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Variable Granularity in Route Directions

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This paper addresses changes of spatial granularity in route directions in relation to information needs in multi-modal traveling. We outline a model of variability in granularity and apply this model to empirical data. Results reveal that human as well as computer generated route directions provide one-dimensional route elements in hierarchically structured ways that reflect the salient structure imposed by multi-modal traveling. However, human route directions account for asymmetric information needs in a more flexible and coherent way. In particular, they exhibit more flexibility regarding switches in areal granularity, and they provide more detailed information at complex locations or decision points.
Keywords: route directions, information needs, granularity, symmetry, spatial language

1 Introduction

Consider traveling from your home town to a public place in an unfamiliar city. What kind of information will you seek in order to reach your destination efficiently? Almost certainly, you will need more detailed information about the destination area than about the early parts of the route. Recent research has increasingly been concerned with such aspects, highlighting both the flexibility of human route descriptions, and the importance of variable spatial granularity in generating route directions (e.g., Richter, 2008; Rüetschi and Timpf, 2005; Tomko and Winter, 2008). In fact, such flexibility concerns shifts of scale in more than one respect. The linear sequence of spatial segments up to the final goal, but also

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the goal itself as well as every location and action along the way can be described on various levels of granularity. Shifts of scale can be observed in route directions for any mode of traveling, but in particular for traveling through environments of varying complexity, or for traveling with transfers between modes.

Current research has only started to explore the precise nature of this diversity and interplay of granularity levels in light of the actual requirements of wayfinding across modalities. Therefore we start out by first proposing a model of this variability, aiming to adequately capture diversity in granularity concerning three aspects: segmentation in a linear or network structure (1D granularity), zoom factor in references to locations and regions (2D granularity), and elaboration by different types of references or additional information. In light of this model, the question arises whether and in which ways route directions reflect the available variability, and in how far they address actual information needs by a wayfinder. Automatically generated (online available) route descriptions are particularly interesting in this regard since they pose a widely accessible resource for present-day wayfinders.

According to Allen (1997), "it is suggested that technological innovations aimed at providing verbal information to assist wayfinding activity be incorporated within a framework focused on the ecology of wayfinding behavior" (p. 363). We investigate two questions in this respect.

1. To what extent are human directions an adequate measure for cognitive ergonomic directions? Can we discern variability concerning the ways in which actual pragmatic information needs are met with respect to the required changes of granularity?

2. Assuming standard features of human directions as a norm for cognitive ergonomic directions, which capabilities of flexible change of granularity are lacking in automatically generated directions?

To address these questions we compare in a case study two sets of route directions for a particular route involving different modalities, walking and public transport; one set automatically generated and provided by web services, the other provided on request by people with recent experiential knowledge of the route. We hypothesize that corresponding to the varying need for detail, all directions should reveal general patterns as well as flexible changes between the levels of spatial granularity and elaboration, especially with respect to multiple modes of transport and the transfers between them.

The paper is structured as follows. Section 2 summarizes previous work related to the granularity of route descriptions and introduces the notions of *1D* versus *2D* granularity as well as elaboration, supported by the more general finding that cognitive spatial representations as well as reasoning exhibit a hierarchical structure. Section 3 outlines our model concerning the ways in which shifts between levels and information detail can be reflected in route directions. In Section 4 we develop the information needs of a wayfinder for the route targeted in our case study, covering different travel modalities. Then, in Section 5, we analyze the granularity effects and information coverage provided by automatically generated route directions for this particular route. This is contrasted with the analysis of a small corpus of written route directions produced by humans for the same route, presented in Section 6. In Section 7, the results are compared, followed by our conclusions in Section 8.

2 Granularity in Spatial Representation and Information

We presume that people travel along networks, using active or passive locomotion in geographic space. These traveling networks are represented in databases as graphs, with zero-dimensional nodes as primary elements, and one-dimensional connecting edges as dependent elements. Evidence suggests that cognition also relates to connectivity, representing route and survey knowledge in a network-like manner. In terms of Lynch (1960) *path* and *node* are forming the traveling networks in the cognitive images of a city.

In addition, two-dimensional concepts are also relevant in the context of navigation, such as Lynch's *districts*, which can be entered and explored. The grain size of these 2D concepts can vary largely. Spatial databases provide feature classes in hierarchies of scales (Timpf, 1998). Research on spatial cognition provides evidence that mental spatial representations also have a hierarchic structure (e.g., Couclelis et al., 1987; Hirtle and Jonides, 1985; Strohecker, 2000). Accordingly, mental processes can be expected that exploit these hierarchies for route planning and wayfinding behavior. Similarly, cognitively motivated computational models suggest hierarchic procedures for route planning (Rüetschi and Timpf, 2005; Timpf et al., 1992; Wiener and Mallot, 2003), and also for generating route descriptions (Dale et al., 2005; Tomko and Winter, 2008).

2.1 Variability in Granularity

Route directions are always designed to support decisions of a wayfinder. On a homogeneous (mono-modal) traveling network the wayfinder has to decide at each route node with a degree larger than two how to continue traveling. Accordingly, primitive route directions have a *1D granularity* of one instruction per decision point.

However, this natural information need of the wayfinder can also be served by other means, namely by grouping sequences of decision points together. This is called *chunking* by Klippel et al. (2008, 2003), who distinguish, for instance, *numerical* (*turn right at the third intersection*) and *landmark-based* chunking (*turn left at the post office*).

A natural way of chunking is to group decision points together until the next reorientation, implying that no reorientation is required for all decision points in between (Klippel and Winter, 2005; Lee et al., 2003; Michon and Denis, 2001). The examples in the previous paragraph exhibit this property. But this way of chunking is not the only possibility. Numerical chunking can also aggregate direct sequences of reorientation (*turn left twice*), and landmark-based chunking can aggregate decision points including arbitrary reorientations (e.g., *follow the river*, *follow the signs to the airport*).

Chunking changes the 1D granularity of a single route instruction; thus, granularity can change from instruction to instruction within one route description. We measure the 1D granularity of a single instruction in numbers of grouped edges of the traveling network.

In an instruction like *Go to the airport and then turn*, we observe a similar linguistic structure as in landmark-based chunking. However, this instruction does not actually constitute chunking since it is unspecific about how to reach the airport. Route directions describing the location of the destination but not the way how to find it are called *destination descriptions* (Tomko and Winter, 2008). They describe the location of the destination by a set of references to geographical features of different granularity in a hierarchical order, either *zooming in* or *zooming out* (Strohecker, 2000). A passenger instructing a taxi driver: *The goal is in the central business district, close to the city hall* is zooming in, and a postal address on a letter is zooming out. Destination descriptions accept vagueness in route directions, expecting the wayfinders to be able to fill in the missing route information by their knowledge of the traveling network, or by information found in the environment itself, such as signs leading to the airport or the city hall. While turn-based route directions may involve the (coarse) information that such signs should be followed, destination descriptions leave such a possibility implicit. Destination descriptions involve *2D granularity*, which is defined by the level of granularity at which the verbal references to geographical locations are chosen. For example, in a hierarchical spatial data set a city hall will have a finer 2D granularity than the central business district of which it is part.

In addition to referring to nodes, edges and locations on various levels of granularity, there is a further way in which references may differ, which we will label *elaboration*. Any kind of entity can be referred to in a range of ways, using various kinds of perspective (Schober, 1998). For example, a particular street may variously be called *the main road*, *King Street*, *the road leading downtown*, and infinitely more. Each description provides a reference on the exact same level of spatial granularity, but since the perspective differs combining several of these descriptions has an elaborating effect. Thus, referring to a road segment simply as *the road*, using a basic-level term in terms of cognitive hierarchies (Rosch et al., 1976), represents a fairly coarse description which can be refined in various ways. Apart from varying types of reference, further types of information about the segment or location can be added, for example, by informing about the distance to be covered, by spelling out particular actions associated with the segment or location for the current purposes of wayfinding, or in fact anything that supports identifying the route and acting as expected with respect to it. It is also possible to elaborate reference to a particular segment by temporarily switching the level of 1D granularity, for example by referring to a landmark along the way to keep the wayfinder on track (Tversky and Lee, 1998).

Elaboration increases the length of route directions. In accordance with Grice's various maxims (Grice, 1975), however, route givers will try to stick to those pieces of information that are considered necessary and relevant for the wayfinder. In the next section, we will address the question how such informational needs can be identified.

2.2 Granularity and Pragmatic Information

According to Frank (2003), messages convey the same *pragmatic information content* if they lead to the same action, i.e., provide equivalent grounds for reaching the same conclusions in a decision. Frank lets this notion depend on the prior knowledge of the receiver of a route instruction: if they already know the full route, any kind of route description would have no pragmatic information content at all. If they have a coarse knowledge of their environment, a relatively short destination description (Tomko and Winter, 2008) may be sufficient and thus may have the same pragmatic information content as a more detailed turn-by-turn description (Richter, 2008). Only with little or no prior knowledge, a detailed turn-by-turn route description will be required and provide high pragmatic information content. Thus, one needs to distinguish between the information content conveyed by the message as such (the number of spatial references, e.g., to landmarks, to route elements, or to distances) and the pragmatic content gained by the receiver. The same message can have different pragmatic information content for different receivers.

In natural dialogue between humans, interlocutors carefully negotiate this potential discrepancy between required and conveyed information on a fine-grained level, often in reaction to subtle cues that may not even be consciously accessible to the humans themselves (Clark, 1996). In route descriptions given to non-present interlocutors in advance of traveling, such adaptation is not available; then the route giver needs to rely on their own assessment of the information required by the addressee. Therefore the descriptions given by a set of different route givers—people or services—could differ substantially and randomly with respect to particular pieces of information that speakers may consider relevant and useful for a non-knowledgeable listener.

According to Denis et al. (1999), humans' descriptions of routes for pedestrians differ with respect to their communicative value, i.e., with respect to the success rate achieved when navigating the route. However, from a set of diverging route descriptions, it is possible to extract the essential information needed for successful navigation, accumulated as a *skeletal description* which is potentially as useful as a more detailed naturally produced route description. Such a description contains those pieces of information that were given by a majority of different route givers independently, abstracting from the variability with respect to further details. From this account, we presume that this skeletal description should contain precisely the kind of pragmatic information content that would be needed by a non-knowledgeable recipient.

However, these considerations do not account for any systematic differences concerning levels of granularity, or switches between these levels. In theory, all that is needed is information on an even level of granularity with respect to any individual decision to be made, such as landmarks at critical nodes as cues for orientation, spatial directions and reorientations, or paths to be followed. But recent research highlights that the level of granularity required by wayfinders is variable even for one mode of traveling, with a need for higher levels of granularity at (re-)orientation points (Daniel and Denis, 2004; Michon and Denis, 2001), which always include the beginning and the end of a route (Allen, 1997; Wunderlich and Reinelt, 1982).

With switches between modes of transport, including the transfers involved, the situation becomes even more complex (e.g., Rehrl et al., 2007). For example, Timpf (2002) has pointed out that the set of concepts (the *ontology*) of a traveler in public transport is different from that of the transport provider as reflected in the transportation information offered to the traveler. And Heye et al. (2003) have developed generic measures for the complexity of transfer points, looking for cognitively motivated characteristics such as the number of transport lines stopping, or the average length of the paths to walk. Although in the context of the journey the transfers are relatively small scale in space and time, they put more responsibility on the wayfinder than the longer legs of the journey. Hence, one can expect a higher information need for transfers.

Additionally, information needs may differ between traveling directions because of the state of knowledge of the wayfinder. Intuitively, for instance, when wayfinders travel a route for the first time they need relatively detailed directions; on the way back they have already acquired some knowledge and may be satisfied with less detailed directions. Also the structure of the environment itself may afford different behavior depending on the direction of the movement. For example, while it is typically easy to find from a train to the main exit of a train station, it can be complex to find from the main entry of the train station to a particular train. Generally, the conceptualization of—and reference to—intersections with identical *structure* changes depending on the actual *function* within a route description (Klippel et al., to appear); this may also depend on the direction the route is currently traveled.

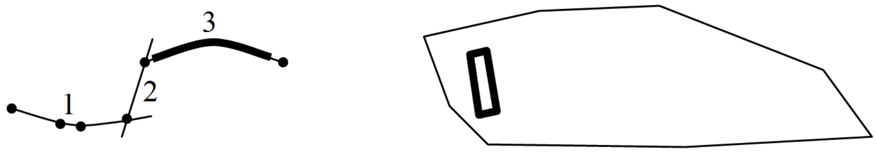

Figure 1: 1D granularity (left): The first segment is split in several edges. 2D granularity (right): a reference to a feature of a coarser level of granularity is complemented by a reference on a finer level of granularity. Elaboration: the third route segment (left) is described from multiple perspectives, and so is the areal feature of fine granularity (right).

Finally, information needs may vary for a wayfinder even along a route of constant complexity. A person who is familiar with the environment surrounding the start location, but unfamiliar with the destination area, will need less detailed information for the first part of the route than for the last part (Srinivas and Hirtle, 2007).

The next section outlines how the various types of granularity and changes between them, as required by the variability in information needs, can be accounted for and combined systematically.

3 Model of Variability in Granularity

Our model of variability accounts for 1D and 2D granularity and for elaboration as motivated above. 1D (linear) granularity may be represented schematically as a line with segments of varying lengths (Figure 1, left). 2D (areal) granularity resembles partonomic polygons (Figure 1, right). Elaboration then enumerates the references to each segment or location along with the actions associated with them; schematically this can be represented by variations in thickness of the lines.

3.1 Changes of Granularity

In our model, changes of one- and two-dimensional granularity in route directions can be described as discrete and finite. 1D granularity is discrete and finite because the travel network is discrete and finite. 2D granularity is discrete if we presume a hierarchy of discrete levels of granularity, as they exist in multi-scale databases. It is finite if we presume a limit in this hierarchy at the basic level of point-like landmarks as used in turn-based descriptions.[1] Elaboration is not finite,

[1]Considering other applications of spatial directions, this basic level of granularity can easily be further refined, as for example when instructing a robot with no vision capacities to move to a certain goal location: Here, each single movement needs to be specified on a very fine level of 1D granularity.

since there is no theoretical restriction to referential variability or environmental, spatiotemporal, or action-related information that may in theory be expressed by a route giver. However, it is also discrete in that each piece of information provided in the route description can be added to the wayfinder's knowledge.

Two fundamental kinds of changes of granularity are possible: from fine to coarse granularity (Figure 2a) and vice versa (Figure 2b). A change of 1D granularity according to Figure 2a would be *at the next intersection turn left, then follow the signs to the airport*, and a corresponding change of 2D granularity would be *To the city hall, in the central business district*. Changing the corresponding reference level in terms of elaboration is exemplified by *Go straight ahead for 400 metres on the main road, then turn left.* Figure 2b simply reverses these changes.

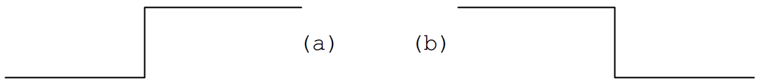

Figure 2: The basic changes of granularity: from finer to coarser granularity *(a)*, or from coarser to finer granularity *(b)*.

These fundamental changes of granularity can be freely combined to compose more complex patterns of granularity change within route directions. Figure 3 sketches a classical pattern: a temporary switch of granularity. For example, Figure 3a corresponds to route directions that temporarily switch to coarser granularity (*from there you can follow the signs until you reach the airport*: 1D granularity change), and Figure 3b corresponds to route directions that temporarily switch to finer granularity (*at the station make sure you go first to the ticket booth before traveling to Bremen*: 2D granularity change). Such temporary switches do not need to be symmetric; the originating level of granularity can differ from the outgoing level. Also, differences in length of segments as shown in the contrast between Figure 3a and c, and between Figure 3b and d, are gradual rather than categorial.

Other characteristic forms of a change of granularity emerge from convolutions of the basic changes (Figure 4). The pattern can zoom in or out uni-directionally (Figure 4a, *after arrival in Bremen take the tram to the city, then walk to the hotel*, as an example for a shift of 2D granularity). Combining both of these, the pattern can also temporarily zoom in, then out again (Figure 4b, *Follow the river for three kilometers, turn right in the direction of Bremen, go straight on for two hundred meters, take the second road to the right, then follow the signs to the airport*;

Similarly, a reference to a location may need to be specified in much more detail - using a finer level of 2D granularity - as soon as a specific spot within a location (typically referred to, for instance, as *intersection at King Street*) becomes relevant. Thus, although the number of granularity levels still remains finite, its actual scope is context-dependent. Our present discussion addresses the context of typical route directions such as how to get to a particular building in a city.

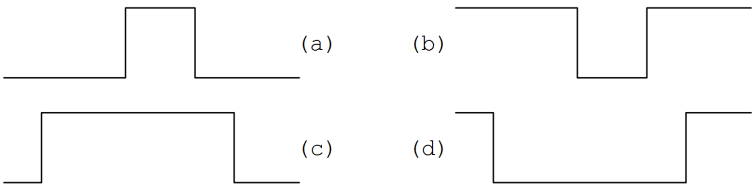

Figure 3: Temporary switches of granularity to a coarser (a, c) or finer level (b, d); here for a short time during the travel (a, b) or just after departure and returning before arrival (c, d).

reflecting a temporary shift towards a fine level of 1D granularity in reference to a complex shift of direction along the route). Again, the changes of granularity do not need to be symmetric; the originating level of granularity can differ from the outgoing level, the intermediate levels can differ from each other, and the numbers of steps can differ.

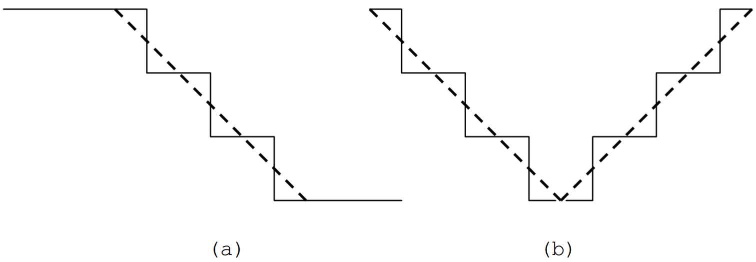

Figure 4: Continuing compositions of fundamental changes form convolutions, which are approximated here by dashed lines. They can be interpreted as *(a)* zooming in (or, analogically, zooming out), or *(b)* combined as temporarily zooming in and out again, or vice versa.

3.2 Combinations of types of granularity levels

Simple turn-by-turn instructions involve no changes of 2D granularity since they refer to decision points on the basic level as mentioned above. Analogically, simple destination descriptions involve no changes of 1D granularity since they omit information about the segments of the route itself. Basic descriptions of both kinds (turn-by-turn or destination-based) might simply refer to the segments or locations without providing further information, thus involving no further elaboration. In practice, however, we encounter various combinations of all types (see e.g., Richter et al., 2008). Our example above, for instance, already illustrates a destination description (*Go to the airport*) continued by a decision point related instruction (*and then turn to the left terminal*). In fact, route givers may freely change levels of granularity on all scales, for example, when a particular location can be conceptualized in more than one way, or is perceived as particularly complex. The following example involves switches on various levels, illustrating a manifold instance of Figure 4b: *take the tram to the station, in the station walk to the display board of departures and find the track information, follow the signs to the track, and then take the train to Bremen*. Here, the *station* is first referred to on a coarse level of granularity as a simple decision point in a route description (where the one-dimensional route is described, as well, on a coarse level by simply referring to the tram). Then, granularity switches both with respect to the route (from the coarse, unspecified spatial reference to the tram-ride ending up at the station to the fine level of walking to the display board), with respect to the concept of the station (from the coarse level of the station as a mere destination point to the fine level of locations within the station), and with respect to action (from using a tram to finding information on a display board). The remaining steps then again reflect switches to higher levels of granularity in all three respects.

From here it is straightforward to classify recent approaches in the generation of route directions accordingly:

- Chunking (Klippel et al., 2008; Richter, 2008) changes the 1D granularity locally by grouping several decision points into one instruction. This pattern can be described by Figure 3a.

- Wunderlich and Reinelt (1982) propose a classical partition of the route into *constructional units*: an orientation phase at the start, the travel phase, and the orientation phase at the destination. This pattern corresponds to Figure 3c, reflecting route directions that start at a fine granularity, stay at a coarser granularity for most of the route, and change back to finer granularity when approaching the destination.

- Destination descriptions (Tomko and Winter, 2008) describe the location of the destination by a monotonous change of 2D granularity, either zooming in or out (Figure 4a).

- Combinations of turn-based directions and destination descriptions (Richter et al., 2008) combine the discrete switches of 1D granularity by chunking with the changes of 2D granularity involved in destination descriptions.

- Providing more detailed information with respect to any kind of entity (segment or location) (Daniel and Denis, 2004) involves additional layers of elaboration.

With these concepts of asymmetry in pragmatic information needs, 1D and 2D granularity, elaboration, and changes of granularity at hand, we are now in a position to address our particular case study. We start by examining the information needs of an imagined wayfinder, then proceed to the analysis of route directions generated by systems and humans in the following sections.

4 Information Needs

4.1 Definition of Information Needs

A route description is most efficient if it has maximal pragmatic information content and minimal redundancy. This is the shortest route description that safely guides a particular wayfinder along a particular route. Then the information need corresponds to the content of this most efficient route description—less is not sufficient for safe guidance, and more is unnecessary. It is worth mentioning that superficially similar route descriptions can have different pragmatic information content. For example, *turn left at the* t*-intersection* has one reference, and so has *turn left after 500m*, and yet wayfinders may find the former easier to recognize than the latter. Therefore, the first description has (at least potentially) higher pragmatic information content for these wayfinders even without a difference concerning any type of granularity level.

However, the information need of a wayfinder depends not only on their own abilities and their own prior knowledge of the environment. Further relevant factors are the information provided by the environment, and the structure or complexity of the route. Thus, in the most trivial cases, either the wayfinder has sufficient knowledge, or the route is clearly marked out in the environment, such that no additional information is needed. In particular, people come always with *procedural knowledge*: they make assumptions about the structure of an environment and apply strategies of wayfinding (e.g., Hochmair, 2005). They may further have *descriptive knowledge* of the layout of the specific route or environment.

If the procedural and descriptive knowledge of the wayfinder together with the information accessible in the environment (clues such as signs) are not sufficient to find the way, additional information is required, such as that provided by route instructions (by humans or web services). Ideally, directions gathered this way provide precisely the complementary information to the knowledge of the wayfinder and the information from the environment. In practice this is impossible since the wayfinder's knowledge is not accessible in any direct way, and the information from the environment, while theoretically accessible, is too multifaceted and dynamically changing to be captured completely. We will demonstrate a practical approach in a case study.

14:20	**NWB** 81374	Delmenhorst 14:35 – Wildeshausen 15:00 – Vechta 15:24 – **Osnabrück Hbf 16:32**	**2**

Figure 5: Entry on the departure plan at Bremen's main train station for a train going to Ganderkesee.

4.2 Case Study

In this case study we accompany a wayfinder as an observer, identifying informational gaps along the route that should be filled by an adequate route description. This procedure follows the approach first applied by Pontikakis (2006). In Section 5 we will study the relevant information obtainable in web travel planning services, and in Section 6 we will study human route directions given by local experts.

Consider this scenario: A lecturer at the University of Bremen (office building: Cartesium) is planning a trip to the high school in Ganderkesee, a place about $30km$ away. This scenario suggests that the wayfinder is knowledgeable about the area around the departure location, which is her work place; it can be assumed that somebody working at the University of Bremen has some spatial knowledge of the university, and most likely also of Bremen. This is supported by an inherent hierarchy of the locations—the campus is *part of* Bremen—, but also by the contextual world knowledge that a person's work place is spatially related to their living, shopping, and leisure places. By complementary reasoning, the scenario also leads to the assumption that the wayfinder is not an expert of the area of the destination.

Using her procedural knowledge, our lecturer guesses that there must be some train service to Ganderkesee, probably from the main station in Bremen. With her knowledge, she has no problems to find her way on Bremen's tram network to the station. Thus, the information needs up to this point are restricted to a quite high level of 2D granularity: a destination-based reference to the main station would be sufficient. Within the station, the lecturer's descriptive knowledge ends. Procedural knowledge lets her buy a ticket. Buying the right ticket is not a problem using the information provided by the environment; the ticket machine knows Ganderkesee. But then, an information gap arises: neither the departure plan (Figure 5) nor the display board list Ganderkesee as a stop of any train.

In this situation, our lecturer needs help for the first time. Lacking in-advance route directions providing a sufficiently detailed level of elaboration (what to do next?) as well as 1D (where exactly to go?) granularity, she will probably approach the friendly staff at the counter or access a web terminal in the hall. The provided information (*Track 2, in 5 minutes*) is sufficient for her procedural knowledge of how to find the platform of Track 2. Note that the same transfer point can exhibit different complexity (Heye et al., 2003) depending on the route. For example, changing trains stopping across a platform is less complex then finding a train from the tram stop. Also different transfer points of the same transport mode can exhibit different complexity. For example, the train station in Bremen gives a wayfinder heading to Ganderkesee a choice between nine tracks at five platforms, further divided into South and North, while the train station in Ganderkesee is single-track. Therefore, the required amount of elaboration should be greater with respect to the train station in Bremen than to that in Ganderkesee.

Once our lecturer has embarked on a train to Ganderkesee, she can rely on the display line in the carriage announcing the next stops, and also on verbal announcements. The next time she is challenged is after disembarking the train in Ganderkesee; she now needs information on a sufficiently detailed level of 1D granularity in order to find the route to her destination. Applying procedural knowledge she finds her way out of the station and discovers a town map in front of the station building, which shows the location of the high school. A town map is a relatively complex form of information in the environment, and an untrained map reader may not realize the presented information to its full extent (Levine, 1982). However, since this particular map provides only the street network but lacks for example the public transport network, the map is only of partial use anyway. Depending on the quality of the map and the lecturer's map reading skills and memory, she will eventually arrive at her destination, where she is confronted with another challenge: she finds herself in a center of primary, high and other schools, a public pool and a gym. Any previous point-like references to the current address - referring to the high school on a coarse level of 2D granularity - are now no longer useful; in order to find her way around on the campus the lecturer needs more fine-grained information. The buildings are not labeled, and there is no campus map; therefore, without prior information her only option at this point is to ask a passerby.

In summary, information needs are asymmetric: our wayfinder is familiar with the start region, but not with the train route and the destination area. Route directions considering this asymmetry would consist of intermediate *destination* descriptions (*Get to Bremen main station*) and subsequent *incremental* descriptions (*Then take the NWB on Track 2*), which will also include those types of information that now need to be obtained (often in awkward and cognitively demanding ways) from the environment, e.g., the town map. At points of change of mode of transport the information need can explode in granularity, and then, for a longer time, no further information is needed. Also, the complexity of a transfer point is route dependent. These observations indicate a hierarchy of granularity levels with respect to the representation of spatial entities, and a non-arbitrary, but complex and route dependent navigation through this hierarchy. Ideally, route instructions should account for these varying requirements with respect to all three types of granularity.

5 Automatically Generated Multi-Modal Route Directions for the Case Study

The results for the information needs along the trip from Bremen University to the high school in Ganderkesee will now be compared with the information provided by web or mobile route planners. By studying the granularity of the provided route directions, our goal is to find out to what extent current services match information needs of travelers, i.e., provide most efficient, individual route descriptions.

Few services provide transport planning that can cope with multiple modes of traveling. We have chosen two of them, both covering the area of our scenario: `bahn.de` is a web-based service provided by the German railway system (Deutsche Bahn AG), which combines internal sources with those of other transportation operators or data providers (e.g., street data stem from NAVTEQ). `efa.de` is a web platform for multiple public and private transportation operators in Germany. Since we found only minor differences relevant to our research questions we focus in this discussion on `bahn.de`.

Both planners, and we may generalize this, are by default mono-modal. Searching for a multi-modal travel, or a travel from place to place, requires a range of actions and decisions by the user, such as switching from standard to extended search mode, and then categorizing their departure and destination information as stop names, points of interest, or postal addresses. Other categories of places are not available.

This categorization is problematic in several ways. Since the categorization is a provider ontology (Timpf, 2002), not a user ontology, users may not know how to describe their departure and destination places in these categories. Our scenario is rich with examples: places such as *Cartesium*, *University of Bremen*, or *Gymnasium Ganderkesee* form proper place names for which it is hard to guess whether to categorize them as a (potential) stop name, a point of interest, or neither, in which case a postal address would be required. Postal addresses are often hard to obtain. Furthermore, in some cases it may not be obvious by which name the destination should be referred to, as there may be more than one option, and the database may use a type of reference unknown to the user. Thus the use of provider ontologies and the lack of transparency in them leaves ample space for frustration and failed communication.

Furthermore, failure may be caused by mixing one- and two-dimensional types of reference. While the provider may treat all three categories as one- or even zero-dimensional, i.e., references along the network, for a user stops are complex areas, points of interest may be extended places, and postal addresses may characterize complex environments outside of the travel networks considered by the service provider. In Lynch's terminology, they are all either districts or landmarks. The provider's limitation to these categories imposes a particular level of granularity. If wayfinders require directions inside of complex environments, such as train or bus stations, malls, or on a campus, or if they require directions to or from small-scale districts, such as downtown, another person could provide information of pragmatic content, but the providers' databases do not match these levels of detail.

Asked for directions between two addresses `bahn.de` generates first an overview of alternative travel options (Figure 6), and on request more detail for a selected travel alternative. This more detailed tabular view provides one row per transport mode (Figure 7), covering route segments on a coarse (transport mode-based) level of 1D granularity. Such a row contains details (satisfying needs with respect to elaboration) such as names of each node (first column), departure and arrival times (second and third column; the second column redundantly repeats the date of travel), track information for trains (column 4), mode of travel and (in case of public transport) numbers of buses and trains (column 5), and further remarks such as estimated walking time, as well as details about the train: whether and how to transport a bicycle, along with a telephone number and even varying prices for such a call (column 6).

This amounts to a fairly complex view of the journey as a whole, containing bits of information that are redundant or not necessarily relevant to the traveler, who presumably does not rely on train numbers, and may not wish to make phone calls concerning bike transport (cf. section 4.2). In spite of this richness of information, the table remains implicit with respect to particular segments of routes or actions to be taken; those need to be either inferred from the overview table or accessed by using further hyperlinks (see below). Differences in prior knowledge or relevance are not accounted for: for instance, there are in fact many equivalent alternatives for traveling to the train station (buses and trams going at least every 5 minutes); this makes it relatively irrelevant to find this particular bus 670 departing 14:02 o'clock. Furthermore, the locations between route segments (nodes) remain zero-dimensional; they are referred to solely as names in column 1, apparently equivalent in nature. In other words, the fact that *Ganderkesee* refers to a fundamentally different type of entity than *Hauptbahnhof / ZOB Gleis 1, Bremen* is not reflected in the table; it needs to be derived from world knowledge: this may pose a problem to users with reduced knowledge of the language used or the type of environment at stake. In other words, the table does not provide any means for switching 2D granularity concerning nodes. As a matter of fact, there is an implicit switch of 2D granularity in column 1, reflected in the difference between *Ganderkesee* and *Ganderkesee, Am Steinacker 12*; here the user needs to infer that the first version presumably refers to the station where the train arrives. At first sight and without further information (such as procedural knowledge), such mixing of 2D levels of granularity appears contradictory and confusing.

For the traveler, the diverse traveling modes are of different complexity and effort, hence, not equal in terms of granularity of information needs; for example, walking requires far more detailed spatial information (a fine level of 1D granularity) than traveling by train. The different requirements for each mode are not

Bahnhof/Haltestelle	Karte	Datum	Zeit	Dauer	Umst.	Produkte	Preis	Rückfahrt
			Früher				**Normalpreis**	
Universität NW1, Bremen Ganderkesee	Fußweg 5 Min. Fußweg 11 Min.	Mi, 12.12.07 Mi, 12.12.07	ab 14:02 an 14:45	0:56	1	BUS, NWB	Verbindung liegt in der Vergangenheit	hinzufügen

Figure 6: The response of *bahn.de* to a request from the address of the Cartesium, University of Bremen, to the address of the high school in Ganderkesee. Only the first of the produced travel alternatives is shown. Note also that the shown departure and destination places do not match with the user's input.

Detailansicht

Bahnhof/Haltestelle	Datum	Zeit	Gleis	Produkte	Bemerkungen
Bremen - Horn-Lehe, Enrique-Schmidt-Straße Universität NW1, Bremen	Mi, 12.12.07 Mi, 12.12.07			Fußweg	5 Min.
Universität NW1, Bremen Hauptbahnhof/ZOB Gleis I, Bremen	Mi, 12.12.07 Mi, 12.12.07	ab 14:02 an 14:10		Bus 670	Bus Richtung: Bremen Hauptbahnhof
Hauptbahnhof/ZOB Gleis I, Bremen Bremen Hbf	Mi, 12.12.07 Mi, 12.12.07			Fußweg	11 Min.
Bremen Hbf Ganderkesee	Mi, 12.12.07 Mi, 12.12.07	ab 14:20 an 14:42	2	NWB81374	NordWestBahn Fahrradmitnahme reservierungspflichtig, Fahrradmitnahme begrenzt möglich, Fahrradmitnahme-Anmeldung unter 01805 - 600 161 *, (*14 ct/Min. aus dem dt.Festnetz via Arcor, Mobilfunk ggf. abweichend), NordWestBahn
Ganderkesee Ganderkesee, Am Steinacker 12	Mi, 12.12.07 Mi, 12.12.07			Fußweg	11 Min.

Dauer: 0:56; fährt nicht täglich, Verkehrstage

Preisauskunft nicht möglich

→ Grafik
→ Zwischenhalte einblenden
→ Details ausblenden

Figure 7: For multi-modal directions the default granularity is one direction per mode.

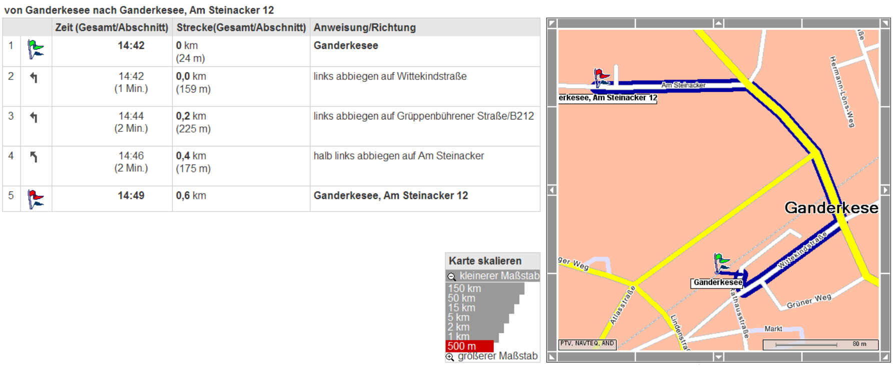

Figure 8: The walking instructions for the last leg of the route described in Figure 7.

reflected by the information provided in Figure 7. However, a more detailed level of granularity is available. In Figure 7, the column labeled *Produkte* specifies the particular mode. Some of these entries are hyperlinks, which can be used to obtain additional information (switching 1D granularity): Buses, trams, and trains are further specified by their stop lists, and a walk is specified by a list of (turn-based) verbal route directions and a corresponding map.[2] Figure 8 gives an example for a walk. The map is zoom- and expandable, hence, for longer walks the wayfinder can access a full overview as well as more detail, i.e., switch 2D granularity for the areas between or around nodes.

However, noticeably, walks are described only along the street network; there is no wayfinding information for the transfer from bus to train (row 3, column 5 has no hyperlink in Figure 7). Consequently, `bahn.de` provides walking descriptions only for the walk from the point of departure to the first transfer point, and from the last transfer point to the destination of the journey.[3] Likewise, the detailed walking instructions in Figure 8 end at the geocoded postal address of the Ganderkesee high school, due to the lack of flexibility in 2D granularity mentioned above. According to our observations above an increased need for detailed instructions can be assumed precisely at this step.

In summary, even though transport planners obviously have a distinctly hierarchic way of modeling and communicating routes, they do provide neither a graphical nor a verbal integrated view of the full route and thus challenge users to combine bits and pieces of information so as to transform them into an action plan, they have gaps at transfer points where travelers need more detail with respect

[2] `efa.de` provides static maps in portable document format, but no verbal route directions.
[3] `efa.de` provides maps for transfer points, but skips the need for exploded detail also.

to 2D granularity, they provide detail (in 1D granularity as well as elaboration) where pragmatic needs do not require it, and they have no concept of destination descriptions (again lacking flexibility in 2D granularity). Basically, their design still assumes a prototype level of 1D granularity, which can be increased on request for single legs. In principle, such a design can cope with the asymmetric descriptive knowledge of a wayfinder: a wayfinder familiar only with the departure environment could focus on the details offered for the destination. In practice, however, we identified a range of critical discrepancies between information needs and information provided.

6 Human Natural Language Multi-Modal Route Directions for the Case Study

Most empirical work on route directions given by humans excludes multi-modal travel and transfers. We collected natural language data describing the same route as before, involving travel on foot and by public transport. Our analysis focuses on systematic patterns concerning the choice of, and switches between, levels of granularity.

6.1 Data collection and hypotheses

The data were collected during a visit of a class of 11th grade students (around 17 years old) from the high school in Ganderkesee at the University of Bremen (Cartesium) in April 2007. They had met at the railway station in Ganderkesee that morning and traveled together to the university. Their first task (Task I) was to describe - on a blank piece of paper - the way from Bremen University to their school in Ganderkesee, with the following instruction (translated here from German):

> *Please describe the way from here to the high school in Ganderkesee. In doing this, imagine that the reader of this route description works at Bremen University and would like to visit you there at school. (Please write the route description in the way you think, and don't discuss it with your fellow students!)*

Additional information was provided verbally that the participants should assume public transport as medium of transportation. Afterwards (Task II) they were simply prompted verbally:

> *And now please do the same again for the opposite direction.*

14 descriptions by female and 12 by male students (all of them native speakers of German) were collected in Task I, and 13 descriptions by female and 11 by male students in Task II. All participants who did Task II had already done Task I.

Since there is one obvious way by public transportation, and since the participants themselves had just traveled from Ganderkesee to Bremen, they all described the same route.

Given the nature of this study as an unconstrained free production task, and its focus on the comparison of generalized features of granularity levels in comparison to automatically generated descriptions, the study is exploratory in nature, and the analysis is predominantly qualitative (supported by quantitative relative frequency data). For each of our predictions reported next, more than one reason and motivation for differences is given. We expect that this kind of study will serve as a useful basis for motivating more controlled studies in which the relative weight of each of the factors now jointly contributing to the observable patterns in the results can be addressed systematically.

We hypothesized that the participants' descriptions would depend in some way on their assessment of what was necessary and relevant information in light of how they understood their task. The following aspects are seen as crucial in this respect and should therefore be reflected in the data with respect to the various types of granularity.

6.1.1 General differences according to the task, i.e., the direction of traveling

Task I is based on a hypothetical situation; the route (in this direction) had not been traveled by the students, and the instruction described the addressee as a person from the university of Bremen who could not be expected to know the destination town. Therefore, building on the expectation of minimal or no knowledge at least concerning a part of the route, fairly detailed instructions could be expected. In contrast, Task II may have triggered less explicit descriptions for several reasons: Part of the route (from the railway station in Ganderkesee to the University of Bremen) had just been traveled by the students, though not all of it (the distance from the school to the railway station was not covered). Also, this was the second task given to the students and so they had just described the route in the opposite direction. Finally, this task was formulated in a much less elaborate way (for example, without information concerning the wayfinder's knowledge), and so the students may have taken it less seriously.

6.1.2 Specific differences along the route

We expected differences with respect to the levels of granularity along the route, for example, with respect to particular decision points including the beginning and the end of a route, and transfer points which may be particularly complex, as explained above. Different parts of the route may afford different levels of attention, for example, some parts of the route are covered by public transport and may therefore not be described in detail at all. Since Task I involves a wayfinder familiar with the departure environment (Bremen) but not the destination (Ganderkesee), more details should be provided for the destination than for the starting location in Task 1, but not necessarily in Task II.

6.1.3 Systematic patterns and gender differences

Finally, the data should exhibit further systematic patterns in two respects. On the one hand, people should provide more detail with respect to those spatial parts of the route that were considered as crucial by the majority of participants, rather than adding in information at random places. On the other hand, there is ample evidence in the literature (Montello et al., 1999) for gender-related distinctions concerning wayfinding abilities. Our data provides a good basis for a comparison since the numbers of male and female participants was fairly balanced, while a range of other individual factors such as age, background knowledge, native language, and general ability were kept rather constant.

6.2 Analysis

6.2.1 Segmentation and Aggregation

The data were segmented into informational units, following Denis et al. (1999). Then an intersection of all data sets was accumulated that contained a generalized schema of the spatial information provided in any data set. In contrast to Denis et al. (1999), who accumulated all pieces of information in one large "mega description", we distinguish between *crucial elements*, *spatial units*, and *detail units*, yielding a three-level hierarchical structure. This enhanced structure reflects underlying granularity levels and their salience for route givers as follows.

Spatial units are abstract, spatially based categories that reflect the basic level of 1D granularity without elaboration: each spatial unit represents one segment of the route as recognizable in the linguistic data and / or one reference on the basic 2D granularity level.

Detail units reflect switches to finer levels of granularity and elaboration by way of explanations, sub-actions, reformulations, and further detail in varying order of mention concerning the spatial unit at hand. For example, the spatial unit *Go to the tram station* (a destination description) could be specified by further details concerning the destination node: stating that the tram station was located *at (or: in front of) the university* or *near the parking place*, or that it was called *NW1/Universum* (an alternative type of reference on the same level of 2D granularity). As another example, one large basic spatial unit (the main road in Ganderkesee) was further specified variously by repeated uses of *straight ahead*, by mentioning various landmarks along the route (*past a [Shell] gas station [on the left hand side], past Inkoop [on the left hand side], past a street [on the left hand side], past the Russenviertel, past some doctor's practices*), by specifying the end of the segment (*until an intersection, until [you see] the Futterkrippe, until the [next] traffic light, until the street Am Steinacker [on the left]*), or the distance to be covered (*about 500 meters*). All of these serve to specify this particular segment without necessitating a particular order of mention, supporting the classification of this spatial segment as basic-level. Switches to lower levels of 1D or other types of granularity are then captured by the detail units.

Crucial units are those spatial units that are mentioned explicitly and distinctly (i.e., not as part of a chunked description) by nearly all participants (with max. one exception). This measure reflects how speakers make use of levels of 1D granularity coarser than basic. Coarser levels of 2D granularity were not expected in our scenario because of the nature of the task given to the students (route rather than destination descriptions).

6.2.2 Annotation

The units were annotated according to the generalized schema, i.e., for each item in the schema, it was noted whether the information was contained in the description. This provides the basis for assessing the relative level of detail of each description. On the one hand, this concerns the general assessment of how much information is provided by any individual (e.g., only crucial elements, a turn-by-turn-based basic-level 1D granularity description, or even further details). On the other hand, more specifically, differences between particular locations could be determined, providing insights about which parts of the route were often described in detail, and which ones were regularly treated superficially.

6.3 Results

6.3.1 General differences according to the task, i.e., the direction of traveling

Table 1 summarizes the spatial units and crucial elements identified in the two tasks (left and right columns). The overall number of *spatial units* is similar in both directions, in line with our expectations of the existence of a basic level of 1D granularity. Differences concern a few segments that were not made explicit in one or the other direction. However, the number of *crucial elements* (marked in bold in the table) is reduced in the second task (right column). This is due to some participants' choice to only start their route description at the train station in Ganderkesee. This choice reflects an unexpected shift to a coarse level of 2D granularity: these participants simply referred to the train station as a sub-destination without explaining how to get there, presupposing a high amount of prior knowledge by the (undefined) addressee of the route description. If we ignore these 8 participants for the assessment, two further crucial elements (marked in italics) emerge.

Table 1: Spatial units and crucial elements (marked in bold) in the two tasks (left and right column). The middle column represents spatial units mentioned in both tasks.

All spatial units University-Ganderkesee	Shared spatial units (reverse order for Ganderkesee-University)	All spatial units Ganderkesee-University
1. Starting point: the university	19. Goal building	1. Starting point (high school)
2. Walk over the hill	16. Walk down the hill	2. Turn left
3. Go to the tram station	15. Arrival at the university	3. Walk [the next leg]
4. **Take the tram to the central station**	14. Take the tram to the university	4. *Turn right*
5. Arrival at the central station	13. Go to the tram station	5. Walk [the next leg]
6. Walk to the central station	12. Leave the railway station	6. Cross the railway track
7. **Find / take the train**	10. Find / take the train	7. *Turn right*
8. Exit the train		8. Walk [the next leg]
9. Leave the train station	9. Train station	9. **Train station**
10. **Turn left**		10. **Find / take the train**
11. Walk [the next leg]	8. Walk [the next leg]	11. Exit the train
12. **Turn left**	7. Turn right	12. Leave the railway station
13. Cross the railway track	6. Cross the railway track	13. Go to the tram station
14. Walk [the next leg]	5. Walk [the next leg]	14. **Take the tram to the university**
15. **Turn left**	4. Turn right	15. Arrival at the university
16. Walk [the next leg]	3. Walk [the next leg]	16. Walk down the hill
17. **Reach the goal**	1. Starting point: the high school in Ganderkesee	17. Cross the parking space
18. Walk into the school		18. Follow / cross the street
		19. Goal building

Table 2: Quantitative distribution of spatial information in the two tasks.

	Task I	Task II
Average word count	95.5	59.2
Shortest description (number of words)	44	16
Longest description (number of words)	202	155
Average number of spatial units mentioned by one participant	7.8	7.6
Average number of detail units mentioned by one participant	**15.8**	**10.2**
Sum of different crucial elements (cf. Table 1)	6	3(5)
Sum of different spatial units (cf. Table 1)	18	19
Sum of different detail units	**102**	**73**

The middle column shows the spatial units that emerged from the descriptions in both directions, represented by their Task II descriptions in opposite order. The only crucial element that does not even appear as a spatial unit in the opposite direction concerns the turning direction after leaving the train station (spatial unit no. 10 in the left column). Thus, while all route givers found it important to provide the correct orientation at that point, in the opposite direction the movement towards the train station was not conceptualized as a turn. However, the train station as such appears as a crucial element in Task II; in Task I, the station also appears as a spatial unit, but was not mentioned frequently enough to be classified as crucial. In general terms, the same real world situation is conceptualized—and verbalized—in different ways according to the route traveling direction, in accord with Klippel et al. (to appear).

In contrast to the homogeneity in the results concerning the verbalization of spatial units, Table 2 shows considerable differences regarding the amount of more detailed granularity levels of various kinds, as reflected in the references to detail units. These results suggest that, corresponding to our predictions, there is a general difference according to the direction of traveling which concerns the amount of *details* given in the spatial instructions, but does not affect the choice of *main route elements* as reflected in the spatial units.

6.3.2 Specific differences along the route

In order to assess the relative weight of pieces of information along the route, we analyzed the average number of mention per participant for each spatial unit including detail information. While the distribution is generally quite heterogeneous as expected, a range of regular patterns emerge.

Our hypothesis that references to public transport appear regularly and are particularly enhanced by detailed information was overwhelmingly confirmed. In fact, the procedure of finding and taking the train emerged as the spatial unit exhibiting the highest score in both directions of travel: In Task 1, each participant provided more than 4 informational units on average for this particularly crucial route direction element (unit 7 in Table 1, left column), and in Task 2, the average was almost 3 (unit 10 in Table 1, right column). These details almost exclusively concerned elaboration beyond the basic reference level, i.e., specifying actions to be undertaken in the station and information needed to identify the train. No other spatial units were represented by more than two informational units on average by each participant across both tasks. As many as 13 different pieces of detailed information were mentioned in relation to the train in Task 1, and 7 in Task 2. In other words, route givers came up with many different pieces of information to provide to the wayfinder in order to support the process of identifying the correct train, such as *Take the NWB (track 2) which leaves 20 minutes past each hour in the direction of Osnabrück.* Only very few people restricted their instructions to a sparse description such as *Take the train to Ganderkesee*.

In Task 1, very much detail is also provided for the walk between the Ganderkesee train station and the school, this time with respect to a finer level of 1D granularity. Particularly detailed information is given for the long path along the main road in Ganderkesee as well as the identification of the correct turn when leaving it (spatial units 14 and 15), and the description of the goal area, namely the school with its own complexities as described above (spatial unit 17). Thus, our hypothesis that more details will be provided for the destination than for the starting location in Task 1 is confirmed, as well as the hypothesis that particularly complex decision points (crossings) are accounted for by providing more detail than elsewhere.

In Task 2, both the tram ride to the university and the destination tram station are mentioned regularly (spatial units 14 and 15), as are the train station in Ganderkesee (spatial unit 9) as well as the crossing leading to that station (spatial unit 7). However, as mentioned above 8 participants only started their route description at the train station in Ganderkesee, leading to a complete omission of the route section from the school to the station. This may be due to an enhanced focus on the destination area, mirroring the findings from Task 1.

6.3.3 Systematic patterns and gender differences

Since the length of descriptions as well as the degree of detail provided varied greatly between individuals (cf. Table 2), participants obviously differed in their assessments of the information needed in the description. However, these differences cannot be traced back to gender: the average number of units provided by females is in both tasks similar to that provided by males (24 units by females vs. 23 by males in Task 1, 19 units by females vs. 16 by males in Task 2). Furthermore, 5 males and 3 females only started their description at the train station in Ganderkesee in Task 2.

Finally, we were interested in how details were provided by participants with respect to spatial units, i.e., if some participants merely chose to provide more details at random places. To assess this we investigated how many times each participant provided more than one detail with respect to (a) non-crucial spatial units and (b) crucial spatial units. This approach provides insight not on the amount of detail given (as addressed earlier) but on the places where additional detail is provided at all by any individual. Since there were far more non-crucial spatial units than crucial spatial units (cf. Table 1), in case of a random distribution, the results of our counts should yield a *higher* frequency of detail mention in non-crucial spatial units than in crucial spatial units. However, rather the opposite is the case. In Task 1, 14 participants provided additional detail more often in crucial than in non-crucial spatial units, as opposed to only 7 participants for whom the reverse was the case. In Task 2, numbers were 11 (more detail in crucial units) as opposed to 9. For 4 participants in Task 1 and 5 in Task 2, numbers are equal. This result supports our hypothesis that people provide further details particularly for those route elements that are considered as crucial, rather than distributing details at random places. This pattern highlights the systematic hierarchical nature of the conceptual route representation that is reflected in the linguistic data.

7 Comparison

On a basic level of granularity, the most crucial route elements are accessible in all our data, given the present scenario in which the environmental information together with the average wayfinder's procedural knowledge already covers much of the information needed to reach the goal. Also, both sets of route directions exhibit a clear hierarchical structure. As predicted, the various kinds of traveling mode turned out to be particularly salient. Thus, even the most sketchy descriptions contain some mention of the train ride between Bremen and Ganderkesee, along with reference to foot paths. None of the sets provided spatial information about the exact routes taken by buses and trains; these were obviously implicitly assumed to be irrelevant for travels by public transport. Switches of granularity levels (particularly 1D granularity and elaboration) most saliently co-occur with switches of travel mode. This corresponds to our observation that multi-modal travel imposes a salient structure of its own.

Both the human and the automatically generated route descriptions provide additional information on various levels of granularity, though with different foci in each case. The web-based services show a range of alternatives of traveling by public transport, which play only a minor role in the human descriptions. More precisely, while the web-based information does not reflect differences in relevance concerning alternatives, the human descriptions never contained clocktime information concerning the trams from the University to the station (and back)—but regularly (by half of the participants) about the departure time of the hourly train to and from Ganderkesee. Also, for people the direction of traveling makes different features relevant (e.g., finding the exit of a large train station on arrival is easier than finding the correct track on departure); transport planners do not make this distinction. Thus, the human route directions are more flexible concerning functional complexity. Additionally, to a certain degree the wayfinder's prior knowledge is accounted for by an increased level of detail in the (unknown) destination area. Such adaptivity to actual requirements would presuppose a great amount of implemented world knowledge in any system providing automatically generated route descriptions.

In spite of the general hierarchical nature of route directions that in basic respects corresponds to the identified information needs, in a range of specific aspects the particular information required and provided differs substantially in the two data sets. For example, already the specification of the destination (at the desired level of 2D granularity) may turn out to be difficult in travel planners, as they expect postal addresses rather than references to building names and functions such as *the high school in Ganderkesee*, or *the Cartesium*. Also, switches between granularity levels are potentially disruptive in the web-based systems: specific information about some (but not all) parts of the route may be accessed by user action, but is not integrated coherently. Crucially, the increased information needs identified for the more complex route aspects is not reflected in any systematic way; rather, the web services provide crucial along with redundant information in tabular views that need to be translated to the corresponding actions to be performed by the traveler. It seems that the system design in its current form does not allow for a more cognitively adequate selection and presentation of diverse kinds of information, partly due to the fact that the information is derived from various sources.

In contrast, the human route directions constitute coherent and spatiotemporally structured texts, providing various types of information without any apparent discontinuity whenever switches of granularity occur. The instructions contain particularly detailed information for precisely those parts of the route for which a greater need for information was identified, such as when changing travel mode, or in order to identify the correct turn after a lengthy footpath. However, the absence of graphical depictions (in our data set which in this aspect resembles many naturally given route descriptions) may pose a problem with respect to the development of a mental map suitable for the current wayfinding purposes.

Our empirical findings are limited, in particular concerning the more detailed aspects, in a range of ways, most of which can be traced back to the peculiarities of the particular case study that we have focused on. Nevertheless, we hope to have identified a range of generalizable features of route directions that truly reflect the flexibility in humans' descriptions and their (granularity-based and coherent) adaptivity to actual information needs, as opposed to the fairly rigid but multi-layered and multi-modal presentation of information in web-based services. It remains to be seen in future evaluation research to what extent the features of each description mode identified here may be particularly useful for the wayfinding process.

8 Conclusions

Our case study highlights a range of aspects that are characteristic for different types of route descriptions. Throughout, hierarchic structures can be detected with respect to one-dimensional (linear) and two-dimensional (areal) granularity as well as elaboration. However, humans are particularly flexible in providing information of changing detail in a consistent and coherent way, adapting to the addressee's assumed asymmetric information needs, even if they do not have access to multi-modal representation types (as in our scenario). In contrast, automatically generated route directions present different levels of detail in heterogeneous and sometimes incomplete ways, and they do not account for differences according to travel direction or prior knowledge. Nevertheless, the option of presenting information in various ways (pictorial, tabular, and verbal) has a high potential for fulfilling a wide range of information needs. Therefore a promising target of further research is to address the potential of automatically generated variable and multi-modal, yet coherently integrated, route information along with enhanced variability in the diverse types of granularity levels.

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