Sketch maps and verbal descriptions in structuring space

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Abstract

This paper reports the preliminary results of a study that aims at designing an intelligent navigation system providing automated scene descriptions and effective directions for a wayfinder. In general, there are two ways for humans to communicate about a route and its surroundings, which are verbal descriptions and graphic depictions (for instance sketch maps). Spatial preposition in language and spatial arrangement of depicted objects reflect how humans select and localise spatial objects relating to a route in navigation. This information is critical to the development of an effective cognitive model for an intelligent navigation system. An experiment including two different sizes of environments was carried out. Participants were asked to provide route instructions using both sketch maps and verbal directions. The comparisons of the two types of route instructions focus on spatial disposition and are based on the linguistic conceptual framework proposed by Talmy. The results demonstrate the basic distinctions of geometry and spatial relation in structuring a walking space.

Keywords: sketch map, verbal description, navigation, language, Ground, Figure.

1 Introduction

Various navigational systems have been developed as aids in wayfinding. The majority of them provide users with sequence-based (or turn-by-turn based) route instructions. They assist people in gaining the ability to get from one place to another, without getting lost in most of the time. The problem is when a person follows a specific route instruction, the configurational understanding of his/her travel space is not usually acquired or used. *Configurational knowledge* is commonly referred to as a part of cognitive map or mental map, the knowledge of relative locations including the distances and directions between those locations in a physical environment (Siegel & White, 1975). This knowledge allows us to think up a new short-cut, to follow a familiar route, to point toward places we cannot see, and to know where the real North is (Kuipers, 1978). The lack of such configurational knowledge can cause disorientation and poor spatial awareness when a navigation device is not available (Krüger, Aslan & Zimmer, 2004).

Ideally, an intelligent navigation system should facilitate both the ease of wayfinding and the acquisition of configurational knowledge of its user. An effective cognitive model is necessary to the design of such system. In general, there are two ways, verbal descriptions and sketch maps, for humans to communicate about a route and its surrounding space. Unlike computerised route instructions provided by existing navigation systems, verbal and sketch descriptions are incomplete, schematised, abstract, and qualitative rather than quantitative (Talmy, 1983; Wang & Schwering, 2015). These two useful forms of route descriptions extract the essential and relevant information for navigation and eliminate the inessential and irrelevant one. Schematisation found in both forms reflect the schematisation in cognitive maps, which enables us to process and acquire spatial information effectively.

In this paper, we are interested in comparing people's views of space in navigation externalised in both language and sketches. The current study concerns with the basic spatial distinctions that verbal descriptions and sketch maps mark in structuring a walking route and its surrounding environment. Talmy's (1983) work on how language structures space is used to guide this comparison. By doing that we attempt to answer the following two questions.

- What are the basic geometric distinctions between verbal descriptions and sketch maps in describing a route?
- Does spatial scale influence such distinctions, and how if it does at all?

We believe knowing the answers are critical in developing an effective cognitive model, which facilitates both wayfinding and spatial knowledge acquisition, especially configurational knowledge during wayfinding.

2 Background

Freundschuh (1991) proposed a model that suggests three kinds of hierarchical spatial knowledge. The first type is the landmark knowledge, which Freundschuh named it as geographic facts.

Geographic facts are the facts of the existences, characteristics and locations about places. The second type is the route knowledge that links together several landmarks. “At a minimum, route knowledge consists of a set of choice points [landmarks], the paths that link these landmarks [roads, etc.], and the action executed at these landmarks [go left/right, go straight]” (Freundschuh, 1991:p.170-171). Configurational knowledge is the third type of spatial knowledge and is usually built up from observations gathered as a person travels through the environment (Kuipers, 1978). It connects together route knowledge to form a network among multiple places. According to Freundschuh (1991), landmark knowledge is a basic and necessary component of both route and configurational knowledge, and configurational knowledge can be acquired from the initial route knowledge plus increased navigation experiences. All the three types of spatial knowledge exist in cognitive maps and enable us travel with efficiency and confidence.

Spatial knowledge can be externalised as (or communicated through) either verbal descriptions or sketch maps. Researchers utilise both forms to assess and understand acquired spatial knowledge stored in cognitive maps. Sketch maps are used to study survey knowledge of an area (Wang & Schwering, 2015) and to study a particular route (Rovine & Weisman, 1989; Münzer, Zimmer & Baus, 2012; Wang & Li, 2013). These sketched maps are analysed either qualitatively (Kettunen *et al.*, 2013; Schwering *et al.*, 2014) or quantitatively (Gardony, Taylor & Brunyé, 2016). For verbal descriptions, cognitive psychologists are interested in understanding the visuospatial process that transferring linguistic descriptions into cognitive maps to support decision making. Denis (1997) collected participants’ route descriptions and developed a minimal set of verbal descriptions called skeletal descriptions. The skeletal descriptions were tested in several wayfinding studies (e.g., Daniel *et al.*, 2003) and were used to study how verbal descriptions support spatial orientation in wayfinding (Schwering *et al.*, 2017). Linguists identify and categorise words, especially prepositions in verbal descriptions to study how spatial information is conveyed by language. Spatial expressions in language distinguish figure and ground objects in relation to their background objects and use multiple reference frames to describe spatial relations (Talmy, 1983; Levinson, 1996).

The comparison between verbal and sketch descriptions in this study is on the basis of Talmy’s work. Talmy (1983) provided critical evidences from linguistics on how space is structured in language. He stated the important cognitive-linguistic research thread in cognitive geographical research (Mark *et al.*, 1999). His most relevant work to the current study is the finding of the geometric characterisations of objects and their spatial relationships to each other within different reference frames. We elaborate it with more details in Section 3.2 as part of our methodology.

Researchers suggest that the spatial scale of an environment is an influential factor in the acquisition of spatial knowledge, which results in qualitatively different spatial knowledge and wayfinding strategies (Bell, 2002). As the major motivation of this study, we aim to look at the spatial knowledge provided for wayfinding in a small campus and a larger metropolitan area and investigate their differences in both visual and verbal formats.

3 Methods

3.1 Experiment

We designed a behavioural experiment to collect sketch maps and verbal descriptions from participants. Participants were asked to externalise their spatial mental representations of an environment in the context of wayfinding. Given that the influences of spatial scale were taken into account in this study, we considered two study areas of different sizes, a university campus and a metropolitan area. We used one author’s university campus (uptown campus of University at Albany) and the city of New York as the two testing environments and two pairs of origin-destination points were chosen. For each testing environment, participants were asked to be in a scenario that someone who has never been to the testing environment wants to get from the origin to the destination.

So far eight qualified participants (four male and four female) joined this study. Participants were recruited not from a particular discipline or class but throughout the entire campus. The only selecting criterion was that they were familiar with both uptown campus and Manhattan in New York City. Participants should have spent more than half a year at the uptown campus and came from the metropolitan area of New York. This was to make sure that all participants’ familiarity with both environments are similar. All participants were enrolled in an academic program here on campus with an average age of 23.10 (SD = 5.69). Each participant completed two scenarios in counter order to avoid the training effect. Upon receiving each scenario, each participant was provided a blank sheet of paper to draw the sketch map showing the direction. When sketch maps for both given scenarios were drawn, the participant was provided with a computer to type his/her verbal descriptions.

3.2 Talmy’s linguistic grammer of space

The comparison between verbal and sketch descriptions follows Talmy’s linguistic conceptual framework (1983). We elaborate his work as part of our method as follows.

It is human nature to locate objects with respect to other objects in a relativistic way (Svorou, 1994). Talmy (1983) observed that the way we locate objects with respect to one another in language involves the recognition of an asymmetrical relation between the object we want to locate (Figure) and the object with respect to which we locate it (Ground). For example, a possible spatial relation between a cup and a table is when the cup is on the table (we usually do not say a table is under the cup). Talmy borrowed the terms Ground and Figure from Gestalt psychology to distinguish the two types of objects in the asymmetrical spatial relation:

> The *Figure* is a moving or conceptually moveable object whose site, path, or orientation is conceived as a variable the particular value of which is the salient issue. The *Ground* is a reference object (itself having a stationary setting within a reference frame) with respect to which the Figure’s site, path, or orientation receives characterization (Talmy, 1983:p.232).

People attend to and recognise asymmetrical relations with respect to size, containment, support, orientation, order, direction, distance, motion, or a combination of these (Svorou, 1994). The Ground object is usually more permanently located, more backgrounded, larger in size with known spatial characteristics, while the Figure object is usually more moveable, more salient, smaller in size with spatial variables to be determined (Talmy, 1983). In general, the Figure is schematised solely as a point or related simple extension, while the Ground is usually conceived with greater geometric complexity. Talmy summed up the ranges of geometries of both types together with the prepositions that are used to indicate these geometries.

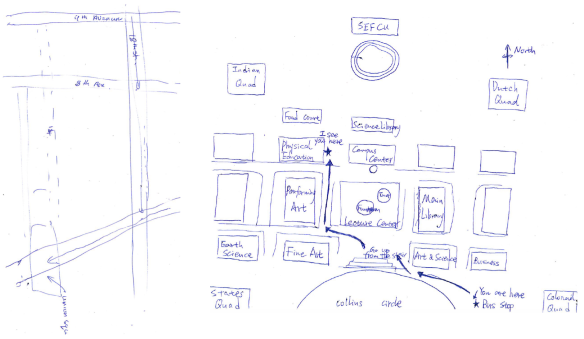
Geometries of the Ground are described with bias in language. Talmy introduced three situations of biasing: biasing of parts, biasing in directedness and using the earth as reference object with biased geometry. He also discussed the application of reference frames in language and the linguistic schematisation in describing space.

To conclude, according to Talmy (1983), a spatial arrangement of two or more spatial objects can be described using language in a number of ways regarding geometric and dimensional distinctions of the Ground and the Figure objects within certain reference frames. The speaker's choice of construe a way of spatial arrangement reflects the underlying linguistic frame. This is why we are unlikely to say "the table is under the cup" but rather we would say "the cup is on the table". Following Talmy's work, we studied the spatial arrangement of objects found in our verbal descriptions and later compared them with sketch maps.

4 Results and Discusions

Overall, participants tended to draw more objects (mostly buildings, streets and paths) with more details (names, relative sizes with respect to other objects) to describe the route and its surroundings in the sketch maps of the smaller campus than the larger metropolitan area. On average 19 objects were sketched in the small area while only 9 objects were sketched in the large area. Most participants only included the origin, the destination and the (abstracted and incomplete) streets connecting them in the sketch maps of large area. In contrary, sketch maps of small area included more objects that are either along the walking route or located at decision points. Figure 1 shows an example of the sketch maps of the two different areas.

Figure 1: Large area (left) *vs*. small area (right).



The same situation was not found in verbal descriptions. In general, we found longer verbal descriptions of the large environment containing more objects that are either along the route or located distantly. According to the classification framework proposed by Anacta *et al*. (2017), these objects are local or global landmarks facilitating spatial orientation of wayfinders. These objects in language, however, were not found in the sketch map from the same participant. For example, the participant who drew Figure 1 (left) included the detailed information of the Time Square in his/her verbal description ("You will notice Times Square, it has lots of huge oversized neon billboards"), which cannot be found in the sketch map. According Talmy (1983), it is natural that language permits an elaboration of references made to the same configuration, and it is a positive feature of language organisation that people can refer repeatedly and from different perspectives to the same referent. We did not find significant differences in the linguistic elaboration between the two test environments.

The distinction of the Ground and the Figure is explicit in verbal descriptions by using certain prepositions. In the small area, the relative frame is used primarily for the scene that can be viewed from the observer's current location. In the large area, the verbal descriptions contain both extrinsic reference frames as in survey descriptions and intrinsic reference frames with a person as the central reference object (Taylor & Tversky, 1996). The earth is used as the Ground object along with the body to structure the large metropolitan area, and the three-way opposition (up and down, north and south, east and west) appears frequently, e.g., "go south on Broadway for a block as you look for a street that will take you right or west". We categorise the geometry of the Ground and the Figure found in the verbal descriptions in Table 1.

Table 1: Geometry of the Ground and the Figure found in verbal descriptions.

Type	Example
point-point	in-between two large towers
point-plane	on level surrounds the fountain
point-line	walk down the road
line-line	Two parallel streets
line-plane	walk through the parking lots

The characterisation of location by using more than one reference object is also found often in verbal descriptions. For the large environment, participants commonly used the directed space set up by the earth as secondary reference object (The Ground). Consider the expression "go west towards Times Square on 42st". Here the Times Square is the primary reference object as an end-point and the path of the Figure (the participant who imagine himself/herself as the wayfinder) towards the end-point is determined by the secondary reference object (the earth). According to Talmy (1983:p.247), the 'west' expression requires "looking outside the primary reference object, to the arrangement of the earth's orientation, in order to effect a comparable narrowing down of locale". For the small environment, participants also used secondary reference object for localisation such as "walk all the way down to the Education building". However, here the use of the earth as the secondary reference object is not as common as it is in the large environment.

Sketch maps do not explicitly distinguish the Ground and the Figure. The drawing style cannot reveal the Ground/Figure distinction because they are probably both sketched as rectangles or blobs with similar sizes next to each other, which we cannot tell if one shape looks more prominent and backgrounded than the other. The drawing sequence may indicate some kind of reference/referent distinction. We found that participants usually draw waypoints (origins, destinations and decision points) and the paths connecting them first, and then locate other objects (as referent objects) that are either adjacent to these waypoints (as reference objects) or along with the paths (as reference objects). Regarding reference frame, due to schematisation and distortion, local reference frames are usually used for measuring spatial relations (Schwering *et al.*, 2014). No significant impact of spatial scale is found on sketch maps of different testing areas.

Different from sketch maps which are able to provide spatial relationships among spatial entities at the configuration level (Wang & Li, 2013), verbal descriptions embed an egocentric perspective that spatial relationships are established between a person and his/her surrounding entities to support spatial orientation. The prepositions used in the verbal descriptions indicate both dimensional property and the type of spatial relations between the Figure and the Ground (usually positional and orientation relations). For example, in the expression "you are on the level surrounds the fountain" the preposition surround indicates that the Figure (observer's current location) is inside the Ground (a 2-D enclosure) which contains a fountain as the secondary reference object.

5 Conclusions and Future Work

Both verbal descriptions and sketch maps are good tools for wayfinding, and schematised routes from sketch maps are very much the same way as verbal descriptions (Tversky & Lee, 1998). Comparing with computerised route instructions with accurate metric information used by existing navigation systems, these two formats communicate spatial information in a schematised and abstract way. Verbal descriptions contain the information of dimension, salience, and size difference although the exact information of shape and magnitude is considered irrelevant and usually abstracted away. The reference/referent distinction is explicit in verbal descriptions and local spatial relations can be inferred from the prepositions used. Sketch maps have no explicit distinction between reference and referent objects regarding shape, dimensionality and magnitude. Spatial objects and their geometric complexity found in linguistic expressions are not always found in corresponding sketch maps. This is due to the positive feature of language organisation that people can refer repeatedly and from different perspectives to the same referent. Sketch maps allow the computation of configurational knowledge using some kind of sketch interpretation method (Wang & Worboys, 2017) while verbal descriptions are good at representing the relative and egocentric spatial relations (landmark and route knowledge) facilitating spatial orientation. We also found the influences of spatial scale on number of objects and type of reference frames.

This study contributes to the understanding of the differences between language and sketches as the two forms of route guidance for wayfinding. With the support of continuing data collection, we can inform a new design of pedestrian wayfinding aids by using the most effective form to represent spatial information for specific purposes.

The future work based on the current study is listed as follows. Arrangement of environment affects how humans perceive and learn an environment and consequently the acquisition of spatial knowledge (Lynch, 1960; Freundschuh, 1991). In Lynch's study, residents of Los Angeles (gridded regular environment) had little difficulty in maintaining direction on the paths while residents of Boston (winding irregular environment) found many localisation difficulties and were easily disoriented. The current study has gridded regular environment and another irregular environment will be added to our following study.

Language shapes thought. There exists influences of cross-language differences in structuring space, e.g., different languages make use of different sets of reference frame; or these languages may use the same set of reference frames differently; or these languages may use a same set of reference frames differently (Bloom & Keil, 2001). Some languages do not use the relative reference frame but an extrinsic reference frame instead. A different language will be introduced in the future e.g., Chinese use extrinsic reference frame much more often than English speakers.

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References

Anacta, V.J.A., Schwering, A., Li, R. & Muenzer, S. (2017) Orientation information in wayfinding instructions: evidences from human verbal and visual instructions. *GeoJournal*, 82 (3), 567–583.

Bell, S. (2002) Spatial cognition and scale: A child's perspective. *Journal of Environmental Psychology*, 22 (1–2), 9–27.

Bloom, P. & Keil, F. (2001) Thinking through language. *Mind & Language*, 16 (4), 351–367.

Daniel, M.P., Tom, A., Manghi, E. & Denis, M. (2003) Testing the value of route directions through navigational performance. *Spatial Cognition and Computation*, 3 (4), 269–289.

Denis, M. (1997) The description of routes: A cognitive approach to the production of spatial discourse. *Cahiers de Psychologie Cognitive*, 16 (4), 40–458.

Freundschuh, S.M. (1991) The Effect of the Pattern of the Environment on Spatial Knowledge Acquisition. In: David M. Mark & Andrew U. Frank (eds.). *Cognitive and Linguistic Aspects of Geographic Space*. Dordrecht, Springer Netherlands, pp. 167–183.

Gardony, A.L., Taylor, H.A. & Brunyé, T.T. (2016) Gardony

Map Drawing Analyzer: Software for quantitative analysis of sketch maps. *Behavior Research Methods*, 48 (1), 151–177.

Kettunen, P., Irvankoski, K., Krause, C.M. & Sarjakoski, L.T. (2013) Landmarks in nature to support wayfinding: The effects of seasons and experimental methods. *Cognitive Processing*, 14 (3), 245–253.

Krüger, A., Aslan, I. & Zimmer, H. (2004) The Effects of Mobile Pedestrian Navigation Systems on the Concurrent Acquisition of Route and Survey Knowledge. *Mobile HCI*, 39–60.

Kuipers, B. (1978) Modeling spatial knowledge. *Cognitive Science*, 2 (2), 129–153.

Levinson, S.C. (1996) Frames of Reference and Molyneux's Question: Crosslinguistic Evidence. In: *Language and Space*, pp. 109–169.

Lynch, K. (1960) *The image of the city*. MIT Press.

Mark, D.M., Freksa, C., Hirtle, S.C., Lloyd, R., et al. (1999) Cognitive models of geographical space. *International Journal of Geographical Information Science*, 13 (8), 747–774.

Münzer, S., Zimmer, H.D. & Baus, J. (2012) Navigation assistance: A trade-off between wayfinding support and configural learning support. *Journal of Experimental Psychology: Applied*, 18 (1), 18–37.

Rovine, M.J. & Weisman, G.D. (1989) Sketch-map variables as predictors of way-finding performance. *Journal of Environmental Psychology*, 9 (3), 217–232.

Schwering, A., Krukar, J., Li, R., Anacta, V.J., et al. (2017) Wayfinding Through Orientation. *Spatial Cognition and Computation*, 17 (4), 273–303.

Schwering, A., Wang, J., Chipofya, M., Jan, S., et al. (2014) SketchMapia: Qualitative Representations for the Alignment of Sketch and Metric Maps. *Spatial Cognition & Computation,* 14 (3), 220-254.

Siegel, A.W. & White, S.H. (1975) The development of spatial representations of large-scale environments. *Advances in Child Development and Behavior*, 10 (C), 9–55.

Svorou, S. (1994) *The Grammar of Space*. Typological Studies in Language. Amsterdam, John Benjamins Publishing Company.

Talmy, L. (1983) How Language Structures Space. In: *Spatial Orientation*. Boston, MA, Springer US. pp. 225–282.

Taylor, H.A. & Tversky, B. (1996) Perspective in spatial descriptions. *Journal of Memory and Language*, 35 (3), 371–391.

Tversky, B. & Lee, P.U. (1998) *How Space Structures Language*. Springer, Berlin, Heidelberg, pp. 157–175.

Wang, J. & Li, R. (2013) An Empirical Study on Pertinent Aspects of Sketch Maps for Navigation. *International Journal of Cognitive Informatics and Natural Intelligence*, 7 (4), 26-43.

Wang, J. & Schwering, A. (2015) Invariant spatial information in sketch maps — a study of survey sketch maps of urban areas. *Journal of Spatial Information Science, 11(2015), 31-52*.

Wang, J. & Worboys, M. (2017) Ontologies and representation spaces for sketch map interpretation. *International Journal of Geographical Information Science*, 31 (9), 1697–1721.