Proceedings of the Annual Meeting of the Cognitive Science Society

Title

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Permalink
https://escholarship.org/uc/item/2f68g8pr

Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 34(34)

ISSN
1069-7977

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Publication Date

2012

Elaborate Descriptive Information in Indoor Route Instructions

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Abstract

The following paper presents the enhancement of indoor route instructions with descriptive generation strategies. We consider the latter to be highly important for the quality and helpfulness of automatically generated indoor route instructions. We conducted an experiment showing that participants receiving route instructions enriched with elaborate descriptive information instead of step-by-step procedural information for crucial route segments performed better in objective and subjective measures than those receiving only basic prescriptive route instructions. Based on the gained knowledge, we conclude that descriptive strategies are an important part of indoor route instructions and should be actively considered in system development.

Keywords: indoor route instructions; descriptive information; wayfinding; spatial cognition; navigation

Introduction

Both navigation in indoor and outdoor environments profit from the use of landmarks since they are distinctive, easily recognizable and highly memorable (Sorrows & Hirtle, 1999). Humans select landmarks for their distinguishing characteristics (Presson & Montello, 1988). Although the importance of landmarks in route instructions is well established (Allen, 1997; Denis, 1997; Richter, 2007; Raubal & Winter, 2002), most research in automatic generation of route instructions focuses on one aspect of landmarks, namely to indicate the location at which a reorientation should take place in a network of paths. The main assumption of this approach is that good route instructions contain tightly coupled descriptive and prescriptive information. Therefore, current systems rely almost entirely on what Denis (1997) classified as Type 2 utterances – utterances coupling an action with a landmark. This leads to highly concise route instructions, but also limits the amount of descriptive information for each reorientation point to the mentioning of one landmark, possibly locating it with respect to the user.

While this approach is particularly useful for car navigation (Brenner & Elias, 2003) which occurs in network space, i.e. along a street network where clearly identifiable nodes (intersections) are connected by edges (streets), in pedestrian navigation the case is different. Pedestrian navigation includes many areas that belong to scene space: open areas which are characterized by the absence of clearly identifiable nodes and edges (Rüetschi, 2007; Schuldes et al., 2011). In network space, wayfinding consists mainly of selecting a path at each decision point, whereas in scene space, wayfinding is characterized by activities such as searching, exploring, and matching. There are no clear paths to choose from, but large spaces, where piloting between landmarks is necessary. Oriented search might be used if the expected landmark cannot be seen (Allen, 1999). In such areas, route graph representations, and the resulting procedural information do not correspond very well to the needs of the wayfinder, as the function of landmarks changes from identifying a turning point to more vague orientational aid. Indoor navigation has elements of both network and scene spaces. In addition, indoor spaces are characterized by a very limited amount of different landmark types and a lack of highly salient landmarks. Usually landmarks consist mainly of doors, corridors and staircases, only very few of which are highly distinctive in comparison to outdoor landmarks which can be very diverse (a church, a petrol station, multiple intersections of different types, etc.). For this reason, the central roles of landmarks, i.e. signaling where actions should take place, as well as confirmation, are difficult to obtain in indoor scenarios. Additionally, this increases the difficulty of memorization, as it leads to instructions which contain a series of highly similar utterances.

A possible solution for these problems is the integration of more elaborate descriptive information into indoor route instructions. This can be realised by basing instructions on a scene space representation of space, and using a descriptive strategy for generating route instructions for those areas that can be characterized as scene space: Instead of superimposing abstract network representations onto open space areas, thereby producing a number of turning points and paths for an area which is viewed by a wayfinder as a coherent whole, this scene is described as one entity, and the location of the scene exit is described with respect to the scene. We assume that by introducing more elaborate descriptive information into indoor route instructions we can gain configurations of landmarks that can serve as highly salient landmarks, where simple landmarks will yield no sufficient differentiation. Moreover, we expect that the scene descriptions will enable more efficient localization of scene exits in the descriptions, minimizing the number of prescriptive statements. In contrast, the imposition of abstract networks onto open spaces will yield extra turns. We expect route instructions which integrate the descriptive approach to make it easier for participants to build up a mental image of the route in advance, leading to better memorization and increased confidence. In addition, mixing scene descriptions with prescriptive statements should yield more diverse route instructions, thereby additionally supporting memorization.

While our route instruction system has already been successfully evaluated (Cuayáhuitl, Dethlefs, Richter, Tenbrink, & Bateman, 2010), the goal of the present study is to explore the boundaries and potential for further development of the system by using a particularly difficult route which contains areas for which we consider the current (standard) approach lacking. For this purpose we first conduct and present an experiment which compares the wayfinding performance of participants receiving instructions, based either on solely procedural strategies as used by the system, or on a systematic mixture of procedural and descriptive strategies which the system currently does not provide. The results are presented and discussed with respect to the insights that can be gained for the development of route direction systems using natural language generation. In conclusion we propose directions that future research in the area could take.

Experimental Setup

The experiment was conducted in GW2, a building at the University of Bremen which is notorious for its complexity. Each of the four floors has a different layout consisting of one or two main areas. The route (figure 1) was specifically chosen to be long and difficult, contain many turns and lead through a large portion of the 3rd level of the building. Secondly, it should contain two areas (A and B in figure 1) characterized by scene space rather than by network space. In both cases a diagonal crossing of the open area was necessary.

In our experiment the participants made use of an indoor route direction system called Infokiosk, developed as part of the I5-DiaSpace[1] project. Infokiosk (Cuayáhuitl et al., 2010) is a multimodal interactive spoken dialogue system for indoor wayfinding in complex buildings. It was developed based on a general computational dialogue system architecture and framework named DAISIE (Ross & Bateman, 2009), and can be described with the following three key components: 1) Dialogue management with a formal unified dialogue modeling approach combining information state update theories with generalized dialogue models (Shi, Jian, & Rachuy, 2011). 2) Route instruction generation with a combined computational model for generating unambiguous high-level context-specific route instructions (Richter, 2007). 3) Natural language generation with the probabilistic context-free representational underspecification framework (Belz, 2008) and the KPML natural language generation system (Bateman, 1997).

In the basic condition, the participants received route instructions generated automatically by Infokiosk. The instructions contained only procedural sentences in imperative mood, directly linking body turn actions to landmarks. An artificial route graph based on network space was superimposed onto the two open areas (figure 1, dotted grey lines), and they were described accordingly. Example (1) shows an instance of the instructions generated by the system in the basic condition for area A in figure 1:

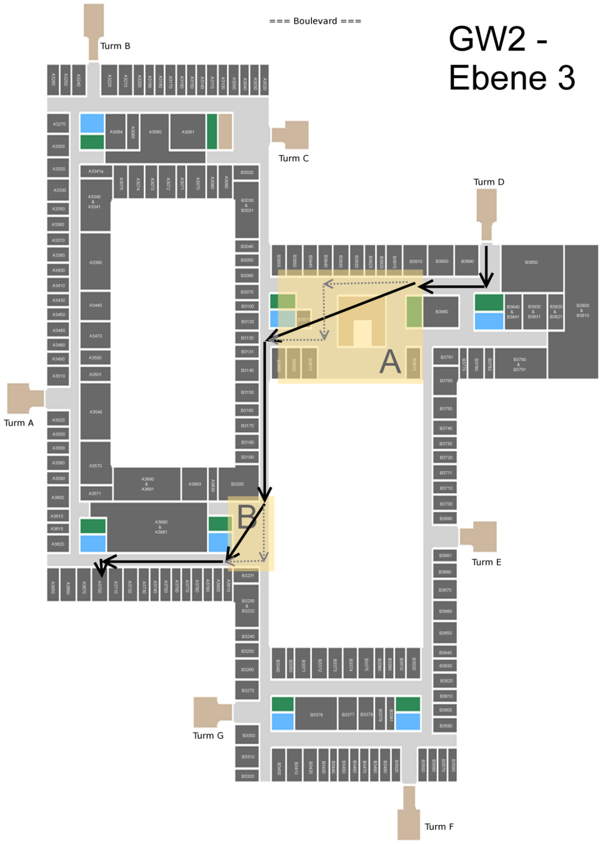

Figure 1: The selected route for the experiment. Grey dotted lines show the superimposed route graph for the basic condition.

(1) *"... go straight on until the third turning point on the left. Turn left, and go straight until the first glass door on the right. Turn to the right,... "*

At the current stage, representations appropriate to the descriptive strategy, and the generation of the corresponding utterances are not supported by the Infokiosk. The integration of that capability in the system is not straightforward and should only be approached if such elements do show to improve wayfinding in indoor environments. Thus, in the descriptive condition, the participants received hand-crafted instructions by interaction with the dialogue system. In these instructions, imperative and declarative clauses were used, and the two scene space areas were described with full scene descriptions containing an introduction to the general structure of the area, one or more intermediary landmarks, or configurations of landmarks, and a localization of the goal exit with respect to the intermediary landmarks. Example (2) shows the instructions received for area A in figure 1 in the DC.

(2) *"... straight on until you reach a big hall area. In the middle of the hallway there is a staircase. Behind the*

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[1] http://www.diaspace.org/

> *staircase there are two glass doors which are partly hidden by concrete pillars. Go through the left door."*

It must be emphasized that the difference between the two conditions is not merely quantitative in nature, i.e. including a higher amount of descriptive information in the instructions. There is a qualitative difference, as the basic condition relies on superimposing an artificial route graph on areas characterized as scene space, giving a high amount of procedural information which precisely specifies the path for crossing an open area while reducing descriptive information to the minimum. In the descriptive condition, however, scene space areas are considered as holistic scenes with an entry point and an exit point. The scenes are described as seen from the entry point, and the position of the exit point is identified with respect to the described scene without any procedural information mentioning the path to take to get there. The descriptive instruction is only slightly more verbose (98 words, as compared to approx. 85 in the basic condition), but a different kind of information is chosen for verbalization.

Participants

32 participants were tested. Two participants had to be excluded from the overall evaluation, because they found the goal by accident due to its location close to their position in the route. These participants explicitly stated that they expected the goal to be at a different position and were not using a search strategy, but saw the final goal by mere coincidence. The remaining 30 participants were used for evaluation, 15 in each of the two conditions (basic vs. descriptive). The participants were mostly first semester students at the University of Bremen. All had native or near-native competence of German and were between 19 and 31 years old (mean: 22). There were 21 female and 9 male participants.

The participants had little or no prior knowledge of the building. On a 7-point Likert scale, scores for the basic condition ranged from 1 to 4 (median 2; mean 2.3; standard deviation (sd) 0.88) while in the descriptive condition the range was from 1 to 3 (median 2; mean 1.6; sd 0.63). Scores for the basic condition were significantly higher than for the descriptive condition. (Wilcoxon rank sum test (one-sided): W = 161, p = 0.02)[2].

The experiment was conducted with respect to a route on the 3rd level of the building. Most participants had been to the 3rd level either never, or less than five times before the experiment with no difference between the two groups (Wilcoxon rank sum test (two-sided): W = 123.5, p-value = 0.64). Five participants (3 in the basic condition, 2 in the descriptive condition) reported having been to that particular floor more than five times.

There was no significant difference for spatial abilities between both conditions, as measured by the Questionnaire on Spatial Strategies (Münzer & Hölscher, 2011) ("Global self-confidence, related to egocentric strategies", Wilcoxon rank sum test (two-sided): W = 88, p = 0.32); "Survey strategy" (Wilcoxon rank sum test (two-sided): W = 99.5, p = 0.60); "Knowledge of cardinal directions" (Wilcoxon rank sum test (two-sided): W = 74.5, p = 0.10).

Procedure

The overall procedure consisted of several steps that we describe in the current section.

First, participants were brought to the starting point via a route that did not cross the target route – they reached the starting point by entering the floor directly from the elevator.

Then, all participants were asked to fill in a short pre-questionnaire concerning age and prior knowledge of GW2.

After the pre-questionnaire the experimenter instructed the participants. Their goal was to find the room of a given person and for that they were only allowed to use the help of the Infokiosk. The participants were strongly encouraged to acquire the information solely using natural language. Handling of the microphone was explained in a short briefing. At this stage, participants were told that they should follow the route given to them by the system from their own memory, as far as this was possible. They were not informed that they would be able to recheck the instructions en-route. In this way, we enforced that they attempt full comprehension and memory of the route instructions in advance.

Right after the dialogue with the system, the participants were asked to answer 3 questions regarding perceived helpfulness of the system, confidence that they would find their goal, and how well they could visually imagine the route.

In the next step of the procedure they were instructed that they should follow the given route as closely as possible from memory, but that they could recheck a printout of the instructions as often as they wanted. The experimenter informed them that in case of doubt it was preferable to recheck the instructions than take a wrong turn.

The participants followed the route accompanied by the instructor. The experimenter did not answer any clarification questions (except for the initial perspective from which the instructions were given, i.e. "the system has explained the route as from the position in which you were seated when you received the instructions"), but whenever participants were indicating they were unsure about the route to follow, asked clarification questions, or explicitly stated that they were lost or had forgotten the instructions, the experimenter informed the participants that it was no problem at all to recheck the instructions as often as they wanted. Whenever participants explicitly stated doubts that they were going to be able to find the goal, the experimenter informed them that it was possible for them to give up if they wanted to.

At last, after finding the goal (or giving up), the participants were asked to give a retrospective report of their wayfinding and any doubts or problems that had occurred at the decision points. They were brought back to the starting point to fill in a final questionnaire about their performance and the perceived

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[2] As the data was not normally distributed, a non-parametric test was chosen. The same applies for all the following statistical tests where non-parametric methods were chosen.

Table 1: Participants' task success in both conditions.

	participants	
	BC	DC
failed	7	0
succeeded	8	15

helpfulness of the system, and the Questionnaire on Spatial Strategies by Münzer and Hölscher (2011).

Hypotheses

With respect to objective performance measures we expected the descriptive condition to improve task performance, yielding a higher task success rate, a lower number of wrong route segments travelled and a lower number of total route segments travelled. We also expected the descriptive condition to improve memorization, leading to less frequent consultation of instruction printouts.

With respect to subjective performance measures, the descriptive condition was expected to lead to higher self-ratings for confidence of being able to find the goal, subjective helpfulness of the instructions, and mental imagery.

Annotation

In order to evaluate task success, the experimenter followed the participants in the wayfinding task and made a protocol of the path travelled and any instruction consultations. With respect to the used annotation scheme, the path was divided into segments, where each segment consists of the path between two decision points. At the end, every wrong segment that the participant travelled was counted. Only those segments were counted where the participant either travelled a segment that was not part of the intended route, or walked in the wrong direction along a segment that was part of the intended route. Wrong segments that were travelled several times in a task were counted several times accordingly. In order to be able to count the number of instruction consultations, participants were only given the instructions if they explicitly requested this and were not allowed to move while holding the instruction sheet. If participants had not moved at all between two consultations, this was counted as one consultation.

Results

Task Success

Task success is an objective performance measure indicating the number of participants that managed to find the target. As indicated in table 1, in the basic condition 7 out of 15 participants for that setting did not find the goal at all. Yet, in the descriptive condition all 15 participants managed to find the goal. The resulting difference is significant (Pearson's Chi-squared test with Yates' continuity correction: X-squared = 6.7081, df = 1, p = 0.01). This result strongly supports our hypothesis that enriching route instructions with descriptive information significantly improves wayfinding success.

Wrong Segments Traveled

Another objective performance measure that we considered is the number of wrong segments traveled during the wayfinding process. In the descriptive condition there were overall 82 wrongly traveled segments, with single participants travelling from 0 to 31 wrong segments (mean:5.47, sd: 8.51), while in the basic condition there were 169 wrongly travelled segments altogether, single participants' error scores ranging from 0 to 27 (mean: 11.27, sd: 7.34).

In the descriptive condition, one participant contributed over 35% of overall wrong segments (31 out of 82) due to an exceptional misunderstanding that was not reproduced by any of the other participants. But even including this exceptional case, there remains a significant difference, indicating that participants receiving the basic instructions travelled more wrong segments than those receiving the descriptive instructions (Wilcoxon rank sum test one-sided, with continuity correction: W = 166.5, p = 0.01).

Number of Instruction Consultations

The number of instruction consultations during wayfinding is as well an objective performance measure. It indicates how easy the given system instructions were to understand and memorize. The participants in the basic condition consulted the instructions en-route 74 times overall, ranging from 1 to 10 consultations (mean: 4.93, sd: 2.76) while the participants in the descriptive condition rechecked the instructions only 31 times, individual scores ranging from 0 to 6 (mean: 2.07, sd: 1.53). Participants in the basic condition consulted the instructions significantly more often than those in the descriptive condition (Wilcoxon rank sum test one-sided, with continuity correction: W = 180.5, p = 0.002).

Confidence

As subjective performance measure we considered the participants' confidence. Immediately after they had finished the dialogue with the system, participants were asked how confident they felt that they would find their goal. This was before they were informed that they would be able to consult a printout of the instructions en-route. For this reason, confidence levels were generally fairly low, reflecting the difficulty of the task. In the basic condition, they ranged from 1 to 5 on a 7-point Likert scale (median: 3, mean: 3.13, sd: 1.30), while ranges in the descriptive condition were from 1 to 6 (median: 4, mean: 4.13, sd: 1.41). Confidence in the basic condition was significantly lower than in the descriptive condition (Wilcoxon rank sum test with continuity correction, one-sided: W = 70, p = 0.04).

Mental Imagery

The level of mental imagery across all participants in both conditions shows the effect of the descriptions in both conditions on the participants' capability to envision the environment. Asked directly after the dialogue with the system, how well they could visually imagine the described route, participants in the basic condition gave scores from 1 to 5 on a

7-point Likert scale, (median: 3, mean: 2.93, sd: 1.39). Participants in the descriptive condition gave scores from 1 to 7 (median: 5, mean: 4.6, sd: 1.59). The difference is highly significant, indicating that participants in the descriptive condition could visually imagine the route better than those in the basic condition (Wilcoxon rank sum test, one-sided: W = 49.5, p-value = 0.004).

Perceived helpfulness of the instructions

The scores participants gave for the helpfulness of the instructions given by the system show an interesting effect. Both conditions were perceived as equally helpful directly after receiving the instructions - in both conditions, scores ranged from 2 to 7 on a 7-point Likert scale with a median of 5 (basic condition: mean: 4.6, sd: 1.55; descriptive condition: mean: 4.73, sd: 1.58; Wilcoxon rank sum test with continuity correction, two-sided: W = 110, p-value = 0.47). After navigating the route, however, this changed. In the final questionnaire, scores for helpfulness in the basic condition ranged from 1 to 7 with a median of 3 (mean: 3.54, sd: 1.81), constituting a significant drop in comparison with pre-navigation scores (Wilcoxon rank sum test with continuity correction, one-sided: 155.5, p-value = 0.036).

For the descriptive condition, on the other hand, they stayed at the same high level, ranging from 3 to 7 with a median of 5 (mean: 5.27, sd: 1.49). Thus, the perceived helpfulness after navigation is significantly higher in the descriptive condition than in the basic condition (Wilcoxon rank sum test with continuity correction, one-sided: W = 51, p = 0.005).

Discussion

The results clearly show that descriptive strategies can improve wayfinding in indoor environments. Participants in the descriptive condition had a higher success rate and walked the route with less wrong segments traveled than those in the basic condition. They also needed to consult the instructions less often. This is most likely due to the fact that the different structure of the environment, as compared to street networks, leads to differences in wayfinding strategies, and therefore different needs with respect to route instructions.

An important finding of this experiment is, that descriptive elements not only improve objective performance measures, but also subjective ones. The improvement of participants' confidence and mental imagery in the descriptive condition is a factor that is important for cognitively ergonomic route instructions. Humans should not only find their goal with automatically generated instructions, they should also feel comfortable and secure while doing so. The scores for perceived helpfulness of the system show an interesting effect: before wayfinding participants rate the instructions as equally helpful in both conditions, which is in contrast to the other subjective measures. After wayfinding the values change, resulting in a significantly higher value for the descriptive condition, matching objective performance and the other subjective measures. This might be due to the fact that before performance participants were not as secure about their quality judgement as after, and possibly answers were influenced by their wish to be polite.

There are several reasons that might account for the better performance of subjects that were given the descriptive instructions. Firstly, the significantly higher values for mental imagery before setting off suggest that better mental imagery might be one of the factors that helped participants find their way more easily. Visuo-spatial imagery is an important factor in understanding and memorizing route directions (Denis & Fernandez, submitted). In addition, successful mental imagery involves deep semantic processing and the formation of a coherent situation model which have been shown to improve memory performance (Craik & Tulving, 1975; Kintsch, 1994). The greater difficulty of participants in the basic condition to visually imagine the route in advance indicates that these participants were not able to construct as good a situation model as those in the descriptive condition.

Another central aspect that was verified by statements of several participants in the retrospective reports is that configurations of landmarks can improve error-recovery and confidence en-route, acting as substitutes for highly-salient landmarks which rarely exist in indoor environments.

Finally, it is probable that the highly repetitive style which results from generating only prescriptive utterances yields a Ranschburg effect: The occurrence of several tokens of the same type in the input within a short time is known to have a negative effect on memorization (Jahnke & Bower, 1986; Kanwisher, 1987, compare). The Ranschburg effect has mainly been studied in series of unrelated numbers or words, but it is highly probable that the underlying mechanisms have an effect on the memorization of a series of highly similar sentences containing repeated instances of certain words, as seen in the basic condition of this experiment. The more varied linguistic structure and semantic content of the descriptive instructions neutralize this effect, thereby improving memorization.

Conclusion and Future Work

Our work shows that the use of elaborate descriptive information into indoor route instructions can significantly improve the quality of automatically generated instructions. The reported results indicate that both objective and subjective performance measures rank the use of descriptive strategies higher than the the condition in which only the prescriptive strategy was used. It needs to be shown, however, that the improvement remains significantly large when using computer-generated instructions based on the descriptive approach.

Also, buildings differ with respect to their structure. While this approach may be very useful for buildings that contain a high proportion of open spaces, it may not be necessary for buildings that consist entirely of long and narrow corridors with clearly identifiable intersections and can therefore be represented sufficiently by network space. It would be insightful to compare the two different approaches over a wider variety of routes in order to investigate how the two strategies can best be combined, and how they interrelate with issues of conciseness: How much descriptive information is necessary, and at which points in a route should this type of information be provided? How do route length and dominance of scene space characteristics interact to favor one or the other type of instructions? It should also be examined whether the findings hold for pedestrian navigation in general.

Although we have hinted at some mechanisms that might underlie the performance improvements, a more detailed analysis of these mechanisms should be undertaken, in order to be able to clearly distinguish which aspects of the descriptions improve comprehension and memorization in which ways.

Natural language route direction systems for indoor (and pedestrian) navigation should take these results into account and find ways of modeling spatial information that allow for a more flexible combination of prescriptive and descriptive information.

Acknowledgements

This research was supported by the SFB/TR 8 Spatial Cognition (Deutsche Forschungegemeinschaft, DFG). We would also like to thank the I5-[DiaSpace] project group, and especially Thora Tenbrink for support and insightful discussions.

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