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RESEARCH REPORT

Landmarks in nature to support wayfinding: the effects of seasons and experimental methods

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Abstract Landmarks constitute an essential basis for a structural understanding of the spatial environment. Therefore, they are crucial factors in external spatial representations such as maps and verbal route descriptions, which are used to support wayfinding. However, selecting landmarks for these representations is a difficult task, for which an understanding of how people perceive and remember landmarks in the environment is needed. We investigated the ways in which people perceive and remember landmarks in nature using the thinking aloud and sketch map methods during both the summer and the winter seasons. We examined the differences between methods to identify those landmarks that should be selected for external spatial representations, such as maps or route descriptions, in varying conditions. We found differences in the use of landmarks both in terms of the methods and also between the different seasons. In particular, the participants used passage and tree-related landmarks at significantly different frequencies with the thinking aloud and sketch map methods. The results are likely to reflect the different roles of the landmark groups when using the two methods, but also the differences in counting landmarks when using both methods. Seasonal differences in the use of landmarks occurred only with the thinking aloud method. Sketch maps were drawn similarly in summertime and wintertime; the participants remembered and selected landmarks similarly independent of the differences in their perceptions of the environment due to the season. The achieved results may guide the planning of external spatial representations within the context of wayfinding as well as when planning further experimental studies.

Keywords Landmark · Wayfinding · Thinking aloud · Sketch map · Nature · Seasons

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Introduction

Landmarks are important as reference points for understanding spatial structures through spatial relations as well as for identifying decision points and monitoring progress during navigation (Sorrows and Hirtle 1999). Consequently, the level of landmark knowledge has important implications for all human spatial activities. Landmark knowledge can be acquired through direct experience with the environment or through external representations of the environment, such as verbal descriptions, photographs or maps (Presson and Montello 1998). External spatial representations are particularly utilised within the context of unfamiliar environments when initial spatial knowledge about a previously unknown environment is needed. External representations are always generalised in one way or another. The generalisation in visual external representations involves selecting relevant information for the purpose and visualising that information in an understandable way (Sarjakoski 2007). Similarly, the verbal spatial descriptions consist of landmarks that are relevant for the particular activity in question (Hirtle et al. 2011). In order to be useful navigation aids, external spatial representations should represent landmarks that are appropriate for wayfinding. The appropriateness of using particular features as landmarks depends primarily on their saliency in the environment, but also on environmental conditions such as the season and type of terrain (Sarjakoski et al. 2011), which pose considerable challenges when selecting the particular features that should be represented.

In this paper, we examine the way in which people perceive and remember landmarks along a nature route through a study that we carried out in both summertime and wintertime. We collected the data using two methods in both seasons: the thinking aloud method while walking along a route and the method of drawing a sketch map of the route afterwards. We aimed to identify how different landmark groups are used in different seasons, which may guide the selection of landmarks for creating external spatial representations of routes. We also analyse how the use of landmarks differs between the two experimental methods, which increases understanding of the methods and provides guidance for selecting appropriate methods for future experiments.

Related research

There is a long tradition of studying human spatial knowledge of physical environments, or internal spatial representations, beginning with the Lynch's (1960) pioneering work on the conceptualisation of urban spaces. A major difficulty in studying spatial knowledge is that internal representations cannot be measured directly; rather, they require experimenting with indirect methods, in which subjects externalise their knowledge either explicitly or through their behaviour while performing spatial tasks (Newcombe 1985). Indirect measuring methods include such externalisations as distance and direction estimates, drawn sketch maps and verbal descriptions. Different indirect methods easily yield different results for the same tasks because derivation is needed for transforming the collected data into the knowledge about internal representations. Therefore, the methods for investigating internal spatial representations should be as direct as possible, that is, a minimal amount of derivation should be applied when computing the results from the data (Newcombe 1985). Careful consideration of the particularities of the methods is necessary in the experimental studies of spatial knowledge.

The method in which participants draw sketch maps is rather direct because the participants externalise their conception of the environment directly in a spatial setting. However, drawn sketch maps contain simplified, distorted information that is relevant for the purpose of the sketch and that depicts the conceptual structure of spatial information rather than the actual structure of an environment (Tversky 2002). The sketch map method was already frequently being used and had proven to be efficient for assessing spatial knowledge at the time of Newcombe's (1985) review. The method achieved additional reliability a few years later when Blades (1990) showed that an individual's sketch maps remain similar over time. Blades (1990) asked subjects to draw route maps and additionally observed that the direction of the route did not affect the contents of the sketch maps. Researchers have also established cross-method validity for the sketch maps and verbal descriptions: both methods have been shown to reflect similar spatial knowledge (Lohmann 2011; Tversky and Lee, 1999). Lohmann's (2011) results are also interesting because they verify from a behavioural standpoint the neuropsychological finding that verbally and visually acquired spatial information is processed in similar ways in the human brain (Mellet et al. 2000).

Thinking aloud during spatial tasks is another rather direct method for measuring spatial knowledge. The method of concurrent thinking aloud has been applied in a wide range of tasks (Ericsson and Simon 1998), from usability tests (van Elzakker et al. 2008; van den Haak et al. 2003) to text comprehension (Kaakinen and Hyönä 2005). Thinking aloud protocols can be analysed qualitatively and quantitatively, both manually and more automatically, with verbal data or protocol analysis (Chi 1997) methods and different natural language processing (NLP) methods (Manning and Schütze, 1999). For spatial tasks, successful qualitative applications of the thinking aloud method have been carried out in order to identify the spatial contents of sentences, such as route actions and landmark descriptions (Denis 1997; Brosset et al. 2008). A quantitative analysis using NLP was carried out by Sarjakoski et al. (2011) with the same thinking aloud data that is used in the present analysis. Landmark class counts resulted in outcomes that verified the qualitative observations that were made during the experiments and by reading the protocols.

The formation and organisation of long-term spatial mental representations have usually been studied on small, room-sized scale. The participants have first learned the configuration of an array of objects, and then they have defined the directions between objects from a certain imagined spatial orientation (Marchette et al. 2011; Marchette and Shelton 2010; Valiquette et al. 2007). The results have shown that spatial representations require a preferred spatial direction and orientation, and this seems to apply also for large-scale spaces (McNamara et al. 2003). The encoded orientation depends on the possible environmental axes elicited by the structure of the environment and egocentric experience, which depends on the user's direction of movement and orientation when they are exploring and learning about the environment (McNamara et al. 2003). In addition to the configuration of objects, the properties of the objects themselves may provide reference direction for encoding the spatial layout (Marchette and Shelton, 2010).

The importance of landmarks for human route descriptions is a well-known, scientifically confirmed fact (e.g. Denis, 1997; Ross et al. 2004; Brosset et al. 2008; Sarjakoski et al. 2011). Denis's (1997) classification of the contents of route descriptions has provided a scientific tool for many studies on the subject. For example, the frequency of landmarks in route descriptions has been observed to vary between urban environments and nature (Brosset et al. 2008; Sarjakoski et al. 2011). Denis (1997) focuses attention particularly on the reorientation points along a route where landmarks are typically used together with route actions and claims that most of the references to landmarks are introduced at these points. Landmarks in reorientation and decision points have indeed been shown to play an important role in route descriptions (Michon et al. 2001; Janzen and van Turennout 2004).

While a landmark can be any element in an environment used to define the locations of objects, familiarity with the environment affects the selection of the kinds of landmarks to use when defining locations and describing routes (Lovelace et al. 1999; Sorrows and Hirtle 1999). Sorrows and Hirtle (1999) divide landmarks into three different (non-exclusive) categories: visual, cognitive and structural landmarks. Visual landmarks are those landmarks that are prominent and easy to perceive and remember. Cognitive landmarks provide some particular meaning to a person and, therefore, can be missing in an unfamiliar environment. Structural landmarks are distinguishable, organised constructions such as signs, town squares or cross-roads. In addition to the properties of landmarks, the locations of landmarks affect their use in route directions.

Lovelace et al. (1999) found that the extent to which participants are familiar with the environment affects the landmarks that they select for high-quality route directions. The landmarks in their study were divided into four groups: landmarks at decision points, landmarks on route (not at decision points), landmarks at potential decision points (existing in the environment but missing from the route directions) and landmarks off the route. The results showed that the total number of mentioned landmarks was higher in the descriptions of unfamiliar routes than in the descriptions of familiar routes. Contrary to the results by Denis (1997), 40–50 % of the mentioned landmarks were on route and correlated with the quality of the route directions, which indicates that not only are the landmarks at decision points important for wayfinding but also that the landmarks between decision points are important as well. However, the number of landmarks at decision points correlated strongly with the quality of the route directions for unfamiliar routes, whereas the correlation between the number of landmarks at the potential decision points and the quality of the directions was high with the route directions for familiar environments. This finding suggests that for internal representations of a familiar environment, the potential decision points and alternative routes are represented, while they are missing in the representations of unfamiliar environments. Despite these contradictory results, recent neuroscientific results from wayfinding experiments in virtual mazes support the findings about the different roles of the landmarks depending on their locations or sequence on a route: even though the differences did not appear in the behavioural results, the results from the brain imaging data showed significant differences in the activation of certain areas of the brain according to the locations or the order of the encountered objects in a virtual maze (Wegman and Janzen 2011; Janzen and van Turennout 2004; Janzen and Weststeijn 2007).

Empirical research on the kinds of landmarks that people use during navigation and to the extent which they use them has been more thorough in urban environments (e.g. May et al. 2003; Elias et al. 2009) than out in nature. Consequently, scientifically based categorisations of landmarks in nature have been missing, and the categorisations of landmarks in nature have mainly been expert-created legends on topographical and orienteering maps. Rehrl and Leitinger (2008) analysed the verbal route descriptions used by ski-tourers and demonstrated that landform-type landmarks dominate the landmarks in the descriptions. Snowdon and Kray (2009) asked subjects to name natural landmarks on landscape photographs and found that peaks and water courses were the most frequently named landmarks, followed by woods, rocks, lakes and landforms. In a previous analysis of the thinking aloud data that is used in this paper, structures ranked as the most frequently used landmarks in nature (Sarjakoski et al. 2012). We found important differences between the seasons in terms of the extent to which the participants used passages, landforms and vegetation-related landmarks. To the best of our knowledge, these are the only empirical results thus far on the ways in which different seasons influence landmark perception and cognition.

Methods

Experimental set-up

We collected the thinking aloud protocols and sketch maps in two separate experiments. Ten participants took part in

Table 1 Participants' experience

(a) Hiking in nature	
Frequency	Number of participants
Daily	1
A few times a week	9
A few times a month	9
Fewer than once a month	1
Never	0
(b) Region of the experiments	
Number of previous visits	Number of participants
More than 3 times	6
1-3 times	6
Never	8

the summer experiment (25–51 years old, 2 females, 8 males) and eleven in the winter experiment (19–53 years old, 5 females, 6 males). Before the test sessions, the participants filled in a background questionnaire in which they reported their experience with hiking in nature and on the region of the experiment (Table 1). Overall, the participants were rather experienced hikers and many of them had visited the region before. However, none of the participants indicated that they had walked through the whole route that was used in the experiment.

The participants were driven to a national park, and during the drive, the assignment of the thinking aloud part of the experiment was given to them both in written and in spoken form. Otherwise, they did not get to know the purpose of the experiment. In the national park, the participants first completed the thinking aloud task along a 1.3 km long hiking route; this took about half an hour (Fig. 1). They did not get any additional information about the region of the experiment and did not use any navigation equipment, such as maps, compasses or positioning devices. The whole route was in a forest and wooded environment, and half of it ran on hiking routes, whereas the other half was on footpaths. There was one hiking centre consisting of several buildings beside the route and also an information point with information boards. Overall, the region was a typical recreational area in a national park, which we would refer to as "nature". The hike was guided by an experimenter who recorded video of the journey and pointed out the right direction when necessary (Fig. 2). After the hike, the participants took a break for 15–30 minutes, and then they were driven back to the starting point. During the return drive, the participants were asked to draw a sketch map from memory without any time restrictions. However, each participant finished the drawing by the end of the drive, which took about half an hour. The assignments for the experiment were as follows:

1. Thinking aloud while walking the route: "Describe everything that you find remarkable in the surroundings and explain their locations. Stop when you have to make a decision about which route to take. Describe the options in detail".
2. Sketch map drawing after walking the route: "Draw the route that you walked. Mark and explain the most memorable things along the walk".

The summer experiment was conducted in typical summer conditions: the trees had leaves and there was undergrowth. The winter experiment was conducted mainly in very snowy conditions, which meant that the experimenter had to walk along the paths after snowfalls in order to make them equally visible for all participants. The experimental set-up is discussed more thoroughly by Sarjakoski et al. (2011).

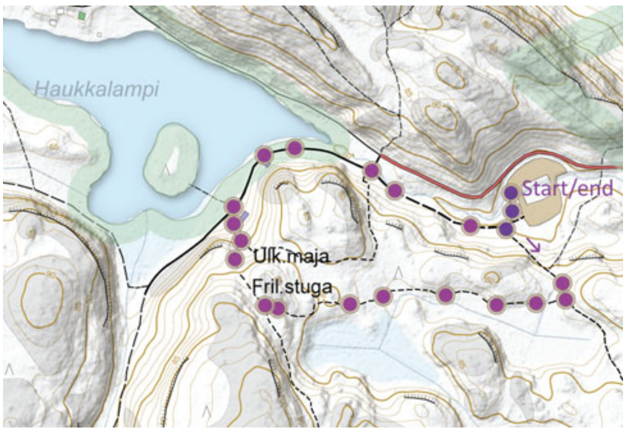


Fig. 1 Map of the route in the experiments. *Circles* show potential decision points where participants may have stopped for getting direction from the experimenter

Fig. 2 Participants described their surroundings by thinking aloud while walking. An experimenter gave directions and *video* recorded the participant. The whole route was in a forest and wooded environment

Analysis

We transcribed the thinking aloud recordings and carried out natural language processing (NLP) analysis in order to find out what landmarks were used and how frequently they were used during the experiments (Kettunen and Sarjakoski 2011). Landmark concepts were extracted from the transcriptions using the following NLP process:

1. Transformation of the inflected words into a basic form;
2. Creation of a list of all words in the experiments;
3. Selection of words that denote landmark features;
4. Confirmation of the meanings of the selected landmark words in the transcriptions;
5. Collection of bigrams denoting landmarks based on the two preceding words (e.g. “fallen tree”);
6. Gathering synonyms together as landmark concepts (e.g. “path” and “track” → “path”).

We then grouped the landmark concepts into semantically homogeneous landmark groups and ended up with eight groups. The distribution of landmark terms in these groups provides an overall knowledge of the relative frequencies of different kinds of landmark concepts in the thinking aloud experiments:

1. Structures (man-made and animal-made constructions: house, electricity line, bridge, anthill, bird’s nest, etc.);
2. Passages (routes or parts of routes for walking: road, path, crossing, etc.);
3. Trees and parts of trees (single trees and tree parts: spruce, witch’s broom, stump, etc.);
4. Water landmarks (parts of water systems: lake, ditch, shore, etc.);
5. Land cover (vegetation type: spruce wood, clearing, marsh, etc.);
6. Rock landmarks (rocky features: stone, bare rock area, crack, etc.);
7. Signs (man-made signs: guidepost, information board, route marker, etc.);
8. Landforms (parts of the natural topography: upward slope, hill, pit, etc.).

The elements in the sketch maps have often been classified as landmarks, paths, nodes and boundaries (e.g. Niem Tu and Doherty 2007), based on the Lynch’s (1960) original categorisation. We used our above categorisation of landmarks, in which all of the noted features are regarded as landmarks. Two researchers classified the features into the landmark groups described above and then counted the totals for the groups. We compared and discussed the counting results among the classifiers, eliminated errors and established uniform counting rules. We settled on counting all passage sections of the path or road between crossings separately. The “water landmarks”, “land cover” and “landforms” landmark groups required similar attention: the features in these groups were continuous not only in one, but also in two dimensions, and it was difficult to determine the borders of the objects. Eventually, we found the homogenisation of the landmark counts to be straightforward, with minor revisions, and believe that we have achieved replicable results. A sample classification of a sketch map is presented in Fig. 3.

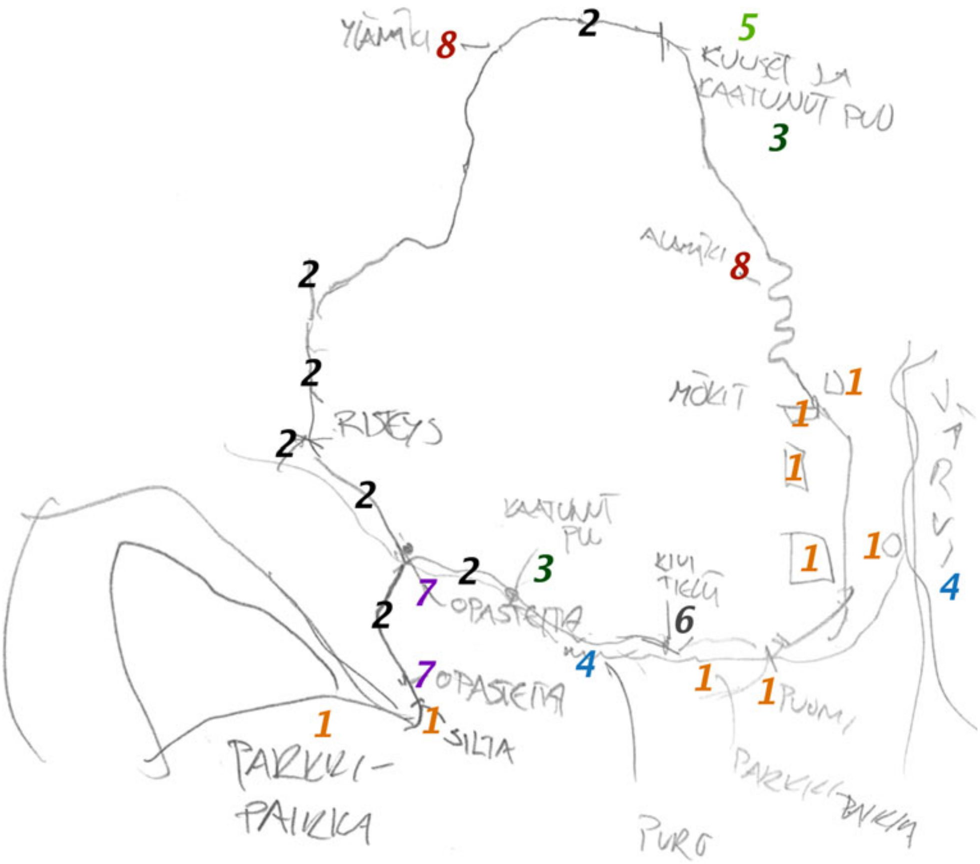
Next, we calculated the relative frequencies of each landmark group for all participants by dividing the count of a particular landmark group by the total count of all of the landmarks used by the participant. Therefore, the verbosity of the participants did not affect the comparisons between seasons or methods. We used the median to measure the averages of the relative frequencies for the landmark groups. The distributions of the relative frequencies between seasons were compared using Wilcoxon rank-sum tests and between data collection methods using Wilcoxon signed rank tests. When comparing the data collection methods, we used the 18 participants from whom we had obtained both thinking aloud protocols and sketch maps in Finnish (10 for summer and 8 for winter).

Results

With the thinking aloud method, the participants produced a total of 1662 landmark references in summer and 1223 in winter, whereas they draw 327 landmarks in summer and 273 in winter. There were clearly more landmark counts for the thinking aloud method than for the sketch map method due to the fact that single features were mentioned several times in the protocols but they were only drawn once on the sketch maps. Still, the number of single features seemed higher in the thinking aloud protocols, but we will verify this later—in the present study, we concentrated on the relative frequencies of the landmark groups, which we present below. The participants used fewer landmarks in the wintertime for both methods. When exploring the protocols and sketch maps, we found that this was because many landmarks were covered with snow in the wintertime.

The differences in the median of the relative frequencies of the landmark groups between methods are presented in Fig. 4, whereas the differences between seasons are presented in Fig. 5. For the differences between methods, the respective values and statistical significances are listed in Table 2. The differences between the thinking aloud and sketch map methods were relatively large and many of them were statistically significant (Fig. 4; Table 2): the participants used “passages” and “structures” more in the sketch maps, whereas “rock landmarks”, “trees and parts of trees”

Fig. 3 An example of the classification scheme used when analysing the sketch maps: (*1*) structure, (*2*) passage, (*3*) tree or part of a tree, (*4*) water landmark, (*5*) land cover, (*6*) rock landmark, (*7*) sign and (*8*) landform



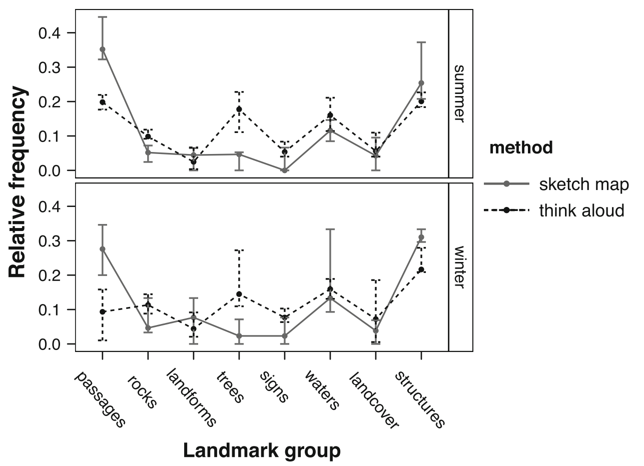


Fig. 4 Comparison of the relative frequencies of the landmark groups between methods. The *error bars* depict a 95 % confidence interval for percentile bootstrapped medians

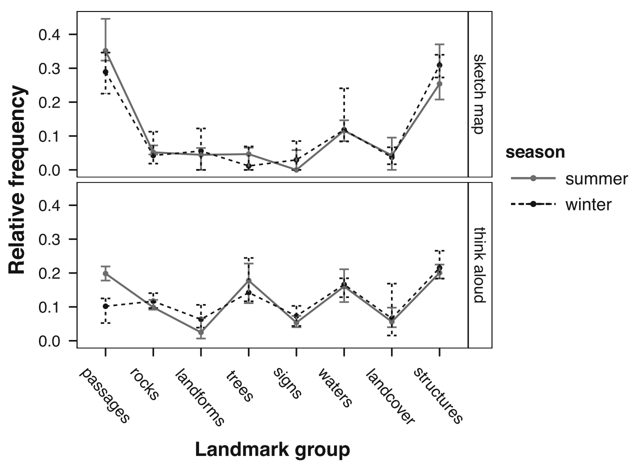


Fig. 5 Comparison of the relative frequencies of the landmark groups between seasons. The *error bars* depict a 95 % confidence interval for percentile bootstrapped medians

and “signs” appeared more frequently in the thinking aloud data. These significant differences were present in both seasons for each landmark group apart from “structures”.

In terms of the differences between seasons, we only found two statistically significant differences, both of them in the thinking aloud data: the participants used “passages” 9.6 percentage points (pps) less in the wintertime (p = 0.0001) and “landforms” 3.9 pps more in the wintertime (p = 0.045).

For the sketch maps, we found no statistically significant differences when comparing the different seasons. In total, the participants drew more features in the summertime, but the distributions of landmarks among the landmark groups remained similar in both seasons.

Table 2 Differences in the medians of the relative frequencies of the landmark groups between methods and the significance of the differences

Landmark group	Season	Difference in medians (sketch maps minus thinking aloud, pps)	p value (two-tailed Wilcoxon signed rank test)	significance (* $p < 0.05$; ** $p < 0.01$)
Passages	Summer	15.4	0.002	**
	Winter	20.3	0.004	**
Rock landmarks	Summer	−4.7	0.004	**
	Winter	−5.3	0.03	*
Landforms	Summer	2.0	0.53	
	Winter	0.9	0.73	
Trees and parts of trees	Summer	−13.1	0.002	**
	Winter	−13.1	0.004	**
Signs	Summer	−5.4	0.049	*
	Winter	−3.8	0.02	*
Water landmarks	Summer	−4.5	0.06	
	Winter	−5.8	1	
Landcover landmarks	Summer	−1.3	0.56	
	Winter	−7.4	0.13	
Structures	Summer	5.6	0.06	
	Winter	9.4	0.008	**

Discussion

The thinking aloud method introduced significant differences in the use of landmark groups between seasons, whereas the sketch map method did not. The method of concurrently thinking aloud measured instantaneous, perceived spatial knowledge, while the sketch maps were drawn based on long-term memory. This result suggests that differences in the perception of the environment did not lead to differences in the resulting internal representations of the route environment presented on the sketch maps. The participants developed similar spatial and mental representations of the environment in both seasons, and, in light of our data, used similar criteria for the landmarks they chose to draw on the sketch maps. They also recalled landmarks similarly independent of the season.

Exploring the protocols revealed that the seasonal differences with the thinking aloud method resulted mainly from snow cover: “passages” were mentioned less frequently in the wintertime because the surfaces of the paths and roads were not visible during the winter—the participants just saw walked trails and ploughed tracks in the snow. They mentioned “landforms” more frequently in the wintertime because these became more visible due to the smooth snow surface as well as the lack of undergrowth and leaves on the trees—the participants saw large trends in elevation more clearly than in the summertime.

Method-wise comparisons support the conclusions drawn from the seasonal comparisons. “Passages” play a central role on route-like sketch maps and all of our participants drew them, whereas they mentioned “passages” much less often with the thinking aloud method. “Structures” occurred on a significantly frequent basis on the sketch maps in the winter experiment but not as much in the summer experiment, which indicates that “structures” were perceived and recalled to a greater degree in the wintertime when they were more salient. The participants observed “rock landmarks”, “trees and parts of trees” and also “signs” to a significant degree with the thinking aloud method, but they did not draw as many landmarks for these groups on the sketch maps.

The observed differences seem to result from the preconceptions that the participants had regarding what is important to draw on the sketch maps and what they can fit on such a restricted media as a two-dimensional A4 sheet, but also from what the participants were able to remember. The presence of “passages” in both seasons and “structures” in the wintertime was apparently considered important and the participants remembered them quite well, whereas they probably did not consider “rock landmarks”, “trees and parts of trees” and “signs” to be as important, and they did not recall or chose not to draw such small, individual features on the sketch maps. Additional information on the observed differences between methods and seasons may be found by analysing the use of individual landmarks, which comprises a part of a study that we plan to do in the future.

It must be noted that the relative frequencies compared here do not exactly measure the number of landmark features; rather, they measure the relative frequency of landmarks in a landmark group among all of the landmarks used by a participant for each method. During the thinking aloud phase, participants referred to the same landmark several times, while it appeared only once on the sketch map drawings. Hence, the data acquired via the thinking aloud method are more redundant compared to the data acquired via the sketch map method. This supports a previous finding, according to which verbal route descriptions contained more landmark options than route depictions (Tversky and Lee 1999). However, the relative frequencies of the landmark groups can be compared between methods because participants are likely to mention each individual feature equally often in lengthy thinking aloud protocols. Nonetheless, this issue needs to be studied more thoroughly.

An additional aspect to consider in these experiments is that the same participants thought aloud and drew sketch maps. Thinking aloud may change the course of thinking processes, usually by improving performance if the individuals explain their thinking processes while thinking aloud (Ericsson and Simon 1998). In this study, the participants did not have to explain their choices and, therefore, the method had little effect on performance. However, our participants have seemingly always drawn those particular features on the sketch maps that they had mentioned while thinking aloud. Thinking aloud probably enhanced their ability to recall landmarks when drawing the sketch maps because the participants had to explain their observations verbally. This issue calls for further analysis. Moreover, the task assignment could have affected the results, since participants may understand and interpret the word “significance” differently. Some may have mentioned everything they saw, whereas others may have been more selective with regard to what is significant and what they intended to mention.

Conclusions

In this paper, we investigated the use of wayfinding landmarks using the methods of thinking aloud and drawing sketch maps. We collected the data in experiments that were carried out in summertime and wintertime in nature. The relative frequencies of landmark groups differed between seasons in the thinking aloud data, but no such differences were present on the sketch maps that were drawn in a similar way in the summer and winter seasons.

The participants referred to landmarks with differing frequencies when using each method. Of note, they used “passages” more on the sketch maps; in fact, “passages” comprised the core elements of the sketch maps. “Trees and parts of trees” were notably absent from the sketch maps, even if they were frequently mentioned with the thinking aloud method. The participants may not have considered them important for sketch maps, or they may not have remembered such small and common features when drawing the maps. The differences may also have occurred due to the differences in the methods.

To conclude, there are differences in what kinds of landmarks people note in nature when the thinking aloud and sketch map methods are used and when the season changes. These differences should be considered when selecting landmarks for different kinds of external spatial representations of nature to support wayfinding, depending on the purpose of the representation. Also, the particularities of the methods must be carefully considered in studies on spatial cognition by focusing on the differences between data received through perception and recall memory.

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