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Bachelor's thesis Media Informatics

Formation of hierarchical representations of space: The role of narratives

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Abstract

By exploring an environment we form an internal representation of the perceived environment in our mind - a so-called cognitive map. Research suggests that cognitive maps have a hierarchical structure. Regions are spatial entities of this hierarchy and it has been shown that they influence human route planning behavior. Language also seems to interact with spatial cognition and since semantic connections between words can create similar hierarchies to geographical units, the paper hypothesizes that regionalization can also be induced by semantic relatedness between adjacent language cues. For this purpose, an experiment was conducted in a virtual environment in which test persons had to perform pathfinding tasks. The results imply a regionalization effect, but since the number of participants was relatively low, these effects could be falsified.

Contents

List of Figures

List of Tables

1 Introduction

Wayfinding is a basic skill that we humans make use of every day. It is "the process of determining and following a path or route between an origin and a destination" (Golledge, 1999, 6) - whether for the way to work or just to the fridge - we always need our route planning skills in order to navigate there successfully. Being able to orientate oneself at all, basic knowledge about the environment is essential. To accumulate this information, there are different approaches. The easiest or fastest way is probably to look down on the area from a birds-eye perspective, i.e. studying a map, to become familiar with it's structure (Golledge, 1999, 9).
But we do not always have a map at hand and for familiar surroundings we do not even need one. For these situations, one can rely on cognitive maps.

1.1 Cognitive maps and hierarchies

A map may be a quick and easy solution, but it is not the only way to gather information about the environment. Instead, you can explore it without previous knowledge. Our brain constantly updates the memory of our surrounding, adds new information or corrects incorrectly stored data. This internal representation of the spatial information is commonly called a "cognitive map". The term was first introduced by Tolman (1948) after he discovered a behavior in rats that suggested that rodents store spatial information of the environment. Although the expression contains the word 'map', it does not mean that this internal representation resembles one or looks the same for everyone. Our brain filters out some information from the environment, others are only stored rudimentarily or distorted, i.e. a cognitive map is not an image of reality (Tversky, 2000). There are different theories of how the mental representation of space could look like. Overall, research suggests that the spatial organization is hierarchical (McNamara, 1986):
Stevens & Coupe (1978) dealt with people's judging of spatial relations and found that the inner representation of geographic environment is subject to a certain structure. They detected that the geographical relation between spatial entities is distorted by superordinate structures resulting in their conclusion that spatial information is stored hierarchically. Similar results found Hirtle & Jonides (1985) with people judging distances across regions as longer and distances within regions as shorter. And also McNamara (1986) indicates in his paper 'Mental representations of spatial relations' that "locations in the same region [are] 'closer' in subjects' memories than locations in different regions, regardless of euclidean distance", which means that people seem to store places of the same unit in a closer relationship than of different ones.

This can also be seen as evidence for a hierarchical structure.
With the help of graph-like structures, the hierarchical representation of spatial memory can be portrayed very well: A node describes a spatial unit in the construct, e.g. a place or region, and it is connected to some of the other nodes by links, which are labeled with the action neccessary to go from one node to the other, for example 'turn right' (Schick, Halfmann, Hardiess, Hamm & Mallot, 2019). According to the definition of Schick, Halfmann, Hardiess, Hamm & Mallot (2019), a place is a "portion of space visually accessible from one position", i.e. it is a small spatial unit with a lot of detail at low level in the hierarchy. Several of these low-level nodes located close to each other can connect to a node of a higher level to form - geographically speaking - a region. Being closely located is a necessary criterion for the formation of regions, but there are further aspects that provoke the regionalization of an evironment, e.g. a common functionality, which is shown in university districts or a mall, to name a few (Schick, Halfmann, Hardiess, Hamm & Mallot, 2019). However, regions are coarser spatial units and thus contain less detail. This means that spatial knowledges beocmes increasingly more detailed with lover levels. This has an effect on human route planning behavior to distanc loctaions: Wiener & Mallot (2003) suggest the *fine-to-coarse* route planning strategy that states that the planning of a route becomes less and less detailed for more distant places. This correlates with the *construal level theory* by Trope & Liberman (2011), that persons imagines objects more abstract the further away they are from them. Regions can be spatially limited by clear boundaries such as roads, fences or rivers, however, this is not required: "Spatial clustering of landmarks that belong to the same object category are sufficient to establish regions in subject's spatial memory" (Wiener & Mallot, 2003, 337). Visible or not, barriers have a clear effect on people's spatial perception: Routes that do not cross borders are perceived to be much shorter than distances of equal length that do cross them (Hirtle & Jonides, 1985, 209). In this context, the findings of Wiener & Mallot (2003) agree, namely that people are influenced by regions in their route planning behavior: In general routes that cross fewer regional boundaries are preferred.

1.2 Language and spatial cognition

Animals show that no language is needed to acquire spatial knowledge (Tolman, 1948). With language, however, we can communicate spatial linkage very well: People are quite good at using speech to find out information about an environment, as giving directions proves (Tversky & Lee, 198). If we are looking for a certain place in a city that is foreign to us, it is usually sufficient listening to a purely verbal description to be able navigating to the destination correctly. Even more significant is the fact that people can draw accurate maps of an unknown environment based on a purely verbal description (Bryant, 1997, 242). This could mean that people do not necessarily have to experience the environment itself to form a correct cognitive map in their mind. Therefore, perception could be not the only decisive factor for the development of a cognitive map. From this we can make the assumption that language must interact with spatial cognition at a certain point, to communicate "effectively about perceptual experience" (Bryant, 1997, 241).

1.2.1 Semantics and hierarchies

Semantics is a linguistic term and deals with the meaning of words. "Semantic similarity and relatedness investigates how alike two or more objects are (...) and allows to infer knowledge and categorize objects into kinds" (Pirró & Euzenat, 2010, 615). By clustering semantic similarly terms under a coarser expression - an umbrella term -, we can gather information about their meanings and connections. An example for an umbrella term could be 'vehicle', whereas 'tractor' could be interpreted as an subset of vehicle.
Clustering words into categories creates a hierarchical structure which can be compared very well with the hierarchical representation of space: In both, more specific entities are combined into coarser units based on certain aspects. Since language occupies such a large part in our everyday lives, it would be interesting to see, if semantic related language cues influence our reception of the environment, which will be discussed in more detail in the following chapter.

1.3 Purpose of this study

This paper examines the role of language in connection with route planning behavior. As mentioned in section 1.1 *Cognitive maps and hierarchies*, people cluster places into regions based on certain aspects and these regions affect our wayfinding strategies to such a degree that we prefer paths crossing fewer regions boundaries. Semantic correlations in language can also create clusters that could be interpreted as regions. Thus, it will be investigated whether semantic connections in language trigger a similar effect in an environment and thereby influence people in their wayfinding strategy.
For this purpose, an experiment will be conducted in a virtual environment in which test persons have to perform pathfinding tasks. As clues, they only have place names that show semantic connections.
With respect to the linguistic aspects regarding spatial cognition, discussed

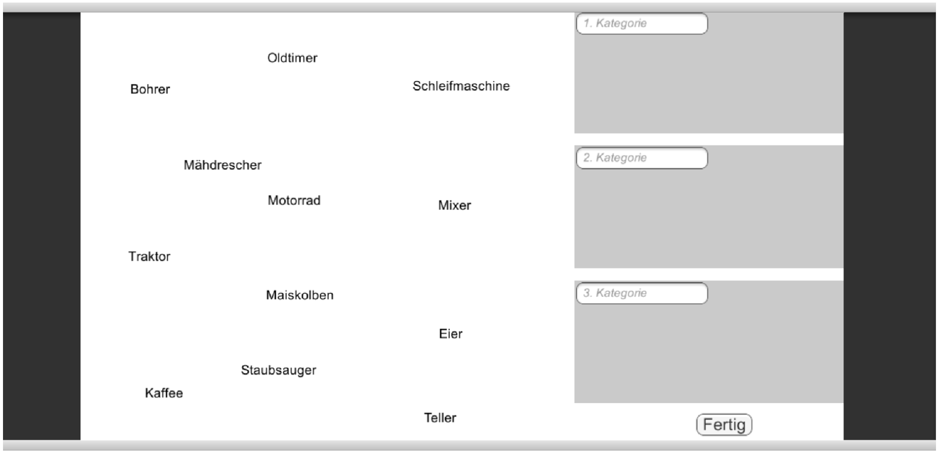

Figure 1: Part 1 of the experiment - classification task. The subjects was supposed to divide 12 words into 3 categories (grey) so that each category contains 4 words. They also had to label each of the groups with names consistent with the assigned words.

in chapter 1.2 *Language and spatial cognition*, the hypothesis of this paper is, that language provokes a regionalization of the environment.

2 Methods

2.1 Experimental setup

The experiment was created with *Unity* (Version: 2018.3.0f2), a game engine developed by *Unity Technologies*. Most of the experiment itself was performed in virtual reality, with the subject wearing an Occulus Rift. The rest of the experiment took place on a laptop with a screen size of 15 inch.
The experiment was divided into three parts: A short classification task, a navigation part in virtual reality and a questionnaire.
In the first part, the participants sorted 12 words into 3 categories. The only restriction was that each category had to contain exactly 4 words in the end. They were also supposed to label their groups with names consistent with the assigned words. Figure 1 shows the representation of the task on the computer. The words used are examined in more detail in section 2.2 *Language cues*.
For the second part, the test person performed various navigation tasks in a virtual environment. The environment consisted of 12 places connected by straight roads. 6 places were a dead end, the remaining 6 were laid out in a

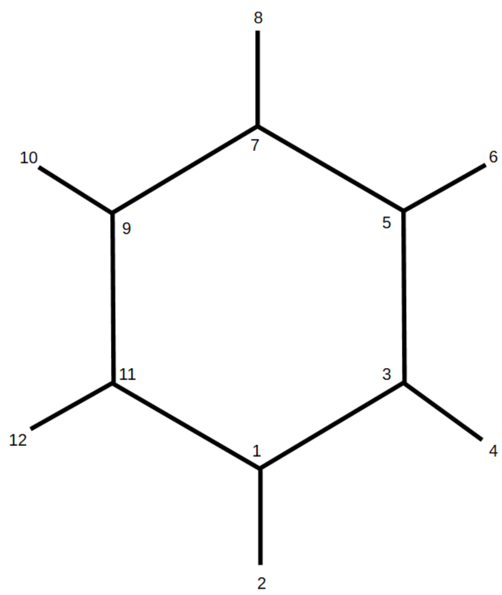

Figure 2: Basic structure of the virtual environment: Each number represents a place; even numbers are dead ends.

hexagonal structure, presented in figure 2. For the experiment, places were defined as simple junctions, where three roads meet and only three signs displaying the name of the respective place as reference points. The three signs are placed in a certain way to deny the subjects a geographic reference point. The installation can be seen in figure 3. In order to not bias the subjects in some manner, all streets had the same length and met in a 120 degree angle to each other at every place. Places located in dead ends could be differentiated from places within the hexagonal ring structure because of street barricades (see figure 4) blocking the entries to two adjacent streets. Though the entries to these roads were visible, they were not be accessible. Streets were lined with hills obscuring the subjects' view to distant places. In order to get to a neighboring place, the probands had to turn their bodies to face the free road leading there. By clicking the left mouse button, the person was moved to the corresponding location with a continuous movement. The language cue of a neighboring place was only recognizable when the person had arrived there.
The navigation part itself consisted of 3 phases: Exploration, training and test phase. During the exploration phase, probands explored the surroundings; for training and test phase, route tasks to one or more destinations had to be mastered. The aim of these missions were to find specific places from different starting points using the shortest path possible. The destinations

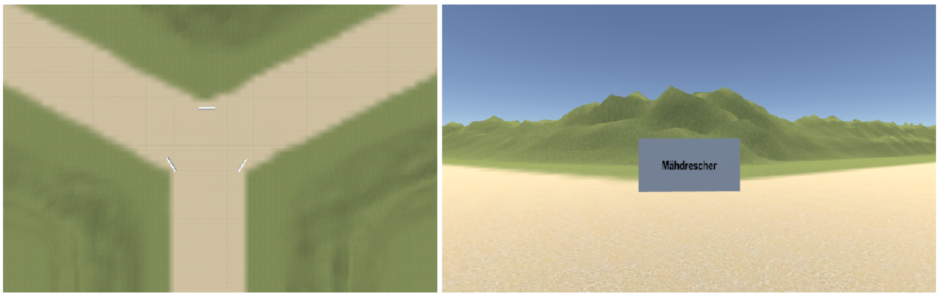

Figure 3: At each location 3 signs were installed. The image on the left gives a birds-eye perspective onto the scene. The signs are the white rectangulars positioned in the corners. The signs displayed the name (image on the right) of the respective place. The place name here was *Mähdrescher* (*combine harvester*). These language cues and if places were dead ends or part of the ring were the only information about the geographical position for the subjects.

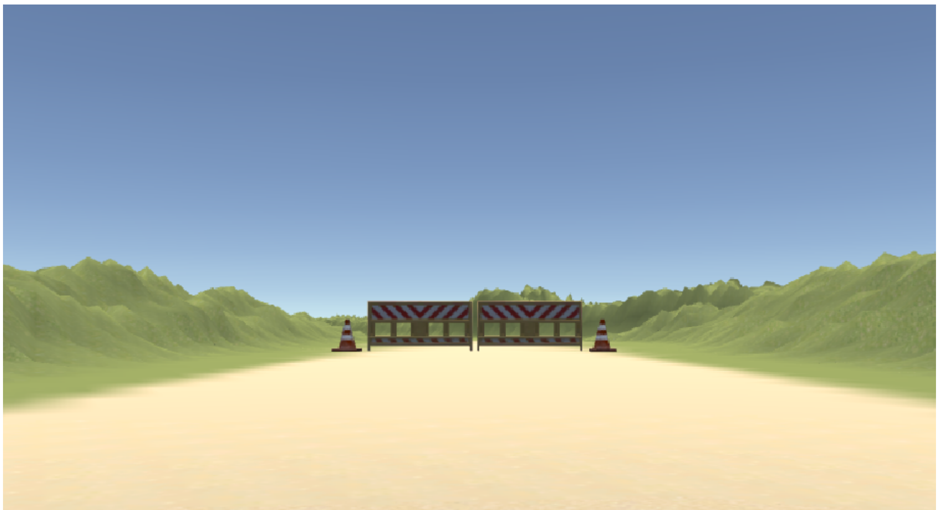

Figure 4: Either of the two adjacent paths to the dead ends were blocked by street barricades. Subjects could see the paths leading somewhere, but could not access them.

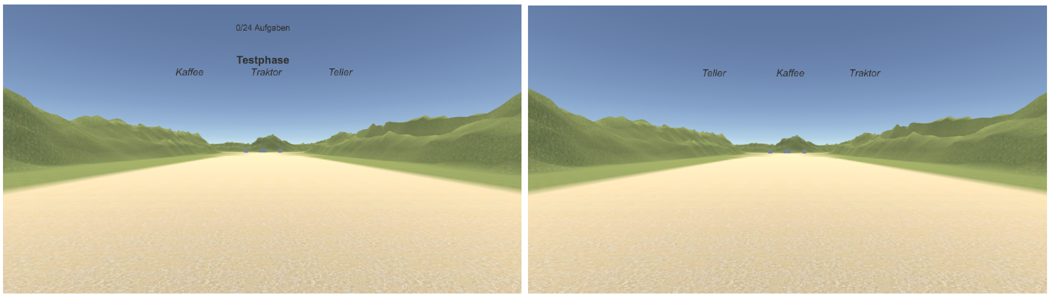

Figure 5: The image on the left depicts the information text that was displayed at the beginning of each route task telling the participant how many exercises had been completed already of the overall number of routes tasks. During the test phase 3 targets were to be found. The order of the displayed destinations changed every 2 seconds to avoid a bias of the subjects.

that needed to be found were displayed in the upper half of the field of view. If the task contained more than one destination, the order of the displayed target places changed in order to not bias the subjects' route planning. Figure 5 shows the displayed destination in one exercise of the test phase. The order of the displayed destinations changed in regular intervals. The left picture in the figure also shows the information text depicted at the beginning of each task, which informed the probands how many exercises they had already mastered from the total number.

The navigation part was followed by a short questionnaire consisting of six questions addressing several aspects of the experiment. Subjects had to draw a sketch map of the environment as well.

2.2 Language cues

The language cues used in the first and second part of the experiment can be seen in table 1. The terms were chosen in such a way that they had semantic connections to each other. For example, *tractor*, *combine harvester*, *vintage car* and *motorcycle* are all vehicles and thus can be clustered to a group under the umbrella term *vehicles*. The composition of language cues was designed to allow for or rather provoke two classification schemes, i.e. there was an alternative categorization for each word. Table 2 shows both classification models.

In the environment the language cues were arranged in such a way that each of the words were located within both possible categorizations. Figure 6 illustrates this. One possible grouping is on the left side (in red), the other on the right (in blue). The language cues do not change position, but it is

	Language cue and translation
1	Traktor (*Tractor*)
2	Mähdrescher (*Combine harvester*)
3	Motorrad (*Motorcycle*)
4	Oldtimer (*Vintage car*)
5	Schleifmaschine (*Grinding machine*)
6	Bohrer (*Drill*)
7	Mixer
8	Staubsauger (*Vacuum cleaner*)
9	Teller (*Plate*)
10	Kaffee (*Coffee*)
11	Eier (*Eggs*)
12	Maiskolben (*Corn cob*)

Table 1: The 12 language cues (and their translation) used in the first and second part of the experiment. The numbers of the words match with the arrangement of figure 2.

Classification X:

Fahrzeuge (*Vehicle*)	**Elektr. Geräte** (*Electric devices*)	**Essen** (*Food/Meal*)
Traktor	Schleifmaschine	Teller
Mähdrescher	Bohrer	Kaffee
Motorrad	Mixer	Eier
Oldtimer	Staubsauger	Maiskolben

Classification Y:

Bauernhof (*Farm*)	**Werkstatt** (*Garage*)	**Haushalt** (*Household*)
Traktor	Schleifmaschine	Teller
Mähdrescher	Bohrer	Kaffee
Eier	Motorrad	Staubsauger
Maiskolben	Oldtimer	Mixer

Table 2: Each table shows a logical classification pattern of the 12 words with the respective umbrella term.

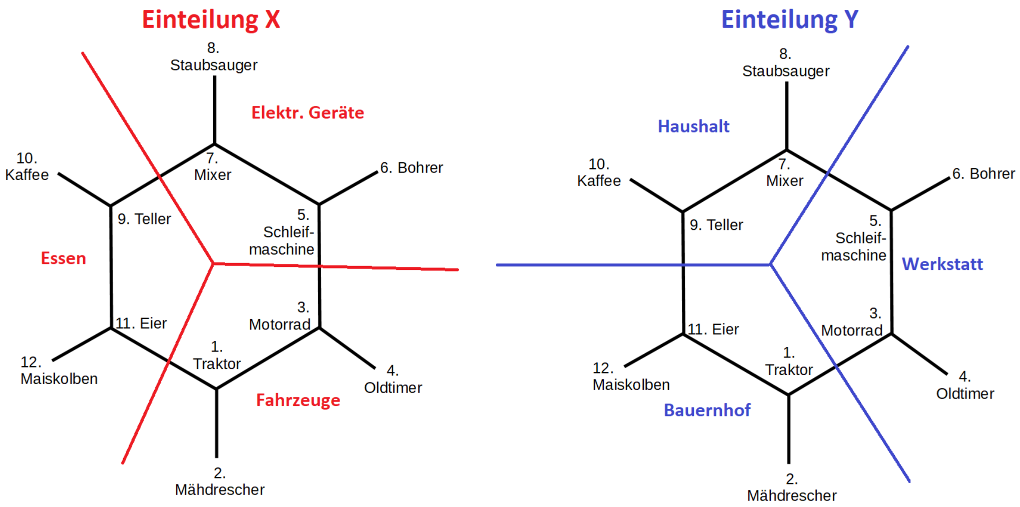

Figure 6: Arrangement of the words in the environment. Although words do not change position, it is possible to recognize a second classification scheme. The graphic on the left shows classification scheme X, the graphic on the right classification scheme Y (compare table 2). The umbrella terms for each cluster are written in red and blue respectively.

still possible to recognize a different classification scheme. Each word was located in an area of overlapping clusters - or rather *regions*. The classification task of part 1 was supposed to bias the test person to the extent that the chosen categories were interpreted as regions during the navigation task since there were no other indicators of region boundaries beside the language cues. It was then examined if the regions triggered a regionalization effect. The case that a subject's clustering did not match either of the two classification schemes was not covered. The arrangement of the words in the hexagon-environment stayed the same regardless the categorization a subject chose. To ensure that this case did not occur at all or only very rarely, the 12 language cues were tested on different subjects in a survey first. The people were asked the same conceptual formulation as in the classification task to create an equal situation for the later, actual experiment. The survey showed that most of the participants chose one of the two classification schemes and that both of them were almost equally represented. The words were therefore found to be appropriate.

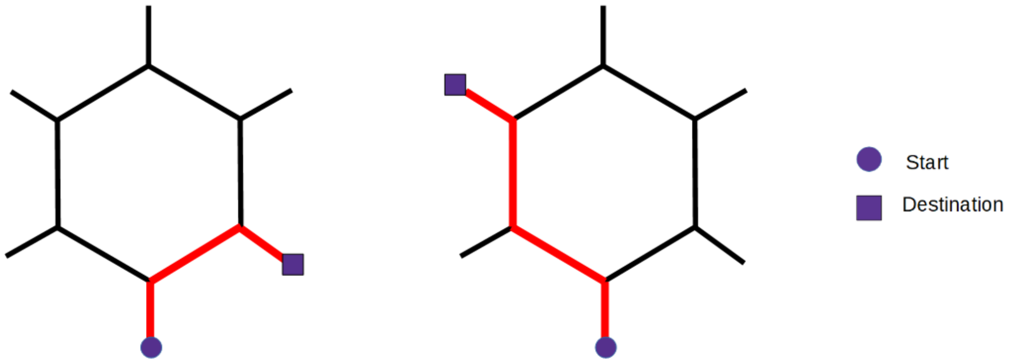

Figure 7: The graphic illustrates the structure of the route tasks of the training phase. Overall there were two types of exercise, either 3 or 4 segments long.

2.3 Procedure

After querying age, gender and current occupation (student or worker), the classification task was conducted. The test person had no restrictions regarding the instruction and was only supposed to find and label three categories that made sense for the 12 words.
After that the navigation part in virtual reality started. At first, the *exploration phase* was executed, in which the participant explored the environment. The phase ended when the subject had walked around the surroundings for at least 5 minutes and had visited all places at least once. The exploration phase was followed by a *training phase*, in which the subject had to navigate to one target place on the shortest route possible. For each of the route tasks, there was only one possible solution. If the shortest route was not found, the task was mixed back into the exercise catalog and repeated later. For time reasons, tasks for which subjects failed to find the shortest path 4 times, were removed from the catalog and labeled as 'completely failed' in their data file so that this could be taken into account in the evaluation later. Training phase ended when the catalog was empty. In total, there were 12 route missions chosen in such a way that the person started twice from each dead end. Overall there were 2 types of routes (with 6 routes respectively), the strucutre of these can be seen in figure 7.

The assignment for the third and last phase (*test phase*) was to find the shortest route connecting 3 destinations instead of only one. The subject had to decide in which order to visit the target places. There were a total number of 24 route tasks, consisting of 6 A-routes, 6 B-routes and 12 distractor-routes. Figure 8 illustrates the different route types of the test phase. Both, type A and B offered an alternative shortest path that crossed more regional boundaries, though. Only these two types were interesting for the evaluation; the distractor routes were just supposed to ensure that the test person did not see through the symmetric structure of the route types.

After completing the navigation tasks, the test person completed a questionnaire and was asked to create a sketch map of the environment. The questionnaire included six questions. The subject was asked about satisfaction level and difficulty regarding the classification task and it's influence, specific strategies during the nagivational exercise, sense of orientation and experience with video games. In the analysis only the subjects' satisfaction level regarding their classification and the sketch map was evaluated.

2.4 Variables of interest

Since the paper tries to find out whether language can trigger regionalization in an environment, the main focus of the experiment was on subjects' navigational behavior. Variables of interest were error rate, region dependent route choices and region consistency at first choice. From the questionnaire only satisfaction level regarding classification and the sketch maps were evaluated. The A- and B-route types were relevant for this research question and they were considered separately for each of the variables.

2.4.1 Error rate

The error rate is the average amount of errors per subject until the shortest route could be found.

2.4.2 Region dependent route choice

The term region dependent route choice refers to the test person's behavior to choose the routes that cross fewer regional boundaries. A- and B-routes each offer two solutions of the same length, one traversing more regions than the other. The regions are determined by the classification task of part 1. For this variable, only the number of successfully completed A and B routes was considered.

2.4.3 Region consistency at first choice

The test person's decision at the first junction is regarded as first choice. If the subject chooses the path that leads to a place in the same region, the decision is considered region-consistent. Consequently, the decision is region-inconsistent, if the path crosses a region boundary. Routes that were

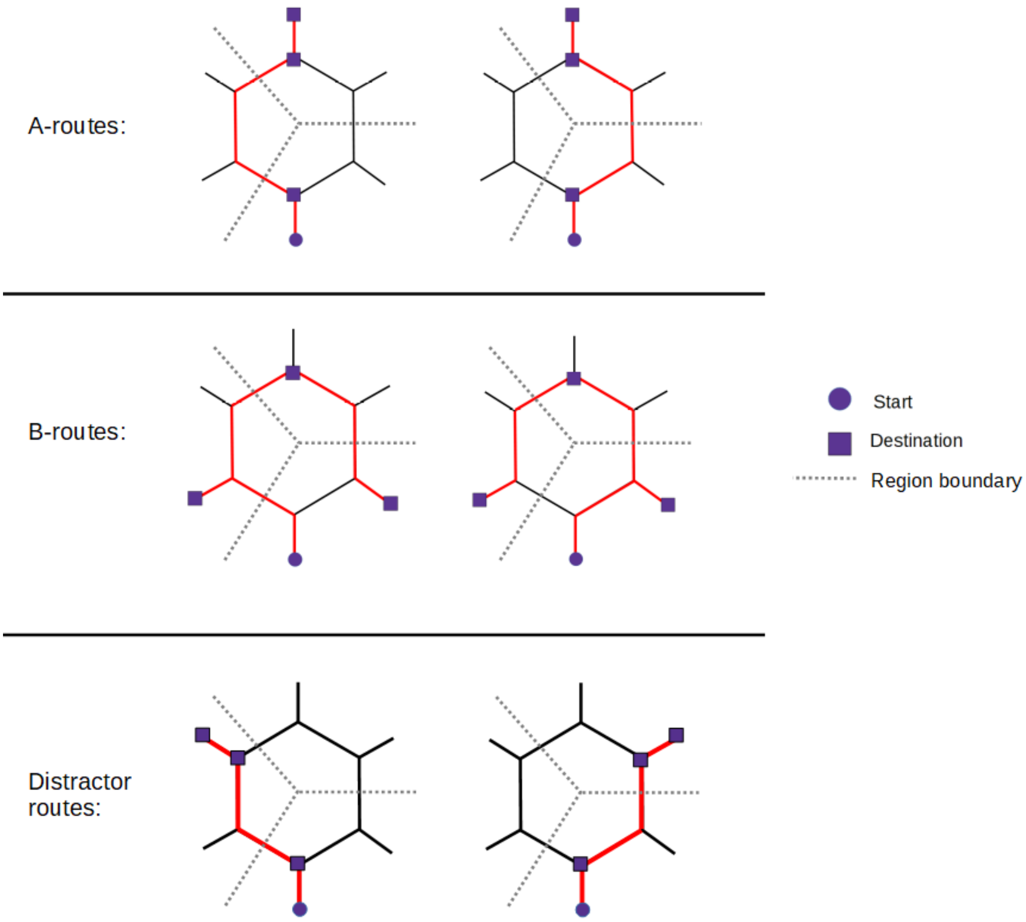

Figure 8: The graphic illustrates the structure of the route tasks of the test phase. There were 3 route types: A, B or Distractor routes. A- and B-routes both offered an alternative shortest path solution that crossed more regional boundaries. Distractor-routes were supposed to distract the subject from the symmetric route structure.

not successfully completed at the first time could also be evaluated.
The variable is represented as the percentage of region consistent decisions.

2.4.4 Satisfaction level and regionalization effect

In the questionnaire, participants were supposed to answer the question how satisfied they were with their classification of words into categories. The options were 'happy', 'neutral' and 'discontent'.
It is assumed that people who were satisfied with their classification are subject to a stronger regional effect, as the coherence of the classification may be perceived more intensely.

2.4.5 Sketch map

Since sketch maps provide a good overview of the subject's understanding of the environment, it was assessed against the following criteria:

(i) Successful recognition of the hexagon structure

(ii) Correct assignment of the words to the respective region

(iii) Correct arrangement of the language cues

2.5 Results

2.5.1 Participants

A total of 22 people took part in the experiment. The vast majority were students of the University of Tübingen, of them 12 male and 10 female. The age range was 19 to 31. All participants in the study received a written consent form and were reimbursed for their expenses.
Test persons who had to stop the experiment prematurely or failed more than 6 route tasks during the test phase were excluded from further analysis to reduce noise. In the end, only the data of 12 participants could be evaluated. Of these, 9 were male and 3 female. Thus, the gender ratio was 3:1.

2.5.2 Error rate

On average, a test person made 0.75 mistakes on A-routes. The number of errors on B-routes was much higher with 2.08 mistakes, see figure 9.

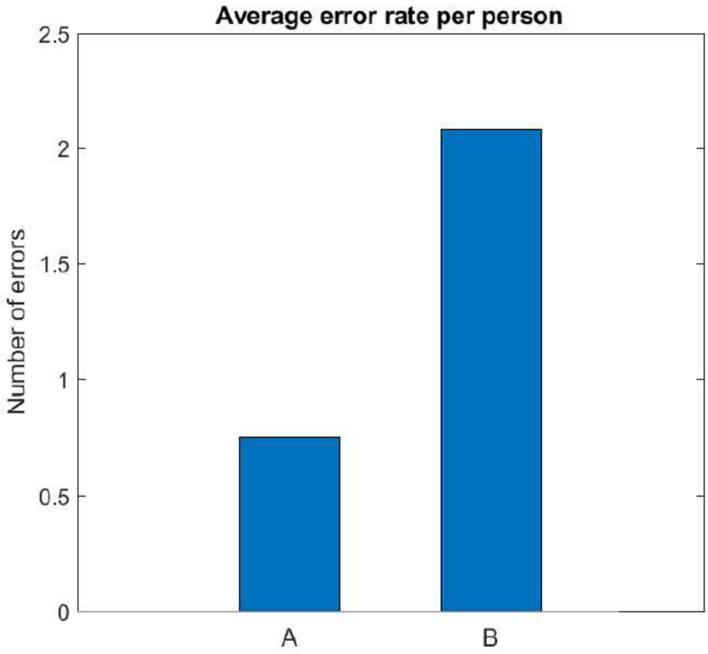

Figure 9: The diagram visualizes the average number of errors per person for A- and B-routes, respectively.

2.5.3 Region dependent route choices

The average number of region dependent route choices was 69.45% for A-routes and 59.72% for B-routes. The number of routes were not enough to fulfill the Laplace condition of $\sigma > 3$ in order to execute a t-test, so it cannot be said whether these numbers are a random fluctuation or indication of a regionalization effect. An u-test demonstrated that there is no significant difference regarding region dependent route choices for both route types; the significance level was $p = 0.15$, which is close to the limit, though.
Figure 10 visualizes the distribution of region dependent route choices. Route type A is well above the chance level of 50%; the majority of them are between 70% and 80%. Route type B, on the other hand, is rather weaker and lies in the range of 50% to 66%. At least for A-routes, a regionalization effect could be likely.

2.5.4 Region consistency at first choice

On average, for A-routes, test persons decided 68.4% of the times region-consistent at first choice. For B-routes, this was significantly lower at 58.52%. An u-test with significance level of $p = 0.16$ showed no significant difference

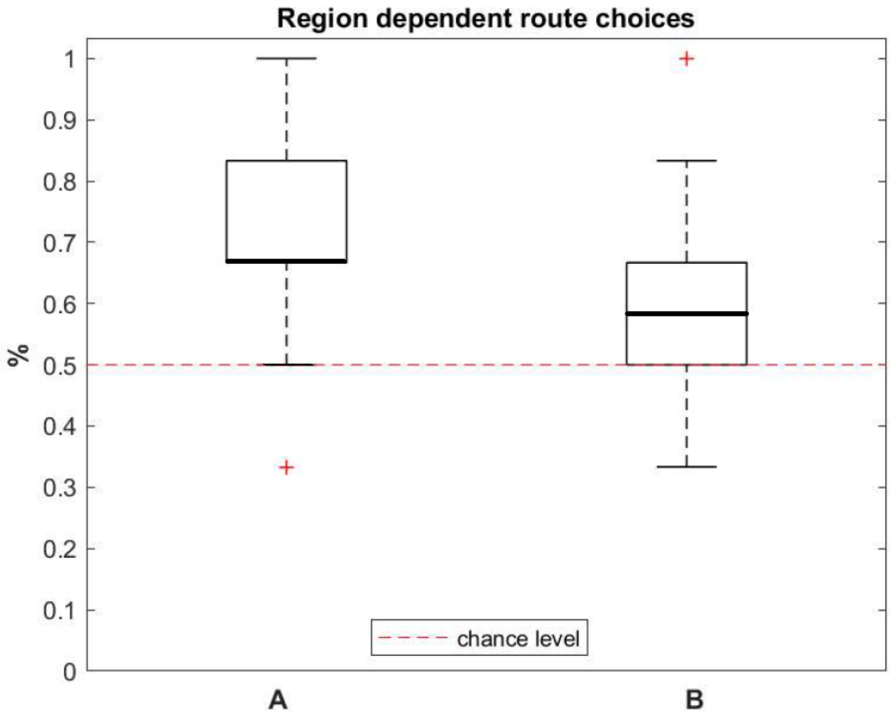

Figure 10: The diagram illustrates the distribution of region dependent route choices. Only completed A- and B-routes were considered.
For A-Routes the average number of region dependent route choices was 69.45% and for B-routes 59.72%.

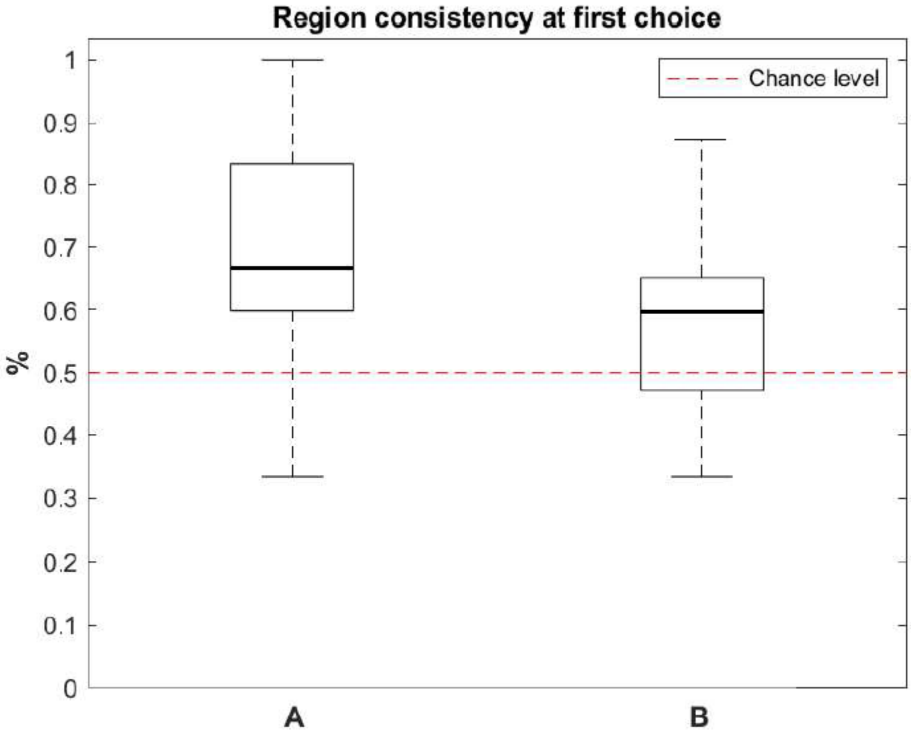

Figure 11: The diagram illustrates the distribution of region consistencies at first choice. All A- and B-routes - failed ones included - were evaluated. For A-Routes the average number of region consistency was 68.4% and for B-routes 58.52%.

with regard to region consistency for these two route types.
In figure 11 the distribution of region consistencies at first decision is pictured. Region consistent first choices were taken between 60% and 80% of the time for A-routes, and between 50% and 70% for B-routes.

2.5.5 Satisfaction level and regionalization effect

None of the participants was dissatisfied with their clustering from part 1. Nine out of 12 people were very satisfied, 3 people neutral. With the help of a right-sided u-test, it was examined whether persons who were content with their classification had significantly higher region consistencies than people who had voted neutral. However, with p=0.18 for A-routes and p=0.5 for B-routes, this hypothesis was rejected.

2.5.6 Sketch map

(i) All participants who succeeded in the experiment, also recognized the hexagonal structure of the environment.

(ii) Almost all of the language cues were correctly assigned to the respective regions for all sketch maps.

(iii) One quarter of the test persons had two adjacent word couples swapped, e.g. the position of the couple *Traktor* and *Mähdrescher* was swapped with *Motorrad* and *Oldtimer*, see figure 12. These swaps occured exclusively within the same regions for each of the four affected subjects. However, the swaps happened in different regions.

Occasionally subjects did not know a place, but most of the sketches were correct.

3 Discussion

The purpose of this paper was to investigate whether language - based on semantic connections - provokes regionalization in an environment. This would then influence the route planning behaviour of the test persons as shown by Wiener & Mallot (2003). Research has shown that language and spatial cognition interact to some degree as giving directions shows. Therefore the hypothesis is made that language cues influence the respondent's route choice.

Subjects had to cluster the words in part 1 on their own, so that they were sensitized for the semantic connections. This also assured that the persons would choose the classification that made the most sense to them. This is one of the reasons why a composition of words was important that permitted two classifications. The other reason was that this would make it possible to test both groups for region effects. Both classification schemes were supposed to be chosen by about the same number of people. Despite a survey to guarantee the suitability of the words, this was not the case in the end. All participants chose classification scheme X (*vehicles*, *electronic devices*, *food/meal*; see table 2). This preference could have been triggered by the vehicle category: In comparison with the other clusters, the vehicle-group solely contains objects that are vehicles. In contrast to that, the other categories contain expressions that can only be associated with their umbrella term. For example *Teller (plates)* and *Eier (eggs)* are both part of the food/meal category, but plates

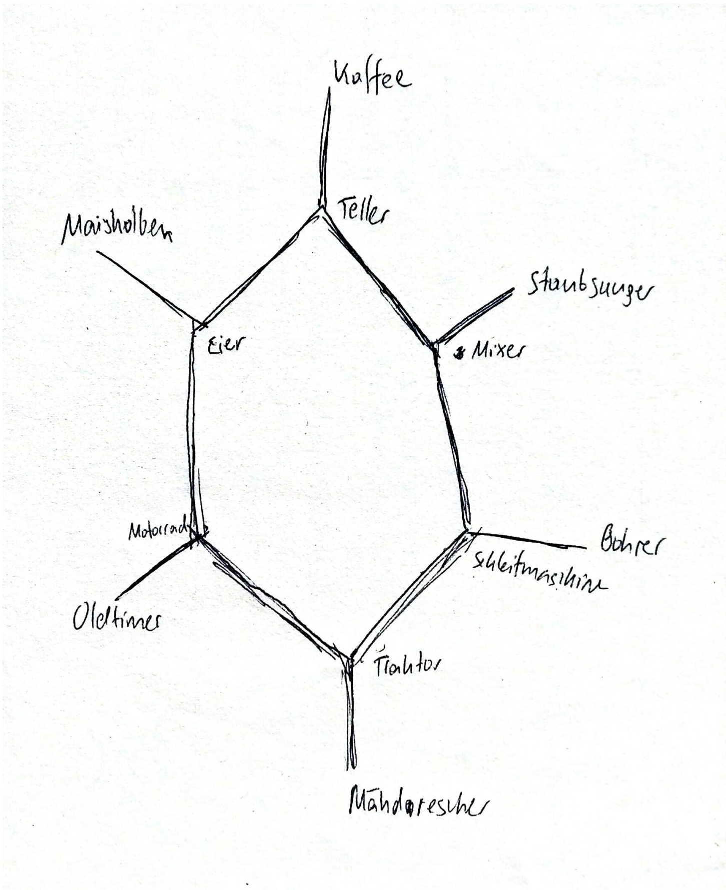

Figure 12: Incorrect sketch map from one of the participants. The positions of the word pairs *Traktor* and *Mähdrescher* are swapped with *Motorrad* and *Oldtimer*. The swap occured within the same region.

are a tool to eat from wheras an egg is food. This could make the vehicle category enhance the vehicle group and influence the subject's subsequent choice.
The pre-selection of the words was supposed to bias the test person with regard to the regions in the navigation task. The results of the experiment show a regionalization effect in A-routes and a smaller effect in B-routes. Since no significant t-test could be performed, it cannot be said whether it is a random fluctuation or a real regionalization effect; this is at least true for B-routes. In contrast to that, routes of type A are mainly above the chance level and thus fluctuation seems unlikely.
The high error rate in B-routes (2.08 in average) compared to A-routes (0.75 in average) suggests that B-routes were more difficult to complete than their counterparts. On the one hand, this can be attributed to the different length of the route types. Routes of type B were considerably longer with 9 segments than routes of type A with only 5 segments. On the other hand, B-routes could be perceived as more demanding because the 3 destinations to be found are all located in different categories. With A-routes, only destinations from 2 different categories are addressed. This makes B-routes more complex, requiring a higher cognitive effort. Due to this inequality of complexity, it probably makes more sense to weight A-routes more strongly than B-routes in terms of the regional effect.
Since failed routes were also evaluated for the variable *region consistency at first choice*, considerably more data could be evaluated. However, the percentage for both route types is almost the same as for region dependent route choice, even a little bit weaker. For A-routes this could be due to the fact that the error rate was very low, so not much more new data was added to the evaluation. The high error rate in B-routes could suggest that subjects were not familiar enough with the environment. The findings could be falsified if the person did not find the correct way the first time and therefore decided to take the other path the next time as a result of incomplete knowledge about the vicinity.
There was no correlation between satisfaction regarding the classification and a possibly higher regional consistency in path selection. This came unexpectedly, as the pre-selection of words was specifically intended to provoke a bias towards the corresponding regionalization and thus a stronger effect. An explanation for this could be that the gradation of the rating scale with 3 levels ('happy', 'neutral' and 'discontent') was too coarse and the test persons felt compelled to pick a rather strong opinion.
As was to be expected, all participants who successfully completed the experiment were able to recognize the hexagon structure of the environment. There were only problems with the correct arrangement of the language cues

to the corresponding position. One quarter of the test persons, executed the arrangement of the locations incorrect, but still arranged the places in such a way that the regions remained. This could be an indication of regionalization effect for these persons.
The experiment also suggests a gender effect: Male participants performed better than their female counterparts. Gender effects are no novelty in navigation and orientation research and have often been the subject of scientific papers. For example, Linn & Petersen (1985) have shown that men have better spatial perception and mental rotation skills than women. However, since the number of participants was relatively small, this presumptive gender effect could simply be due to a random fluctuation.
Schick, Halfmann, Hardiess, Hamm & Mallot (2019) conducted a similar experiment like this one: They tested, whether the relationship between names of neighbouring places provoked regionalization. Their experiment procedure was relatively analog to this one and the route types (A and B) were the same. There was no prior classification of the words to the navigation task, though. Results of the experiment showed a weaker regionalization compared to landmarks as region indicator. However, the findings seem to be fainter compared to the outcomes of this paper: Especially the A-routes show a significantly higher percentage of region dependent route choices (almost 70% in contrast to less than 60% from the mentioned paper). For the B-routes, the results are more similar. The same applies to region consistency at first choice. This could indicate that the selection of words could have been helpful in provoking regions. Alternatively the used language cues might have been more suitable than the ones Schick, Halfmann, Hardiess, Hamm % Mallot had used.
Regarding the results, there are a few aspects that could be improved for future experiments:
The high drop out rate, the high error rate of the B-routes and the partly faulty sketch maps imply that the test persons had not yet learned the environment well enough. Maybe this could be settled with a longer exploration phase or an adapted training phase that asks for two desintations instead of one to prepare the subject better for the test phase.
A stronger regionalization could also be caused by more suitable language cues. As already noted, the categories could have been assessed differently by the test subjects: The vehicle category consisted of vehicles, while the garage category, for example, contained objects that could only be associated with a garage. The category 'household' could also be too abstract to intuitively deduce. In addition to more qualified language cues, the test persons could also be given a bias regarding a categorization, for example in the form of a short story before the categorization task. This could help to form two equal

sized groups with respect to the chosen classification scheme.

Finally, it should be mentioned that since the experiment took place in virtual reality, the experimental results could have been influenced by this. An attempt was made to implement a certain degree of spatiality, for example, the test subjects had to rotate in order to see and enter the full environment, but results could differ nonetheless when conducted in reality.
Also, the number of participants was very low, so the effects mentioned above could be falsified.

4 Conclusion

Cognitive maps are internal spatial representations of the environment and of hierarchical structure. We use cognitive maps in wayfinding, which is an indispensable aspect in our everyday life. But there is still a lot to learn. Language seems to interact with spatial knowledge at some points and could give us more insights in our route planning behavior. The paper investigated whether semantic relationships between language cues of neighboring locations trigger a regionalization effect in subjects and thus influences their navigating strategy. It was assumed that this was the case since semantics in language form hierarchical clusters similarly to geographical entities.
The results of the experiment described in this paper support this thesis. Although the effects were not strong, there was a visible increase regarding the regional effect compared to a similar experiment of Schick, Halfmann, Hardiess, Hamm & Mallot (2019).
Since the number of test subjects was relatively small, further research should be directed towards this issue. Nevertheless, the results so far are promising.

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6 Appendix

6.1 Questionnaire

1. Wie zufrieden bist du mit deiner Einteilung der Wörter in Kategorien?
   How satisfied are you with your classification of words into categories?

2. Ist dir die Einteilung der Wörter in Kategorien schwer gefallen?
   Did you find it difficult to categorize the words?

3. Hast du eine besondere Strategie verwendet, um dich im zweiten Teil des Experiments (Navigation) besser zurecht zu finden? Zum Beispiel die Umgebung in Regionen unterteilt?
   Did you use a special strategy to find your way better in the second part of the experiment (navigation)? For example, the environment divided into regions?

4. Hat die Klassifizierungsaufgabe im 1. Teil des Experiments deine Strategie bei der Naviationsaufgabe beeinflusst?
   Did the classification task in the first part of the experiment influence your strategy of the navigation task?

5. Wie würdest du deine Orientierungsfähigkeiten einschätzen?
   How would you rate your orientation skills?

6. Hast du Erfahrung mit Videospielen?
   Do you have any experience with video games?

7. Zeichne nun bitte auf das Blatt Papier die Umgebung aus dem 2. Teil des Experiments. Beschrifte nach Möglichkeit die Orte mit ihren entsprechenden Namen.
   Now please draw the surroundings from the second part of the experiment on a sheet of paper. If possible, mark the locations with their corresponding names.

Declaration of Authorship

I, Leonie Mödl, hereby declare that this research paper is entirely my own. Where I have consulted the work of others this is always clearly stated. This bachelor's thesis was not submitted in the same or a similar form in any other course to receive credit points.

Date: 26.08.2019
Signed: Leonie Mödl