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Chapter 1

Perception and recall of landmarks for personal navigation in nature at night versus day

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Abstract Wayfinding at night in nature is challenging due to limited lighting and a low number of clearly identifiable landmarks. However, several activities in nature involve wayfinding at night, such as rescue services or hiking, but only a few human navigation studies have addressed these conditions. In the present study, we investigate the effects of night on the perception and recall of landmarks along a nature trail using the thinking-aloud and sketch map methods. The results reveal significant differences in the perception between day and night, which mainly originated from a restricted vista at night. In contrast, the landmark recall did not differ between day and night according to the sketch maps, which reflects uniform conceptualisation of the route in both times of day. The observed differences in the perception of landmarks may be applied to the adaptation of geospatial navigation applications that provide real-time wayfinding support, such as interactive maps and navigators, according to the day and night conditions.

Key words: landmark, wayfinding, night, nature, thinking-aloud, sketch map

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1.1 Introduction

People usually find wayfinding at night in nature challenging due to limited lighting and difficulty of identifying landmarks. Supporting wayfinding in such demanding conditions with landmark-based route directions, maps or navigators would be very useful for many wayfinders (See Rehrl et al, 2010). The present study empirically identifies landmarks that people easily perceive in typical night conditions in nature and that could thus be prioritised for giving real-time route directions in these conditions. We also study the recall of landmarks and compare the results of perception and recall in the day and night conditions in order to identify the need of adaptation in route directions between the times of day.

We begin with the background of our research and review previous research related to limited lighting conditions and landmarks (Sect. 1.1). Next, we describe the experiments performed in order to study the landmarks in nature during the day and at night, and present the conducted analysis (Sect. 1.2). We briefly discuss the results (Sect. 1.3) and then move to general discussion (Sect. 1.4) where we present a synthesis of the knowledge gained and address the limitations of the study. Finally, we state our conclusions and suggest future directions of research (Sect. 1.5).

1.1.1 Background and motivation

People inherently employ physical features or objects in the environment in order to structure in their minds the routes that they move on. These objects or *landmarks* constitute a fundamental basis for *cognitive maps* encoded and processed in memory (Tolman, 1948). Landmarks are used to describe the environment or routes to others, to analyse the properties of the environment, to plan routes and to navigate along routes in the environment (Presson and Montello, 1988). People form landmark ontologies that are used for thinking spatially and for creating external spatial representations, such as maps and navigation applications (Smith and Mark, 2001). The landmark ontologies in the spatial thinking vary according to the application domain, the aim of the task and the conditions of use (Winter et al, 2005; Snowdon and Kray, 2009; Kettunen et al, 2013). In order to understand and support such multifaceted spatial perception and memory for navigation, the landmarks must be studied in different kinds of scenarios.

In spatial cognition research, the term "landmark" has many meanings. Lynch (1960) found landmarks to be one of the basic elements that people utilise for spatially perceiving a city environment, defining them as particular external reference points for wayfinders. Since then, the term landmark has been commonly used to refer to a particularly prominent feature in the environment. However, while studying the characteristics of landmarks, researchers have often adopted the broader meaning of a landmark as any feature in the environment to which spatial thinking refers (eg, Presson and Montello, 1988; Denis, 1997; Brosset et al, 2008; Caduff and Timpf, 2008; Rehrl et al, 2009). We employ this broader meaning in the present study because our motivation of wayfinding support requires the consideration of not only the most prominent global landmarks but also local landmarks that are often less prominent in nature.

Most of the empirical landmark research conducted so far has been restricted to urban environments and daytime conditions (eg, Denis, 1997; Rehrl et al, 2009). Nature sets particular challenges for wayfinding due to the difficulties in estimating travelled distances because of landmarks that are easily confused due to their resemblance (eg, Cohen et al, 1978; Okabe et al, 1986). The changing vegetation and conditions also challenge a wayfinder, as shown in studies on novice nature hikers (Kaplan, 1976), orienteers (Omodei and McLennan, 1994), rescue cases (Heth and Cornell, 1998) and experienced, but lost wayfinders (Whitaker and Cuqlock-Knopp, 1992; Hill, 2013). The night time makes the wayfinding challenges even more apparent and sets further difficulties mostly related to visibility in terrain (Kumagai and Tack, 2005). In the present article, we investigate the weakly studied role of lighting in the perception and recall of landmarks in nature.

To understand and technically support wayfinding during all times of day is important for round-the-clock activities that require active navigation in such domains as the rescue services, police and army. Scientific research on the perception and navigation between lighting conditions has been rare but everyday experience shows that changes are drastical. People see different kinds of landmarks and apply different wayfinding strategies between day and night (Winter et al, 2005; Kumagai and Tack, 2005). Geospatial applications already exist in which map colours adapt to night lighting. However, maps and other geospatial applications that provide landmark ontologies do not change according to the change in the lighting conditions. The motivation of our study is to address these changes in the ontologies used during the day and at night. This can later help to develop adaptation in geospatial applications, for example a terrain navigator that could more effectively support people's wayfinding in the varying lighting conditions by providing the user with easily perceptible landmarks related to navigation decisions.

1.1.2 Previous studies on landmarks and wayfinding at night

There have been only a few studies that have investigated landmarks in real environments under varying lighting conditions, particularly at night. The investigations that have been carried out in nature are even fewer. We thus base our present literature review mainly on landmark studies that consider experiments in virtual environments and daytime conditions.

Kumagai and Tack (2005) conducted a wayfinding experiment at night in nature with soldiers using night vision goggles. Based on performance time, traversed distance and direction estimations, wayfinding proved to be significantly more challenging at night compared to the day. The experiment did not guide participants to rely on landmarks for navigating but instead the participants were asked to detect enemy targets in the woods, a task which resembles a visual landmark search.

The detection of targets was significantly weaker under night conditions since night vision goggles provided only a low contrast view at close distances.

Gauthier et al (2008) also focused on night visiong goggles and conducted their landmark search experiment indoors in a small artificial maze where they could set the lighting level similar to half moonlight for the goggle group. The control group participated without night vision goggles in full lighting and performed significantly better in the search, direction estimation and map drawing task. This indicated that night vision goggles affected negatively both wayfinding performance and the acquisition of spatial knowledge. The decrease in spatio-cognitive performance while using night vision goggles suggests that similar restricted vistas, such as while using a headlamp at night, are also likely to bring lower performance.

Winter et al (2005) showed their participants panoramic images of city intersections photographed during the day or at night and asked them to score the prominence of facades in the images. The scores resulted in significant differences between day and night groups, which indicated that participants would use the facades as landmarks differently for day than for night conditions. Winter et al (2005) also found that the participants ranked the criteria for the prominence of facades differently between day and night conditions.

We know from experience that day and night appear differently when navigating in relation to local and global landmarks. Darkness causes distant global landmarks largely to disappear while it emphasises local landmarks at close distances as well as all illuminated features. Presumably, this has an important effect on wayfinding at night, because local and global landmarks play divergent roles when navigating on the route. Local landmarks support route actions in vista space, whereas global landmarks support the conceptualisation of environmental space and construction of a cognitive map (Steck and Mallot, 2000). Steck and Mallot (2000) created day- (local and global landmarks), night- (local landmarks) and dawn-like (global landmarks) conditions in a virtual street environment in which they investigated human navigation strategies. The participants made turning decisions only slightly worse in the night-like and dawn-like conditions, when only one type of landmark was present, compared to day-like conditions. We hypothesise that in reality, both day and night environments provide people with both local and global landmarks, but these may be different for the two lighting conditions. A similar change of navigation strategies between environments may be necessary, as observed in the experiment of Steck and Mallot (2000): those participants who relied on only one landmark type were readily able to start using the other landmark type if the preferred type was not available.

The lack of ambient light and long-distance visibility makes night navigators highly dependent on simultaneously available spatial information in personal memory or technical navigation equipment, such as maps or navigators. Waller et al (1998) showed that blindfolded participants traversed an indoor maze significantly faster if they had a priori spatial knowledge from a map or virtual environment than those without prior knowledge. In addition, repetition did not make the participants without prior spatial knowledge advance to the level of the participants who had studied the maze initially. This implies that blindfolded navigation only gave access to information on the closest spatial features and not even to the extent of daylight vista space. Presumably, the similar difficulty of constructing complete spatial knowledge for unfamiliar environments also applies to limited light conditions even when the perceptually accessible environment is larger.

Low-lighted night environments set challenges not only for wayfinding but also for directing locomotion. Adams and Beaton (2000) showed that people become significantly slower in approaching stairs and sharp turns in an urban environment at night and at twilight than during the day. Nature as a locomotion environment is full of obstacles of diverse sizes, which presumably slows down locomotion in a similar manner at night. The insufficient support for visual perception presumably also causes different landmarks to be observed at night than in day since the perceptual salience (Caduff and Timpf, 2008) of the landmarks changes. Cognitive and contextual salience (Caduff and Timpf, 2008) certainly also play their roles at night, but these may not change much compared to the daytime.

Some studies have addressed useful types of landmarks in nature during the day. Whitaker and Cuqlock-Knopp (1992) interviewed orienteers and military scouts for their particular memories of navigation experiences in their personal history and analysed the named landmarks. Man-made cues were mentioned the most frequently due to their particularity in the environment, then elevations as marked by contours and next, water and vegetation landmarks. Brosset et al (2008) found orienteers in nature refer more often to linear features than in urban settings. Rehrl and Leitinger (2008) observed that landform-related landmarks dominate the navigation expressions used when ski touring. Snowdon and Kray's (2009) questionnaire revealed that people consider peaks and water courses as the most typical landmarks in nature, with woods, rocks and lakes being less important.

Montello et al (1994) as well as Pick et al (1995) observed the reading of elevation contours by experienced map users in hilly terrains and found that the users often relied on hills and large valleys (Pick et al, 1995) as well as in flat areas (Montello et al, 1994) that were easily distinguishable on the map. Montello et al (1994) also investigated features recalled from landscape photographs and reported terrain and vegetation features as clearly the most referred to. In contrast, atmospheric, geological or other features were rare in the collected sketch maps and protocols.

Sarjakoski et al (2012) and Kettunen et al (2013) studied the differences in human landmark use in nature between seasons. The participants walked through a route in a national park while thinking aloud about the prominent features around. They perceived structure and passage landmarks most readily, followed by trees, waters, land cover, rocks, signs and landforms (Sarjakoski et al, 2012). Overall, it must be noted that the landmarks highlighted in all the cited studies above reflect to some extent the types of terrain in the experiments.

The aim of this study is to achieve new knowledge of the role of lighting in the perception and recall of landmarks in nature. The final goal of our research is to gather information about the need of adaptation for the employed landmark sets in navigation applications according to the seasonal and time of day conditions. We hypothesise that ontologies used for describing landmarks in nature differ from those in urban environments and that the importance of different landmark categories varies with the time of day conditions.

1.2 Methods

We studied the effect of night on the perception and recall of landmarks in nature trail experiments in which we brought groups of participants to hike in a forested national park area both in day and night. In this section, we describe the set-up and analysis of the experiments.

1.2.1 Experimental set-up

1.2.1.1 Participants

Our experiment included 22 participants (10 men and 12 women) who were evenly distributed into the day (5 men and 6 women) and night (5 men and 6 women) condition groups. The participants were 19–68 years old (median 42 years). None of them reported that they had walked the nature trail used in the experiment before and seven reported to have previously visited the area. During the experiments, we noted no prior spatial knowledge, such as recognition of places or scenery, that would have caused bias in the results. The participants were rewarded for their participation with travel costs and two recreation tickets.

In the background questionnaire, we asked if the participants were bilingual (McLeay, 2003) and how often they used to visit nature and utilise common types of maps (range of 0–4: never, less often, monthly, weekly, daily). Only one of the participants was bilingual, so no bias by bilingualism is assumed to occur in the results. The participants averaged monthly nature visits (mean 2.2) and used maps on a weekly to monthly basis (mean of maximums of map type use values by a participant, 2.7). They had used city maps most (mean 2.6), followed by road maps (1.8), terrain maps (1.4) and, much less frequently, orienteering maps (0.7). Statistical tests did not highlight differences between the day and night groups in these measures ($W < 79.5, p > 0.19$ in the two-tailed Wilcoxon rank sum test).

The participants filled in the Santa Barbara Sense-of-Direction Scale (SBSOD) questionnaire, which is a self-report measure designed for assessing spatial abilities in the environmental scale (Hegarty et al, 2002). The SBSOD form was translated as part of the study. Based on this measure, the day (median score 70, mean 66.18) and night groups (median score 60, mean 67.73) had no difference in the spatio-cognitive abilities ($W = 56, p = 0.79$ in the two-tailed Wilcoxon rank sum test).

1.2.1.2 Environment

The route of the experiment followed a marked nature trail on footpaths and outdoor tracks that go around a low brook valley in woods. In this article, we call the environment "nature" because it is dominated by wild natural growth, such as spruce and birch trees, with only some roads and constructions along the route. There was a significant difference between the two routes. The first route followed a lakeshore, crossed a road and a river along a dam and contained no steep slopes. The second route followed an outdoor track and ran over a forested hill with considerably steep slopes and cliffs. The terrain conditions were considerably wet during the whole experiment because the preceding summer had been very rainy, and the footpaths were muddy and slippery.

1.2.1.3 Procedure

Test sessions began with participants filling in the consent form, background questionnaire and the SBSOD form. Next, the experimenter instructed the participants on the thinking-aloud method (Ericsson and Simon, 1998) and gave them the first of the two route traversal assignments on a written form: “Walk a route with the experimenter and memorise the route so that you are able to *walk through it again without guidance*. The experimenter walks after you and guides when necessary.” The experimenter asked the participants to think aloud their observations along the route while performing the task. Before the actual task, the participants practised thinking aloud while walking to the beginning of the route (150 m, 2–3 min). The first route traversal task ran on a 650 m long route and lasted for 11 to 19 minutes, after which the experimenter interrupted the task and gave another written assignment, modified from the previous one: “...memorise the route so that you are able to *describe it to another person who is to walk through the same route...*” The second part of the route was also 650 m long and took 8 to 16 minutes. After the second part, the experimenter asked participants to tell whether they found any difference between the two tasks during the traversal. We gave the two different task assignments for the thinking-aloud tasks in order to investigate if memorising for oneself or to another person would change the manner of thinking aloud. We made all the participants complete the tasks in the same order so that they focused similarly on the same parts of the routes and the contents of the collected data were comparable. Finally, the participants walked back to the starting point of the session guided by the experimenter, still memorising but without thinking aloud (150 m, 3–5 min).

At night, the participants wore a 900-lumen LED headlamp that provides a bright and targeted view up to several dozens of metres in an open area. This kind of lighting condition is typical to night-time activities in nature, in which similar ligth sources are typically used. In both day and night, the participants carried an audio recorder for saving the thinking-aloud recordings. The experimenters recorded video of the participants while walking after them.

After the route walkthrough, the participants had a break for 15 minutes in order to ensure that the short-term memory would not affect the recall tasks. The next task was to draw a sketch map on a blank paper according to a written assignment: “Draw the route you walked and explain your markings thinking aloud”. We set no time restrictions for drawing, and it took 2 to 22 minutes for the participants to complete. We recorded the drawing both in audio and video.

1.2.2 Analysis

By landmarks, we mean all permanent and distinguishable features in the environment that participants noted during the tasks (as in, eg, Denis, 1997; Rehrl et al, 2009). We counted clearly determinate mentions of vegetation as landmarks, such as “spruce trees” or “snag”, but ignored indeterminately introduced mentions of unbounded vegetation such as “grove” or “moss”. We also ignored temporary features, which would be unreliable to use in route guidance at a later date due to common but occasional natural changes. For example, with “mud”, participants described the underfoot condition of the path due to an exceptionally rainy summer.

1.2.2.1 Thinking aloud during route traversal

In order to analyse the thinking aloud during the route traversal, we transcribed the recordings and applied a previously developed natural language processing (NLP) analysis on the transcripts (Sarjakoski et al, 2013). The NLP analysis was carried out by a team of two researchers, who made joint decisions on the selection and classification of landmarks, proceeding as follows:

1. Transformation of the inflected words into the basic form (Helsinki Finite State Transducer: Lindén et al, 2009);
2. Collection of the landmark words from the list of all words (Python scripts, Natural Language Toolkit NLTK: Bird et al, 2009);
3. Checking that the landmark words were really used for denoting landmarks in the transcripts (string searches in the transcript files);
4. Gathering of the landmark word synonyms together into landmark concepts,
5. Identifying bigrams that the participants used as landmark concepts, such as “fallen tree” (the two words preceding and the two words following the landmark words in the transcripts; Python scripts, NLTK);
6. Grouping of the landmark concepts under the previously defined landmark groups that fitted well in the present case: “Structures”, “Passages”, “Trees and parts of trees”, “Waters”, “Land cover”, “Rocks”, “Signs” and “Landforms” (Kettunen et al, 2013); and
7. Counts of the landmark concepts in the transcripts (Python scripts, NLTK).

We based the comparison of the two route-perception tasks (memorising for oneself and for another person) on a qualitative comparison of the answers that the participants gave when we asked about the differences between the tasks. The question was added in the experiment just after the first sessions, which is why there are no answers from three participants in the night group who were not asked the question.

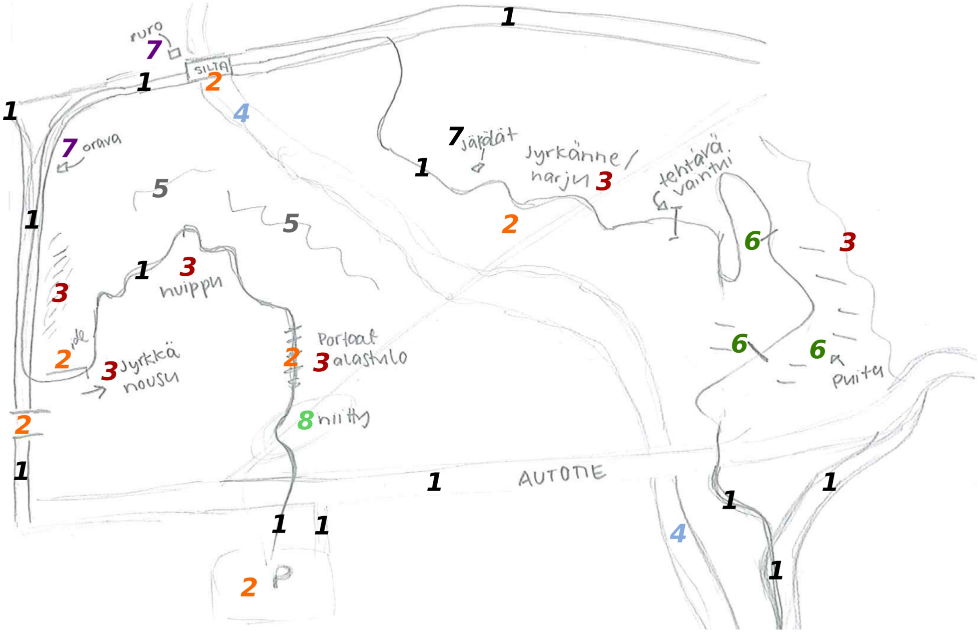

Fig. 1.1: An example of counting landmarks on a sketch map: *(1)* passage, *(2)* structure, *(3)* landform, *(4)* water landmark, *(5)* rock landmark, *(6)* tree or a part of tree, *(7)* sign and *(8)* land cover

1.2.2.2 Sketch map drawing

We analysed the sketch maps similarly to the analysis of our previous experiment (Kettunen et al, 2013): drawn and written features were classified according to the categorisation of the thinking-aloud part of the experiment. Two individual researchers completed the classification, using both the finished sketches and a video recording of the drawing participants. In case of the few differences that occurred in the classifications, the classifications were synthesised through the group work. Every marked feature was regarded as a landmark and separate sections of continuous landmarks were treated as individual landmarks in the “Passages”, “Waters”, “Land cover” and “Landforms” landmark groups (Fig. 1.1). We did not count landmarks that were mentioned during the thinking aloud while drawing if they were not also actually drawn on the sketch map.

1.2.2.3 Statistical calculations

In order to identify landmark concepts that the participants used in significantly different frequencies between conditions, we ran two-tailed Wilcoxon rank-sum tests for each landmark using the Scipy Python package (Jones et al, 2001–). In all the statistical calculations, we used significance level $\alpha = 0.05$.

In order to detect differences in the use frequencies of landmark groups between different conditions, we ran permutational multivariate ANOVA (PERMANOVA;

Anderson, 2001) using the R software (R Core Team, 2013) to test the main effects of time of day and task as well as their interaction effect ($50,000$ permutations). We chose the non-parametric PERMANOVA because our samples are small and the normality of landmark frequency distributions is doubtful: Shapiro-Wilk multivariate normality test showed non-normality for the thinking aloud data from night ($W = 0.68, p = 0.001$) and for the sketch map data from day ($W = 0.54, p = 0.00003$). The high number of variables in relation to observations also prevented the use of the parametric MANOVA. The use of PERMANOVA is appropriate as the statistical power of the applied test is similar or higher compared to that of the exact version of the test (Anderson and Braak, 2003). In the case of significant main effects in the PERMANOVA, we ran non-parametric Wilcoxon rank-sum tests for comparing day and night and the Wilcoxon signed rank test for comparing thinking aloud and sketch maps. We used relative frequencies of landmark groups for calculations (the count of a group divided by the total count of landmarks by a participant), in order to prevent verbosity affecting the results as well as to enable comparability between the two tasks. We tested for main effects of the background variables of the participants (Sect. 1.2.1.1) one by one against the measured relative landmark group frequencies using the PERMANOVA ($50,000$ permutations within the tasks).

1.3 Results

This section presents the results of the experiments together with direct notes of their causes, whereas the synthesising overall discussion is provided in Sect. 1.4.

1.3.1 Thinking aloud during route traversal

The participants used on average 2 min 39 s more time (median difference) for walking through the two routes in the night condition than during the day ($W = 32, p = 0.02$). The slower locomotion previously found in an urban night environment (Adams and Beaton, 2000) also seems to occur in nature because people are more attentive to hazards on the route.

The participants spoke on average more words at night (all words counted; median $1,120$; 1^{st} and 3^{rd} quartiles 908 and $1,532$) than during the day (921; 676, $1,320$). They mentioned 55 different landmark concepts during the day and 56 concepts at night (overall 62). The participants used these landmark concepts on average 105 times during the day (80, 128) and 123 times at night (100.5, 164.5).

Six landmark concepts were used by every participant in the thinking aloud during route traversal: “road”, “fallen tree”, “hill”, “footpath”, “bridge” and “boat shore”. These were located directly on the route and were clearly visible under both lighting conditions. In the day condition, everyone also used “stairs”, which were not necessarily visible at night as they were wooden and worn out. At night, every-

Table 1.1: The 15 landmarks that were most used in the day and night conditions

Number of participants[a]	Relative frequency[b]	DAY Landmark	Rank	NIGHT Landmark	Relative frequency[b]	Number of participants[a]
11	13.3%	road	1	route mark	13.7%	11
9	9.1%	route mark	2	road	11.1%	11
9	7.1%	river	3	river	5.1%	11
11	6.2%	fallen tree	4	signboard	4.6%	10
8	4.8%	info board	5	fallen tree	4.3%	11
11	4.3%	hill	6	hill	3.9%	11
11	3.6%	footpath	7	outdoor track	3.9%	11
10	3.4%	outdoor track	8	info board	3.4%	11
7	3.2%	signboard	9	spruce trees	3.3%	11
8	2.8%	hillside	10	bare rock area	3.2%	9
11	2.7%	boat shore	11	hillside	3.2%	9
10	2.6%	underpass	12	underpass	2.8%	11
10	2.6%	spruce trees	13	footpath	2.7%	11
11	2.6%	bridge	14	boulder	2.7%	9
9	2.6%	water	15	bridge	2.5%	11

[a] The number of participants who mentioned the landmark (out of 11 per condition)

[b] The relative frequency of a landmark compared to the total number of landmarks in the respective time of day condition

one also used “route marking”, “river”, “outdoor track”, “information sign”, “spruce trees”, “underpass” and “streetlamp”. These were mostly features close to the route that were well lit in the headlamp spot.

The participants used some landmarks only during one of the conditions. During the day, these were “water slide”, “graffiti”, “leaning tree”, “traffic island”, “courtyard” and “slope ramp” (3 out of 6 in the “Structures” group). Most of these landmarks were distant or wide and thus impossible to see in the darkness even with the headlamp. At night, “pine”, “conifer trees”, “tall grass”, “bushes”, “goat willow”, “flat” and “boulder field” (3 out of 7 in the “Land cover” group and 2 in the “Trees or parts of trees”). It seems that vegetation landmarks hit by the spotlight were often mentioned in the night condition, whereas they did not stand out during the day.

The most used landmarks were mainly the same during the day and at night (Table 1.1). Among the 15 most used landmark concepts, 13 were exactly the same in both conditions (exceptions being “boat shore” and “water” during the day and “bare rock area” and “boulder” at night).

Four individual landmarks showed statistical significance when testing the differences in use frequencies between day and night among the participants: they used “footpath” (median difference 0.9 pps, $p = 0.05$; no difference in number of users) more during the day and “boulder” (1.9 pps, $p = 0.01$; 6 users more), “standing rootstock” (1.2 pps, $p = 0.005$; 6 users more) and “streetlamp” (0.9 pps, $p = 0.008$; 2 users more) more at night. “Footpath” gained more attention during the day, probably due to its greater presence in the field of view, which was restricted at night. “Streetlamp” was noted more frequently at night, often distantly, due to its emission

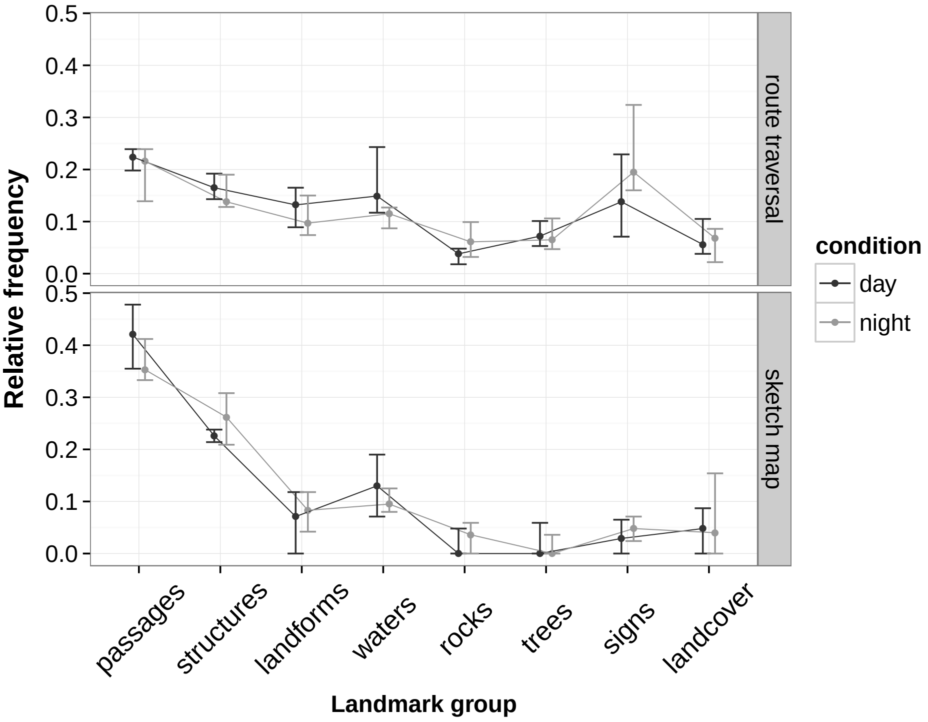

Fig. 1.2: Comparison of the relative frequencies of the landmark groups between day and night. The *error bars* depict a 95% confidence interval for percentile bootstrap medians

of light. “Boulder” and “standing rootstock” were probably more salient when seen in the spotlight than in daylight.

“Passages” and “Signs” were the two most used landmark groups for both day and night conditions, but in different order (Fig. 1.2). “Structures” was the third largest group in both conditions, while “Rocks” was the least used in both cases. The ranks of the landmark groups reflect the route and its environment: “Passages” was frequently used due to the route running on passages, and “Signs” were present all along the route to guide walkers. The higher use frequency of “Signs” compared to “Passages” at night was probably caused by the higher visual salience of signs in the spotlight of the headlamp.

The two-way permutational multivariate ANOVA resulted in significant main effects for both the time of day ($F = 2.92, p = 0.03$) and task ($F = 26.99, p < 0.001$). No significant interaction effect occurred ($F = 0.00, p = 0.99$). Consequently, we continued statistical analyses using univariate Wilcoxon tests, in which two landmark groups among eight scored statistical significance for the differences of relative frequencies between day and night. The participants used the “Waters” landmark group 3.4 pps (median difference) more during the day ($W = 91, p = 0.05$) and “Rocks” 2.3 pps more at night ($W = 24.5, p = 0.02$).

The one-way PERMANOVAs for demographic variables showed significant differences for age ($F = 2.43, p = 0.002$) and experience with orienteering maps

($F = 1.40, p = 0.05$). No significant differences were present for gender or on the SBSOD scale and not for the experience of nature, area, or with other map types. Pair-wise regression analyses showed a slightly positive correlation between age and the frequency of water landmarks ($\rho = 0.35$) and a slightly negative correlation with the frequency of sign landmarks ($\rho = -0.34$). Experience with orienteering maps correlated negatively with the frequency of water landmarks ($\rho = -0.40$).

Pair-wise regression analyses between the demographic variables showed that age correlated negatively with experience with orienteering ($\rho = -0.47$) and topographic maps ($\rho = -0.48$) and positively with the frequency of going out in nature ($\rho = 0.49$). These findings suggest that although the younger participants went out in nature less frequently, they used orienteering and topographic maps more often compared to the older participants, resulting in slight differences in the perception of water and sign landmarks between age groups.

With regards to the question about the differences of the task assignments (memorising for oneself and for another person), the day participants were divided (yes 6, no 4, 1 answer lacking) whereas the night participants answered mostly positively (yes 8, no 1, 2 answers lacking). The answers suggest that the dark night environment made the participants more attentive when perceiving the route for guiding another person, and they also noted the change themselves. The darkness possibly facilitated perceiving the route in the environment from someone else's perspective or otherwise made cognitive processing unconstrained and diverse, similarly to the studies of Steidle et al (2011).

1.3.2 Sketch map drawing

The participants drew on average 21 landmark features on the sketch maps during the day (median; 1st and 3rd quartiles 17 and 32) and 24 features at night (22, 27). The rank of the landmark groups was similar in both conditions: "Passages" was the largest group, followed by "Structures" and "Waters" (Fig. 1.2). "Trees and parts of trees" was the least used landmark group in the sketch maps. Video recordings revealed that the participants often framed the sketch map with route and water landmarks and then added structure and other landmarks.

For sketch maps, there were no statistically significant differences between day and night in the frequencies of any of the landmark groups.

1.3.3 Comparison between tasks

The participants used the landmark groups with differing relative frequencies while thinking aloud during the route traversal and in the sketch maps (Fig. 1.3). In the day condition, we recorded statistically significant differences for the "Passages" (median difference 19.7 pps; $V = 0, p = 0.001$) and "Structures" (6.1 pps;

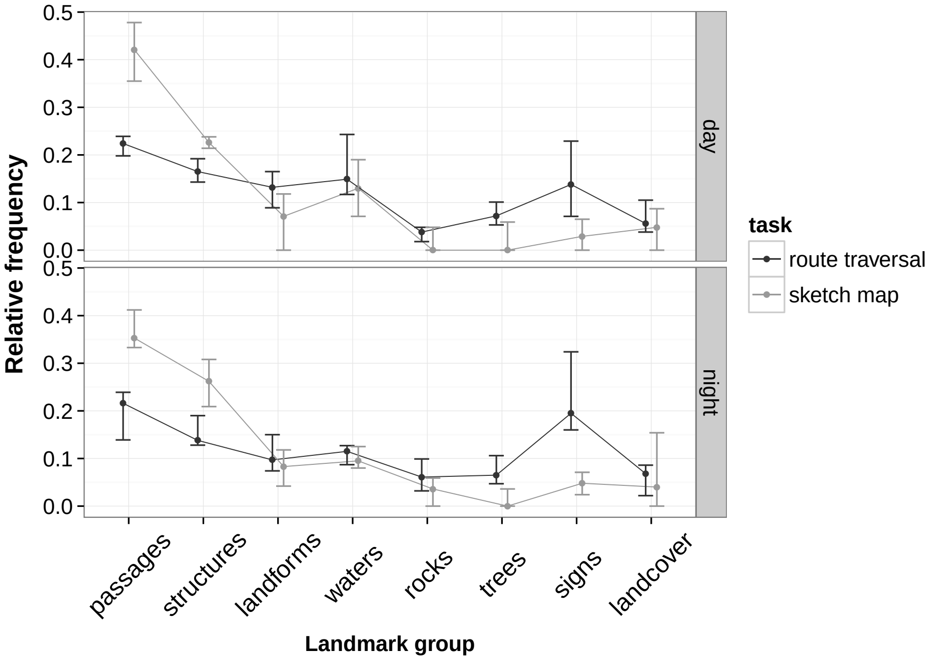

Fig. 1.3: Comparison of the relative frequencies of the landmark groups between the thinking aloud during route traversal and sketch maps. The *error bars* depict a 95% confidence interval for percentile bootstrap medians

$V = 10, p = 0.04$) landmark groups, which were used more in the sketch maps and "Signs" (10.8 pps; $V = 45, p = 0.01$), "Trees and parts of trees" (7.2 pps; $V = 65, p = 0.002$) and "Landforms" (6.0 pps; $V = 57, p = 0.03$), which were used more while thinking aloud during the route traversal. In the night condition, the participants used "Passages" (13.7 pps; $V = 0, p = 0.001$) and "Structures" (12.4 pps; $V = 4, p = 0.007$) more in the sketch maps at the statistically significant level, and "Signs" (14.7 pps; $V = 66, p = 0.001$), "Trees and parts of trees" (6.5 pps; $V = 65, p = 0.002$) and "Rocks" (2.5 pps; $V = 52, p = 0.01$) more in the thinking aloud during route traversal.

1.4 Discussion

The presented study investigated differences in the perception and recall of landmarks along nature routes between day and night. Significant differences were found in the perception of individual landmark types and landmark groups, whereas no differences were present in the recall as measured by sketch maps.

The limited lighting condition at night was characterised by the brightly lit spotlight of the headlamp and weak ambient light originating from the diffusion of lights in the surrounding urban region. The contrast between the spotlight and ambient light was high, causing participants to mostly see features under the spotlight. The results of the study reflected this restricted vista through an increased perception of close features with notable visual salience under the spotlight. On one hand, these features were relatively small and clearly bounded, such as “boulder” and “standing rootstock”, which were lighted one by one at night whereas perceived more as groups in daytime. On the other hand, the spotlight highlighted vegetation features at close distance that the spotlight did not penetrate, such as “spruce trees” and “tall grass”. These types of features did not necessarily contrast in the more extended ambient light vista by daytime. The significantly higher use frequency of the “Rocks” landmark group in the night than in the condition can thus be understood to be caused by the restricted spotlight vista at night. The same applies vice versa for the “Waters”; the dark colour of the water surface due to the lack of the reflected ambient light made “Waters” invisible at night compared to during the day. “Waters” were also distant from the route. Acoustic salience was only little involved in the study, mainly related to the noises of vehicles.

Although the vistas at night were restricted to the spotlight of the headlamp, the perception of distant and global landmarks was not completely missing, which agrees with our hypothesis. We observed the use of distant lights as orientation landmarks during the route traversal, most importantly lines of streetlamps that efficiently provided the participants with the directions of distant roads and outdoor tracks. The observation was confirmed statistically with the landmark concept “streetlamp” being used significantly more frequently by the night participants compared to the day participants. Even more convincingly, each night participant mentioned “streetlamp” during the route traversal.

In daylight, the participants used another set of distant and global landmarks. No individual landmark or landmark group was highlighted quantitatively, but the experimenters’ observations confirmed that when people can see far away, they take the distant features in use as landmarks. The day participants used distant landmarks, such as “water slide” and “traffic island”, in the “Structures” landmark group during the route traversal, which did not occur in the night data at all. The high salience of structures as landmarks in nature was confirmed in the experiment (previously found in Sarjakoski et al, 2012). The perception of some spatially extensive features was also notable during the day, most clearly water landmarks that were significantly more used compared to night. In addition, some spatially extensive surface-related landmarks, such as “courtyard” and “slope ramp”, were only mentioned in the day condition when they were visible over a wide area.

Surprisingly, the differences in the perception of landmarks between day and night did not transfer to differences in the recall. With regards to the use amounts of landmark groups, sketch maps were drawn similarly in both conditions. A similar lack of difference in sketch maps between conditions occurred also in our previous study considering different seasons (Kettunen et al, 2013). People seem to recall and choose similar kinds of landmarks to draw in sketch maps of routes, independent of the conditions. Naturally, route-like sketch maps come to contain the route as the frame of the map, but there seems to be more in the observed similarity. A likely explanation for this phenomenon is that people apply common ontologies of landmarks while drawing sketch maps. This impression is supported by a qualitative observation from the present study that during the map drawing, several participants thought aloud about many landmark concepts belonging to the “Land cover” and “Landforms” landmark groups but still did not draw these features. Commonly used maps probably play an important role in people’s conceptions of landmark sets that should be used when drawing sketch maps. In the present study, the applied landmark ontologies may have been importantly based on the landmarks that are typically presented on topographic maps.

In addition to the preconceptions that the participants seemed to have on what to draw on sketch maps, the differences in the frequencies of landmarks between the thinking aloud during route traversal and sketch maps were partly related to the characteristics of the two media. Most of the participants drew sketch maps based on the course of the route, which caused a surplus of passage landmarks compared to the thinking aloud during route traversal, even if the passage under foot was mentioned often also during the route traversal. On the other hand, salient features belonging to the “Trees and parts of trees” and “Rocks” landmark groups were repeatedly mentioned during the route traversal, which played a role for the significance.

The rest of the significant differences between the tasks most probably account for salience aspects. Structures were probably more noted in the sketch maps due to their visual salience (Caduff and Timpf, 2008), for which reason they were readily recalled while drawing. The visual salience potentially explains at least part of the significantly lower degree of use for trees and parts of trees in the sketch maps, also known from our previous study (Kettunen et al, 2013): such common nature features were not effectively recalled even if many distinguishable instances were mentioned during the route traversal. In the case of signs, which were significantly less used in the sketch maps than had been expected, the cognitive salience (Caduff and Timpf, 2008) may have played a role: people may have mentally merged the constantly observed sign landmarks as self-evident parts of the route that they drew on the maps as passage landmarks.

The discrepancy between the results obtained using the thinking-aloud protocol and those obtained using sketch maps is a central finding of the study and apparently caused by the nature of the tasks. Thinking aloud is an online task that reflected what the participants perceived and found important to mention. In contrast, the sketch maps reflected memory performance and they emphasise the most memorisable features on which the participants used to construct their spatial representation of the environment and that they would use later to find their way or to describe the route. The result that the memory performance does not differ between night and day conditions, although the online perception measure does, suggests that the absolute importance of different landmark groups is similar for the spatial representations of individuals even though the perceptive input differs significantly.

The present study applied a recently introduced method for analysing thinking aloud protocols using natural language processing (Sarjakoski et al, 2013). Its results reflect the distribution of selected landmark terms in the collected thinking-aloud protocols. The thinking-aloud method has been extensively used in probing human thinking processes (Ericsson and Simon, 1980), but doubts have been presented on its validity in concurrent use (eg, Smagorinsky, 1998). Thinking aloud concurrently easily affects task performance if a participant strays to free-flow speech and forgets the task at hand. However, properly instructed, trained and undisrupted, thinking aloud has been shown to provide reliable data on the thoughts of test participants (Ericsson and Simon, 1998; Boren and Ramey, 2000). We took these prerequisites into account when directing the thinking-aloud tasks and consider the collected data to be reliable with regards to people's perception of landmarks along the route. Another shortcoming of the concurrent thinking-aloud method is the probable incompleteness of the data: participants may be unable to verbalise all of their thoughts and actions related to the task, particularly in non-verbal practices, such as spatial thinking (eg, Whitaker and Cuqlock-Knopp, 1992). In the present study, we instructed participants to memorise the route and to think-aloud about their perception of it, which directed the participants' concentration to the surrounding features along the route and made them verbalise at least those features that they saw as important for following the route. Consequently, the results do highlight those landmarks that are potentially effective in route directions, but they should be regarded as an explorative rather than a comprehensive set of all the prominent landmarks.

Technical wayfinding support by geospatial applications is most effective when given in real time, landmark by landmark, during the navigation (Rehrl et al, 2010). Therefore, the landmarks in wayfinding maps and navigators should be selected based on the real perception in the environment. The found loss of perceptive differences between conditions in the recall phase highlights the need for perception-based directions in real-time navigation guidance—human conception and memory do not always inherently focus on the most perceptible landmarks. The results from studies like ours in the present paper provide sets of empirically verified, perceptionally prominent landmarks to be employed in geospatial navigation applications.

1.5 Conclusions and future work

The present study addressed the open question of the perception and recall of landmarks in nature under limited light conditions at night. We approached the issue by means of a thinking-aloud study on a nature trail with participant groups in the day and night conditions and used previously developed natural language processing and sketch map methods for the analysis of the experiments (Kettunen et al, 2013). The study concentrated on the perception of landmarks along a route using a thinking-aloud task, and on the recall of landmarks afterwards using a sketch map task. According to the results, the perceived landmark types differed between day and night due to the absence of ambient light and the visual focus on the spotlight of the headlamp at night. Similar factors have been previously observed to affect the wayfinding with night vision goggles (Kumagai and Tack, 2005; Gauthier et al, 2008). However, the recall of landmarks did not differ according to the sketch maps: the drawn landmark groups remained similarly frequent between day and night. The participants' prior ontologies about the important landmarks on maps appeared to influence the sketch map drawing, as many well-recalled landmarks were observed to be left consciously undrawn. Significant differences in the use amounts of landmark groups between the tasks further confirmed these conclusions.

The found feature-specific particularities in the perception of landmarks at night in nature can be applied to the development of adaptation of real-time navigation applications, such as maps or navigators. Such adaptation to time of day would better support the navigation in nature not only during the day but also at night, which is essential for many round-the-clock activities. In particular, water landmarks should be avoided in nightly route directions, whereas salient point-like landmarks, such as rocks, can be more helpful at night than during the day. In addition, the study highlighted illuminated features to be particularly perceptible as distant landmarks at night. However, their use for route directions must be carefully considered concerning their impermanence and homogeneity.

The analysis presented above may be further extended in the future, particularly regarding the study of landmark recall according to the sketch maps, which showed no differences between day and night. Further study of the sketch maps in regard to the omitted landmarks, spatial correctness and individual landmark types might reveal differences between the spatial recall at day and at night. Further synthesising investigation would also be beneficial, considering our previous study between seasons (Kettunen et al, 2013) together with the present study. In general, confirming studies on the use of landmarks in nature at night would be important. The use of more exact behavioural methods than the ones in the present study, such as mobile eye-tracking, could be considered. Moreover, there is still a lack of comprehensive night navigation studies in real urban environments.

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