</td>
<td>.4</td>
</tr>
<tr>
<td>Chance</td>
<td>GPS, Paper map</td>
<td>10.15</td>
<td>42</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>11.15</td>
<td>54</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>13.7, 13.3</td>
<td>81</td>
<td>.8</td>
</tr>
</tbody>
</table>

Considering the literature and participants’ utterances, four main categories were defined for route control strategy, which is to make sure they are on the right track. These were based on using: 1) path integration, 2) piloting, 3) the Brisbane River, and 4) cardinal points. There was no significant association between the groups in the use of cardinal points, and path integration strategies. But there was a significant association between navigational aid group and how likely the participants were to use the Brisbane River [H (2) =18.9, p=.000], and piloting [H (2) = 11.84, p=.003] as their route control strategy. Table 4 shows Mann-Whitney U test results between the groups, indicating that the local-signage-only group used the Brisbane River
significantly more than the two other groups. The GPS group also used the *piloting* strategy less than the two other groups.

Three categories of utterance were found for *closure*, which is the last phase of wayfinding behaviour where one confirms one’s destination. The three groups of participants differed significantly for the proportion of utterances in the categories of *reading names of places* \[H (2) = 6.7, p=.03\], *semiotic knowledge* \[H (2) = 6.2, p=.04\], and *asking others for confirmation* \[H (2) = 7.44, p=.02\].

**Table 4:** The Mann-Whitney test between pairs of groups for route control strategies

<table>
<thead>
<tr>
<th>Route control</th>
<th>Groups</th>
<th>Mean rank</th>
<th>Mann-Whitney U</th>
<th>Asymp. Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Brisbane River</td>
<td>GPS, Paper map</td>
<td>12, 13</td>
<td>66</td>
<td>.3</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>8.5, 17.8</td>
<td>24</td>
<td>.002</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>8.96, 17.39</td>
<td>29.5</td>
<td>.000</td>
</tr>
<tr>
<td>Piloting</td>
<td>GPS, Paper map</td>
<td>8.17, 16.93</td>
<td>20</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>9.25, 17.14</td>
<td>33</td>
<td>.004</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>14.42, 12.71</td>
<td>73</td>
<td>.56</td>
</tr>
</tbody>
</table>

Participants in the paper map and GPS groups often failed to describe how they recognized their destinations, participants only uttering statements such as “cultural centre station, found it”. Only participants in the local-signage-only group *asked others for confirmation* to make sure they have arrived in their desired destination. The Mann-Whitney test between pairs of groups (Table 5) shows that the local-signage-only group used all three closure strategies significantly more than the two other groups.

**Table 5:** The Mann-Whitney test between pairs of groups for closure strategies

<table>
<thead>
<tr>
<th>Category</th>
<th>Groups</th>
<th>Mean rank</th>
<th>Mann-Whitney U</th>
<th>Asymp. Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading names of places</td>
<td>GPS, Paper map</td>
<td>13.08, 11.92</td>
<td>65</td>
<td>.6</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>10.08, 16.43</td>
<td>43</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>10.08, 16.43</td>
<td>43</td>
<td>.03</td>
</tr>
<tr>
<td>Semiotic knowledge</td>
<td>GPS, Paper map</td>
<td>12.58, 12.42</td>
<td>71</td>
<td>.9</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>9.79, 16.68</td>
<td>39.5</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>10.67, 15.93</td>
<td>50</td>
<td>.07</td>
</tr>
<tr>
<td>Asking others for confirmation</td>
<td>GPS, Paper map</td>
<td>12.5, 12.5</td>
<td>72</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>11.5, 15.2</td>
<td>60</td>
<td>.04</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>11.5, 15.2</td>
<td>60</td>
<td>.04</td>
</tr>
</tbody>
</table>

There were also differences between the groups as to how likely participants were to use *asking others for direction* during the earlier stages of wayfinding \[H (2) = 13.17, p=.001\], and their overt *local signage usage* as a wayfinding tool \[H (2) =11.3, p=.004\].
The GPS navigators were more anti-social, having significantly lower utterances asking for direction than either the paper map or local-signage-only groups. As expected, the local-signage-only group employed local signage usage significantly more than the other two groups (Table 6).

Table 6: The Mann-Whitney test between pairs of groups for local signage usage and asking for directions

<table>
<thead>
<tr>
<th>Category</th>
<th>Groups</th>
<th>Mean rank</th>
<th>Mann-Whitney U</th>
<th>Asymp. Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local signage usage</td>
<td>GPS, Paper map</td>
<td>14.5, 10.5</td>
<td>48</td>
<td>.1</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>9.8, 16.6</td>
<td>40</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>8.6, 17.6</td>
<td>26</td>
<td>.002</td>
</tr>
<tr>
<td>Asking for direction</td>
<td>GPS, Paper map</td>
<td>9.5, 15.5</td>
<td>36</td>
<td>.006</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>8.5, 17.79</td>
<td>24</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>11.46, 15.25</td>
<td>59.5</td>
<td>.1</td>
</tr>
</tbody>
</table>

4.2.2 Descriptive comments

The statistical analysis showed no significant differences between groups in terms of mentioning “anxious”, “uncertain”, and “negative” comments, although it was expected that GPS navigators experience less uncertainty and anxiety compared with two others.

There were differences across the groups in the mention of positive \[H (2) = 4.66, p<.1\], rehearsal \[H (2) = 4.83, p<.1\], and mistake making \[H (2) = 4.86, p<.1\] statements, though these were barely statistically significant. There were clearer differences across the groups in the mention of anticipatory \[H (2) = 17.04, p<.000\], and recognition \[H (2) = 6.47, p<.05\] statements. The Mann-Whitney test between pairs of groups (Table 7) shows that people in the paper map group mentioned more positive and rehearsal statements about their surrounding environment compared with the local-signage-only group. Somewhat illogically, but in line with others’ findings (Chang, 2015) the GPS group mentioned more mistake making statements compared with the local-signage-only group.

Table 7: The Mann-Whitney test between pairs of groups for descriptive statements

<table>
<thead>
<tr>
<th>Statements</th>
<th>Groups</th>
<th>Mean rank</th>
<th>Mann-Whitney U</th>
<th>Asymp. Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>GPS, Paper map</td>
<td>10.92, 14.08</td>
<td>53</td>
<td>.2</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>15.46, 11.82</td>
<td>60</td>
<td>.2</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>16.79, 10.68</td>
<td>44.5</td>
<td>.04</td>
</tr>
<tr>
<td>Mistake making</td>
<td>GPS, Paper map</td>
<td>13.5, 11.5</td>
<td>60</td>
<td>.6</td>
</tr>
<tr>
<td></td>
<td>GPS, local-signage-only</td>
<td>17.25, 10.29</td>
<td>39</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td>Paper map, local-signage-only</td>
<td>15.08, 12.14</td>
<td>65</td>
<td>.3</td>
</tr>
<tr>
<td>Anticipatory</td>
<td>GPS, Paper map</td>
<td>11.04, 13.96</td>
<td>54.5</td>
<td>.3</td>
</tr>
</tbody>
</table>
This relates to the corrective function of the GPS app in highlighting one’s navigational error, a function not available to the local-signage-group, in particular. As expected, participants in the local-signage-only group mentioned less anticipatory comments compared with the two other groups and the GPS group mentioned less recognition comments compared with the two other groups.

5. Discussion

The results are mostly in line with expectations and generally confirm the results of previous studies in this field. These relate to: 1) efficiency of navigation and walking speed; and, 2) choice of wayfinding strategy. The results also highlight the advantages of the think-aloud method for use at this scale.

Firstly, the GPS navigators in this particular urban environment were more efficient than those relying solely on local signage, but GPS offered fewer advantages over traditional paper maps. This result is inconsistent with the findings of Ishikawa et al. (2008). One possible reason for that could be that individuals are more familiar with a GPS-based navigation system at our study that conducted in 2016, and they followed the shortest routes offered by their devices. However, the local-signage-only group were not excessively inefficient in their wayfinding compared with the paper map group. Brisbane, with its useful CBD wayfinding signage system and its relatively logical orthogonal grid in the downtown area, proved not too difficult for them to navigate.

Navigating with GPS was associated with walking slower, in line with previous studies that showed paper map users walking faster than GPS users (i.e. Chang, 2015). GPS navigation requires constant checking of the next turn, given it is difficult to see multiple moves ahead on a small screen, and we’d turned off the audio guidance feature. Those using the larger paper maps could prepare for and undertake a series of turns from memory, increasing their pace. The local-signage-only group walked fastest and furthest, taking fewer stops. Their opportunities to stop and orient themselves on a map were very few, with maps fixed to only a couple of large hub signs located at strategic locations, such as the top of the Queen Street mall.
They may also have walked faster to compensate for errors made in navigation, catching up time.

Secondly, choice of wayfinding strategy differs markedly when one is provided different navigational aids. The GPS and paper map users mostly adopted route-following wayfinding strategies, the local-signage-only group used alternative approaches. But our methods revealed how and why, thanks to the use of think-aloud. The local-signage-only group used the edge-following, compassing, aiming and educated seeking strategies much more than the two other groups, roughly as expected. The local-signage-only group relied on edge features of the surrounding environment, such as the Brisbane River and key highways, in line with previous findings (Hutchins, 1995, p.30). More likely because of the conceptual map provided for them, they used compassing strategy far more. And they especially aimed themselves in the general direction of the destinations using other built environment features. Indeed, aiming was their most common strategy, particularly as they started a trip from one destination to another (much less so when approaching their destination). The local-signage-only group also used the screening strategy much more than the GPS group, visually scanning and screening the built environment, especially whilst approaching their destination. They based more of their decisions on knowledge built up by previous experiences (educated seeking).

The results of the present study differ from findings from similar previous studies conducted in buildings, including studies that have used similar methods such as think-aloud. Schnitzler & Hölscher (2015) found no significant difference in terms of wayfinding strategies used by three groups of participants navigated by different navigational tools (paper map, digital mal and signage); in their study navigators’ wayfinding strategy preferences mainly was shaped by the shape of building or people’s individual differences rather than by type of navigational tools.

GPS navigators are anti-social; our results add more evidence as to how GPS has changed the social interaction of navigators with their surrounding environment (McCullough & Collins, 2018). The GPS group used social navigation strategies least. Our study showed just how strongly GPS users became committed GPS navigators and just passively followed the directions provided by their devices. They often deliberately ignored social information, such as crowds of people. Both the local-signage-only and paper map groups paid attention to the crowded areas, such as Queen Street mall, and sought to understand what was happening there.
and used this as input into their wayfinding. Only two participants in the GPS group used this strategy. Similarly, the GPS users asked others for direction much less.

GPS navigators also become oblivious to the surrounding built environment. The GPS group found their destinations by chance significantly less. But this was not always a good thing. Somewhat comically, some GPS users were so committed to following their route-following strategy to a particular destination, and unaware of their surrounding environment, that they failed to notice they were walking directly past another destination that was part of their wayfinding task. Participants in the GPS group made less recognition comments, demonstrating they were less aware of landmarks and features around them. This result is in accordance with results from previous studies (Cheng, 2015; Ishikawa, 2008) that found GPS users gain less spatial knowledge about their surroundings.

Contrary to expectations, GPS navigation is also not necessarily going to make navigation a less anxious cognitive process. The type of navigational aid did not have any significant impact on reporting uncertain, anxious or negative statements. GPS navigation may have been more efficient, but whilst navigating the participants made similar proportions of uncertain and anxious statements, compared to the other two groups.

Paper maps have advantages that GPS navigation does not yet provide. Whereas the local-signage-group and GPS groups provided the least number of positive statements about the surrounding environment, having spent too much time walking along navigation friendly edges, such as major highways, or on less attractive street segments, it was the paper map group that made the most positive statements. The tourist paper map provided helped participants identify and choose street segments that offered more than just a shortest-path to their destination. This included key land uses such as retail, cafes and green areas.

Implications of this paper include that we can bring much of what we have found out about wayfinding strategies from studies inside buildings across to the urban neighbourhood scale, albeit with some notable cautions. We need to continue to invest in wayfinding signage systems and other visual treatments in cities, and avoid the impulse to rely only on digital GPS navigation, given the way that even the GPS users relied often on other wayfinding strategies and aids in navigating the city centre. Cities also need to consider when and how they might wish to disrupt GPS navigation, especially for out-of-town visitors and tourists; to bring people back to routes that help maximize commercial and retail opportunity, to re-engage visitors with the built environment, and to reduce the tendency to be anti-social when using GPS navigation.
Further research opportunities include: testing for and finding improved GPS navigation aids that meaningfully reduce pedestrian’s uncertainty and anxiety, compared to other wayfinding approaches; applying the research methods in cities with much more complex spatial arrangements (i.e. mediaeval cities that do not have orthogonal grids); and exploring differences in the wayfinding strategies of particular types of travellers, including those with specific language abilities and/or cultural differences.

References:


8. Discussion

This chapter begins with a general summary of the thesis, including its objectives, methods and outcomes. A brief overview of the key findings of the study is provided, followed by the contributions of the research, study limitations and recommendations for future research.

8.1 Research Summary

This study aimed to explore: a) the effects of different wayfinding tools, such as paper maps, GPS and non-mapping on an individual’s spatial cognition; b) the effects of urban form and navigational aids on people’s wayfinding performance; c) the effects of urban form and navigational tools on navigators’ social and spatial interaction with space; and, d) how people make sense of an unfamiliar urban environment and find their ways within it while using different types of navigational aids.

8.1.1 Response to research questions

This study had four primary research questions:

**RQ1:** How do different approaches to wayfinding, such as paper maps, GPS and local signage only, affect navigators’ wayfinding behaviour and spatial cognition?

The study findings suggest that the GPS navigators in this particular urban environment were more efficient than those relying solely on local signage, but GPS offered fewer advantages over traditional paper maps. However, the local-signage-only group were not excessively inefficient in their wayfinding compared with the paper map group. With respect to the acquisition of spatial knowledge, there were significant differences among the three groups broadly in line with the previous literature. For landmark recognition, the local-signage-only group performed better than the two other groups, in line with Chang (2015). The navigational assistance provided to the two other groups reduced their dependence on landmark knowledge to navigate. They still observed landmarks, in that there was no significant difference in the number of mentioned (perceived) landmarks across the three groups. But the local-signage only group had to rely on this landmark knowledge more, and inscribed it in their spatial memory. In other words, the GPS and paper map groups were, as seen in previous studies, more often only observing and perceiving the urban environment, instead of exploring and conceiving it (Bakdash et al. 2008; Burnett and Lee 2005; Farrell et al. 2003; Gaunet et al. 2001; Parush et al. 2007). For route knowledge acquisition, there was no significant difference in terms of map goodness; drawn travelled routes between destinations; between the local-signage-only and the two other groups. However, the paper map group in our study performed better in terms of
route accuracy than the two other groups. This was somewhat different from two previous studies’ findings (Ishikawa et al, 2008; Chang, 2015), who found the group without any navigational aid performed better than the GPS group in terms of route knowledge. However, all these findings confirm that navigation by GPS has no privilege in route knowledge acquisition. The GPS group could rely on simple turn-by-turn directions, and did not have to think as much about their route choices, and looking down at their devices made it more difficult to view both their location and destination at the same time. In line with Chang’s findings the local-signage-only group more accurately located landmarks on drawn routes than the GPS group. The paper map group were the most likely to remember the name of the streets they travelled, than the two other groups, presumably as the paper map users needed to look for the names on the map to locate themselves in the actual environment, and needed to see and understand the street names to know where to turn. It is cognitively more demanding. This result differed from that of Chang (2015), one possible reason for that could be the difference in methods used in two studies. In addition, In Chang (2015) study, majority of study participants were foreigners. They might have difficulties remembering the street names which are presented in Roman spelling. Another reason could be, differences in study areas used in the two studies. The grid street pattern of Brisbane city and its street naming strategy might have made it easier for participants to remember the street names.

The think-aloud data showed that the GPS group used the environmental information in their surroundings significantly less than the two other groups. They only focused on their devices to update their spatial information, and just followed it (for more details see Chapter 4, section 4). In addition, the space syntax analysis showed that people in the GPS group were unaffected by the syntactical properties of the urban layout and they simply followed the routs shown by their devices (see Chapter 5, Section 6).

**RQ2:** What is the relationship between urban form and wayfinding behaviour? How does digital wayfinding influence route choice behaviour in combination with urban form?

The findings suggest that GPS navigation is changing visitor’s route choice behaviour and their use of and interaction with the city. Our research confirms that the spatial configuration of urban layout has significant influence on route choice decision-making of visitors, but only for the paper map and local-signage-only groups. These two groups behaved much as we expected, following routes with strong choice (through-movement) and integration (to-movement) values, in line with past studies (i.e. Hillier & Iida 2005). The results suggest that ubiquitous apps like Apple Maps and Google Maps are creating a set of first-time visitors who become
rigid digital navigators. Once locked into this mode of wayfinding, they stick pretty closely to the turn-by-turn instructions provided them and generally walk along the shortest metric routes. There was great uniformity in the routes they choose to walk. These GPS navigators are unaffected by (or, emancipated from) the theory of natural movement. In addition, the findings emphasize the importance of considering land use in wayfinding studies. At least in the central Brisbane case, some land use variables were more powerful than syntactical measures in predicting route choice behaviour. This outcome is contrary to the findings of Kubat et al. (2012), who found no relationship between land use and visitors’ wayfinding behaviour in their study area, albeit in an environment that likely had a more homogenous set of land uses compared to central Brisbane. Future syntactical studies should look at the interplay between the two (for more details, see Chapter 5, Section 6).

**RQ3:** How do different navigational aids, including paper maps, GPS and local signage influence navigators’ interactions with their surrounding social and spatial environments?

The study findings confirmed that there is an interrelation between the type of navigational aid, and the navigators’ spatial interaction. The paper map and local-signage-only groups behaved much as we expected, either following routes with strong choice (through-movement) and integration (to-movement) values, which is in line with previous studies (Hillier & Iida 2005); or, in the case of the local-signage-only group, choosing routes with lower values, but that were a natural edge, along the Brisbane River (Hutchins, 1995). But the results also suggest that modern GPS navigation systems appear to overpower syntactic variables, such that digital navigators given turn-by-turn instructions by their hand-held devices are unaffected by (or emancipated from) the theory of natural movement, and they preferred to follow the offered routes by GPS which was generally the shortest metric paths. Therefore, it is necessary to consider this new movement pattern in urban planning, such as designing suitable land use or public spaces in streets offered by the GPS based devices.

On the other hand, the rise of GPS devices is changing visitors’ social engagement with space. Whether positive or negative, relying on GPS has reduced using social navigation strategy among navigators, including asking others for assistance and following others, and new types of wayfinding strategies, such as “avoiding the crowd” is arising. According to the participants’ think-aloud utterance, on the contrary to the paper map and local-signage-only groups, who preferred to follow others and direct themselves towards more crowded areas to benefit from social interaction, some people in the GPS group preferred to walk in the less crowded areas in order not to interrupt pedestrians’ walking and have time to find the right
route in their smart phones with more comfort. Although GPS might allow the navigators to independently navigate in unfamiliar environments, at the same time, it is making them “anti-social”. In an unfamiliar environment, this “anti-social” behaviour can also directs them towards “anti-social paths”, which are less crowded and could be unsafe to walk in. As, the Brisbane CBD is a safe place for visitors and offered route by GPS are well-designed and planned for tourists, further studies are required to have clear understanding about all these.

Similar to previous studies (McCullough & Collins, 2018), local-signage-only group significantly had more social interaction, in terms of asking for assistance, than two other groups. However, there was no significant difference between paper map and local-signage-only groups for following the crowd (for more details see Chapter 6, Section 7).

RQ4: How do different approaches to wayfinding, such as paper maps, GPS and local signage, affect navigators’ wayfinding strategies in unfamiliar urban environments?

The findings suggested that the choice of wayfinding strategy differs markedly when one is provided different navigational aids. The GPS and paper map users mostly adopted route-following wayfinding strategies, the local-signage-only group used alternative approaches. But our methods revealed how and why, thanks to the use of think-aloud. The local-signage-only group used the edge-following, compassing, aiming and educated seeking strategies much more than the two other groups, roughly as expected. And they especially aimed themselves in the general direction of the destinations using other built environment features. Indeed, aiming was their most common strategy, particularly as they started a trip from one destination to another (much less so when approaching their destination). The local-signage-only group also used the screening strategy much more than the GPS group, visually scanning and screening the built environment, especially whilst approaching their destination. They based more of their decisions on knowledge built up by previous experiences (educated seeking). The results of the present study differ from findings from similar previous studies conducted in buildings, including studies that have used similar methods such as think-aloud. Schnitzler & Hölscher (2015) found no significant difference in terms of wayfinding strategies used by three groups of participants navigated by different navigational tools (paper map, digital mal and signage); in their study navigators’ wayfinding strategy preferences mainly was shaped by the shape of building or people’s individual differences rather than by type of navigational tools. Contrary to expectations, GPS navigation is also not necessarily going to make navigation a less anxious cognitive process. The type of navigational aid did not have any significant impact on reporting uncertain, anxious or negative statements. GPS navigation may have been more efficient, but
whilst navigating the participants made similar proportions of uncertain and anxious statements, compared to the other two groups. Paper maps have advantages that GPS navigation does not yet provide. Participants in the GPS group made fewer recognition comments, demonstrating they were less aware of the landmarks and features around them. This result is in accordance with results from previous studies (Cheng, 2015; Ishikawa, 2008) which found that GPS users gain less spatial knowledge about their surroundings. Whereas the local-signage-group and GPS groups provided the least number of positive statements about the surrounding environment, having spent too much time walking along navigation friendly edges, such as major highways, or on less attractive street segments, it was the paper map group that made the most positive statements. The tourist paper map provided helped participants identify and choose street segments that offered more than just a shortest-path to their destination. This included key land uses such as retail, cafes and green areas (for more details, see Chapter 7, Section 5). This result in line with the results of the multivariate regression conducted in the Task 3 and showed that the effect of land use on the paper map group’s frequency of segment use was more than two other groups (see Table 2 in Chapter 5).

The next part of the discussion provides a summary of the key contributions made across the different chapters of the thesis.

8.2 Contributions

8.2.1 Conceptual/theoretical contributions

Whilst most of the contributions of this thesis are methodological and applied, there are a small number of modest theoretical contributions. The further insights revealed by this study into how GPS navigators ‘lock in’ to use of their devices, almost always following the suggested shortest path, and how they switch off part of their cognitive functioning and have less effective spatial knowledge acquisition, confirms the findings of Münzer et al. (2006) and others, in a different research setting and with a different research sample. The study provides further evidence to support the growing theories of brain plasticity (Maquire et al. 2000) and ‘brain damage’ (Neyfakh and So, 2013) caused use of GPS navigation. This emerging theory suggests that relieving oneself from the tasks of memorising landmarks and routes, or generating a sophisticated cognitive map, leads to decline in spatial ability. The study showed these effects in the short term. The study cannot answer questions about long-term decline in ability, or whether there is indeed damage to that part of the brain that supports spatial memory and navigation; that is for the neuroscientists to clarify. But the study’s findings do support the
notion that GPS travellers are indeed switching off these parts of their brains and reducing their spatial ability.

Those who had to rely on local signage or on paper maps followed routes with strong choice (through-movement) and/or integration (to-movement) values (theory of natural movement), while the GPS group were unaffected by the syntactical properties of the city. In this sense, we suggest GPS users are being emancipated from the theory of natural movement. This may have both positive and negative effects. Syntactical properties have, over time, helped shape the fortunes (somewhat literally) of commercial streets and have helped create parts of activity centres that have more, or less, retail and commercial activity. By being ignorant of such properties those using GPS may make less use of those routes that are commercially vibrant.

8.2.2 Methodological contributions

There are modest methodological contribution in this research that has employed the innovative application of the think-aloud methodology along with GPS tracking, cognitive mapping and space syntax techniques, in order to observe and analyse human wayfinding behaviour. No other study using these methods in combination has yet been identified. Though past studies have advanced our understandings of how navigational aids, and the built environment, shape wayfinding and travel behaviour, and influence spatial knowledge acquisition, the think-aloud method allows one to explore further why we obtain such results. For instance, think-aloud provided further insight into how landmark knowledge was generated, or, more importantly, wasn’t generated, across the three groups. The GPS navigators vocalised roughly as many utterances about landmarks as the other two groups, but they weren’t memorising that environment. The methods reveal that it is not that GPS travellers aren’t seeing the built environment, per se, and instead are always looking down at their screens. The think-aloud results suggest they are seeing their surrounds well-enough. It’s just that the navigators aren’t coding and memorising that information as landmark or route knowledge. They are like a person cleaning their watch, who is later asked the time and can’t remember. GPS navigators are seeing the objects, but not coding and memorising key information about them.

The space syntax technique in combination with GPS tracking and land use analysis, in Chapter 5 allowed us to gain more insight into the effect of urban form and navigational aids in combination on the navigators’ route choice behaviour and their interaction with the city.

In Chapter 6 the combination of methods allowed a comparison of the social and spatial interaction of the three groups of participants in their surrounding environments during a
wayfinding task. This provided the opportunity to investigate the social and spatial interaction of navigators with the city before, during and after the wayfinding task.

In addition, in Chapter 7, a combination of the use of the think-aloud technique and the post-test interview to investigate the influential role of urban features in wayfinding behaviour and acquired spatial knowledge was novel. The combination of these methods allowed us to gain better understandings of how urban features get memorable and how they affect navigators’ route choice behaviour.

8.2.3 Applied/practical contributions

A range of applied contributions also emerged.

As noted above, the study showed that navigational aids play an important role in affecting an individuals’ spatial knowledge acquisition. Navigators relying on just the existing signage system and environmental cues, were less accurate in their wayfinding, but they gained better landmark knowledge, as they had a need to observe the actual surrounding environment and to use any available information to navigate. Wayfinding by maps (whether paper maps or digital) reduced the navigator’s dependence on and generation of landmark knowledge. This result confirms the results of previous studies (Chang, 2015) in the Australian context, with a different sample.

The study also confirmed that paper map users were more accurate in route accuracy, compared with GPS users, as noted by Hou (2014). However, the image provided by a paper map allows navigators to gain a better understanding of the relationships of streets in terms of location and direction and street names, in comparison with navigation using a digital map or navigating without a map.

The results of the post-test interviews confirm the importance of urban and building design in creating a better mental urban image in individuals’ minds. For example, the existence of attractive or noticeable buildings along the streets made them memorable in participants’ minds.

One finding at odds with previous research was in terms of the importance of considering land use in wayfinding studies. At least in the case of the central Brisbane district, some land use variables (commercial and recreational) were more powerful than syntactical measures in predicting route choice behaviour. This is contrary to the findings of Kubat et al. (2012), who found no relationship between land use and visitors’ wayfinding behaviour in their study area, albeit in an environment that was likely to have a more homogenous set of land uses compared
to central Brisbane. Future syntactical studies could look at the interplay between the route choice behaviour and urban form, in terms of land use and urban configurational layout.

Using think-aloud the study showed that relying on a GPS reduces the use of the social navigation strategy among navigators. Fewer GPS navigators asked others for assistance or followed others, and new types of wayfinding strategies, such as ‘avoiding the crowd’ are arising, so the use of the GPS is contributing to an ‘anti-social’ type of mentality. The paper map users and local signage only groups preferred to follow others and purposefully directed themselves towards crowded areas to benefit from social interaction. Some in the GPS group preferred to walk in the less crowded areas so that they did not interrupt pedestrians, and so that they might find a quieter space in which to find the right route on their smart phones. In an unfamiliar environment, this ‘anti-social’ behaviour can also direct them towards ‘anti-social paths’, which were less crowded and which could, by implication, be less safe to walk in.

8.2.4 Implications

There are a number of implications from the research effort. To begin, the implications from Chapters 5 and 6 are that urban planners and designers now need to consider how they design, manage and operate the street and pathway networks that are likely to be suggested by GPS navigation. A town’s high streets may not necessarily be the shortest path between, say, a central public transport node and a major tourist attraction, especially when that public transport node is retrofitted into an older urban fabrication. Designers may need to use cues and signage to deliberately disrupt digital navigation. They may need to find new ways to help digital navigators to ignore the guidance line shown by their devices. Designers will need to experiment with the best methods to discourage digital navigators from taking less desirable routes and encourage them to walk down street segments with greater commercial and recreational activity. For the broader public, some useful alternatives to shortest path algorithms could be based on space syntax. Identifying these options, programming them into an app and testing them with real-world users is an avenue for future research.

On the other hand, based on the results presented in Chapter 6, the use of GPS in hand-held devices is helping to create somewhat anti-social people, who prefer to look at their devices and may be directed down routes that offer shortest-paths but do not make use of the social amenity, or draw one into the social life, of the city. In particular, urban planners and designers
need to pay more attention to the safety of the routes offered by GPS, given the propensity to direct travellers down little-used laneways and cut-throughs.

The implications of Chapter 7 are that we can bring much of what we have found out about wayfinding strategies from studies inside buildings out into urban spaces, albeit with some notable caution. We also need to continue to invest in wayfinding signage systems and other visual treatment in cities, and to avoid the impulse to rely only on digital GPS navigation, given the way that even the GPS users in our study also often relied on other wayfinding strategies and aids in navigating the city centre. City authorities need to consider when and how they might wish to disrupt GPS navigation, especially for out-of-town visitors and tourists; to bring people back to routes that help maximize commercial and retail opportunities, and to re-engage visitors with the built environment.

8.3 Limitations and Future Research Directions

There are some limitations to this study which have implications for further research. Firstly, there were limitations with the sample, including:

- The modest sample size is an obvious limitation. Think-aloud and GPS tracking requires significant transcription and analysis. The combination of methods was therefore more labour intensive than in most previous studies and the sample size was slightly lower than in some previous research (i.e. Chang 2015). Table 8-1 represents the sample size of similar studies that employed the think aloud method.

<table>
<thead>
<tr>
<th>Authors, year</th>
<th>Sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hölscher et al., 2009</td>
<td>32 participant, 16 people in each group.</td>
</tr>
<tr>
<td>Schnitzler et al., 2015</td>
<td>41 participants:</td>
</tr>
<tr>
<td></td>
<td>• 13 people in paper map group</td>
</tr>
<tr>
<td></td>
<td>• 14 people in digital map group</td>
</tr>
<tr>
<td></td>
<td>• 14 people in signage group</td>
</tr>
<tr>
<td>Hölscher et al, 2011</td>
<td>Experiment 1: 11 participant</td>
</tr>
<tr>
<td></td>
<td>Experiment 2: 14 participants</td>
</tr>
<tr>
<td></td>
<td>Experiment 3: 24 participants; 12 participants in each group</td>
</tr>
<tr>
<td>Kato &amp; Takeuchi, 2003</td>
<td>16 participants, 8 people in each group</td>
</tr>
</tbody>
</table>
• The sample was diverse in ethnicity, gender and background, but not in terms of age, being drawn from a university campus, skewing towards college-aged participants. Using sub-population enquiries to explore whether key results are similar for younger and much older pedestrians is important, especially given the need to create age-friendly cities, and the increasing reliance of city authorities on digital wayfinding.

There were limitations with the research methods, some of which include:

• Due to resource constraints, no one followed or continually observed the participants to make sure they were following the instructions, with us relying on GPS tracking and voice recording instead. The voice recordings provided confidence that participants were adhering to instructions and not, for instance, using digital navigation on their own smartphone when part of the paper map group; but without direct observation throughout we cannot be certain.

• Participants might have provided some incomplete representations of their salient thoughts during the think-aloud task. For example, as documented in Chapter 7, participants’ recognition of their destinations (closure) were not identified as being certain, based on the utterances of the GPS and paper map groups, and it was supposed that the navigational aids helped to confirm their arrival at their destinations. As in any survey enquiry, there might also have been issues with communication in the post-test interviews that prevented some of the participants, especially those from a non-English speaking background, from accurately communicating with the researcher, though every attempt was made to mitigate this issue.

• The quality of any sketch map (as documented in Chapter 4) can be influenced by the drawing ability of the participants.

• There can always be important variables omitted from a spatial analysis, that may skew the results, though the methodological triangulation here attempts to reduce this effect. There are also possible alternative statistical approaches that might reveal further insights from the data obtained. And, as always, there is potential for ‘by chance’ findings of significance in statistical tests with confidence levels often set at 95%.

• The results in Chapters 5 and 6 are limited by the effect of having all participants start from the same point of origin and the same end destination. A greater diversity of origin points, with a larger sample, would reduce the risk of bias from having a single point of departure for other aspects of the study.
There were limitations due to the study location:

- The study took place in only one Australian city centre, which comprised a CBD with a clear grid layout. Exploring how wayfinding is influenced by different navigational aids in cities with a distinctively pre-modern pedestrian street layout (i.e. a mediaeval city) may or may not produce different results.

In addition, we could not control fully participants ability to possibly look at a map of the study area in the days prior to their wayfinding task. Perhaps one or two did so, and this map affects their cognitive maps. This facts has been added to the limitation of the study.

Care should therefore be taken in applying these results, especially to locations that are very different to the central city of Brisbane. In spite of these limitations, considerable insight into the role of navigational aids in spatial knowledge acquisition of first-time visitors, as well as how some understandings of specific characteristics that contribute to legible urban environment, have been achieved. Together, these findings can be used to improve the effectiveness of navigational aids and legibility of urban environments.

There are a number of other opportunities for further research that new technologies have opened up. Eye-tracking technologies may allow researchers to identify exactly what navigators are looking at as they wayfind through a city, including hand-held devices, maps, street signs and other objects. In combination with think-aloud, this might allow for a richer understanding of what participants are doing, and thinking, through a wayfinding task. There are also a number of outstanding research needs in the field of wayfinding. Significant investment is being made in wayfinding systems, both in permanent installations of signage across city centres and tourist locations, but also for temporary events such as large sporting and cultural events. But there seems to have been very little scholarly enquiry into the efficacy of these systems, and their key elements, to give robust evidence-based support for these investment, or to guide designers in what is most effective.

8.4 Summary of the Chapter

The thesis aimed to explore how using different navigational aids could affect people’s wayfinding behaviour and spatial cognition. Table 8-2 represents a summary of the thesis findings.
### Investigated Factor

<table>
<thead>
<tr>
<th>Investigated Factor</th>
<th>Effects of navigational aids</th>
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<tbody>
<tr>
<td>Traveled distance</td>
<td>• GPS is more efficient than signage system, but has no advantages over paper map. There was no significant difference between paper map and signage system.</td>
</tr>
</tbody>
</table>
| Spatial Interaction | • Following GPS significantly reduces navigators’ interaction with surrounding environment compared with paper map and local signage system. Consequently, participants in the GPS group significantly used the environmental information less than two other groups to wayfind. In addition, the space syntax analysis showed that people in the GPS group were unaffected by the syntactical properties of the urban layout and they simply followed the routs shown by their devices.  
• Commercial and Recreational land use had significant impact on wayfinding behaviour of navigators using GPS, or paper map or local signage only. However, river had only significant impact on wayfinding behaviour of local-signage-only group.  
• The effect of land use on the paper map group’s frequency of segment use was more than two other groups. |
| Social Interaction  | • Navigation by GPS would significantly decrease peoples’ social interaction with their surrounding environment. |
| Spatial knowledge Acquisition | • Navigation by solely using local signage system, could help people to gain significantly better landmark knowledge compared with using GPS or paper map. They still observed landmarks, in that there was no significant difference in the number of mentioned (perceived) landmarks across the three groups. But the local-signage only group had to rely on this landmark knowledge more, and inscribed it in their spatial memory.  
• Type of navigational aids had no significant impact on navigators’ map goodness performance.  
• Navigation by paper map has a significant impact on remembering streets’ names.  
• Type of navigational aids had no significant impact on navigators’ distance estimation performance. |
| Wayfinding Strategy | • The GPS and paper map users mostly adopted route-following wayfinding strategies, but The local-signage-only group used the edge-following, compassing, aiming and educated seeking strategies much more than the two other groups. |
| Feeling anxious, uncertain or negative | • The type of navigational aid did not have any significant impact on reporting uncertain, anxious or negative statements. |
| Feeling positive | • Navigation by paper map helped people to choose more attractive routes and feel more positive than two other groups. |


Benedikt, M. L. (1979). To take hold of space: isovists and isovist fields. Environment and Planning B: planning and design, 6(1), 47-65. doi: https://doi.org/10.1068/b060047


Iglói, K., Zaoui, M., Berthoz, A., & Rondi-Reig, L. (2009). Sequential egocentric strategy is acquired as early as allocentric strategy: Parallel acquisition of these two navigation strategies. *Hippocampus*, 19(12), 1199-1211. doi:10.1002/hipo.20595


Appendix A: Griffith University thesis preparation policy

1. Inclusion of papers within the thesis

Higher degree by research is a program of independent supervised study that produces significant and original research outcomes, culminating in a thesis, exegesis or equivalent (refer to Higher Degree by Research Thesis). Inclusion of papers within a thesis is not a suitable thesis format for all research projects, for example: collaborative projects where there may be several co-authors for each paper which may make it difficult for the examiner to establish the independence of the candidates work; where primary data is not collected, or results obtained, until late in the candidature; or where the research will not produce a logical sequence of papers that are able to be presented as an integrated whole.

Candidates should also take into account whether this thesis format is an accepted practice within their discipline and likely to be received well by the thesis examiners (refer also to the examination requirements below). Candidates are required to consult with their supervisor(s) early in their candidature to determine if this thesis format is appropriate.

It is expected that candidates will identify as part of the confirmation of candidature milestone if their thesis is to be prepared in this format. Candidates should consult their Group specific guidelines in addition to the requirements detailed below. Candidates are also encouraged to attend the workshop: ‘Inclusion of papers within a thesis’ offered by the Griffith Graduate Research School. Refer also to the Griffith University Code for the Responsible Conduct of Research, specifically the sections pertaining to publication ethics and the dissemination of research findings, and authorship.

Status of papers

A thesis may include papers that have been submitted, accepted for publication, or published. Some disciplines may specify a variation to the status of papers requirement, refer to your Group specific guidelines.

Type of papers

For the purpose of this requirement, papers are defined as a journal article, conference publication, book or book chapter. Papers which have been rejected by a publisher must 242
not be included unless they have been substantially rewritten to address the reviewers’ comments, or have since been accepted for publication. Some disciplines may specify a variation to the type of papers requirement, refer to your Group specific guidelines.

**Number of papers**

A thesis may be entirely or partly comprised of papers. A paper maybe included as a single chapter if the paper contributes to the argument of the thesis, or several papers may form the core chapters of the theses where they present a cohesive argument. Where a thesis is entirely comprised of papers, there is no minimum requirement for the number of papers that must be included (except as noted below) and is a matter of professional judgment for the supervisor and the candidate. Overall, the material presented for examination needs to reflect the research thesis standard required for the award of the degree. For example, PhD candidates, on the basis of a program of independent supervised study, must produce a thesis that makes a significant and original contribution to knowledge and understanding in the relevant field of study. This remains a matter of professional judgment for the supervisor and the candidate. Where a thesis is entirely comprised of papers, some disciplines may specify a minimum number of papers to be included, refer to your Group specific guidelines.

**Authorship**

The candidate should normally be principal author (that is, responsible for the intellectual content and the majority of writing of the text) of any work included in the body of the thesis. Where a paper has been co-authored, the candidate is required to have made a substantial contribution to the intellectual content and writing of the text. Co-authored work in which the candidate was a minor author can only be used and referenced in the way common to any other research publication cited in the thesis. A signature from the corresponding author is required in order to include co-authored material in the body of the thesis, refer to the declarations section below.

For co-authored papers, the attribution of authorship must be in accordance with the Griffith University Code for the Responsible Conduct of Research, which specifies that ‘authorship must be based on substantial contributions in one or more of:

- conception and design of the research project
• analysis and interpretation of research data
• drafting or making significant parts of the creative or scholarly work or critically revising it so as to contribute significantly to the final output’.

Some disciplines may specify a variation to the authorship requirement, refer to your Group specific guidelines.

Quality of papers

Candidates should endeavour to publish their research in high quality peer reviewed publications. Papers to be included in the body of the thesis should be published (or submitted for publication) in reputable outlets that are held in higher regard in the relevant field of research. Candidates should consult their supervisor(s) for advice on suitable publications specific to their research discipline. Some disciplines may specify quality standards that must be met for papers to be included, refer to your Group specific guidelines.

The library also provides support and advice to candidates on choosing a journal. Candidates are advised to note in particular advice in order to avoid ‘predatory’ publishers.

• Research Guide: Higher degree research candidates - Get Published

• Publishing in Open Access journals

Copyright

As copyright in an article is normally assigned to a publisher, the publisher must give permission to reproduce the work in the thesis and put a digital copy on the institutional repository. Information on how to seek permission is available at: Copyright and Articles in thesis. If permission cannot be obtained, students may still include the publication in the body of the thesis, however following examination the relevant chapter(s) will be redacted from the digital copy to be held by the Griffith University Library so that the copyright material is not made publicly available in the institutional repository. Students are required to advise the copyright status of each publication included in the thesis via a declaration to be inserted in the thesis, as detailed below.
Students requiring further advice regarding copyright issues can contact the Information Policy Officer on (07) 3735 5695 or copyright@griffith.edu.au.

Group and discipline requirements

Some Groups or Elements may specify additional requirements for including papers within a thesis, refer below:

• Arts, Education and Law
• Griffith Business School (PDF 214k)
• Griffith Health
• Griffith Sciences

2. Format of thesis

General

Consult the thesis preparation and formatting guidelines for general information about the requirements for formatting the thesis. Some disciplines may specify a variation to the thesis format requirements below, refer to your Group specific guidelines.

Structure of thesis and linking chapters

The structure of the thesis will vary depending on whether the thesis is partly or entirely comprised of papers. Whatever the format, the thesis must present as a coherent and integrated body of work in which the research objectives, relationship to other scholarly work, methodology and strategies employed, and the results obtained are identified, analysed and evaluated.

In general every thesis should include a general introduction and general discussion to frame the internal chapters. The introduction should outline the scope of the research covered by the thesis and include an explanation of the organisation and structure of the thesis. The general discussion should draw together the main findings of the thesis and establish the significance of the work as a whole, and should not just restate the discussion points of each paper.
It is important that candidates explicitly argue the coherence of the work and establish links between the various papers/chapters throughout the thesis.

Linking text should be added to introduce each new paper or chapter, with a foreword which introduces the research and establishes its links to previous papers/chapters.

Depending on the content of the paper(s) and nature of research, a research methods chapter may also be necessary to ensure that any work that is not included in the paper(s), but is integral to the research, is appropriately covered.

Any data omitted from a paper may also be included as an addendum to the thesis.

For further information on the thesis structure, refer to the following examples of acceptable ways to format the thesis when including papers.

**Format of papers**

The papers may be rewritten for the thesis according to the general formatting guidelines; or they can be inserted in their published format, subject to copyright approval as detailed above.

**Pagination**

Candidates may repaginate the papers to be consistent with the thesis. However, this is at the discretion of the candidate.

**Declarations**

All theses that include papers must include declarations which specify the publication status of the paper(s), your contribution to the paper(s), and the copyright status of the paper(s). The declarations must be signed by the corresponding author (where applicable). If you are the sole author, this still needs to be specified. The declaration will need to be inserted at the beginning of the thesis, and for any co-authored papers, additional declarations will need to be inserted at the beginning of each relevant chapter. You may wish to consult the declaration requirements for inclusion of papers diagram to ensure that you insert the correct declaration(s) within the thesis. Please note that completion of the declaration(s) does not negate the need to comply with any other.
University requirement relating to co-authored works as outlined in the Griffith University Code for the Responsible Conduct of Research.

3. Examination requirements

Assessment by examiners

Candidates who wish to include papers within their thesis, and who have determined that this thesis format is appropriate to the research project, should also consider whether this thesis format will be well received by the thesis examiners. The inclusion of papers may negatively impact on the thesis upon assessment by the examiners where: the thesis format is not a common or accepted practice within the candidates discipline area; where the inclusion of co-authored papers makes it difficult for the examiner to establish the independence and originality of the candidates work; where the thesis does not present to the examiner as an integrated whole; or where there is too much repetition in the thesis which an examiner may view as a weakness.

Theses that include papers are subject to the same examination criteria as theses submitted in the traditional format. It should also be noted that the inclusion of published papers within the thesis does not prevent an examiner from requesting amendments to that material.

Candidates should discuss the suitability of this thesis format for examination with their supervisor(s).

Nomination of examiners

It is the responsibility of the principal supervisor to nominate thesis examiners, and the process dictates that the principal supervisor must approach all nominees to determine their willingness to examine. Where a candidate’s thesis is formatted to include papers, the principal supervisor must also ensure that the examiners are familiar with and/or accepting of, this thesis format.

Upon dispatch of a candidate’s thesis to an examiner, the examiner will be reminded that the thesis has been formatted to include papers. The examiner will also be provided with the relevant information and regulations regarding this thesis format.
Appendix B: Recruiting Email and Information Sheet

You are invited to help Griffith students and staff with their research projects by participating in surveys or other research activities or by passing information to people you think might be interested.

This month, volunteers are being sought for studies about:

- The Effects of Urban Form on People’s Wayfinding Behaviour and Cognitive Mapping in an Unfamiliar Urban Environment
- The Effects of Way-showing Tools on People’s Wayfinding Behaviour and Spatial Knowledge

Effects of Urban Form and Navigational Aids on Visitors’ Spatial Cognition and Wayfinding Behaviour

The main aim of this study is to investigate a) how people make sense of an unfamiliar urban environment b) The effects of urban layout and land use on wayfinding performance of people; c) The effects of different approaches to wayfinding such as paper maps, GPS and non-mapping on individual’s mental image of the city.

Type of volunteers needed

Students who are over 17 years old without any disabilities that can affect their wayfinding performance like visual or mobility impairments. They are supposed to think aloud in English; so, participants need to have a good English speaking skill. None of them have visited the studied area before the experiment.

What would I be asked to do? How much time would it take?

The participants in this research will be requested to take part in a city exploration test of approximately 2 hours. The journey would start from the Roma Street train station and ends in COWCH cafe and participants are supposed to find destinations individually. You will be asked to think aloud while finding your ways through 7 predetermined landmark locations in the CBD of Brisbane; such as what you see, read, feel, and why you go to certain directions and so on. Pre-determined landmarks are the most popular tourist
attractions in the Brisbane CBD. Brisbane CBD is generally a safe destination for tourists in addition your journey will be undertaken during the day.

Whatever you say will be recorded by provided smartphones. Your route choosing behavior will be observed by GPS tracking method; GPS on the same smart phones will be used to record travel routes as well as travel times. After completing the exploration you will be asked to draw your mental maps of the observed environment. After the test when you are arrived in COWCH café you will be asked to fill in a questionnaire about your wayfinding experience in the Brisbane CBD.

The participants will be assigned into one of three conditions, considering their preferences:

Paper map (n=12), 2) a digital map (n=12) and 3) no map, using the signage and environmental information to find their way (n=14).

What’s in it for me?
The total travel cost from Gold Coast to Brisbane will be paid to participants; in addition they will receive $50 incentive payment.

The expected benefits of the research

Your contribution to this study will allow for a better understanding of how people make sense of an unfamiliar urban environment, create mental imagery and use it to find their ways; it also will help us to find out what aspects of Brisbane CBD are confusing. In addition, we can understand how the comparison among the generated sketch maps would enable the researcher to find out how method of wayfinding might affect people’s spatial cognition and in additions, what aspects of environmental information create meaning in urban observers’ minds.

Risk to you

There are no foreseeable risks caused by this research to the participants or the research team; no risks to the environment and no risks that could impact on your career. You can call Sima Vaez at 0478201484 whenever you need any assistant.

Your participation is voluntary and you may withdraw your participation at any time. There are no penalty or loss benefits for not participating or for discontinuing your participation.
Your confidentiality

The records of this study will be kept private. All your responses will be coded for analysis to remove individual identification. None of the specific records will be used for wider purposes other than researcher’s academic program including academic publication such as journal articles, conference presentations, social media and PhD thesis. In any report to be published, no information will be provided that could identify you. As required by Griffith University, all audio recordings will be erased after transcription. However, the research data (interview and think-aloud transcripts and analysis) will be retained in a locked cabinet and/or a password protected electronic file at Griffith University for a period of five years before being destroyed.

Your participation is voluntary

Participation in the research study is entirely voluntary and as mentioned above, you are free to withdraw from the test, without any negative consequences or prejudice.

Questions / Feedback to you

If you have any questions regarding this study, please contact Miss Sima Vaez by telephone on (07) 3735 5534 or by email: sima.vaezeslami@griffithuni.edu.au.

All participants will have the opportunity to know the results of this research, in a two page summary report via email.

The ethical conduct of this research

Griffith University conducts research in accordance with the National Statement on Ethical Conduct in Human Research. If you have any concerns or complaints about the ethical conduct of the research project, please contact the Manager, Griffith Research Ethics on (07) 3735 4375 or research-ethics@griffith.edu.au.

Privacy Statement

Please include the following privacy statement on the participant information sheet: The conduct of this research involves the collection, access and/or use of your identified personal information. The information collected is confidential and will not be disclosed to third parties without your consent, except to meet government, legal or other
regulatory authority requirements. A de-identified copy of this data may be used for other research purposes. However, your anonymity will at all times be safeguarded. For further information consult the University Privacy Plan at http://www.griffith.edu.au/about-griffith/plans-publications/griffith-university-privacy-plan or telephone (07) 3735 4375.

How can I volunteer or find out more?
To access the screening questionnaire please use this link: <link>
Please contact Sima Vaez at sima.vaezeslami@griffithuni.edu.au or phone 0478 201 484 for further information.

Cities Research Centre; School of Environment | PhD candidate | <GU ref. no 2016/900>

***** Please print this information sheet for your records. *****
To print, right click and select print.

The total travel cost from Gold Coast to Brisbane, food and drink costs will be paid to participants; in addition they will receive $30 incentive payment.

By selecting accept below, I confirm that I have read and understood the information sheet and in particular have noted that:

- I understand that my involvement in this research will include the completion of almost 1 hours exploration in the CBD of Brisbane, and a post-test 10 minutes interview;
- I understand that other than the total travel cost to Brisbane, and $50 incentive payment no other direct benefit is guaranteed to me from my participation in this research;
- I understand that my participation in this research is voluntary and that I am free to withdraw at any time without negative consequences or prejudice;
- I understand that information I provide will be stored as de-identified data and may be used in future studies;
- I understand that if I have any additional questions I can contact the research team;
- I understand that my personal email details will be collected for further communication regarding study participation;
- I understand that I can contact the Manager, Research Ethics, at Griffith University Human Research Ethics Committee on (07) 3735 4375 (or research-ethics@griffith.edu.au), if I have any concerns about the ethical conduct of the project;
- I agree to participate in the project.
The purpose of the following questions is to find out if you fit the specific study criteria. If it turns out that you do, a researcher will contact you via email to provide further info and set up a time for your first testing session. Some questions contain a "let's talk about it option". Selecting this indicates that you are uncertain as how to answer the question. If you select this and fit the other study criteria a researcher will contact you to clarify any points.

Please provide an email by which the experimenter can contact you

What is your age?

I identify as

- Male
- Female
- Other
- Are you able to attend a teaching session on (day …), to learn about the test?
  - No
  - Yes
  - Let's talk about it (please specify)

Do you have any mobility impairments?

- No (please specify)
- Yes

Do you have any form of speech impairment?

- No
- Yes (please specify)

Are you able to think in English and verbalise your thoughts in English (i.e. be a native speaker or having 6.5 for speaking in an IELTS test)?

- No
- Yes

Thank you for answering these questions. If you are eligible for participation a researcher will contact you with further information.
Appendix C: Recruiting Poster

You are invited to

a FREE TRIP to Brisbane
Tourists Landmarks

Participate in the SCUL Study and gain:

- A free trip to Brisbane
- $50 for your time

To Participate You Must:

- Never have visited the Central Brisbane
- Be over 17 years old
- Be Good in English Speaking

Description of project: The aim of this study is to investigate how people make sense of an unfamiliar urban environment and the effects of different approaches to wayfinding such as paper maps, GPS and non-mapping on individual’s mental image of the city.

This research is being conducted in the Cities Research Centre at Griffith University. To learn more contact Sima Vaef at: sima.vaefslami@griffithuni.edu.au

You can also use the QR code to learn more information: link of screening questionnaire

Griffith Research Ethics: (07) 3735 4375 / research-ethics@griffith.edu.au
Appendix D: Lists of participants and policy documents for Tasks-1,2,3,4

- Details for the participants

<table>
<thead>
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<th>ID</th>
<th>Group</th>
<th>Gender</th>
<th>Age</th>
<th>Nationality</th>
<th>Date</th>
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Appendix E: Consent Forms

Effects of Urban Form and Navigational Aids on Visitors’ Spatial Cognition and Wayfinding Behaviour

Consent Form for Participation in Research (Group A)

Griffith University Ethic Reference Number: 2016/900

Research Team member:

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Contact email: m.burke@griffith.edu.au

Dr. Tooran Alizadeh (Associate Supervisor)
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Sima Vaez (PhD Candidate)
Contact Phone: + 61 (0)7 3735 5534
Email: sima.vaezeslami@griffithuni.edu.au

This is a study about effects of urban form and wayfinding tools on wayfinding and mental Image of visitors. Participants are students of Griffith University, Gold Coast Campus who have never visited the Brisbane CBD. Our goal is to understand how people make sense of an unfamiliar urban environment and wayfind through it. In addition, this test seeks to understand how way-showing tools affect individuals’ mental image of their surrounding environment. Your participation will help us achieve this goal.

In this test, you will be exploring through the CBD of Brisbane by using a paper map of the area, individually. We’ll ask you to perform tasks a typical tourist might do, such as finding 7 landmark locations in the Brisbane CBD. You will be asked to verbalize your thought and decision making process (to think-aloud). When you talk all your words will be recorded by a smartphone which is already provided for you; to others on the street it will look like you are talking on the phone.

Your wayfinding behaviour will be observed by GPS tracking; Geotracker app on the same smart phones will be used to record travel routes as well as travel times. After finishing the test you will be asked to draw your mental image of the area that you
explored. Moreover, a short interview (almost 10 minutes) will be done about your wayfinding performance at COWCH café.

You can call Sima Vaez @ 0478201484 whenever you need help or have question.

The total travel cost from Gold Coast to Brisbane will be paid in addition you will receive $50 incentive payment.

This is research seeks to understand the relation between urban form and wayfinding behaviour of urban users and we are not testing your sense of direction. All information collected in the session belongs to the research team and will be used for academic purposes.

You may take breaks as needed and stop your participation in the study at any time.

**Statement of Informed Consent**

I have read the description of the study and of my rights as a participant. I voluntarily agree to participate in the study.

Name : _________________________________________________________

Signature : _________________________________________________________

Date : _________________________________________________________
Effects of Urban Form and Navigational Aids on Visitors’ Spatial Cognition and Wayfinding Behaviour

Consent Form for Participation in Research (Group B)
Griffith University Ethic Reference Number: 2016/900

Research Team member:

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This is a study about effects of urban form and wayfinding tools on wayfinding and mental Image of visitors. Participants are students of Griffith University, Gold Coast Campus who have never visited the Brisbane CBD. Our goal is to understand how people make sense of an unfamiliar urban environment and wayfind through it. In addition, this test seeks to understand how way-showing tools affect individuals’ mental image of their surrounding environment. Your participation will help us achieve this goal.

In this test, you will be exploring through the CBD of Brisbane by using Google maps app, individually. We’ll ask you to perform tasks a typical tourist might do, such as finding 7 landmark locations in the Brisbane CBD. You will be asked to verbalize your thought and decision making process (to think-aloud). When you talk all your words will be recorded by a smartphone which is already provided for you; to others on the street it will look like you are talking on the phone.

Your wayfinding behaviour will be observed by GPS tracking; Geotracker app on the same smart phones will be used to record travel routes as well as travel times. After finishing the test you will be asked to draw your mental image of the area that you explored. Moreover, a short interview (almost 10 minutes) will be done about your wayfinding performance at COWCH café.
You can call Sima Vaez  @ 0478201484 whenever you need help or have question.

The total travel cost from Gold Coast to Brisbane will be paid in addition you will receive $50 incentive payment.

This is research seeks to understand the relation between urban form and wayfinding behaviour of urban users and we are not testing your sense of direction. All information collected in the session belongs to the research team and will be used for academic purposes.

You may take breaks as needed and stop your participation in the study at any time.

**Statement of Informed Consent**

I have read the description of the study and of my rights as a participant. I voluntarily agree to participate in the study.

Name  : _________________________________________________________

Signature  : _______________________________________________________

Date  : ___________________________________________________________
Effects of Urban Form and Wayfinding Tools on Wayfinding and Mental Image of Visitors

Griffith University Ethic Reference Number: 2016/900

Consent Form for Participation in Research (Group C)

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This is a study about effects of urban form and wayfinding tools on wayfinding and mental Image of visitors. Participants are students of Griffith University, Gold Coast Campus who have never visited the Brisbane CBD. Our goal is to understand how people make sense of an unfamiliar urban environment and wayfind through it. In addition, this test seeks to understand how way-showing tools affect individuals’ mental image of their surrounding environment. Your participation will help us achieve this goal.

In this test, you will be exploring through the CBD of Brisbane by using local signage only, individually. We’ll ask you to perform tasks a typical tourist might do, such as finding 7 landmark locations in the Brisbane CBD. You will be asked to verbalize your thought and decision making process (to think-aloud). When you talk all your words will be recorded by a smartphone which is already provided for you; to others on the street it will look like you are talking on the phone.

Your wayfinding behaviour will be observed by GPS tracking; Geotracker app on the same smart phones will be used to record travel routes as well as travel times. After finishing the test you will be asked to draw your mental image of the area that you explored. Moreover, a short interview (almost 10 minutes) will be done about your wayfinding performance at COWCH café.
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You may take breaks as needed and stop your participation in the study at any time.

**Statement of Informed Consent**

I have read the description of the study and of my rights as a participant. I voluntarily agree to participate in the study.

Name : _________________________________________________________

Signature : _________________________________________________________

Date : _________________________________________________________
Appendix F: Instruction

Effects of Urban Form and Navigational Aids on Visitors’ Spatial Cognition and Wayfinding Behaviour

Thank you so much for your participation. The aim of SCUL project is to find out how people make sense of an unfamiliar urban environment to find their way toward their desired destinations; in other words, it tries to investigate the effects of urban form and urban elements on wayfinding behaviour of tourists. Another aspect of this study is to investigate the effects of wayshowing tools (GPS, paper map, and signage) on people’s spatial cognition. In this regard, we have divided the participants into three groups.

You will be requested to take part in a city exploration test of approximately 2 hours. You need to find several pre-determined landmarks in Brisbane CBD which are the most popular tourist destinations. The journey will start at Roma Street Station and then you need to find Queen Street Mall, Street Beach Southbank, Brisbane City Hall, St Stephen’s Cathedral, South Bank Train Station, and Cultural Centre, the end of the trip is Cowch Dessert cocktail Bar (meeting point). So there are 7 destinations that you need to find. The sequence order depends on your decision. Participants will be divided into three groups: those who find their destinations by GPS, the second group will use the paper map and the third group will use the existing signage on the streets.

You will be asked to verbalize your thoughts and decision making process (to think-aloud). When you talk all your words will be recorded by a smartphone which is already provided for you; to others on the street it will look like you are talking on the phone.

Think aloud method:

Think-aloud protocols involve participants thinking aloud as they are performing a set of specified tasks. Participants are asked to say whatever comes into their mind as they complete the task. This might include what they are looking at, thinking, doing, and feeling.

Please verbalize:
• What you are doing and why you are doing that
• What you are looking at, moving toward and…(describe the buildings and try to find out their function)
• Which street you chose/why. for example:
  I choose Edward Street because it is the shortest/ fastest route
  Or
  I choose Margaret St. because I don’t like to turn a lot, it is a straight route
  Or
  I like to walk in the shade so I head down to that street….
• What attracts your attention/confound you
• What you feel (Safe, scared, board, confused…) and why
• Every time that you feel lost
• Every time that you look at your map
• Which direction (left/right) you are looking at (when you are at a decision point).
• How you find your way by using your navigation aid (for example: I will use Edward street because it seem shorter)
• The degree of useability of your navigation aid (local signage is/isn’t easy to understand.)
• The degree of certainty of your decision making (yes I am sure I should go that way because….. or …I am taking that route by chance, because….)

Please avoid entering indoor spaces such as shopping malls and museums for some reasons:

1) Your GPS tracker might be disconnected
2) The floor plan of buildings are not the aim of this research
Appendix G: Sketch mapping test

Cognitive Mapping Test
Please draw a sketch map of your trip (Brisbane city), including all elements you remember; such as, streets and streets names, buildings, transport stations, key landmarks, etc. You do not need to recall what it is, just draw how you see the city (the accuracy is not the answer).
Appendix H: Sample of drawn cognitive maps

Cognitive Mapping Test

Please draw a sketch map of your trip (Brisbane city), including all elements you remember; such as, streets and streets names, buildings, transport stations, key landmarks, etc..
You do not need to recall what is, just draw how you see the city (the accuracy is not the answer).
Cognitive Mapping Test

Please draw a sketch map of your trip (Brisbane city), including all elements you remember; such as, streets and streets names, buildings, transport stations, key landmarks, etc.
You do not need to recall what it is, just draw how you see the city (the accuracy is not the answer).
Cognitive Mapping Test

Please draw a sketch map of your trip (Brisbane city), including all elements you remember; such as, streets and streets names, buildings, transport stations, key landmarks, etc.

You do not need to recall what it is, just draw how you see the city (the accuracy is not the answer).
Appendix I: Recognition test

(1)  

(2)  

(3)
Appendix J: Distance estimation task

Please score the distance between each pair of landmarks from 0 to 9; where 0 means next to each other (no distance) and 9 means the longer possible distance between two landmarks on this trip. (eg. The distance between South bank station and COWCH Café is 1)

1) Roma Street station and Brisbane City Hall

2) South Bank Beach and St Stephens Cathedral

3) South Bank Station and Roma Street Station

4) Cultural Centre Station and Roma Street Station

5) Cultural Centre Station and Queen Street Mall
Appendix K: Street Naming Task

Street Naming Test
Based on your memory, please write the street names correctly on the real map of Brisbane as many as possible you can.

ID: _______________
Appendix L: Sample of Transcriptions

S14 (Signage)

1) So I see a sign for river side, which is the river,
2) I’m gonno turn left walk up the hill,
3) I presumed it is parallel to the river.
4) This pathway has a lot of people, trees,
5) I am going to cross to the right.
6) It is mostly shadow which makes it a bit cold.
7) There is a new development,
8) oh I cant cross the road here.
9) Looks inviting.
10) Now I see the courte,
11) oh I see a sign toward King George square cycling centre,
12) ok so I revise my plan,
13) I was going to the cathedral at first,
14) but I am so close to king geroge square
15) so I go that way.
16) I am seeing someone riding
17) so I assume I am on the right direction.
18) I can see another sign indicating to my left
19) but I cannot read it yet.
20) I see the sign of George street,
21) and I see a sign toward south bank.
22) That sign shows 200m to cycling centre and 400 m to queen street mall.
23) This pathway is very wide and inviting.
24) I just read another sign which says cycling centre is 100 m that way
25) which means the direction that I came from
26) so it is annoying because the sign are in a U-shape.
27) There is no shops in this area,
28) and many alley ways that is not so inviting.
29) Just a blank big wall.
30) No one walks in this street either.
31) I see motorcycles parking under the bridge which is not nice.
32) I did do a U-shape because I saw this court before .
33) I can see the sign.
34) I presume I go back were I was and then turn left.
35) I see a church.
36) Some advertisements about the museum which means I am closing.
37) I see a building that I presume it is the city hall.
38) I go cross the road ro read the sign.
39) Ok the sign says I should cross the road.
40) It looks like a square,
41) ok I can definitely see the Brisbane city hall.
42) I see a lot of people.
43) Ok the river express way is on my left now.
44) I resume I should follow the people where the mall is.
45) Oh I see an alley way ending to a café which is cool.
46) Ok the way is going to the opposite direction where I am
47) I am coming from left to right and it is from my left to right..
48) I can see a yellow sign,
49) botanic garden to my south
50) Oh I see a sign information on queen street mall.
51) Ok I am at the queen street mall.
52) So if I walk one block to my left I should be at Elizabeth street and then cathedral,
53) I saw it on the map here in the signage.
54) I just walk one block in Queen st mall toward Edward Street,
55) because it is full of people and shops.
56) When I get to the Edward street I will turn toward Elizabeth
57) and then walk from there toward North Quay, .
58) I see Brisbane Arcade.
59) Winter Garden!
60) I have chosen to go to the right side, it is more cozy and crowded.
61) This is the Edward st here so I need to turn right.
62) Because nobody is there maybe I keep going straight.
63) The cathedral could be in a place with more walk.
64) It is nice tree, over hanging.
65) I see a big square, general post office, a big crossing on my left.
66) So here is definitely not the place for curch it is occupied by banks.
67) I gonno cross the road,
68) I decided to walk in this side because more people here.
69) Ok I am hoping the cathedral is on my left because the sign says Elizabeth st.
70) Ok looks lke a church is coming up.
71) I am hoping this is it.
72) I can see its sign yes it is the cathedral.
73) Now that I founf all three in this site.
74) So lets check ... 
75) now my next one is going to be the cultural centre station busway.
76) Just want to walk down in this street.
77) At the next intersection I will turn left
78) I presume it goes to the river.
79) Ok I am pretty sure the brige was the opposite to the roma street were I was
80) which means I should keep walking down Edward st.
81) I see so green areas maybe that is the edge of the river.
82) I look at the right and I see more people,
83) I am back in the Queen street mall.
84) I keep heading up.
85) I can see another buildings.
86) I keep walking in line with Queen st mall,
87) I am sure I am in the right direction.
88) I turn to Queen st mall
89) because at least when I am there I know where the cuktural centre is.
90) I like to wait and cross in the shade.
91) Ok I can see the wheel from here,
so I am sure I should go that way.
no access to footpath, so I have to turn right,
if I go left there is no shade.
I see some people walk down to the ferry,
I can see the bridge with a sign show to melbourne st.
so I go there, Victoria bridge.
I see two other bridges in my left and right.
Brisbane treasury.
Ich can see the GU and Conservatorium, art gallery, state library, museum.
But I am looking for the cultural centre,
Ok I see the bus way.
I am going to the right way.
I go to check what station it is.
Ok I should take the elevator.
Ok I saw the sign of the cultural centre.

From there I need to walk toward south bank beach, south bank station and Café.
Ok if the river is there I need to go that way.
I will follow the river.
I do not choose that way because the footpath is narrow and not inviting.
I choose walking beside the river because I can orient myself toward the beach.
Ok I see a playground. I can see kids in swimming costume so I am closing.
Ok I see a sign going to read.

Turn right for cafés.
No, I can see people with towels, if I go that way it is the beach.
Ok I see the beach over there, quite nice.
I can go to the right or left.
I choose the left because it looks nice.

Now I am looking for the road which says park avenue at south bank.
Ok where am I....
looking at the map on signage,
maybe here is called park avenue.
Ok I go to the park avenue apartments.
To the left toward southbank station.
I see another pink sign, so I go toward that.
I gonno walk down heal, I see a green sign.
Maybe that building is it so I just go to see.
Here is another pink sign, south bank rail station.
I go toward that.
I stay in this side because it has wide pedestrian road.
Most people in this side also.
Oh I see a very small sign for south bank platforms.
I am at the top of the station.
Now I should find the COWCH café, it is toward park avenue.
I will go back and I hope I see it.
I keep walking straight and if I need I will ask.
Marivale street. There is a construction so I have to cross now.
I am looking down the heal, toward Merivale
I cannot see the river, I go ...to see if I can see the river.
I think I am kind of lost.
I see the bus station I think the river is that way.
I need it to orient myself.
She looks at the map on the signage and maps her route.
I can see the train crossing where the bus way is.
I cross the other side because it is shadowy.
The palces on this street are residential so the café cannot be here.
Do you know where the COWCH café is?
From the map I know the Grey st has stuff on it.
Which means I might turn right and left again which is Grey st, based on my memory.
I see U of sunshine coast.
I am on the right direction.
Keep walking straight under the bus way.
I can see a sign left to the cultural centre,
I see cafes so I go that way to look for cowch.
I see a yellow sign post I go to check that.
There is no map on that.
If I look at the map on left is shorter than my right.
I go to look at that transport sign.
I go left to see which direction has the more density of cafes.
The café could be on that little one there.
I look at the map you gave me and compare it with this map.
COWCH is a block back away maybe it is on Gelang st.
I am going to walk up Grey until Gelang.
There is more students around.
I want to check this side first.
Cowch could be over there in Arbourne area.
It is not here..
Excuse me where is the COWCH Café? (She asks).
Oh was it there,
no way, I was at that intersection.

M08 (Map)

1) I wanna choose City hall first because I guess it is on my way
2) and then Queens street mall
3) and then the st Stephen cathedral Stephen cathedral.
4) Then I will cross the bridge.
5) Excuse me is City Hall this way? (Someone answered)
6) I love the city it reminds me of Tehran.
7) I prefer the peace in the coast.
8) I am crossing this street to find City hall.
9) I saw the adds of PANDORA. No name is written here.
10) I am crossing the st.
11) There is no signage pointing to the City Hall.
12) It looks like city hall. It is like a hall in fact.
13) But again no signage.
14) There are some signage like Romas st parkland. But no city hall.
15) I see a statue like a soldier on horse George the 5th.
16) I cant find any.
17) Ok this is City hall and I am heading to Queen st mall.
18) This is a Hall by the building itself not finding its name.
19) There is a sign to Albert st.
20) Yes this is Queen st mall, I found it.
21) I am heading to the st Stephen cathedral.
22) This street is very interesting it has many shops.
23) I love the restaurants here.
24) I have to turn right.
25) I think I am on the wrong direction.
26) The signage syas botanic garden.
27) I need to ask someone.
28) Ok I am in Elizabeth str.
29) I am asking someone. (she asked: them explained on the map, if you walk down and turn left and go straight it is there).
30) Ya I see Elizabeth st.
31) I see a building on the corner I cant fond the name of the building.
32) There is a statue of a king.
33) Ok it is on Elizabeth st. but obviously there is no cathedral here,
34) so I should head North.
35) So on the map I need to go to the third one.
36) Sorry where is St Stephen Cathedral? (next block).
37) I am heading straight on Elizabeth st. because there is no sign I had to ask.
38) Here is Hilton hotel.
39) I think the name of hotels and shops are bigger and more obvious than tourist attractions.
40) Now I walk down on Elizabeth st to reach the bridge to go to other destinations.
41) I should pass Victoria bridge and then cultural centre will be on the right.
42) I see a bridge but only for cars.
43) I am in Elizabeth st.
44) I should go to William st and then Victoria bridge.
45) I came back to the building with stature.
46) Oh I see sign of Victoria bridge so that is the bridge.
47) I guess the sigage is teriible in Brisbane.
48) Now I am in william street and I should turn right.
49) I found Victoria bridge.
50) I have to cross the street and then cross the bridge which is for both cars and people.
51) In 30 secsinds I will cross the bridge.
52) I am seeing Performing Art centre.
53) I see Griffith university.
54) I see the art gallery. Maybe behind it.
55) I continue and I will turn right at the first intersection.
56) I see a sign for cultural centre.
57) There is a cultural centre but...
58) ok I will try that way and if it was not behind the musum I will back because on the map it show it is behind the museum.
59) I should check the first street on the right.
60) Otherwise I will back an follow the direction and the end of the bridge.
1) I am on the Roma Street Station.
2) there is a big building in front of me.
3) It seems it is an apartment.
4) I see some signs showing where the food courts, ATMs and stations are.
5) Now I am looking at the gps I am starting from Roma Street Station
6) I prefer look for the closets one which is St cathedral.
7) So I will exit the door in front of the traffic light.
8) I look at the GPS and I would like to find how to go from here to St Stephen Cathedral.
9) I am still using it.
10) I know from my GPS it take 8 min walk and I should cross the street ...
11) but let me try...
12) no I am walking
13) I look at the google map again...
14) yes I am on the right direction
15) I am going to the George Street again
16) I see a police office on my right side ,
17) parking.
18) Oh I just realized that I am on the wrong direction.
19) I should go to the opposite direction ,
20) I am on the George Street
21) I am seeing on my right side .
22) and on my left it is still Roma Station.
23) I see the g hotel and a bridge for pedestrian people can walk from hotel directly to another street.
24) This city is very big.
25) Here there is no so many people just a few people.
26) I passed the hotel GEM.
27) I see a small park designed by Galy.
28) Oh I see big trees inside the park
29) I see red lampion Chinese culture.
30) Now I arrived in a conjunction and I see the sign of Roma street parkland
31) I think I should be in that direction.
32) Now I am heading to cross the road waiting for the red light.
33) OK the light is green
34) I am crossing the road.
35) I see park, flowers ...
36) weather is very good.
37) I see again on my right side a sign
38) I am wondering which path I have to take
39) I think the right one because I think we can pass through the parkland as well.
40) But I see there are more people who use this pedestrian road instead of the parkland road.
41) Ok I am still heading to ..
42) oh from this spot I can see a big cathedral maybe that is the one.
43) But it seems no it is just a church ,
44) my google map syays it is not the St Stephen cathedral .
45) I still have to walk and pass that beautiful church which is a unique church
46) because it is in the middle of modern buildings while it is historical.
47) OH on my right side I see parkland
48) I enjoy the noise of water
49) I realized that my track is a bit steepy so it takes more energy
50) I still feel Ok because I didn't walk that much yet.
51) I am looking at my GPS It says I have to cross the bridge
52) I am so lucky because the light is still green.
53) I think I am heading the wrong direction
54) now I am stopping on the intersection
55) I am a little bit confused because there is a traffic light here and there is a sign of Albert St to my right and Turbot Street to be in front of me
56) I don't know which street that I have to take.
57) So ok I need to take Turbot St and keep going on.
58) I see on my right side again it is look like an old building nice
59) oh it is Queensland University Dental College.
60) I see some people in front of me.
61) On right, I see modern and on left, I see historical city.
62) I am amazed by this city because they still preserve their historical buildings.
63) I am still walking on the Turbot St and then I will find Edward St after this.
64) I see tall buildings and wow.
65) Now I am still look at my GPS because I see some people come out from that building
66) and I am wondering what that building is.
67) I think it is office.
68) I think I am quite close to the intersection in front of me.
69) I look at my GPS again confirm me whether or not I am on the right direction.
70) I have to turn to right according to gps.
71) now I see people make cross I run to follow them.
72) I have a second cross to pass.
73) I see the previous cathedral from it back side...
74) oh now I see it is not a cathedral it is just a café.
75) Looks similar with what I see before.
76) I am walking I see many signs but I am not looking at them
77) I know that the cathedral I am looking for is not around here.
78) But it is amazing the road is coming down from the hill
79) and I see lots of café in front of me.
80) I am looking on my left side and I am seeing the sign of Edward street.
81) I also see the sign of Ann St and Central Station.
82) Now I am waiting to cross.
83) I keep walking..
84) now I see beautiful building which is not very old but not modern one it is a big store.
85) Oh a tall building.
86) I see 7/11.
87) Keep going..
88) waiting for the cross..
89) crossing now...
90) I can go to Adelaide St but I keep going straight.
91) I see nice stores and buildings.
92) I see a beautiful art sculpture.
93) I still see and enjoy this.
94) In front of me I see an old building.
95) Now I am in Queen plaza street.
96) I am seeing the crowed on my right side.
97) I am heading straight ahead.
98) I need to walk 2 more minutes and turn left.
99) On my left I see a bus or train station.
100) MacArthur oh no it is a shipping centre.
101) According to Gps I SHOULD TURN left at this point.
102) I see the top of the cathedral...going to take picture.
103) I am looking in front of the cathedral some people are moving.
104) Now I am glad because I could find one of the destinations.
105) Oh it is really an old one.
106) Oh I see the name of the cathedral...St Stephen.
107) Now I am on Elizabeth St.
108) I look at my GPS, I need to go to Queen St mall,
109) I just passed it so I donot to use my GPS to go there.
110) I know how to go there.
111) After that I need to go to the Brisbane City hall.
112) I am depending on what I have seen before.
113) So I am heading to the opposite and I make a cross.
114) I am heading to Queen st mall and City hall.
115) I am in the Elizabeth st.
116) now I am crossing the street and turning right to the path that I had passed before.
117) Looking at my left and I see shops.
118) I arrived Queen st mall easily.
119) Now I am going to City Hall.
120) This street is crowded but not annoying noisy.
121) I see the crowed.
122) I see a beautiful architectural building facade is full of butterflies.
123) I now looking for a sign to city hall.
124) I havn't find it, so I walking straight.
125) I choose my right side to walk because people are walking on the opposite direction.
126) There is an intersection
127) oh yes I see the Yellow sign maybe it directs me to the city hall.
128) Unfortunately they only show king George square, ...
129) now I am seeing the tower from here so I am heading toward the King George square.
130) I see a market in front of the city hall.
131) I see the sign of King George SQ STATION.
132) I see a cathedral that I saw initially.
133) I need to go to the cultural centre station,
134) I may take the bust instead walking.
135) I look at my Gps to see how to get from here to Cultural centre station.
136) Ya I know it I can go by walk.
It is only 12 min.
I need to take a break.
I try to walk to several direction to find out which one is correct according to GPS.
I am seeing again my google map.
it says I have to turn left to George street
I think I am lost
I donno I am heading right.
I am walking to the wrong direction so I turn back to the opposite.
I am walking on the my right side. I
donno why the Gps shows me that I am walking on the wrong direction.
I know that cultural centre is close to the south bank
so I know can go the direction of south bank written on the yellow sign.
I am sure I am on the right direction.
Lots of people here.
I am heading to Victoria bridge here.
I see my Gps again.
the café has divided the street to the right and left side
I take the right side.
at the end of the Queen st mall I see some different buildings but the different part of this street are so similar
it made me think I already have passed here..
I can see the bridge in front of me.
I am looking again at my map to see whether?
yes it says at the end of the bridge I will be at the cultural centre.
Good I don’t need to look at the map a lot to there.
I am enjoying my surrounding.
I can see a big wheel.
Griffith University building.
it is open space and beautiful.
I am heading the cultural centre.
The river city wheel it is breathtaking!
Very beautiful.
I see the state library.
I think I like to enjoy this city by walking.
It is so open here! Hut and windy.
I can see the art centre, some posters.
Some people riding bicycle.
I can see the cultural centre station.
I don’t use my GPS, because I already had it on my mind
I have to go to street beach in south bank.
I see in front of me there are some people...
I just looking for a sign to park avenue.
oh I cannot see the park avenue
I cannot find the park avenue here,,
ahh..the south bank beach!
Ok...I am looking at Google map again.
I need to go to south bank station first.
Now I am getting confused whether I need to go to the south bank beach.
Because close to the south bank beach
I can see the Cowch Café my final destination.
I like to plan my trip from here.
I like to go to beach and the station and then my final spot (cowch).
I look at the google map it says it takes 10 min walk from here to south bank beach.
Arbour street it says where is it?
ok...I need to make the crossing under the bridge to the Melbourne street.
I am walking under the bridge,
I can see that I have to pass the wheel.
I can see the park avenue is at the end of this road.
I see the sign of south bank parklands.
At my right side I can see the performance.
oH I can see the sign of Brisbane from here.
It is lovely seeing people using bicycle here.
I see a very tall building impressed me (tallest).
I need to walk under the shade.
I like to take a seat and enjoy the scenery in south bank parkland.
I am keep walking.
Now I am looking again at my map to find park avenue.
It is 500 m from here ..it says I am already here,oh,,,,ya I am here.
Now I need to go to South bank station.
I see a market. Now I am walking on this flowery alley.
I look at the gps to see if I am on the right direction.
Ok now I Know where I am it say I should turn right.
Ok ON MY LEFT LOTS F Café.
On my right I see the park.
Now I am really depend on road sign because my gPS stoped working.
Even I don’t knoe where should i....oh now I know the problem.
I had written wrong destination.
I corrected it now I am close.
According to this I should walk straight it should be 5 min from now
. I AM FOLLOWING THE PEOPLE I feel continence not to cross a lot.
I look at Gps again to see where I am.
Now I am trying to look for the sign of the south bank bust staion.
Oh this sign was not for that.
It is showing the restaurant.
I feel lost.
I see cinema like I am in a conjunction and also lots of restaurant.
I know I am near Ernest st but I don’t see any sign to the bus station.
I really need a clue now.
I am looking at the map to see where I am now
. I should go out from ...
it sayd it is on my right side and take 4 min to go there.

I am still walking and I don know...

now I am walking under a bridge

I don’t know what bridge is this.

South bank station....

Oh no I am heading the wrong way.

I can see a signage toward other places but south bank station.

I need to go back and start again from the round about in front of the cinema.

It says I should make a cross in front of the cinema.

I hope I am heading to the right direction.

Yes I can see lots of restaurants and stores.

I am closing to the south bank station on the right direction.

Looking again at GPS it say 3 min

.i am still walking ...

,,I see an under construction building in front of me.

Ya people make a cross I am following them

I feel safer to cross in group.

I see a sign on the wall directs me to the south bank station platform1.

Now I am following the crowed.

I see my GPS it says I will arrive in station in 1 min.

Now I can see the platform of busway station.

I just need to go back to cowch café.

Found it!
Appendix M: Sample of Kruskal-Wallis and Mann-Whitney Tests

Kruskal-Wallis Test

<table>
<thead>
<tr>
<th>Tools</th>
<th>N</th>
<th>Mean Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>positive</td>
<td>12</td>
<td>19.88</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>24.38</td>
</tr>
<tr>
<td>3</td>
<td>14</td>
<td>15.00</td>
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<tr>
<td>Total</td>
<td>36</td>
<td></td>
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Test Statistics$^a,b$

<table>
<thead>
<tr>
<th>Tools</th>
<th>Kruskal-Wallis H</th>
<th>df</th>
<th>Asymp. Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>positive</td>
<td>4.967</td>
<td>2</td>
<td>0.09</td>
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</tbody>
</table>

a. Kruskal-Wallis Test
b. Grouping Variable: Tools

Mann-Whitney Test

<table>
<thead>
<tr>
<th>Anticipatory</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tools 1:00</td>
<td>9</td>
<td>9.69</td>
<td>69.00</td>
</tr>
<tr>
<td>2:00</td>
<td>6</td>
<td>5.17</td>
<td>31.00</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Test Statistics$^a$

<table>
<thead>
<tr>
<th>Tools</th>
<th>Mann-Whitney U</th>
<th>Wilcoxon W</th>
<th>Z</th>
<th>Asymp. Sig. (2-tailed)</th>
<th>Exact Sig. (2*(1-tailed Sig ))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10,000</td>
<td>35000</td>
<td>2.205</td>
<td>0.027</td>
<td>0.058</td>
</tr>
</tbody>
</table>

a. Grouping Variable: Anticipatory
b. Not corrected for ties.