An Analysis of Direction and Motion Concepts in Verbal Descriptions of Route Choices

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Abstract. This paper reports on a study analyzing verbal descriptions of route choices collected in the context of two in situ experiments in the cities of Salzburg and Vienna. In the study 7151 propositions from 20 participants describing route choices along four routes directly at decision points (100 decision points in total) are classified and compared to existing studies. Direction and motion concepts are extracted, semantically grouped and ranked by their overall occurrence frequency. A cross-classification of direction and motion concepts exposes frequently used combinations. The paper contributes to a more detailed understanding of situational spatial discourse (primarily in German) by participants being unfamiliar with a way-finding environment. Results contribute to cognitively-motivated spatial decision support systems, especially in the context of pedestrian navigation.

1 Introduction

Navigation is one of the most common spatial activities of human beings involving a number of spatial abilities and cognitive processes [25]. Navigation requires continuous sense-making of the proximal surrounds ([12], [25]) which is considered to be a challenging task in unfamiliar spatial environments. With the advent of electronic navigation systems [1] better human decision making in such environments seems to be in reach. One of the major research questions is how the process of human spatial decision making can be supported effectively by such systems. Today's electronic navigation systems provide three types of user interfaces: (1) maps, (2) visual turn instructions and (3) textual or voice-based turn instructions. In the domain of car driving voice-based instructions have gained considerable attention in the last years whereas in other navigation domains (e.g. pedestrian navigation) map-based guiding systems are predominant [1]. Guiding pedestrians by textual or voice-based turn instructions is still in its infancies [26].

Among the open questions are the following: Are textual or voice-based turn instructions useful for pedestrian navigation and if so, how should these instructions be structured? Manufacturers of navigation systems currently tend to disable voice instructions upon switching to pedestrian mode and reduce decision support to

K. Stewart Hornsby et al. (Eds.): COSIT 2009, LNCS 5756, pp. 471–488, 2009.

map-based interfaces[1]. Map-based interfaces on small screens lead to problems with map reading performance [7] which gives motivation to explore voice-based interfaces. However, empirical studies testing the performance of voice-based guidance are rare [26]. Several authors explore textual descriptions and come to the conclusion that turn instructions for pedestrians are useful ([4],[24]). In addition elements for good descriptions are suggested [21]. In this context also the importance of landmarks for improved decision support is stressed [5] and the positive impact of landmarks on navigation performance is confirmed [30]. In recent work models for generating turn instructions from combinations of spatial direction concepts and landmarks have been proposed [2]. Also the role of direction concepts in way-finding assistance has been explored [15], resulting in cognitively motivated models for cardinal directions [16]. Striving towards voice-based instructions the role of language in spatial decision support is subject to an ongoing debate (e.g. [16],[35]). One of the established methods to explore spatial discourse are empirical studies ([3],[5],[34]). In experiments participants are asked to verbally describe well-known routes. A review of these studies has identified two major gaps: (1) the lack of in situ studies exploring verbal descriptions of route choices in the context of real world decision situations and (2) the lack of in situ studies involving participants being unfamiliar with the way-finding environment. Due to these gaps we consider the ad-hoc interpretation of spatial decision situations by people being unfamiliar with the way-finding environment as not studied adequately. Studying language use in such situations is crucial for empirically founded turn instructions which do not only reflect expert views (as provided by citizens) but consider perception of space by people being unfamiliar with an environment and thus being spatially challenged. We think that a better understanding of this non-expert view [11] will contribute to user-centered turn instructions and is therefore the main motivation for our study on which we report in this paper.

The structure of the paper is as follows. Section 2 describes the set-up of experiments. Section 3 classifies propositions (following Denis' classification) and discusses results. Section 4 proposes a method for further analysis of spatial direction and motion concepts. In Section 5 and 6 direction and motion concepts are structured in ranked taxonomies. Section 7 discusses cross-classification results and sketches a model for composing turn instructions. Section 8 summarizes and concludes the paper. Since the study was organized in two Austrian cities with German-speaking participants, the primary results are in German language. In order to ensure the validity of the results we primarily refer to German language concepts and try to provide the most suitable English translation (which may differ from the original meaning and should primarily improve readability).

2 Collecting Situational Verbal Descriptions of Route Choices

The analysis of verbal descriptions in spatial context has a long tradition. In one of the first empirical studies [22] Kevin Lynch explored the mental structuring of city-scale spaces [10] in language. The study is one of the first examples of using the method

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[1] This was a finding in tests with Smartphone-based navigation systems Route 66, Wayfinder 8 and Nokia Maps 2.0 and 3.0.

later referred to as “think aloud” [20] for gaining insight into human conceptions of space [10]. The main contribution concerning the analysis of verbal route descriptions comes from Denis ([4],[5],[6]). In [5], Denis grounds a general framework for analyzing route descriptions through spatial discourse and uses the framework for several experiments with participants familiar with the environment ([5],[6]). Although the work of Denis lacks the aspect of the situational use of language, the general framework is well suited to be adopted in similar studies. Other empirical studies explore the use of spatial language in various settings ([27],[34]). Raubal's case study of way-finding in airports contributes to a better understanding of spatial discourse in indoor settings, but lacks the situational context. A recent study by Brosset [2] explores the spatial discourse of orienteering runners in rural environments. This study also does not answer the question about the situational spatial discourse in decision situations. Another recent study by Ishikawa [14] compares the effect of navigation instructions using different frames of reference (absolute and relative). Since the study uses pre-defined turn instructions questions about situational spatial discourse are not answered. Some other contributions deal with landmarks in route directions (e.g. in the context of route descriptions as navigational aids [4] or as enrichment for way-finding instructions [28]) but do not address direction and motion concepts or situational use. Concluding from related work our motivation for the study was twofold:

1. Obviously, there is a lack of in situ studies analyzing situational spatial discourse. However, since human spatial decision making is highly situational, the only way to study human cognitive processes in this context is the situation itself. One of the main motivations for our study is to narrow this gap.
2. Most of the existing studies explore route descriptions by asking participants to recall memorized route knowledge. Until now we do not have empirical evidence how people walking a route for the first time and thus unfamiliar with the spatial surrounds describe spatial decision situations. By studying spatial discourse in such situations we will get verbal descriptions of route choices coming closest to situations where turn instructions by way-finding assistance systems are typically given. Since our experimental set-up fosters such situations we think we can learn from these for composing empirically-founded turn instructions.

2.1 Experimental Set-Up

Selection of routes: The experiments were organized in the two Austrian cities Salzburg and Vienna. In each city we pre-defined two routes, one in the inner city and one in a peripheral district. Routes were composed of 22 and 27 decision points. Different cities and environments were chosen in order to address the question to which extend situational spatial discourse is depending on the physical environment. In order to avoid learning effects the sequence of routes was changed between participants.

Participants: We selected two test groups consisting of 10 participants in each city. Participants in each city were half female and half male. Participants were first term students and stayed in the city for no longer than 3 weeks before the experiment. All participants confirmed to have no or very limited spatial knowledge of the cities and to be unfamiliar with the test routes. Each participant had to complete both routes in one city. In order to avoid problems with the think aloud method [20] we did a pre-test consisting of 3 decision points. The route for the pre-test was separated from the test routes in order to avoid prior acquisition of route and environmental knowledge of participants. Participants were paid (Salzburg) or got credits for a course at the University (Vienna).

Implementation: A test instructor accompanied participants to the starting point of each test route and supervised the tasks defined by the experiment along the predefined route to the end point. At decision points test candidates were asked to (1) describe the surrounding environment and (2) to describe all their possible choices at this decision point as they would explain to another person. Since participants were unfamiliar with the route they described all possible choices at each decision point. We asked participants to refer to the visible spatial environment (the so-called vista space [25]) in their descriptions and to provide unambiguous descriptions of route choices. If the description of a route choice was not considered unambiguous for any other person (e.g. the use of spatial-dimensional terms such as "left", "right" or "straight" without any reference to a fixed spatial entity was not accepted as unambiguous), the participants were asked to continue the description process. Afterwards the test instructor told participants which choice to take. The test instructor used the same wording as participants for giving route instructions in order to avoid any influences on perception as well as language. Decision points were identified by participants themselves (by stopping their walk). If a participant did not identify a decision point, this point was skipped and the test person was directed in the right direction (by gestures). At the end of the experiment each test person was asked to reproduce a summarizing route description. A final survey about demographic data and self-assessment of spatial abilities completed the experiment. Verbal protocols were recorded and transcribed afterwards.

3 Classification of Propositions

Firstly, we classified propositions using Denis' classification [5] (Table 1).

Table 1. Examples from the protocols showing the classification method

Class	German	English
1 Actions	rechts abbiegen	turn right
2 Actions with references to landmarks	in die Straße abbiegen	turn into the street
3 Landmarks without actions	ich bin an einer Kreuzung	I'm at a crossing
4 Landmark descriptions	gelbes Haus	yellow house
5 Others	Überqueren ist hier verboten	crossing is not allowed here

Due to the situational set-up of our experiments participants were able to refer to any kind of spatial entities from the visible environment. Thus, for the classification we treated all kinds of entities as landmarks (since entities were perceived by participants as visually salient, which satisfies the commonly used definition of the term landmark [31]). Nevertheless we are aware that this use of the term landmark may be in contrast to other definitions (e.g. [22]).

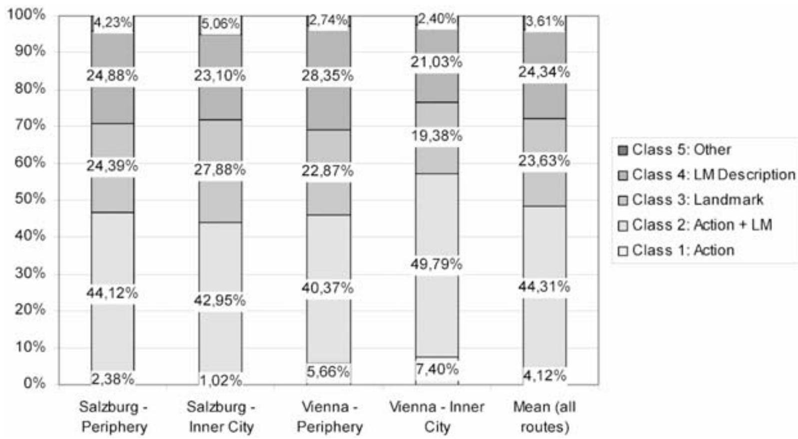

Fig. 1. Comparison of proposition types used throughout the four test routes

We considered 7151 propositions (expressed by 10 participants on 2 routes with 23 and 27 decision points in each city) describing spatial scenery and route choices at decision points for classification (we have not considered 798 additional propositions from route summaries since the focus of this analysis is on the situational use). Fig. 1 compares results from the Denis classification between the four test routes.

The comparison shows that about half of all propositions were used by participants to describe actions (actions without references to landmarks or actions with references to landmarks); the other half of propositions was used by participants to describe landmarks and their characteristics. In the landmark description group (classes 3 and 4, 47.97% mean value) 23.63% propositions are used to introduce landmarks (landmarks which were not referenced before) and 24.34% are used to describe landmarks; most of the propositions in the action group (44.31% out of 48.43%) relate actions to landmarks. Fig. 1 confirms that the overall distribution of propositions in the 5 classes is widely stable between test groups and test routes. Minor deviations occur between test groups in the use of class 1 and class 2 propositions and between the Vienna – Inner City route and the other routes. The increased use of class 1 propositions by the test group in Vienna is considered a characteristic of participants (environmental planning students vs. students of social studies in Salzburg). The increased use of class 2 propositions throughout the Vienna – Inner City route has its origin in differences of the physical environment (more salient landmarks, which do not need further description). All in all the general distribution confirms the extensive use of landmarks in the situational description of route choices (in approximately 90% of all propositions landmarks are referenced), which has been additionally fostered by our experimental set-up.

The comparison with previous studies by Denis [5] and Brosset [2] shows that our results fit in the overall picture. The distribution of action- and landmark-related propositions is half-and-half in all three studies. As expected, our experimental set-up resulted in a higher number of action-landmark relations (44.31% compared to 35 % in the Brosset study and 33.5% in the Denis study). Another noticeable variance is the fact that similar to the Brosset study our study leads to an increased number of landmark descriptions (26.5% in the Brosset study, 24.34% in our study compared to 11.3% in the Denis study). Although Brosset argues that this aspect is influenced by the difference between natural and urban environments our results clearly show that the increased use of landmark descriptions is not only appearing in natural environments, but also in urban environments. Thus we assume that the increased use of landmark descriptions mainly depends on the in situ aspect of the studies, which is common in Brosset's and our experiments, but is missing in the Denis experiment.

To summarize, Denis' classification leads to four findings: (1) the overall distribution of proposition types in verbal descriptions shows a low variance between different routes and test groups which allows for the assumption, that personal or physical variances have only minor influence on used proposition types, (2) the half-and-half distribution between action related propositions and landmark description related propositions is stable for verbal descriptions of routes or route choices in different studies, (3) complementing previous studies our study shows a high-relevancy of route descriptions relating actions to landmarks and (4) also shows a clear tendency towards an increased use of detailed landmark descriptions in situ, which has according to [3] not been sufficiently answered by existing studies.

In the further analysis we focus on propositions classified in the action group (class 1 and 2) and leave the analysis of the landmark description group (class 3 and 4) to future work.

4 Extraction of Direction and Motion Concepts from Propositions

Most of the propositions in class 1 and 2 are so-called directionals expressing a change in the localization of an object ([8],[37]). Directional expressions consist of three main particles which are of further interest to us [2]: spatial relations, motion verbs and landmarks. While we leave landmarks to future analyses, the reported analysis is motivated by the following questions: (1) Which set of spatial direction concepts is used in the propositions, (2) which set of motion concepts is used in the propositions and (3) how frequently are these concepts used by the test groups.

To answer these questions the overall question how to deal with semantics of spatial relations in language has to be considered. According to several authors ([489],[32],[37]) spatial prepositions (and adverbs in the German language) are the main language concepts to express spatial relations. Direction concepts given from the view point of the speaker and thus of interest in the context of our study are denoted as projective relations [13]. According to Herskovits spatial relations can be either spatial-dimensional (e.g. "in front of", "behind"), topological (e.g. "in", "on") path-related (e.g. "across", "through"), distance-related (e.g. "near", "far") or belong to some other category (e.g. "between" or "opposite"). One of the newer accounts contributing to the understanding of semantics of prepositions comes from Tyler and Evans [36]. In their work they integrate previous accounts and propose a theory called principled polysemy as a foundation for analyzing the semantics of English prepositions. According to their account semantics of prepositions is not only determined by the preposition itself but distinct senses rely on the context. They call the semantic nucleus of prepositions a “proto-scene”, building on our daily experiences with our physical surrounds and describing concrete spatial scenes as highly abstract and schematic relationships. Thus "proto-scenes" allow mapping of different spatial scenes on one schematic concept which can be considered as good foundation for a semantic reference system [18].

Our analysis is based on the proposed breakup of spatial propositions into several particles of a "proto-scene". Tyler and Evans denote the "schematic trajectory" (TR), a "schematic background element" (the landmark or short LM), the "spatial relation" between the TR and the LM and "functional elements" of the landmarks determining a spatial relation. Whereas the nature of the TR and LM particles follows closely the primary breakup of a spatial scene proposed by Talmy [32] (the trajectory acts as the primary object and the landmark acts as the secondary object), the distinct sense of the spatial relation is determined by the spatial preposition and the functional elements of the landmark (functional elements specify the functional role a landmark takes in a spatial relation). Following this approach our method for extracting the particles is structured as follows (repeated for each proposition):

1. Extract the TR (primary and often moving object, in most cases a person)
2. Extract the LM (secondary object(s), static reference in the spatial relation)
3. Extract the spatial relation (spatial preposition or adverb in the German language)
4. Extract the motion verb

The resulting particles are tagged with a unique identifier of the participant (PID), the number of the decision point (DP) and a unique identification of route choices at decision points (C). If one of the particles could not be unambiguously identified from the context the corresponding entry in the result table was left empty (Table 2).

If one proposition contained more than one spatial relation, the proposition was split up and each spatial relation ran separately through the extraction process. Verbs were translated to their infinitive. Helper verbs (such as "can") were not considered. In order to adapt the method to German language spatial adverbs were treated like spatial prepositions.

Table 2. Example propositions and the related break-up

Propositions
and I can walk towards the church (und ich kann in die Richtung der Kirche gehen)
there's the possibility to move along the street (es gibt die Möglichkeit sich die Straße entlang zu bewegen)
first cross the zebra crossing (zuerst den Zebrastreifen überqueren)
through a small archway (durch einen kleinen Bogen)

TR	**LM**	**Motion Verb**	**Spatial Relation**	**PID**	**DP**	**C**
I (ich)	church (Kirche)	walk (gehen)	towards (Richtung)	S6	1	A
	street (Straße)	move (bewegen)	along (entlang)	S3	2	B
	zebra crossing (Zebrastreifen)	cross (queren)	across (über)	S4	2	B
	archway (Bogen)		through (durch)	S3	3	C

5 Results from the Analysis of Direction Concepts

The main goal of the analysis was to identify the set of re-occurring direction concepts used by participants. In total 3940 propositions (3652 of them containing spatial particles) of class 1 and 2 have been analyzed. Extracting the spatial particles resulted in a set of 103 different spatial prepositions and adverbs. Since some of the 103 particles belong to a subcategory of a more general direction concept or are synonyms these concepts could be semantically grouped. The rules for semantic grouping rely on related work ([8],[13],[36]) and on a German semantic dictionary[2].

85 particles could be grouped to one of 26 main direction concepts. The remaining 18 particles were not considered for further analysis since the particles were only used in singular propositions. Fig. 2 shows the taxonomy of spatial relations. The classification is adopted from related work ([13],[36]). Main classes are structured by *orientation*, *goal*, *path*, *topology* and *distance*. The mean occurrence frequency of concepts is shown in brackets.

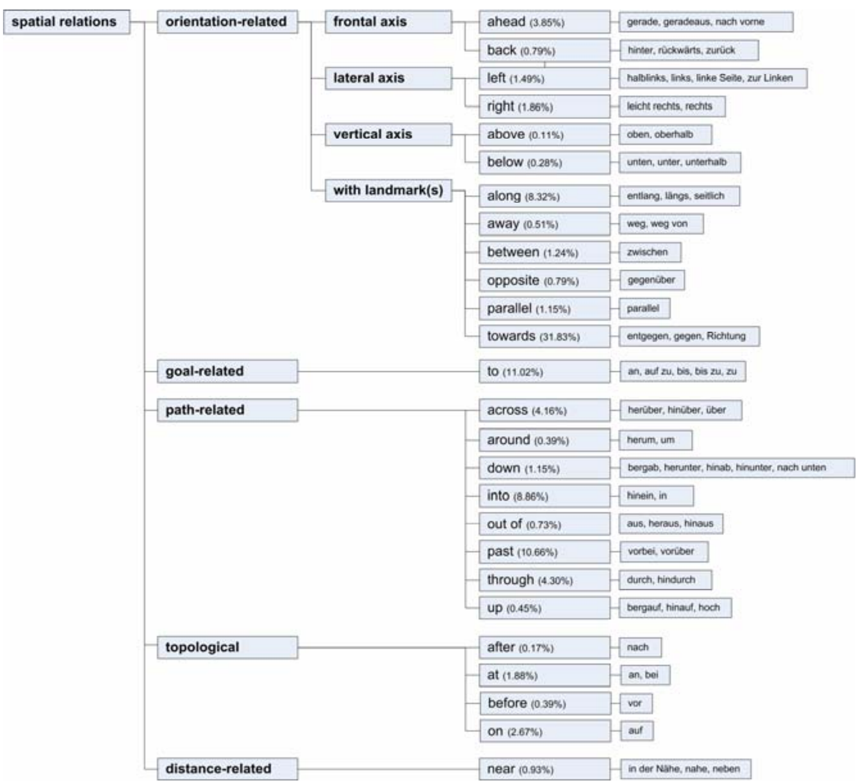

Fig. 2. Taxonomy of spatial relations generated from 3652 propositions

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[2] Online German Semantic Dictionary based on data provided by the University of Thübingen (Germany). Accessible as http://canoo.net.

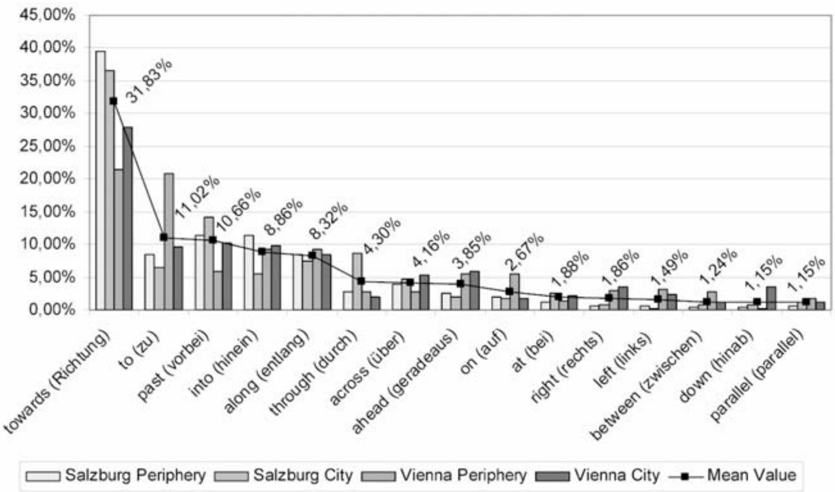

Fig. 3. Occurrence frequency of 15 direction concepts used in more than 1% of all propositions

In the further analysis we compare the 15 most frequently used spatial relations (each class is used in more than 1% of all propositions). We assume that the remaining set of 11 spatial prepositions only plays a minor role in the situational use of verbal descriptions. Fig. 3 compares the usage between the four test routes.

The predominantly used spatial relation in both test groups is "towards" (31.83% mean value). In combination with a landmark or spatial entity "towards" is one of the simplest possibilities to describe route choices in spatial decision situations. The frequent use of this direction concept is in accordance with the frequent use of landmark descriptions (Denis class 4) since landmarks or spatial entities used with "towards" have to be identified unambiguously. Noticeable is a variance in the use of "towards" between the two test groups in Salzburg and Vienna. Considering the whole distribution one will recognize that the test group in Vienna makes more use of "to" as well as the *spatial-dimensional* concepts "ahead", "left", "right" and "between". It seems that instead of the predominant concept "towards" the group in Vienna used a slightly broader range of concepts although variances are not very significant. One interesting question is whether differences in the physical environment influence the use of spatial direction concepts or not. One noticeable variance is the increased use of the preposition "to" along the Vienna – Periphery route (with 20.85% three times higher compared to the mean value of the other routes 8.2%). Since salient landmarks are missing along this route participants frequently referred to structural spatial entities like "streets" or "pathways" and transitively described where these entities "lead them to". Another noticeable variance is the increased use of "through" in the Salzburg – City route. Due to the medieval environment in the old town of Salzburg the number of archways and passages is higher compared to the other test routes. We assume that this aspect of the physical environment is directly reflected in the results, since the occurrence of the concept is more than three times higher (8.56%) compared to the mean of the other routes (2.4%). A similar argumentation is valid for the concept "down", which is more frequently used in the Vienna – City route. This could be explained with differences in the scenery where some streets are leading "down". From the whole distribution we conclude that the use of direction concepts by participants follows a distribution with low variances between the four test routes. We further conclude that the situational use of direction concepts by participants reflects the scenery only in very special cases. We also discovered slight differences in the use of direction concepts between the two test groups. We explain the variances with slightly different skills in the expression of spatial relations (the test group in Vienna used a slightly broader range of direction concepts). Since our study is one of the first studies exploring spatial discourse in real world scenarios we have not found valid data to compare the reported results.

6 Results from the Analysis of Motion Concepts

For the analysis of motion concepts the same 3940 propositions in class 1 and 2 were used (2309 of them containing motion verbs). Extracting the motion particles resulted in 133 different motion verbs (including verbs with different adverbs). We classified motion verb stems into motion verb classes (following Levin classification [19]). Fig. 4 shows relative occurrences of motion verbs in 10 matching Levin classes.

The classification was highly effective since a large number of verbs in German language differ from their stem only because of the attached adverb. 113 verbs could be mapped to one of 10 verb classes. The remaining 20 verbs only occurred in singular propositions or did not express motion and thus were not further considered. The resulting taxonomy (Fig. 5) shows the complete list of used German verbs classified in 10 matching Levin classes.

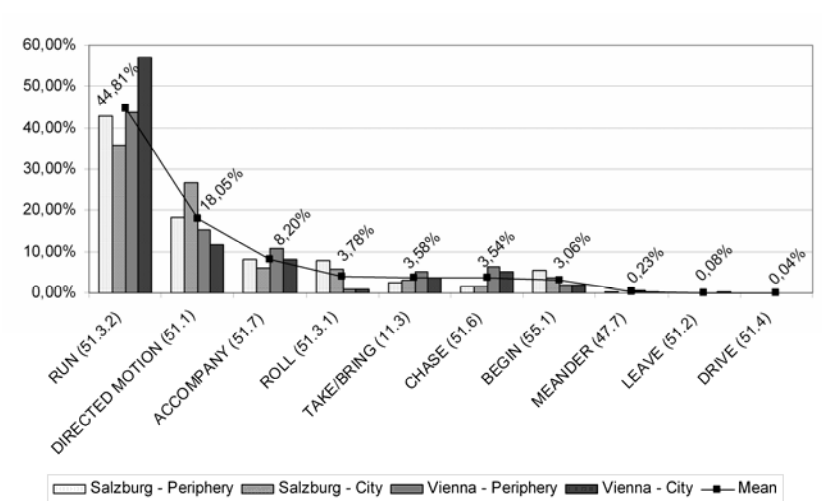

Fig. 4. Relative occurrences of motion verbs in 10 matching Levin classes

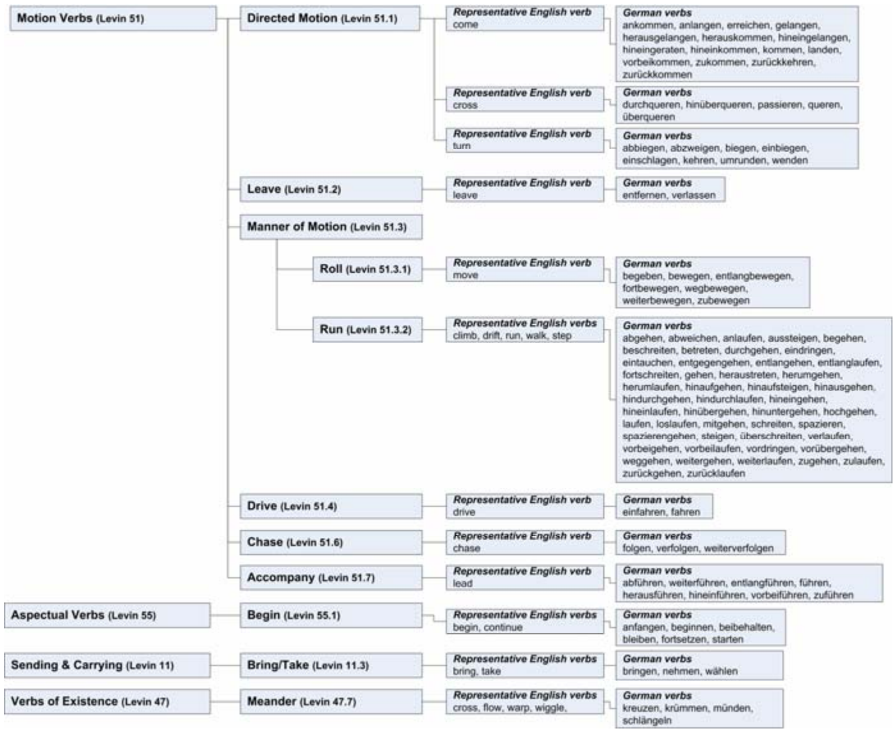

Fig. 5. Taxonomy of motion verbs following Levin classification [19]

The most frequently used verb class is the manner of motion class *run* (Levin class 51.3.2, 44.81% relative occurrences). Since the German language is considered to be a manner-typed language [33] (manner of motion is predominantly expressed in the verb) in most of the propositions the *run* verb "gehen" (walk) in combination with a spatial adverb is used. Other frequently used manner of motion verbs are "laufen" – "run" and "schreiten" – "step". The second largest class is the class of *inherently directed motion* verbs (e.g. the verbs "queren" - "cross", "kommen" – "come" or "passieren" – "pass" are according to Levin considered to be inherently directed). We also classified "turn" in this class since it does not express a manner of motion but is used to express directions. Including "turn" 18.05% of used motion verbs are inherently directed. This percentage could be significantly higher with other languages (e.g. English) since paths are more often directly expressed in verbs and not in adverbs [33]. Worth to mention are also verbs in the *accompany* class (e.g. "führen" – "lead") with 8.2% occurrences. In most of these occurrences the verb is used transitively where the *subject* is not the participant but a spatial entity (e.g. "the path leads us towards the building"). Also the verbs "bring" and "take" are used transitively (e.g. "the path takes me to the building"). The German verb "bewegen" – "move" is classified as *roll* verb. Although the overall use of motion verbs between test groups is very similar, "move" was mainly used by the test group in Salzburg (6.6%). In general, the overall usage of motion verbs shows the predominance of manner type motion verbs in German language. Although experiments with 20 participants are not representative for general conclusions this language characteristic is also confirmed by other authors [33] and thus should be considered in the composition of turn instructions.

7 Cross-Classification Analysis of Direction and Motion Concepts

Results from the distinct analyses of direction and motion concepts lead to the question of combined usage. To explore combined usage we use a cross-classified table revealing occurrence frequencies of 26 direction concepts and 10 motion verb classes (Fig. 6).

In the cross-classification we focus on *orientation*-, *goal-, path-* and *topology*-related combinations occurring more than 50 times in all propositions. Combinations with frequencies less than 50 (except the borderline "on" with 49 occurrences) are not considered as frequently used.

The most frequently (in combinations with spatial relations) used verb class is the class of *run* verbs with 948 occurrences. Verbs in this class are predominantly used in combination with the *orientation* relations *towards* (213, e.g. "in Richtung gehen" – "walk towards"), *along* (145, e.g. "entlang gehen" – "walk along") and *ahead* (60, e.g. "geradeaus gehen" – "walk ahead"). Furthermore verbs are used in the *goal* relation *to* (94, e.g. "gehen zu" – "walk to") and in the *path* relations *into* (94, e.g. "hineingehen" – "walk into"), *past* (68, e.g. "vorbeigehen" – "walk past") and *through* (51, e.g. "durchgehen" – "walk through). There is only one topological relation which is frequently used with a *run* verb: *on* (49, e.g. "gehen auf" –"walk on"). As obvious from the examples above some of the combinations of "walk" with a spatial preposition can also be expressed by path-related verbs in English, e.g. pass, cross or enter. However, in German some of these *directed motion* verbs do not have counterparts and thus have to be expressed with manner type verbs (e.g. walk) and spatial relations as adverbs (e.g. into, out of, through).

The second largest class of motion verbs is the *directed motion* class (e.g. come, cross, turn) with 558 occurrences. Predominant combinations are the *orientation* relation *towards* (94, e.g. "abbiegen in Richtung" – "turn towards"), the *goal* relation *to* (85, e.g. "kommen zu" – "come to") and the *path* relations *into* (108, e.g. "abbiegen in" – "turn into") and *across* (68, e.g. "überqueren" – "cross"). In this class we only

	FRONTAL AXIS		LATERAL AXIS		VERTICAL AXIS		LANDMARK						GOAL	PATH								TOPOLOGICAL				DISTANCE	
	AHEAD	BACK	LEFT	RIGHT	ABOVE	BELOW	ALONG	AWAY	BETWEEN	OPPOSITE	PARALLEL	TOWARDS	TO	ACROSS	AROUND	DOWN	INTO	OUT OF	PAST	THROUGH	UP	AFTER	AT	BEFORE	ON	NEAR	SUMS
DIRECTED MOTION (51	3	5	23	30			5	3	4	10	3	**94**	**85**	**68**	3		**108**	10	18	14		1	29	8	24	10	**558**
LEAVE (51.2)					1	1	1	1		1		1															6
ROLL (51.3.1)				1	2	2	16			1	6	22	12		1		6		1	1	1				4		**76**
RUN (51.3.2)	**60**	8	16	11	5	8	**145**	4	11	5	12	**213**	**94**	26	4	24	**94**	4	**68**	**51**	6	1	18	3	**49**	8	**948**
DRIVE (51.4)							2										1										3
CHASE (51.6)	1		1				3		1			4													3		13
ACCOMPANY (51.7)	3	3		1	6	8	11	4	3		5	19	**58**	7		3	23		26	8			1		11	1	**201**
BEGIN (55.1)	2								2	1	1	29		3			3			2			1		5		49
TAKE/BRING (11.3)				4		9	1					6				3	1		2	1			2				29
MEANDER (47.7)				1											1	0	2										4
SUMS	69	16	40	48	14	28	**184**	12	21	18	27	**388**	**249**	**104**	9	30	**238**	14	**115**	77	7	2	51	11	96	19	**1887**

Fig. 6. Cross-tabulation of used direction and motion concepts

classified inherently directed German verbs. Thus the occurrence frequency would likely be varying with other languages.

The third largest verb class is the *accompany* class with 201 occurrences. There is only one combination above the threshold of 58 occurrences, namely the transitively used verb *lead* with the preposition *to* (58, e.g. "führen zu" - "lead to").

All other combinations are less frequently used. Since the cross-classification is based on empirical data the extracted combinations do not result in a complete set of prototypical combinations of motion verbs and spatial relations. However, the cross-classification clearly indicates combinations which are frequently used by participants throughout all four experiments (despite different environments, different test routes and two different test groups). Based on the empirical data we classify 13 combinations as the relevant ones, noting that the complete set will certainly include further combinations being necessary for the description of different route tasks (good additional candidates may be combinations from the cross-classification with 20 to 30 occurrences). The following table (Table 3) summarizes the 13 relevant combinations ranked by their occurrence frequency. Furthermore we add the usage context (*orientation*, *goal*, *path* or *topology*) and whether the combination is used in context with a spatial entity or landmark.

Table 3. Frequently (>50) used combinations of motion and spatial relation concepts

NO	VERB	RELATION	USEAGE	LANDMARK	FREQ
1	WALK	TOWARDS	ORIENTATION	Yes	213
2	WALK	ALONG	ORIENTATION	Yes	145
3	TURN	INTO	PATH	Yes	108
4	TURN	TOWARDS	ORIENTATION	Yes	94
5	WALK	TO	GOAL	Yes	94
6	WALK	INTO	PATH	Yes	94
7	COME	TO	GOAL	Yes	85
8	WALK	PAST	PATH	Yes	68
9	CROSS	ACROSS	PATH	Yes	68
10	WALK	AHEAD	ORIENTATION	No	60
11	LEAD	TO	GOAL	Yes	58
12	WALK	THROUGH	PATH	Yes	51
13	WALK	ON	TOPOLOGY	Yes	49

The 13 predominantly used combinations shape a set of re-occurring and prototypical *action schemes* [29] relating prototypical actions to prototypical spatial scenes (following the definition of Tyler and Evans [36]). Whereas actions either specify *manner* or *path* [33] of a moving trajector *proto-scenes* express the *spatial orientation* or the *spatial relation*. *Action schemes* combine both particles and are thus considered well suited for the specification of ontologies for route tasks ([17], [34]).

7.1 Modeling Route Tasks with Action Schemes

As proposed in related work ([9],[29]) a route can be topologically described as view-graph (basically a topological network of interconnected local views). View graphs are

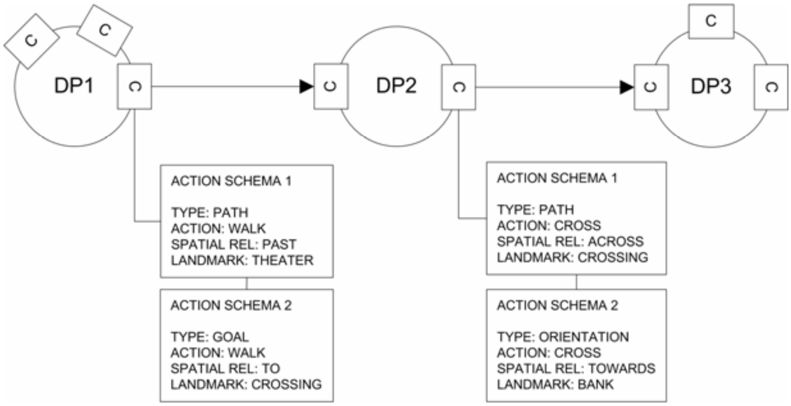

Fig. 7. Example of modeling route choices with *action schemes*

composed from local views and actions linking these views. By executing an *action schema* a trajector can move from one decision point to the next. In our approach we propose a similar model specifying actions and spatial relations in prototypical *action schemes*. A route is modeled by an ordered sequence of decision points where each decision point offers different route choices to trajectors. Decision points are logically linked by a sequence of *action schemes*, allowing trajectors to transit from one decision point to another. *Action schemes* specify the path by relating actions to spatial entities via spatial relations. We differentiate between *orientation*, *goal* and *path schemes*, depending on involved action and relation types. Fig. 7 shows an example of modeling route choices (C) and transitions between decision points (DP). *Action schemes* are attached as ordered sequences to route choices and directed transitions.

In order to complete the route task between two decision points a trajector has to interpret the *action schemes* in their specified order. The task is composed of identifying spatial entities (views), relating actions to entities and performing the actions. Thus *action schemes* have to unambiguously describe the path from one decision point to the next. Instances of *action schemes* may be translated to natural language instructions. Therefore the empirical data from the experiments, the extracted concepts and the *action schemes* model provide the foundation.

8 Summary and Conclusion

In this paper we pursue a user-centered approach analyzing language use in spatial decision situations. We analyzed direction and motion concepts in verbal descriptions of route choices gathered from two in situ experiments in the Austrian cities Salzburg and Vienna. The experiments differ from previous experiments ([2],[5],[27],[34]) in the aspect that the in situ use of spatial language by people being unfamiliar with a spatial environment is explored. In the analysis of verbal descriptions we focus on three questions: (1) How do the results differ from previous studies, (2) which direction and motion concepts are predominantly used by participants and (3) what can we learn for composing turn instruction by analyzing combined usage?

How do the results differ from previous studies?

From the comparison of classified propositions (Denis' classification) with previous studies by Brosset [3] and Denis [5] we conclude that similarities overbalance differences. One interesting finding is that the increased use of landmark descriptions (Denis Class 4) is not a matter of natural environments (as Brosset argues), but likely results from the in situ aspect of the experiments. In this aspect the Brosset study and our study reveal similar results whereas the study by Denis, which does not cover the in situ aspect, shows a clear difference. Additionally, results from both studies provide some evidence that the increased use of propositions relating actions to landmarks is another characteristic of in situ descriptions. Our experimental set-up fostered the use of propositions relating actions to landmarks and increased the overall usage by 10% (compared to the studies by Brosset and Denis). Since the cross-classification in Section 7 clearly benefits from a higher number of class 2 propositions (an increased quantity of actions relating a trajector to spatial entities results in a richer set of qualitative spatial relations) we consider the experiment set-up as successful. Further comparisons of direction and motion concepts have to be postponed to future work due to the lack of comparable studies.

Which direction and motion concepts are predominantly used by participants?

The analysis revealed a set of 15 direction concepts (use in more than 1% of all propositions) and 6 verb classes (use in more than 1% of all propositions) which were predominantly used by participants throughout two experiments and four test routes. Due to a careful experimental set-up (two different test groups, two different cities and two different test routes in both cities) we assume that the overall distribution is only marginally depending on environmental or personal differences. Although test groups with 20 participants are not considered representative for general conclusions, we consider the number of participants as suited for getting first insights into language use in situational descriptions of route choices. Additional experiments exploring cultural as well as environmental influences are needed. However, as a first step towards empirically founded ontologies [17] our results contribute to the task-perspective as to situational aspects. From the experiments we get a bunch of verbal descriptions of concrete route tasks in decision situations. The reported analysis reveals the most frequently used direction and motion concepts. The composition of prototypical *action schemes* has been sketched in Section 7. In contrast to expert ontologies our approach results in empirically founded concepts. We think that the strive towards natural language instructions in electronic pedestrian guidance can benefit from these results. Scholars are encouraged to set up similar experiments for widening the empirical foundation.

What can we learn for composing turn instruction by analyzing combined usage?

The final cross-classification further narrows the set of direction and motion concepts to 13 predominantly used combinations (more than 50 occurrences in all propositions). From the cross classification only 5 motion concepts (come, cross, lead, turn, walk) and 9 direction concepts (across, ahead, along, into, on, past, through, to, towards) remain. We consider the 13 combinations as a good, empirically founded starter set for the composition of semantically enhanced turn instructions. Since the set is based on empirical data it is not likely that it is complete (first attempts to unambiguously describe test routes with the 13 concepts have revealed some missing ones), however the cross classification also reveals further combinations which are used less by participants but may be essential for describing certain route choices (some combinations with frequencies between 20 and 30 have turned out to be among the missing ones). Extending the set is ongoing work. Revealed *action schemes* are tested by describing route tasks along the four test routes. At each decision point we select the most frequently used concepts for the composition of *action schemes*. If the concepts are not among the 13 we further extend the set. Completing all route tasks will lead to a revised set which is considered as a good candidate set for a more generalized model well-suited to describe most of the route tasks in built environments. To complete the model an empirically founded taxonomy of spatial entities and landmarks and their usage in the proposed *action schemes* has to be added. Such taxonomy can be deduced by further analyzing propositions in Denis' class 2.

In future work a second iteration of experiments guiding a new set of participants unfamiliar with the environment along the test routes will show whether the user-centered approach (closing the loop from user descriptions to concepts and back to natural language instructions) is worth to be pursued in the future. If so, the approach complements existing work on route descriptions ([2],[4],[21]) as well as empirical studies on the performance of verbal turn instructions ([14],[30]) and contributes to a foundation for semantically enhanced decision support in future electronic pedestrian navigation systems.

Acknowledgements

The work was mainly accomplished in SemWay, a project partly funded by the Austrian Ministry for Transport, Innovation and Technology in the thematic research program FIT-IT Semantic Systems.

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