View-specific spatial recall

Bachelorarbeit

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der Eberhard Karls Universität Tübingen

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Zusammenfassung

Während egozentrische räumliche Wahrnehmung in Form von Ansichten und allozentrische räumliche Langzeiterinnerungen in Form von sogenannten „view-graphs“ wichtige Grundlagen für die menschliche Orientierung darstellen, sind die Verbindung und Wechselwirkung zwischen diesen räumlichen Darstellungen noch kaum untersucht. Eine in jüngerer Zeit erschienene Studie (Basten, Meilinger & Mallot, 2012) zeigt, dass die Darstellung eines bekannten Ortes im räumlichen Arbeitsgedächtnis von vorheriger Aktivierung (in diesem Fall durch mental travel) beeinflusst wird. In einem weiteren Experiment zeigen Röhrich, Hardiess & Mallot (2014) außerdem die Modifikation der räumlichen Darstellung durch physische Nähe zum dargestellten Ort. Die vorliegende Arbeit untersucht, ob die in der letzteren Studie beobachtete Beeinflussung auch bei Darstellungen von Orten in virtueller Realität auftritt, wenn gleichzeitig ein indirekt auf den vorzustellenden Ort bezogener Reiz gegeben wird. Zu diesem Zweck wurden Studienteilnehmern mithilfe einer Oculus RIFT-Datenbrille 360°-Panoramen von ihnen bekannten Orten in der Tübinger Altstadt gezeigt. Während sie sich innerhalb des Panoramas eines Ortes befanden, wurden die Testpersonen aufgefordert, sich vorzustellen, sie befänden sich an einem der anderen Orte, wurden daraufhin in das Panorama des benannten Ortes hineinversetzt und mussten die zuvor vorgestellte Perspektive durch entsprechende Drehung der Blickrichtung angeben. Die dabei erhobenen Daten wurden mit denen aus einem zweiten Versuchsteil verglichen. In diesem hatten es die selben Testpersonen zur Aufgabe, die jeweils korrekte Perspektive innerhalb eines Ortes (Panoramas) bei Ankunft aus Richtung eines anderen Ortes anzugeben. Zusätzlich wurde an mehreren Bereichen der erhobenen Daten untersucht, ob sich systematische Unterschiede zwischen den Ergebnissen dieses Experimentes bei Verwendung von Tag- oder Nachtpanoramen abzeichnen. Weder eine generelle Beeinflussung der mentalen Darstellung noch ein allgemeiner Unterschied der dafür untersuchten Daten zwischen Tag und Nacht konnten festgestellt werden.

1. Introduction

1.1 Graph Models

Ranging from the most mundane everyday tasks to most important, sometimes life-changing actions, correct navigation and the proper representation of environmental spaces are important for many forms of behavior. Decisive for these skills is, of course, the acquisition of relevant information, but also the processing and storage of it.

Today, it is generally assumed that the acquired information about the spatial layout of the places surrounding us is stored in the spatial long-term-memory in form of a graph. This phrase describes a network of nodes in form of places („place-graph-model") or views („view-graph-model") that are labeled with local spatial information, global metric information, functionality and more (Mallot & Basten, 2009). These nodes are connected to one another via their edges, which are labeled with the appropriate movement information („action label") (See Figure 1). Of course, not all nodes will always be connected to the network, since places might be spatially separated in reality. In this case, when transiting to a separate graph, a person will have to newly orient within it (Wang & Brockmole, 2003). Compared to possible map-like representations of space, graphs have the advantage of being more flexible, be it in weighting different movement options or being able to cope with incomplete knowledge about the spatial layout of the depicted area (Franz, Mallot &Wiener, 2005).

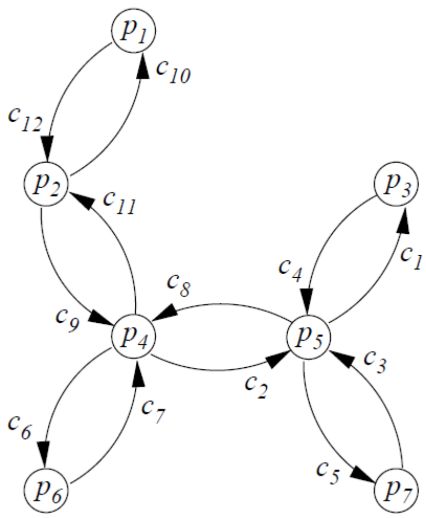


Figure 1: Typical place graph of a simple maze. The nodes/places are denoted by p_i (i = 1,…,7), the connections/corridors by c_j (j = 1,…,12). From: Schölkopf & Mallot, 1995.

The first models proposing a place-graph were developed in the late seventies of the last century (Kuipers, 1978; Byrne, 1979). Since then, many different theories about the form of graphs have been developed, for instance by Kuipers suggesting not just places, but also paths connecting them to be treated as nodes (Kuipers, 2000). A more drastic change of the graph-model was given by Schölkopf and Mallot to the effect that not entire locations are represented as nodes in the representation, but every view (Schölkopf & Mallot, 1995). This so-called „view-graph-model" keeps the approach of a network of nodes connected to one another, but places now consist of several nodes in the form of single visual snapshots which are also connected edge to edge by the means of movement information. This means that distinct physical locations are represented as the sum of their snapshots, often in panoramic form. Some of the views of a place might be remembered more strongly, the reason being for instance the strong salience of a landmark found in the view or the personal importance of it (Röhrich, Hardiess & Mallot, 2014). These views are then called canonical.

1.2 Spatial Image

The spatial information is stored in long-term memory in an allocentric modality. This means that, even though it consists of snapshots taken from the egocentric perspective, the graph network does not change depending on the current position or heading of a person. This would pose a problem when trying to orient oneself according to this unchanging graph while moving through an environment, since the graph would be misaligned with the actual surroundings most of the time. Therefore, to make precise orientation possible, there exists an egocentric representation of space in the working memory parallel to the allocentric one in long-term memory. Said representation consists of a more or less small part of the complete view-graph, ranging from the current view and the ones bordering it to a panoramic representation of the current location, and is therefore a sub-graph (Röhrich, Hardiess & Mallot, 2014; Tatler & Land, 2011). It is called "spatial image", and, as described above, is utilized to support orientation, movement and navigation in the immediate surroundings, including space which is currently out of sight (Loomis, Klatzky & Giudice, 2013). This spatial image is thought to reside in the precuneus.

While the spatial image is indeed a part of the graph network that comprises our mental map, it can not only be attained from long-term memory, but also from the perception of the surroundings (Giudice, Klatzky, Bennett & Loomis, 2013). Indeed, any form of spatial knowledge will be processed in the spatial working memory before eventually being stored in long-term memory. In this process, the hippocampus incorporates newly acquired spatial knowledge into the already existing or newly developing mental representation of space. Meanwhile, the retrosplenial cortices are responsible for matching the egocentric spatial information with the perceived self-movement (Wolbers & Büchel, 2005). The strong interplay of spatial working memory and sensory input can be shown in patients suffering from unilateral neglect: For a long time, this was thought to only impair one side of the visual field directly. Bisiach and Luzzatti showed that the same effect that occurred to directly viewed scenes also applied to views established in working memory by recollection from long-term memory (Bisiach & Luzzatti, 1978).

To be included in the spatial image, spatial information does not have to be perceived visually, other forms of perception (e.g. touch, language) are also valid forms of input for the spatial working memory. Even more, after being established in working memory, information is amodal, meaning its quality does not depend on the form of input it was received from (Loomis, Klatzky & Giudice, 2013). Generally, while wayfinding in an at least somewhat familiar environment, the spatial image will be comprised of both information from long-term memory and current perceptional input, with the proportion of information stemming from allocentric memory being dependent on familiarity of the place, besides other factors (Burgess, 2006).

The spatial image helps us to keep a continuous and sufficiently detailed view of the outside world, even though by far not all of the available information can be processed by our sensory system. To this effect, the detail of the representation will be lower, the higher the movement perceived trough e.g. visual input is, and vice versa. This way, it enables precise enough actions not just while being static but also while moving (Tatler & Land, 2011; Land 2014).

1.3 Spatial Updating and Navigation

Since the spatial image is egocentric, it will be updated according to a person's position, heading and viewing direction, meaning the mental image of one's surroundings in working memory is relative to these factors. This process is called "spatial updating". Like the existence of the spatial image itself, spatial updating can be accomplished with information taken from allocentric long-term memory or through perceptional input (Röhrich, Hardiess & Mallot, 2014). A study by Farrell and Robertson showed that spatial updating is an unconscious process that happens automatically, and that trying to ignore it requires a conscious effort of undoing the updating, which results in longer reaction times and a higher rate of error in experiments (Farrell & Robertson, 1998).

It is notable that spatial updating is separated for environments of a different order. Wang and Brockmole, for instance, found out that while changing of position in a superordinate environment like a university campus leads to spatial updating of a person's perspective relative to both the campus and to objects in a room within the campus, this is not the case vice versa (Wang & Brockmole, 2003). This phenomenon of course requires that the mental representation of space is split up into different parts which may be differing in size by orders of magnitude or be nested into one another. Many models of this partition of space have been proposed over the years, for instance by Montello which divides objects and environments by their size relative to the onlooker into figural space, vista space, environmental space and geographical space (Montello 1993). Mallot and Basten state that there exists a hierarchy in which a (mental) map consists of several routes, which in turn consist of several locations, though this hierarchy is not necessarily followed in all situations, e.g. learning a route by studying a map (Mallot & Basten, 2009).

Generally consented on is the theory that besides places and the connections between them, there are also superordinate regions encoded in spatial memory, whose contents can consist of a variable number of locations. These regions even play a role in route-planning and subsequent navigation, as, when having to traverse region borders, a subject will mostly choose the path that crosses the border the fastest, even when there are several routes that have the same distance from start to destination (Wiener & Mallot, 2003; Mallot & Basten 2009). This so-called "fine-to-coarse-model" also states that locations close to the navigator will be represented with more spatial detail than ones further away to facilitate precise navigation while still conserving memory space, hence the model's name. For navigation per se, many different strategies are used, often simultaneously, and many of these strategies humans share with animals, examples being path integration, perspectival place representation and reorientation via landscape geometry (Wang & Spelke, 2002). This is not surprising, since also the working memory itself appears to be of a similar organization for humans and apes, if not all mammals, and important factors like capacity and storage time of information are thought to be alike, though there are other differences (Carruthers, 2013). Like the spatial image it relies upon, precise navigation is possible by many means of perception, not just visual. Even though it often seems as if visual input or at least some form of visual experience in the past would be needed for proper understanding of space and therefore good navigational skills, experiments show that this is not necessarily the case, at least for path integration (Loomis, Klatzky, Golledge, Cicinelli, Pellegrino, et al, 1993). On a neural basis, wayfinding is managed by the precuneus, the posterior parietal cortex and the parahippocampus, besides others. An important part is also played by the hippocampus which links to the mental map and thus enables precise navigation in the first place. Simple route-following, on the other hand, requires the insula and several cortices to function properly (Hartley, Maguire, Spiers & Burgess, 2003).

1.4 Aim of the study

While sensory input and other forms of perception are crucial for correct orientation and navigation especially in new environments, the retrieval of stored spatial information from long-term memory is just as important for familiar surroundings, even moreso for route-planning. Considering this, many parts of the interaction between working and long-term memory are still pretty unclear. It is known that both interact to the cause of creating, maintaining and updating the spatial image situated in spatial working memory (Giudice, Klatzky, Bennett & Loomis, 2013; Burgess, 2006), and that the parieto-occipital sulcus and the retrosplenial cortex facilitate these processes (Lambrey, Doeller, Berthoz & Burgess, 2012). One of the questions that remain is, when people envision a location which they are not currently at, under what circumstances will the mental image be of an allocentric nature, i.e. be independent from the person's current location and body orientation, and under what circumstances will it be egocentric, i.e. be related to these factors. This is in so far important as the mental image of a further away place can be used in path planning when going to or passing through that location, and thus help facilitate precise navigation later on (Basten, Meilinger & Mallot, 2012). A complete understanding of this phenomenon may hence not only help understand the interaction between spatial working and long-term memory better, but also the more practical skill of planning a route.

In a recently published study by Basten, Meilinger and Mallot, it was tested whether prior mental activation of the stored spatial memory of a familiar place influenced the projection of it in working memory (Basten, Meilinger & Mallot, 2012). For this, passersby were asked to draw sketch maps of familiar places either with or without prior mental travel through it. The maps of most people who mentally travelled prior to drawing showed the place along the direction of the travelled path. The result clearly indicates that activation of a place memory, even if the activation is just imaginary like a mental walk through said place, changes the representation of it, that is, the direction from which the location is displayed in working memory. A second study in this field was conducted by Röhrich, Hardiess and Mallot. Again, passersby were asked to draw maps of familiar places, which were for this experiment either just a few hundred meters or some kilometers away, with no mental travel involved. Here, it is noticeable that the sketches drawn a few kilometers away show no significant tendency to be oriented from or towards the places where they had been drawn or of being influenced by the drawing location in any other way. The maps sketched only a short distance away, on the other hand, are mostly drawn from a perspective as if approaching the sketched location from where the drawing takes place. This suggests that not only mental activation, but also physical proximity can prime a spatial representation to become egocentric (Röhrich, Hardiess & Mallot, 2014).

The objective of this current study is to extend the knowledge about the mental activation of locations gained in the two studies cited above. Since virtual reality (VR) has become an important and common tool for scientific research in the field of cognitive neuroscience over the past years, it is vital to know if mental processes and other findings observed in reality-based studies also apply when in VR. To this purpose, an experiment was conducted in with an Oculus RIFT head mounted display. It was tested whether the priming of imagined places observed in the studies above also occurs while persons are situated in an abstracted virtual replica of a real environment and are given indirect cues pertaining to the location that is to be imagined. The objective here was to determine if proximity to a location in a virtual environment, when combined with an only weak cue about said target location, is enough to prime the mental image of it, like it happens through mental travel or spatial proximity in the real world.

2. Methods

2.1 A Pre-experiment

Before the actual study was conducted, a pre-experiment was held to determine whether only virtual proximity to a location is sufficient to prime the mental representation enough that imagination of that place would depend on the place displayed before. For this, panorama photos were taken of five well-known places in and around the city center of the town of Tübingen, Germany. The locations were the following:

1. The Europaplatz ("Europe Square"): A large square in front of the main station which also houses the main bus station of Tübingen
2. The Neckarbrücke ("Neckar Bridge"): The most prominent bridge over the Neckar, a major river flowing through Tübingen
3. The Holzmarkt ("Timber Market"): A well-known square in front of a large church in the old city of Tübingen
4. The Marktplatz ("Market Place"): A large square in front of the old town hall
5. The Krumme Brücke ("Crooked Bridge"): A bridge over a creek at a small square in the old city of Tübingen

For a layout of the general area as well as the conjunctions of the used locations, as well as the ones used in the main study, a map has been provided in figure 5 in chapter 2.2. From each of the places, pictures were taken in a panoramic manner using a Canon Power Shot G7 camera fixated on a tripod. For every panorama, twelve pictures were taken each with a horizontal angular deviation of 30° to the next one, making it a total 360° panorama. Both panoramas at daytime and at nighttime were shot for each of the locations, with the daytime photos on more or less cloudy days to reduce problems like lens flare, reflections and misguiding shadows, among others. The photos were stitched together and cut into shape using Microsoft Image Composite Editor, the results to be seen in figure 2. To display the finished panoramas on the Oculus RIFT head mounted display, they were uploaded to it by running a C#-code, previously available in this work group, using the program Unity. Since the shots were only panoramic and not spherical, the “ceiling” and “floor”, which would be black by default, were also covered by an appropriate pattern to make the scene look more natural, i.e a gray stone pattern for the ground and a cloudy sky/ starry night pattern for the top of the day/ night panoramas.

Figure 2: The finished panoramas loaded to the head-mounted display and used in the pre-experiment. From top to bottom, pairwise day and night: Europaplatz, Neckarbrücke, Holzmarkt, Marktplatz and Krumme Brücke.

The pre-experiment was carried out in an available office at the laboratory for cognitive neuroscience of the University of Tübingen. There were six test subjects in total, all members of the University of Tübingen. All participated voluntarily and were chosen because of the good knowledge they had of the layout of the old city center. The participants were either seated in a rotating chair or allowed to keep standing, according to their preference. After putting on the head-mounted display, they were first introduced to each of the locations by first having the name displayed on a neutral background and then being "teleported" into the appropriate place. There, they were able to rotate freely in all directions to look around and become acquainted with the place, though no translational movement was possible within the panorama. An example of a typical view is given in figure 3b). After the participants stated to know all the locations and having familiarized with them enough, the experiment was started. They were transported into the panorama of the Marktplatz first and were able to look around like in the introduction phase. Then the display was changed to a neutral, brown-blue-colored background and the subjects were requested via displayed text to imagine another of the five places, an example to be seen in figure 3a). After they stated they were ready, the participants were then transported to the location named and had to turn until they saw the perspective they had previously imagined. The angular data at that point was recorded and the participant was again presented a text asking him/her to imagine the next location. The experiment continued in this fashion until data for all the possible combinations of locations (one imagination end point for each location while coming from every other location, 20 in total) was collected. Since this way each of the locations was shown several times, the initial perspective seen when "arriving" was changed by 90° clockwise each time the same location came up, as not to influence the perspective the subjects would imagine when thinking of that place. Additionally, a parallel timer was run to determine how long it would take for the participants to orient themselves in the different locations. After this the procedure was repeated in the same manner with the nighttime panoramas (see figure 3c).

a)

b)

c)

Figure 3: Examples from the subjects' view while using the head-mounted display. **a)** Instruction seen when transiting from one location to the next, in this case the Marktplatz. **b)** View from the panorama of the Marktplatz at daytime. **c)** View from the panorama of the Marktplatz at nighttime.

In this thesis, neither will all the results of the pre-experiment be shown nor will they be discussed in detail. The reason for this is the purely preparational nature of it. The pre-experiment was only used, as stated at the beginning of this chapter, to determine whether just virtual proximity to a location is sufficient to prime the mental representation enough that imagination of that place would depend on the place displayed before. In addition, it was helpful to optimize the paradigm of the main experiment. Because of this, the results will be presented here and not separately in the next chapter.

Both the angles of the chosen perspectives and the time taken to arrive at those perspectives were analyzed and graphic plots were produced for both using MATLAB. For the angular data, compass-plots were used to clarify the directions of the chosen views when comparing them to a map. For the time, simple plots were created by setting angular data against time. Typical examples for both a compass plot and a time plot are given in figure 4.

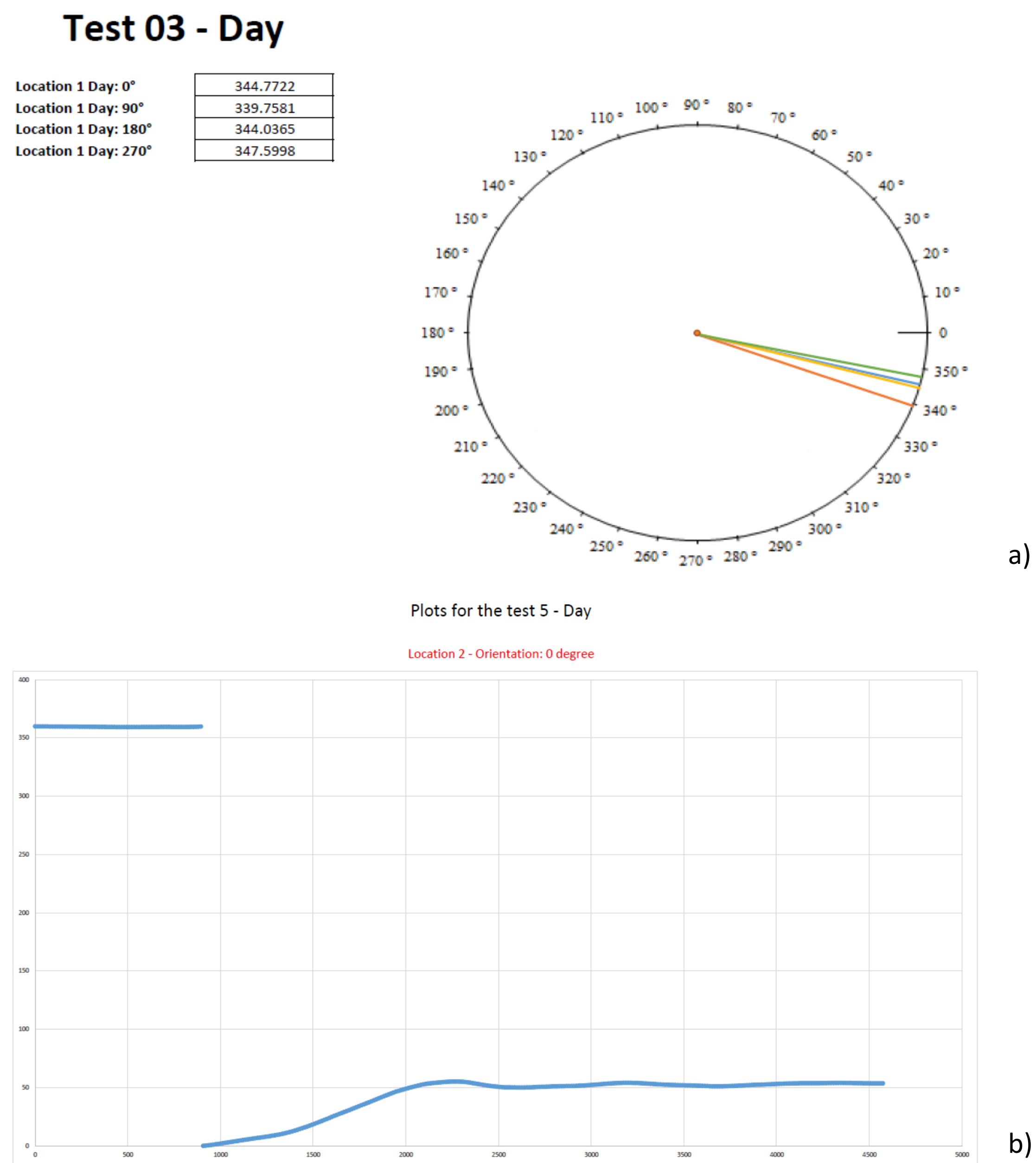


Figure 4: Examples of the plots produced for the pre-experiment. **a)** Compass-Plot of the chosen perspectives of test subject 3 when coming from the other locations to location 1 (Marktplatz). The angles next to the table equal the starting orientation and are also used to indicate the location visited previously to this place. The plot is turned so that up equals north. **b)** Plot of the angles against time taken of subject 5 in location 2 with initial orientation 0°, starting with transport there and ending when the desired perspective is recorded.

The results of this pre-experiment showed that there is no general effect on how one visualizes a location depending on the location previously virtually visited, at least not in this paradigm. Mostly, the participants always envisioned the same perspective of one location, regardless from where they imagined. There also was no systematic difference between the day and night trials. The time plots show that the time taken to orient oneself, though slightly different for each subject, generally decreased with the time spent in the experiment. It was not determined whether this was due to activation of the spatial knowledge about the places or due to getting used to handling the simulation.

From this pre-experiment was determined that more than just showing a virtual panorama of a proximate place is needed to prime the egocentric mental representation of a location. Furthermore, some of the parameters of the experimental paradigm were modified to enhance it, as seen in the next chapter.

2.2 Preparations

The first thing which was changed for the main study was the number of locations presented in the experiment, while three of the previously used were also replaced. Removed were the locations Europaplatz, Neckarbrücke and Krumme Brücke. This had several reasons. For Europaplatz and Krumme Brücke, the most direct way of access, and therefore the direction from which the places would be viewed if the assumed effect were to occur, is the same from all the other four places. Thus, even if there was an observable effect, it would not be recognizable in these locations since the perspectives would not differ from one another. In addition, the Europaplatz but also the Neckarbrücke were sites with strong motorized traffic, including almost all major public transit routes. Since most of the people in Tübingen, with which the study was to be conducted, use public transport, there would be a high chance of them being biased towards the perspective they would usually see when waiting for/ getting on/ off the bus. Also, both Europaplatz and Neckarbrücke are located some distance away from the other three places. This distance might not only mean a loss of the sought-after effect, since the other three places were all located within the old city center this could also lead to some unforeseen effects due to Europaplatz and Neckarbrücke being in another superordinate region, as explained in the introduction. Finally, the Krumme Brücke seemed to be comparatively less known than the other places, which, if kept, could lead to mistakes of the participants because of a faulty mental map.

For these reasons, the three locations were removed from the study and replaced by four new ones, all located in the old city center:

1. The Hafengasse (“Harbour Lane”): Actually the intersection of this street with another. Both streets are well-frequented and known.
2. The Hirschgasse (“Stag Lane”): A well-frequented street a bit further north in the old city.
3. The Hospizberg (“Hospice Hill”): An intersection of alleys and main access to the Tübingen castle.
4. The Neckargasse (“Neckar Lane”): The main alley leading out of the old city to the Neckarbrücke.

The panoramas of the four new places are shown in figure 5. All of the 6 places now in use were now close enough to each other to trigger the priming of the mental view observed by Röhrich, Hardiess & Mallot in their 2014 study, should such an effect occur in this paradigm. The photos for the new panoramas were taken and edited in the same manner and under the same conditions as for the old ones. Their form of appearance on the head mounted display was thus identical, since the parts of the C#-code relevant for the presentation were not changed either.

Figure 5: The finished panoramas of the new places loaded to the head-mounted display and used in main study. From top to bottom, pairwise day and night: Hafengasse, Hirschgasse, Hospizberg and Neckargasse.

For the locations Hafengasse, Hirschgasse and Neckargasse, the names actually pertain to the streets as a whole. Still, it was decided to use those names since the locations themselves do not have a designation on their own. While it would theoretically be possible to name the locations after a salient landmark (e.g. a well-frequented shop near the place), this could lead to an unwanted priming of the test subjects' representation of the place when hearing the name, and was thus refrained from. All of the six places used in the main study are supposedly located in one superordinate region (the old city center), and each of them has at least two possibilities to be reached directly from the other places. In figure 6, a map is shown with all locations used in the pre-experiment, the main study, or both.

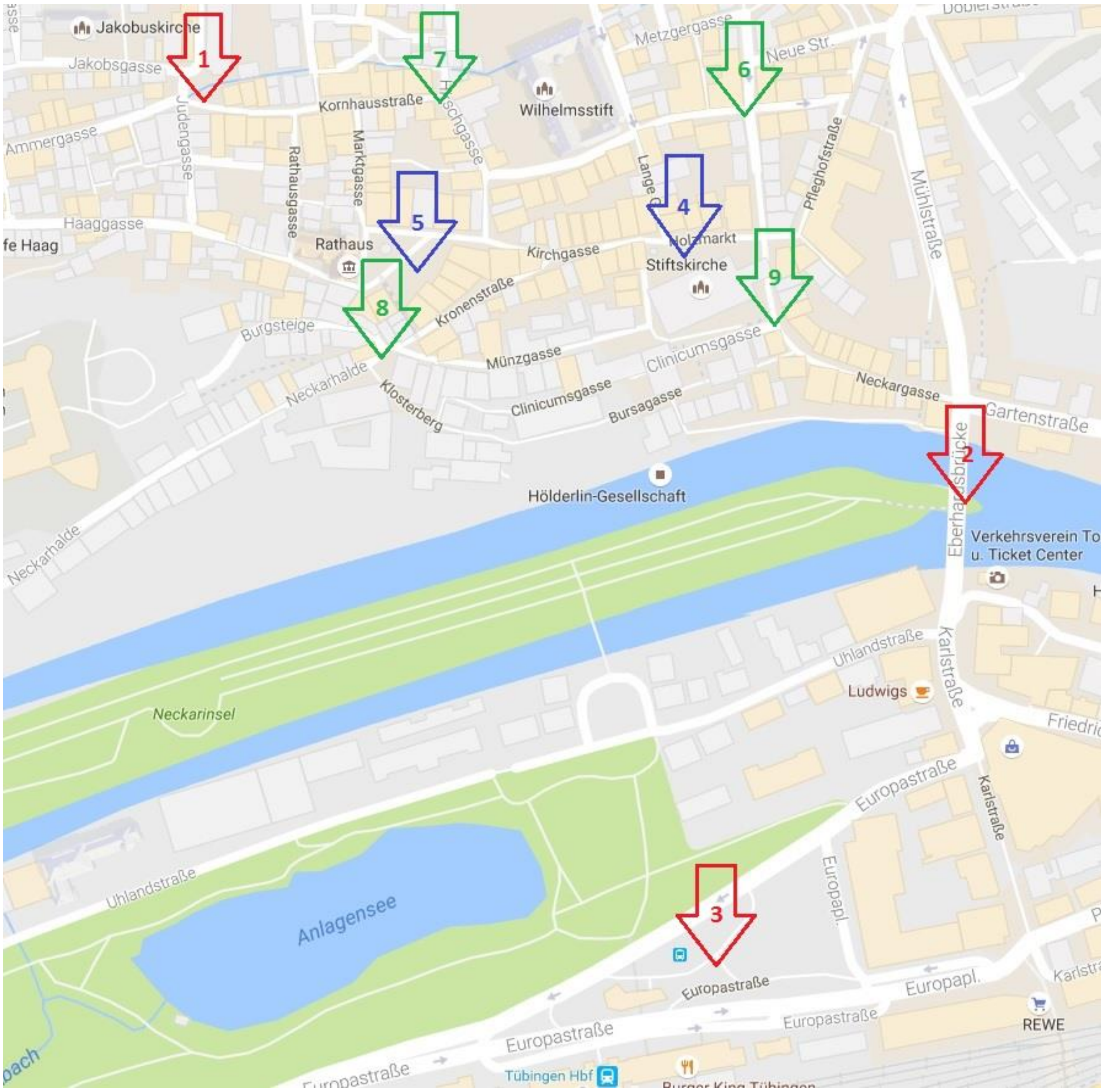


Figure 6: All locations utilized in the pre-experiment (red), the main study (green), or both (blue). The arrow tips indicate the places the panoramas are centered around. Locations by number: 1: Krumme Brücke; 2: Neckarbrücke; 3: Europaplatz; 4: Holzmarkt; 5: Marktplatz; 6: Hafengasse; 7: Hirschgasse; 8: Hospizberg; 9: Neckargasse. The map was taken from Google Maps and modified subsequently.

2.3 Conduction of the Study

In the main experiment, 24 participants, all of them members of the University of Tübingen, were tested. All participated voluntarily after having received an e-mail asking for subjects interested in the study, and all stated to have good spatial knowledge about the old city center of Tübingen. Every participant gave informed written consent to participating, having the data collected and the collected data being anonymized and used for scientific purposes. As compensation for the time spent, participants could choose between a monetary compensation of 8 Euro per hour or getting a certificate for the time spent as a test subject, though all chose the money. Both the participants and the testers were allowed to terminate the experiment at any point without giving a reason. The testers made use of this two times since the concerned test subjects didn't have enough spatial knowledge to make a meaningful contribution by participating. All participants also could request a break whenever they felt it to be necessary. The average duration of an experiment was approximately 40 minutes, though experiments took as short as 30 minutes or as long as 2 hours in some cases.

The study was carried out in the laboratory of the workgroup for cognitive neuroscience of the University of Tübingen. At the beginning of each experiment, participants were allowed to ask questions concerning the conduction. In case they did, the questions were answered as accurately as possible without risking to influence the experimental behavior of the participant. Questions about the aim of the study were not answered until after the experiment was finished. Participants were also asked if they had any previous experiences with using virtual reality and if they had any history of dizziness or nausea while in virtual environments, which all of them denied. They were then allowed to choose whether they wanted to sit on a rotating chair or stand during the experiment. Each experiment was divided into two parts, with each of them consisting of two tests, and the first part with two additional introduction runs. For the duration of the tests, the lights in the laboratory were turned off as to not interfere with the immersion in the virtual world, since the Oculus RIFT Development Kit 2 head-mounted display has openings in its casing through which exterior light would be able to enter. The instructions to the tests and introductions were written down prior to the start of the study, and subsequently read to each test subject to ensure a minimum of differences between the different participants. The instructions were written and read in English and were translated to German by the tester reading them when asked.

Each experiment started with the first introduction. Here, all six panoramas were shown to the participant with the name of the respective place shown centrally while in the panorama. The places' name would always be staying centered within the field of view, thus turning with it in front of the panoramic background. The subject was encouraged to turn around to become acquainted with the places and to remember which name pertains to which location. They could look around each location as long and as often as they wanted, until they found they were familiar enough with it. The instruction text read as follows:

"For the introduction, you will be shown panoramas of 6 places of the old city center of Tübingen. You will be able to rotate freely to become acquainted with the places and their names, which will be shown simultaneously with each respective location. Each location will be shown as often as you find it necessary to become acquainted with."

Following the first Introduction was the first part of the experiment. Here, subjects started in one location (the Marktplatz), and, when ready, were first instructed through text shown on the display to turn towards the exit they would take from where they were to get to another of the locations (whose name was also displayed), in the most direct way possible. This task was added after the pre-experiment for two reasons: firstly, it was to be an indirect cue pertaining to the place later to be imagined, and thus might be a factor priming the representation of said place. Secondly, it was used in the evaluation of the data to see if a subject had good enough spatial knowledge for their data to be considered. For this, see the results in chapter 3. The text giving the task was shown stationary within the field of view, hence moving with him when the participant turned, much as the place names in the introduction. The reason for giving instructions this way, as opposed to setting the text before a neutral background like in the pre-experiment, was to not break the immersion of the subjects "being" at the location they were currently shown. Like this, the simulation could be seen as more realistic, and therefore be more likely to trigger priming of imagination depending on physical proximity to the imagined place.

After having been given this task, the participants would indicate the direction they deemed best by turning towards it and notifying the tester, who would then record the angular data. Thereafter, the subjects would be instructed, again via text, to imagine themselves standing in the location they just chose the exit to, and to remember the first perspective that came to their mind. The text giving the new task was added beneath the old text, much as can be seen for an exemplary location in figure 7.

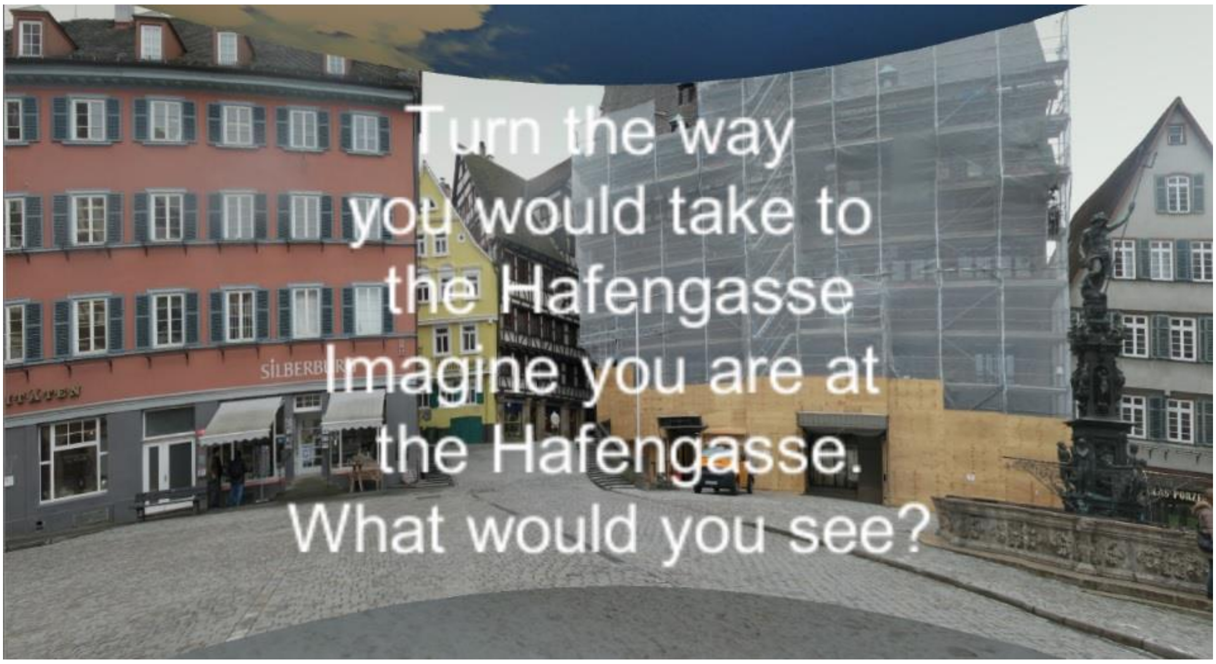


Figure 7: Exemplary subjects' perspective from inside the panorama of Marktplatz at daytime, with both the text for the first and second task given in test 1 and 2, as it would be seen after finishing turning towards an exit.

Being done imagining, the participants would be teleported to the according place where they were to indicate the perspective by turning and notifying the tester, with him recording it. These two tasks were repeated for all combinations of the six locations, in both directions each. The instructions read before this first part were the following:

"For the first part of the experiment, you will start in one of the locations. You will then be instructed via text on the display to think of the exit from this place you would take to get most directly to one of the other five places, whose name will also be displayed. You should then indicate the direction you thought of by turning towards it and telling us when you've reached the appropriate perspective. After this, you will be instructed via displayed text to imagine you are now standing at that next location and you should remember the very first view that comes to your mind. We will then transport you to that location, where you are supposed to indicate the imagined perspective by turning until you see it and then telling us. Then, the same procedure will be repeated from this place to another of the five places, and so on."

Next, both the introduction and the first part were repeated, now using the nighttime panoramas instead of the daytime ones. While the subjects already knew the places and their names, there was another introduction for nighttime for them to familiarize themselves with the differences in the surroundings during darkness. These first and second parts, at day- and nighttime respectively, constituted the part of the experiment referred to as “turning condition”. No changes were made between the test at daytime and the one at nighttime, thereby making comparisons between both results possible. This also resulted in only a short instruction:

“Introduction and first part of the experiment were first done for panoramas of the places at daytime, now we will repeat both with nighttime panoramas.”

In the next part of the experiment, also named “walking condition”, consisting of part 3 and 4 without introduction, a slightly differing paradigm was used. The participants started again in one panorama (Marktplatz). The task this time comprised of the subjects having to actively imagine walking to a named location, again, via the most direct way, and when arriving, imaging the perspective they would see upon arrival. The objective was again given by means of written text displayed onto the panorama participants were seeing. After being transported to the location, subjects were again to show what they imagined by turning, and the angle was again recorded. The idea here was to collect angles of the perspectives as they would be imagined if there was an effect of the previously visited place on the imagination, and therefore a sample of data the angles recorded in turning condition could be compared to. Like in part 1 and 2, the task was repeated for all combinations of locations in both directions, so 30 in total. Also like in the previous parts, this part was conducted for both daytime and nighttime panoramas, for both of which the written instruction was given together:

“In the second part of the experiment, you will again start in one of the six locations and will then be instructed via text to actively imagine walking to the location displayed in the text and then to imagine the appropriate perspective you would see when entering said place at the end of the walk. We will then transport you to that place where you should indicate the imagined perspective by turning until you see it and then telling us. This process will then be repeated from this location to another of the 5 other places and so on. After concluding this part of the experiment for daytime, we will also repeat it with the nighttime panoramas.”

Like in the pre-experiment, times were taken of the durations the test subjects spent in each of the places in each part, with marks at the points where angular data was recorded. These times will not be evaluated in this thesis and are meant for use in further study in this field. After all experiments of the study were completed, the collected angular data points were organized for use in the analysis.

3. Analysis and Results

3.1 Analysis of the Turning Directions

Data points recorded in this study were organized into three tables: The first one consists of the angles recorded for the subjects' turns towards the proper exit in the turning condition. The second and third contain the angles of the participants' imagined perspectives in turning and walking condition, respectively. The tables can be found in the appendix, chapter 5.1, tables A1-A3.

The first data to be analyzed were the angles of turning in the turning condition, because depending on how many errors were made by participants in this task, their data would be either included in the further analysis or removed due to insufficient spatial knowledge about the city center. For this, it was first determined, utilizing a map, which exits from one location to the others are considered valid. A graphical representation of this in form of a map is provided in figure 8.

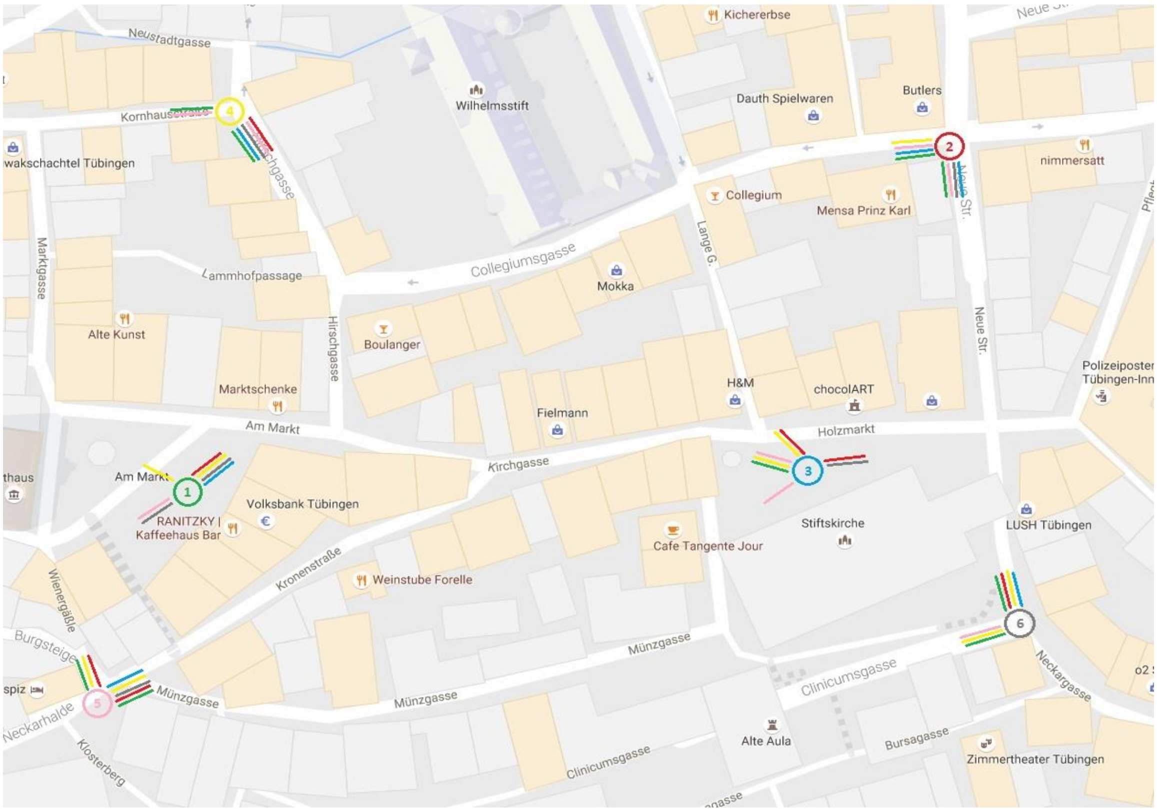


Figure 8: Valid perspectives for the turning task in turning condition. Locations by number: 1: Marktplatz (green); 2: Hafengasse (red); 3: Holzmarkt (blue); 4: Hirschgasse (yellow); 5: Hospizberg (pink); 6: Neckargasse (grey). The colored lines show the valid directions when looking for the exit to the place the line is colored for.

Directional compass plots of the turning end points were drawn using MATLAB (for the specific MATLAB-code see appendix chapter 5.2, figure A1) for each subject for every location both day and night. For the fitting angle of these plots to be equal to north, and thus the plots themselves to be properly aligned to north, the panoramas were viewed on the head-mounted display and, via comparison to a map, the right angles pointing north were recorded. The procedure was then repeated with the nighttime panoramas. This was necessary because the photos of the panoramas at day and night were shot starting from a different perspective, resulting in a different angle equaling north. Both for day and night, the angles indicating north can be found in table 1.

Table 1: Angles equaling north for all locations for daytime and nighttime panoramas.

Location	Marktplatz	Hafengasse	Holzmarkt	Hirschgasse	Hospizberg	Neckargasse
Angle for North Daytime	70°	123°	246°	285°	97°	208°
Angle for North Nighttime	248°	115°	52°	255°	290°	217°

The angular data themselves were not changed according to where north is, instead, the produced plots were turned accordingly. Since the number of plots is overly high to include all of them in this thesis, only 2 examples are provided in figure 9. The entirety of plots can be provided electronically when demanded so. By visual comparison of the map in figure 8 and the plots produced for the turning directions, it was determined how many errors were made by the participants for turning in both day and night. An error was counted when a turning perspective differed significantly from the direction or directions considered valid, as shown on the map. This is the case for turning end points facing an exit in a wrong (e.g. the opposite of the goal point) direction or directly facing a house front.

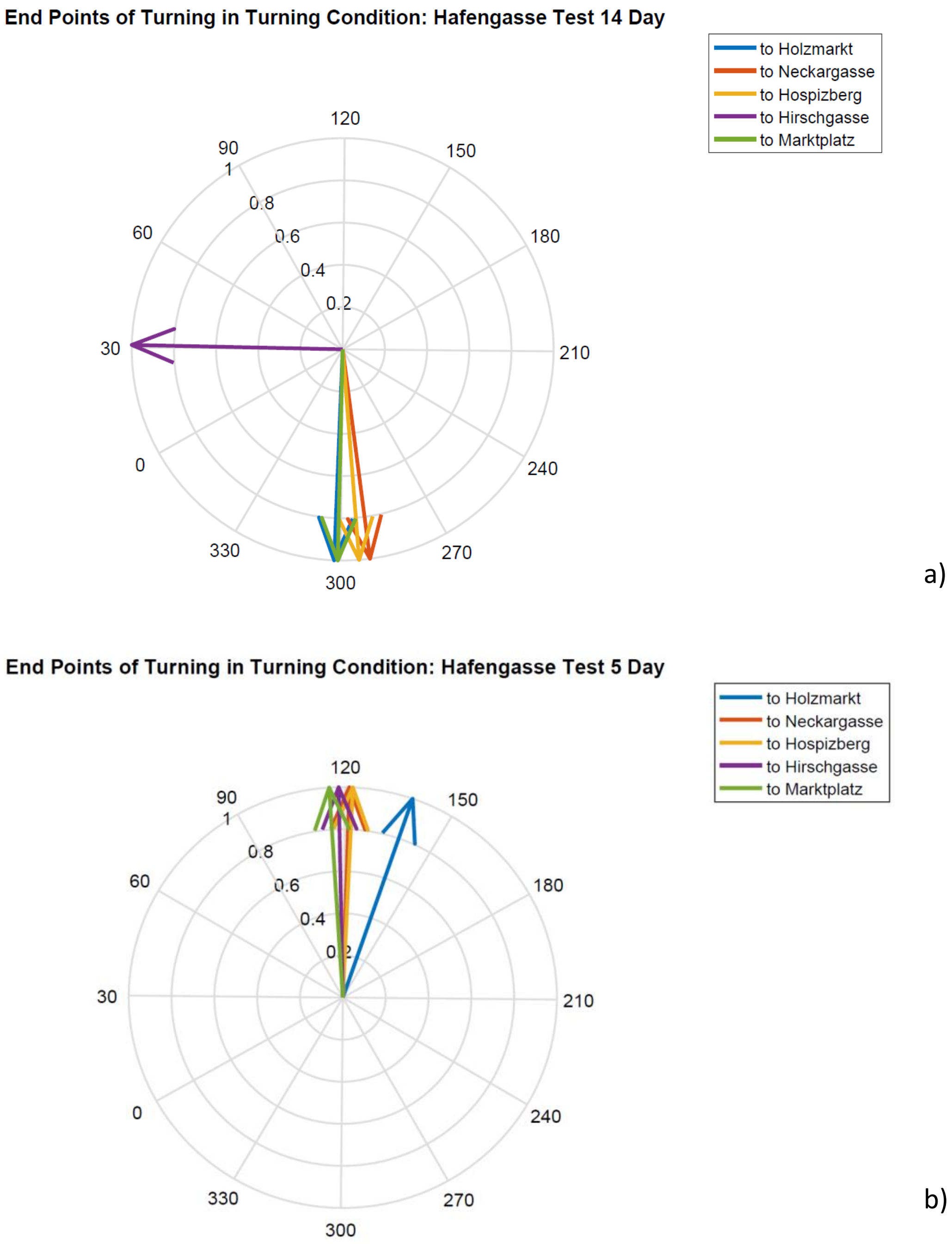


Figure 9: Examples of the compass-plots produced for the turning end points, top equals north. a) End points at Hafengasse at daytime for subject 14. Clearly visible when compared to the map in figure 8 (colors do not match!), all of the turned directions can be considered correct. b) End points at Hafengasse at daytime for subject 5. Here, none of the given directions can be considered correct.

The errors were added up for each participant for day and night and are shown in table 2. As can be seen, error rate is generally low, which implies an overall good spatial knowledge about the concerned region. The criteria for a subjects' data to be included was for him/her to have less than 5 errors in both the day- and nighttime turning task. All but subjects number 5 and 12 pass these criteria, with subject no. 5 failing at both the day and night task with 11 and 9 errors respectively and subject no. 12 failing at the night task with 6 errors. Following this, the data obtained from these two subjects was not used in further analysis.

Table 2: Number of errors made by subjects in the turning task, separated for day and night. Subjects whose data were not used in the analysis are highlighted in red, all others in green.

Subject No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Day	0	2	1	2	11	0	1	2	0	1	3	4	1	0	1	2	0	1	2	0	1	2
Night	0	3	2	4	9	0	1	2	0	1	4	6	1	1	1	2	2	1	1	1	0	2

In addition to checking the number of errors per individual, a two-tailed Fisher-Yates-Test was conducted, comparing the sums of errors over all participants for day and night, numbering 37 and 44, respectively. No significant difference was found, neither at level $\alpha=0.05$ nor at $\alpha=0.10$.

3.2 Examination of the Imagination End Points

Additional to the directed compass plots produced for the turning end points, the same kind of plots were made for the end points of the imagined perspectives in both the turning condition and the walking condition. They were constructed identically to the turning plots shown in figure 9, using the same MATLAB code. These plots, however were not used for a direct analysis of the affiliated data, but rather for better visualization and to get a good overview over this large amount of information. For this reason and because, like with the previous plots, the number is too high to be directly included into this thesis in a reasonable form, they will not be added to this work, but can be given in electronic form if requested.

The main goal of this study was to compare the directions imagined of the turning condition on the one side and the walking condition on the other, and thus find out if there is a high similarity between them, which in turn would suggest an effect of the place a person is virtually located in on the imagination of the other. Firstly though, the imagination end point data were analyzed separately for the two conditions.

For the main comparison of the study, the imagined views of the walking condition were to be used as a “ground truth” the viewing directions of the imagination in turning condition were to be compared to, since in the walking condition, subjects were explicitly asked to turn the direction they would see when coming from the previous location. However, there were still errors to be found in the results of the imagination of the walking condition, since sometimes participants had the wrong idea about which way is the most direct from one location to the other, among other possible causes. For these errors to not distort the data vital for the analysis of the experiments, they were removed. For that, the tester repeated the first part of the experiment while simultaneously comparing their field of view with a map of the area, only recording the viewing directions for the “imagined” perspectives. This way, the angular data logged for each place coming from the other locations showed the appropriate direction very precisely, and could thus be used to determine the wrong angles among the data collected for the walking condition. The newly recorded angles were then also calculated for the nighttime panoramas. These correct angles for day and night can be seen in table 3.

Table 3: Proper view angles for the walking condition as determined by the tester. Different possibilities are feasible for some connections.

	Possibility 1	**Possibility 2**	**Possibility 3**
Marktplatz Day: from Neckargasse	320,49°	91,24°	
Marktplatz Day: from Hirschgasse	320,49°		218,21°
Marktplatz Day: from Hospizberg		91,24°	
Marktplatz Day: from Hafengasse	320,49°		
Marktplatz Day: from Holzmarkt	320,49°		
Marktplatz Night: from Neckargasse	138,49°	269,24°	
Marktplatz Night: from Hirschgasse	138,49°		36,21°
Marktplatz Night: from Hospizberg		269,24°	
Marktplatz Night: from Hafengasse	138,49°		
Marktplatz Night: from Holzmarkt	138,49°		
Hafengasse Day: from Marktplatz	123,32°	192,62°	
Hafengasse Day: from Holzmarkt	123,32°	192,62°	
Hafengasse Day: from Hirschgasse		192,62°	
Hafengasse Day: from Neckargasse	123,32°		
Hafengasse Day: from Hospizberg	123,32°	192,62°	
Hafengasse Night: from Marktplatz	115,32°	184,62°	
Hafengasse Night: from Holzmarkt	115,32°	184,62°	

Hafengasse Night: from Hirschgasse		184,62°	
Hafengasse Night: from Neckargasse	115,32°		
Hafengasse Night: from Hospizberg	115,32°	184,62°	
Holzmarkt Day: from Hafengasse	130,27°	19,68°	
Holzmarkt Day: from Neckargasse	130,27°		
Holzmarkt Day: from Hospizberg			320,48°
Holzmarkt Day: from Hirschgasse		19,68°	320,48°
Holzmarkt Day: from Marktplatz			320,48°
Holzmarkt Night: from Hafengasse	296,27°	185,68°	
Holzmarkt Night: from Neckargasse	296,27°		
Holzmarkt Night: from Hospizberg			126,48°
Holzmarkt Night: from Hirschgasse		185,68°	126,48°
Holzmarkt Night: from Marktplatz			126,48°
Hirschgasse Day: from Holzmarkt	257,91°		
Hirschgasse Day: from Hospizberg	257,91°	359,22°	
Hirschgasse Day: from Neckargasse	257,91°		
Hirschgasse Day: from Hafengasse	257,91°		
Hirschgasse Day: from Marktplatz	257,91°	359,22°	
Hirschgasse Night: from Holzmarkt	227,91°		
Hirschgasse Night: from Hospizberg	227,91°	329,22°	
Hirschgasse Night: from Neckargasse	227,91°		
Hirschgasse Night: from Hafengasse	227,91°		
Hirschgasse Night: from Marktplatz	227,91°	329,22°	
Hospizberg Day: from Hirschgasse	279,01°	338,28°	
Hospizberg Day: from Marktplatz	279,01°	338,28°	
Hospizberg Day: from Hafengasse		338,28°	
Hospizberg Day: from Holzmarkt		338,28°	
Hospizberg Day: from Neckargasse		338,28°	
Hospizberg Night: from Hirschgasse	112,01°	171,28°	
Hospizberg Night: from Marktplatz	112,01°	171,28°	
Hospizberg Night: from Hafengasse		171,28°	
Hospizberg Night: from Holzmarkt		171,28°	
Hospizberg Night: from Neckargasse		171,28°	
Neckargasse Day: from Hospizberg	280,71°	358,32°	
Neckargasse Day: from Hafengasse		358,32°	
Neckargasse Day: from Holzmarkt		358,32°	
Neckargasse Day: from Marktplatz	280,71°	358,32°	
Neckargasse Day: from Hirschgasse		358,32°	
Neckargasse Night: from Hospizberg	289,71°	7,32°	
Neckargasse Night: from Hafengasse		7,32°	
Neckargasse Night: from Holzmarkt		7,32°	
Neckargasse Night: from Marktplatz	289,71°	7,32°	
Neckargasse Night: from Hirschgasse		7,32°	

After the determination of the correct angles, it was calculated which of the view-angles for the walking condition recorded in the tests were to be considered wrong. Each angle deviating more than 35 degrees from the correct one, or correct ones in case of multiple possibilities, was labeled as wrongly directed. Which exact decisions of which participant for which connection of places was labeled as such, can be seen in the table for the data for imagination in the walking condition in the appendix (chapter 5.1, table A3). It was then compared how many directions were misjudged between day and night and in the different locations. This comparison is shown in table 4. A two-tailed Fisher-Yates-Test was performed for the sums of errors at day and night, and revealed no significant difference between them at $\alpha=0.05$ or 0.10.

Table 4: Sums of errors for the imagination in walking condition for every location at day and night, sums over day and night and sums over the locations, and grand sum.

Location	Marktplatz	Hafengasse	Holzmarkt	Hirschgasse	Hospizberg	Neckargasse	Sum for Locations
Day	27	10	12	20	24	2	**95**
Night	39	13	10	18	17	0	**97**
Sum of day & night	**66**	**23**	**22**	**38**	**41**	**2**	**192**

A second comparison was done for the errors of the imagined directions in walking condition. This time, not the errors for each place were counted, but for each connection of locations, i.e. for each place while coming from one of the other places. Additionally, the metric distance of the most direct routes connecting the locations was determined using the wayfinding option of Google Maps. The distance calculated there was also corrected by a small margin if needed, for the used program sometimes did not use the most direct path in more open spaces. Determining this distance was also possible for place connections with multiple accepted routes, since these routes had to have about the same length to be both considered correct. It is to be noted that per connection, there were two sums of errors, one for the imagination of one place while at the other one, and one vice versa. The purpose was to compare the errors made while imagining the locations while coming from each of the other locations to the distance between them to see if it has an effect on the error rate. A table with the herefore collected data is provided as table 5 below. An additional graph model was created to visualize the results, schematically showing the connections between the locations, the sum of errors in each direction for these connections and the affiliated distance. It can be seen in figure 10.

Table 5: Errors for the imagination of the 6 locations while being in each of the other location, and distances in meters for the connections. Note that every distance is found at least twice, as errors were counted for both ways of a connection.

	Errors	Distance
Marktplatz: from Neckargasse	10	260 m
Marktplatz: from Hirschgasse	13	150 m
Marktplatz: from Hospizberg	20	80 m
Marktplatz: from Hafengasse	11	260 m
Marktplatz: from Holzmarkt	12	160 m
Hafengasse: from Marktplatz	2	260 m
Hafengasse: from Holzmarkt	1	130 m
Hafengasse: from Hirschgasse	12	210 m
Hafengasse: from Neckargasse	4	130 m
Hafengasse: from Hospizberg	4	300 m
Holzmarkt: from Hafengasse	2	130 m
Holzmarkt: from Neckargasse	3	90 m
Holzmarkt: from Hospizberg	5	200 m
Holzmarkt: from Hirschgasse	10	210 m
Holzmarkt: from Marktplatz	2	160 m
Hirschgasse: from Holzmarkt	8	210 m
Hirschgasse: from Hospizberg	2	200 m
Hirschgasse: from Neckargasse	5	300 m
Hirschgasse: from Hafengasse	15	210 m
Hirschgasse: from Marktplatz	8	150 m
Hospizberg: from Hirschgasse	6	200 m
Hospizberg: from Marktplatz	6	80 m
Hospizberg: from Hafengasse	8	300 m
Hospizberg: from Holzmarkt	13	200 m
Hospizberg: from Neckargasse	8	250 m
Neckargasse: from Hospizberg	1	250 m
Neckargasse: from Hafengasse	0	130 m
Neckargasse: from Holzmarkt	0	90 m
Neckargasse: from Marktplatz	1	260 m
Neckargasse: from Hirschgasse	0	300 m

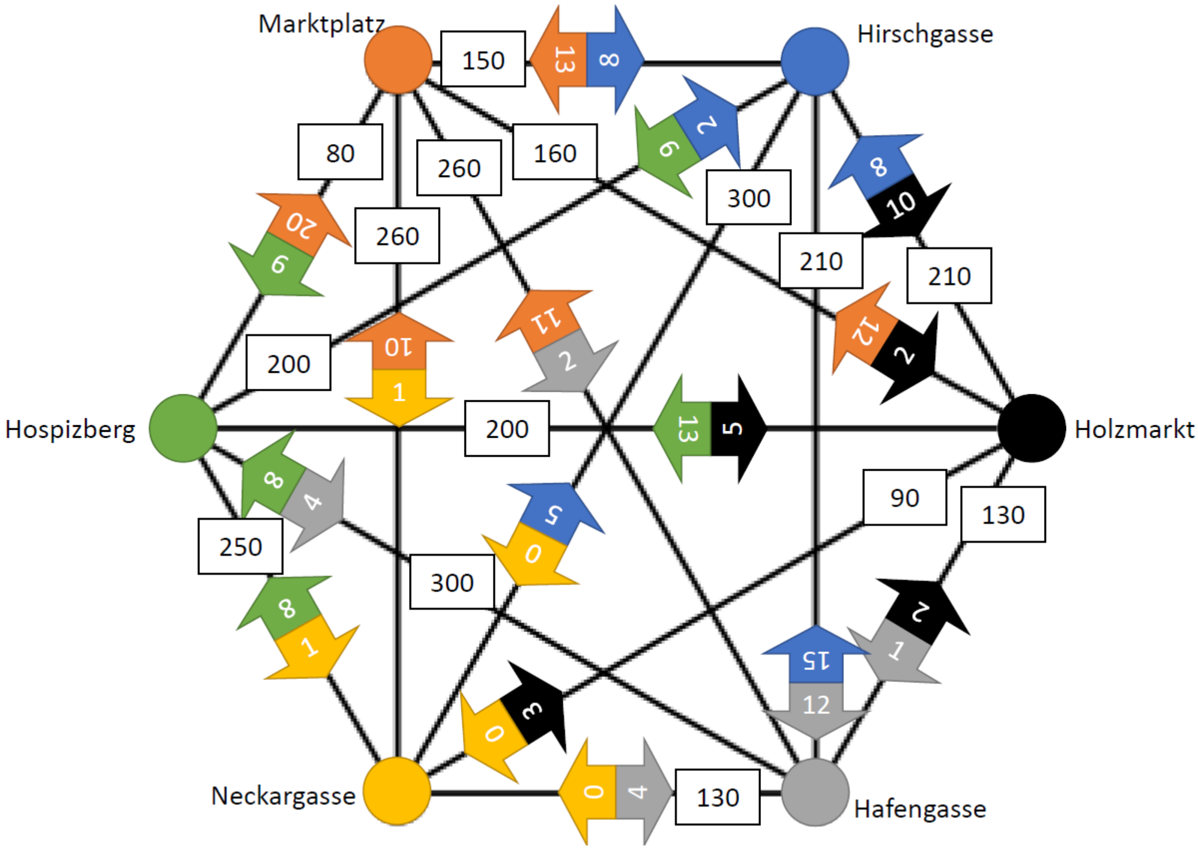


Figure 10: Graph model of the 6 locations and their connections. Distances of the connections in meters are shown in the white boxes. In the colored arrows the total number of errors summed up over all participants imagining one location (indicated by the color) while in another place are shown.

As previously stated, there are from some locations to others several equally long routes, and thus often more than one valid viewing direction in the walking condition. To find out if the same view angles, and hence the same routes are imagined at day and night, the angular data of day- and nighttime were compared for each separate subject. The angles calculated as wrong in the previous comparison with the determined correct angles were not included. Summed up over all subjects, out of 184 chances for different valid views at day and night, 23 times a different perspective was imagined. The results for each subject are shown in table 6.

Table 6: Number of times with different views for day and night out of the number of times where different views are possible. Note that the number of possible different views differs from subject to subject since only data deemed close enough to the correct angles were included, whose numbers vary between the subjects.

Subject #	**1**	**2**	**3**	**4**	**6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
# of possibly different views for day and night	7	9	11	6	10	10	7	11	9	7	11	8	11	10	11	10	10	9	9	8
# of times with different views for day and night	3	0	2	2	2	1	2	3	0	0	0	1	0	0	4	0	0	1	1	1

For the directions of imagined view recorded for the turning condition, it was analyzed in how many of the locations all the imagined views are clustered together, i.e. facing about the same angular direction. This, like it was often the case in the pre-experiment, would imply that the test subjects, rather than having their mental view depending on the location they are in, would always imagine a certain view, e.g. a strongly salient landmark. It is to be noted though, that in 3 of the 6 locations, namely the Hirschgasse, Hospizberg and Neckargasse, a clustering of all views would be perfectly explainable if clustered in the right direction even if the views were to be influenced by the location the imagination took place in, since it is possible to approach these places through one way coming from all the other places. It was determined for which clusters this was the case. Furthermore, it was also looked at how many of the clusters found were directed the same direction for day and night or respectively, how many occurred only for day- or nighttime. The results, including sums, can be seen in table 7. A one-tailed Fisher-Yates-Test was conducted for the 35 cases of identical clusters between day and night out of 85 total possibilities (100 clusters minus 15 at only either day or night). The result shows no significant difference between the number of cases of identical clusters and the number of cases of different clusters at $\alpha=0.05$, albeit it does so at $\alpha=0.10$.

Table 7: Number of clusters for imagined perspectives in the turning condition, number of these clusters in the right direction to be compatible with the idea of a primed imagination, number of clusters with identical direction at day and night, and number of clusters to be found only at either day or night. The data are sorted by test subject, and sums are shown.

Subject #	**1**	**2**	**3**	**4**	**6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**Sum**
# of Clusters	0	11	2	10	0	6	0	0	11	12	12	11	5	1	0	4	10	1	4	0	100
# of Clusters Comatible with Priming	0	3	0	3	0	0	0	0	0	2	0	2	5	0	0	2	0	0	3	0	20
# of identical Clusters for Day & Night	0	2	0	1	0	2	0	0	5	6	6	3	2	0	0	2	5	0	1	0	35
# of Clusters at only Day or Night	0	1	2	2	0	2	0	0	1	0	0	1	1	1	0	0	1	1	2	0	15

Finally, another batch of compass plots was produced for the imagination perspectives in both turning and walking condition for both day and night. In these directed plots, the imagined view angles of all participants for each configuration of places were shown together. This, though not constituting a direct analysis of the test results, greatly helped visualizing how clustered or spread out the perspectives of the different subjects are for the imagination of a location while coming from another. Additional to the view angles themselves, the vector means of all angles from a plot were calculated and inserted into the appropriate plot. These "pair-means" were calculated using the formula $p_{ij} = tan^{-1} * (\frac{1}{k} * \sum_k \frac{\cos(\alpha_{ijk})}{\sin(\alpha_{ijk})})$, with i being the location where the imagination took place, j being the location imagined, k being the test subject, α being the view angle for one configuration of i, j, and k and p being the vector mean of the combination of i and j. This was done for both turning and walking condition. In the walking condition however, only the data determined as close enough to the angles previously determined correct by the testers (see table 3) were used in the plotting of the angles themselves and in the calculation of the vector means. For only the walking condition plots, the correct angles were also inserted into the according plots. The MATLAB code to produce these plots is provided in the appendix, chapter 5.2, figure A2 and A3. As with the compass plots previously produced, the plots drawn here are also too numerous to be reasonably included in the written form of this thesis, and can be requested in electronic form.

Two exemplary plots, one of the viewpoints in turning condition and one in walking condition can be found in figure 11.

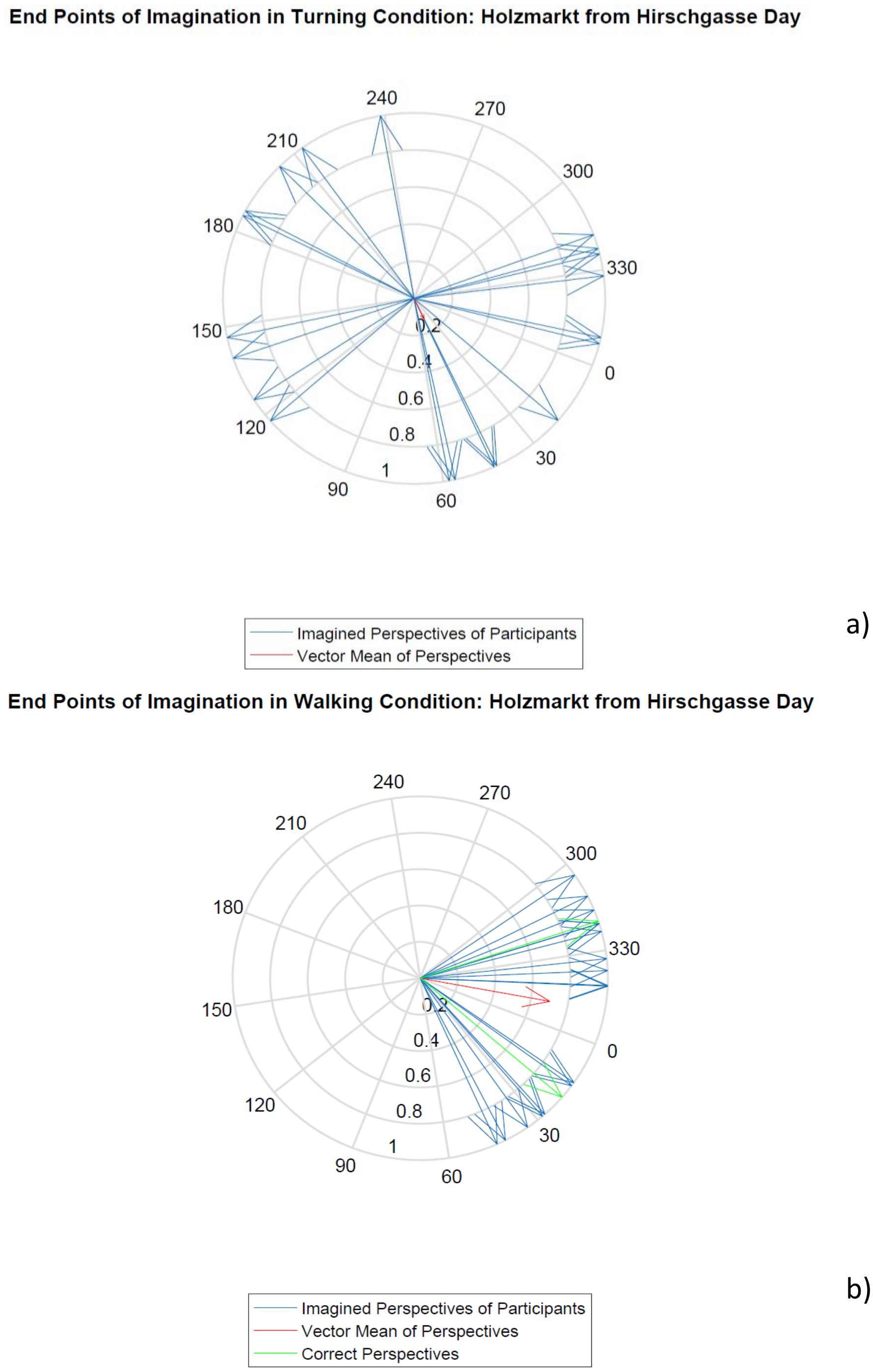


Figure 11: Examples of the compass-plots produced for the imagination end points, summed up by place of imagination and place imagined. Top equals north. a) Plot for the imagination of Holzmarkt from Hirschgasse in turning condition. The directions are spread out noticeably. b) Plot for the imagination of Holzmarkt from Hirschgasse in walking condition. The views are bundled into two directions along the correct angles, since the three wrongly aligned views have been removed.

3.3 Comparison of Imagination in Turning and Walking Condition

To actually compare the imagined views of turning condition and the imagined and corrected views of walking condition to one another, a statistical test was needed. Chosen was the V-Test, a modified version of the Rayleigh-Test. The idea of this test is to compare a sample of angular data to one theoretical angular direction to check if the sample is mainly oriented in the same direction as the set angle.

First, 60 V-Tests were conducted, one test for each imagination of a location while being in another one, for both day and night trials summed up over all of the 20 participants whose data is considered valid. As the data sample, the recorded angles of the imagination in turning condition were used. The theoretical direction against which the sample was tested was calculated by forming the mean angle of the imagined directions in walking condition for the same conjecture of locations. Naturally, only the angles which passed as close enough to the determined correct angle were used to form the mean. The Null Hypothesis which was tested stated that the data sample, i.e. the imagined views in turning condition, is not mainly oriented in the direction of the theoretical angle, i.e. the imagined views in walking condition. This could mean that the turning condition views would either be randomly distributed or clustered in another direction than the mean angle of the walking condition views. The alternative Hypothesis thus stated the sample data to be oriented in the direction of the mean angle from walking condition.

The test statistic in the V-Test is named u and calculated as follows: $u = \sqrt{2 * n} * v$,with n being the amount of single data points in the sample, and v being again calculated with $v = r * \cos(\bar{\varphi} - \theta_0)$. Here, r is the length of the vector mean of the sample vectors, and $\bar{\varphi}$ it's angle. Both had already been calculated for the drawing of the plots of imagination in turning condition in chapter 3.2. Finally, θ_0 is the theoretical angle the data sample was tested against. For each of the 60 modalities the test statistic u was calculated with MATLAB, the code to be found in the appendix chapter 5.2, figure A2. The u-values were then compared to the values u would take in case the Null Hypothesis was correct, called u(α), on the levels 0.05 and 0.10. The Null Hypothesis was rejected when u was greater than u(α). The affiliated u(α)-values can be found in “Circular Statistics in Biology”, along with a more in-depth explanation of the V-Test (Batschelet, 1981). The u-values and the test results on both significance levels, as well as the mean angle of the imagination in walking condition data each test was conducted with can be found in table 8.

Table 8: Results of the V-Tests with undivided means for imagination in walking condition: Mean angle of the views in walking condition the turning condition angles were tested against, the calculated u-values and the test results in significance levels 0.05 and 0.10.

	Mean Angle	u Value	Null Hypoth. on α=0,05	Null Hypoth. on α=0,10
Marktplatz Day: from Neckargasse	339,38°	4.4855	rejected	rejected
Marktplatz Day: from Hirschgasse	306,49°	2.4860	rejected	rejected
Marktplatz Day: from Hospizberg	93,15°	-0.1054	not rejected	not rejected
Marktplatz Day: from Hafengasse	322,42°	3.1663	rejected	rejected
Marktplatz Day: from Holzmarkt	338,65°	4.0516	rejected	rejected
Marktplatz Night: from Neckargasse	163,41°	3.5537	rejected	rejected
Marktplatz Night: from Hirschgasse	124,00°	3.2713	rejected	rejected
Marktplatz Night: from Hospizberg	264,97°	1.0449	not rejected	not rejected
Marktplatz Night: from Hafengasse	150,54°	2.1015	rejected	rejected
Marktplatz Night: from Holzmarkt	160,61°	2.3218	rejected	rejected
Hafengasse Day: from Marktplatz	135,54°	2.0453	rejected	rejected
Hafengasse Day: from Holzmarkt	128,33°	2.0327	rejected	rejected
Hafengasse Day: from Hirschgasse	200,45°	-0.1530	not rejected	not rejected
Hafengasse Day: from Neckargasse	118,77°	1.2814	not rejected	not rejected
Hafengasse Day: from Hospizberg	145,33°	0.2780	not rejected	rejected
Hafengasse Night: from Marktplatz	138,74°	0.5952	not rejected	not rejected
Hafengasse Night: from Holzmarkt	121,01°	1.8108	rejected	rejected
Hafengasse Night: from Hirschgasse	191,31°	-0.5238	not rejected	not rejected
Hafengasse Night: from Neckargasse	111,09°	0.6533	not rejected	not rejected
Hafengasse Night: from Hospizberg	137,35°	0.1669	rejected	rejected
Holzmarkt Day: from Hafengasse	127,21°	1.5470	not rejected	rejected
Holzmarkt Day: from Neckargasse	131,95°	-1.1563	not rejected	not rejected
Holzmarkt Day: from Hospizberg	314,20°	-0.1191	not rejected	not rejected
Holzmarkt Day: from Hirschgasse	351,52°	0.4821	not rejected	not rejected
Holzmarkt Day: from Marktplatz	323,93°	0.0369	not rejected	not rejected
Holzmarkt Night: from Hafengasse	282,28°	2.2651	rejected	rejected
Holzmarkt Night: from Neckargasse	312,89°	2.4702	rejected	rejected
Holzmarkt Night: from Hospizberg	126,68°	-0.1223	not rejected	not rejected
Holzmarkt Night: from Hirschgasse	167,42°	0.7072	not rejected	not rejected
Holzmarkt Night: from Marktplatz	127,85°	1.2563	not rejected	not rejected

Hirschgasse Day: from Holzmarkt	279,87°	0.3036	not rejected	not rejected
Hirschgasse Day: from Hospizberg	285,88°	1.1108	not rejected	not rejected
Hirschgasse Day: from Neckargasse	269,28°	0.1107	not rejected	not rejected
Hirschgasse Day: from Hafengasse	275,11°	0.7512	not rejected	not rejected
Hirschgasse Day: from Marktplatz	280,37°	1.7411	rejected	rejected
Hirschgasse Night: from Holzmarkt	238,69°	2.5534	rejected	rejected
Hirschgasse Night: from Hospizberg	259,61°	1.2910	not rejected	rejected
Hirschgasse Night: from Neckargasse	237,43°	0.3880	not rejected	not rejected
Hirschgasse Night: from Hafengasse	243,35°	-0.1528	not rejected	not rejected
Hirschgasse Night: from Marktplatz	241,04°	2.7842	rejected	rejected
Hospizberg Day: from Hirschgasse	318,14°	0.4355	not rejected	not rejected
Hospizberg Day: from Marktplatz	311,20°	0.1190	not rejected	not rejected
Hospizberg Day: from Hafengasse	343,97°	0.8220	not rejected	not rejected
Hospizberg Day: from Holzmarkt	342,83°	1.5669	not rejected	rejected
Hospizberg Day: from Neckargasse	344,96°	2.3902	rejected	rejected
Hospizberg Night: from Hirschgasse	144,20°	0.8000	not rejected	not rejected
Hospizberg Night: from Marktplatz	140,19°	0.6069	not rejected	not rejected
Hospizberg Night: from Hafengasse	162,44°	0.7993	not rejected	not rejected
Hospizberg Night: from Holzmarkt	163,04°	0.2890	not rejected	not rejected
Hospizberg Night: from Neckargasse	165,22°	0.3560	not rejected	not rejected
Neckargasse Day: from Hospizberg	352,08°	1.0019	not rejected	not rejected
Neckargasse Day: from Hafengasse	1,24°	0.0422	not rejected	not rejected
Neckargasse Day: from Holzmarkt	354,87°	2.0100	rejected	rejected
Neckargasse Day: from Marktplatz	355,41°	1.6591	rejected	rejected
Neckargasse Day: from Hirschgasse	357,63°	0.6015	not rejected	not rejected
Neckargasse Night: from Hospizberg	356,92°	1.1410	not rejected	not rejected
Neckargasse Night: from Hafengasse	6,69°	0.4969	not rejected	not rejected
Neckargasse Night: from Holzmarkt	2,76°	1.8939	rejected	rejected
Neckargasse Night: from Marktplatz	0,48°	1.7278	rejected	rejected
Neckargasse Night: from Hirschgasse	3,47°	-0.4384	not rejected	not rejected

A second group of V-Tests was conducted for the cases in which more than one perspective of the imagined target location was considered valid while coming from a specific other location and where the different participants imagined different ones of these valid views. Here, the correct data samples of the imagination in walking condition were grouped according to which of the valid view directions they pertained to. Then, the angular means for each of these groups were calculated and the V-Test was repeated with all 20 view points from a data sample (imagination in turning condition) tested against one of these means at a time.

The necessity of this lies in the fact that in case there was an effect of the place imagined in on the place imagined, and if there were more than one valid entry view to the imagined place, it would be possible for most or all of the participants to imagine only one of the valid perspectives. If this data was then plotted against the mean angle from imagination in walking condition where the recorded views were to be equally distributed between the different correct directions, this could lead to a negative result in spite of an effect existing.

The means of the different view groups (never more than 2) for the place connections affected, as well as the u-values and the test results on significance levels u(α)=0.05 and 0.10 are presented in table 9 and 10, respectively.

Table 9: Results of the V-Tests for different view groups of imagination in walking condition, group 1: Mean angle of the grouped views in walking condition the turning condition angles were tested against, the calculated u-values and the test results in significance levels 0.05 and 0.10.

	Mean Angle	**u Value**	**Null Hypoth.** on α=0,05	**Null Hypoth.** on α=0,10
Marktplatz Day: from Hirschgasse	232,54°	-1.8190	not rejected	not rejected
Marktplatz Night: from Hirschgasse	34,28°	-1.4689	not rejected	not rejected
Hafengasse Day: from Marktplatz	202,54°	-2.1017	not rejected	not rejected
Hafengasse Day: from Holzmarkt	203,21°	-2.2162	not rejected	not rejected
Hafengasse Day: from Hospizberg	199,84°	-2.1615	not rejected	not rejected
Hafengasse Night: from Marktplatz	189,01°	-1.4408	not rejected	not rejected
Hafengasse Night: from Holzmarkt	195,46°	-1.0410	not rejected	not rejected
Hafengasse Night: from Hospizberg	194,02°	-2.2705	not rejected	not rejected
Holzmarkt Day: from Hafengasse	38,33°	1.5587	not rejected	rejected
Holzmarkt Day: from Hirschgasse	29,24°	0.7552	not rejected	not rejected
Holzmarkt Night: from Hafengasse	196,23°	1.2394	not rejected	not rejected
Holzmarkt Night: from Hirschgasse	135,89°	0.2674	not rejected	not rejected
Hirschgasse Day: from Hospizberg	0,44°	0.2947	not rejected	not rejected
Hirschgasse Day: from Marktplatz	335,24°	0.8870	not rejected	not rejected
Hirschgasse Night: from Hospizberg	316,36°	-0.1189	not rejected	not rejected

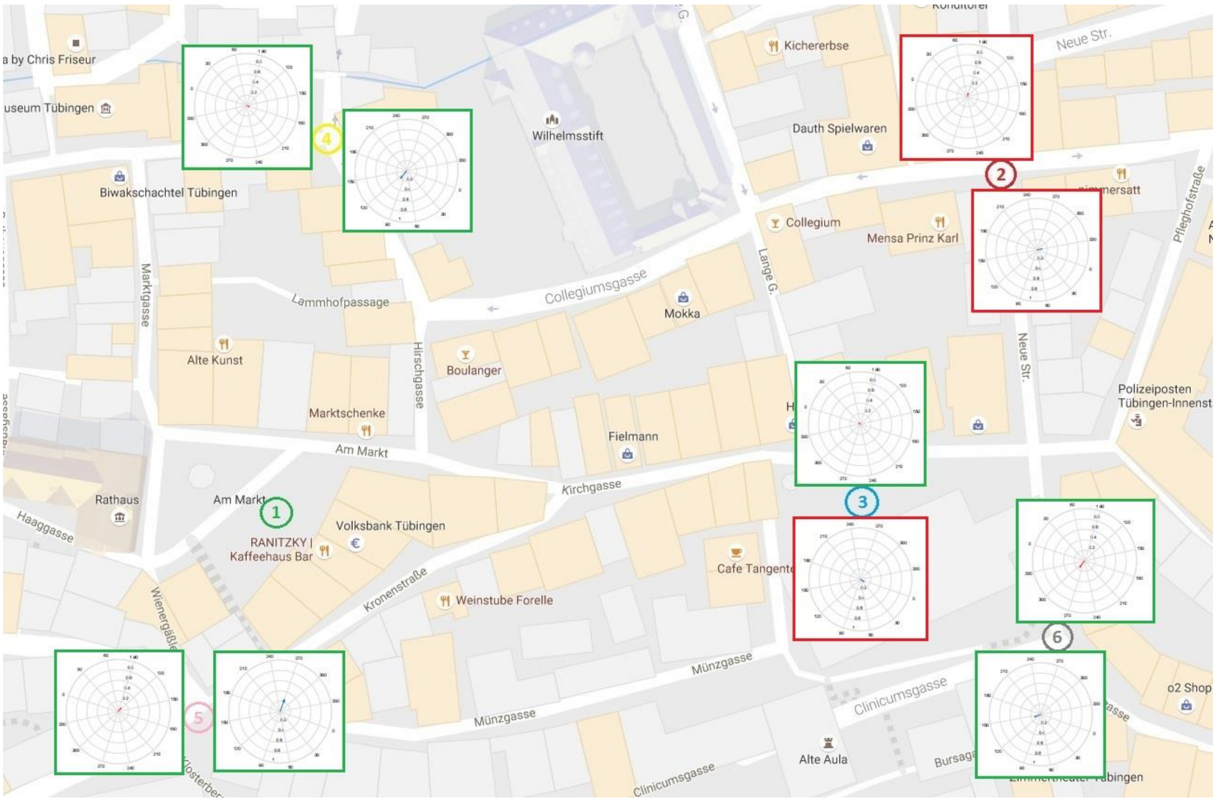
Hospizberg Day: from Hirschgasse	281,01°	-1.4992	not rejected	not rejected
Hospizberg Day: from Marktplatz	273,39°	-1.4341	not rejected	not rejected
Hospizberg Night: from Hirschgasse	169,83°	1.6661	rejected	rejected
Hospizberg Night: from Marktplatz	170,56°	1.1839	not rejected	not rejected
Neckargasse Day: from Hospizberg	303,75°	0.4040	not rejected	not rejected
Neckargasse Night: from Hospizberg	310,18°	1.5854	not rejected	rejected

Table 10: Results of the V-Tests for different view groups of imagination in walking condition, group 2: Mean angle of the grouped views in walking condition the turning condition angles were tested against, the calculated u-values and the test results in significance levels 0.05 and 0.10.

	Mean Angle	**u Value**	**Null Hypoth.** on α=0,05	**Null Hypoth.** on α=0,10
Marktplatz Day: from Hirschgasse	317,87°	2.9517	rejected	rejected
Marktplatz Night: from Hirschgasse	141,94°	3.5697	rejected	rejected
Hafengasse Day: from Marktplatz	117,67°	2.9136	rejected	rejected
Hafengasse Day: from Holzmarkt	119,52°	2.4444	rejected	rejected
Hafengasse Day: from Hospizberg	118,07°	1.5539	not rejected	rejected
Hafengasse Night: from Marktplatz	109,42°	1.6787	rejected	rejected
Hafengasse Night: from Holzmarkt	108,60°	2.1090	rejected	rejected
Hafengasse Night: from Hospizberg	117,11°	1.1347	not rejected	not rejected
Holzmarkt Day: from Hafengasse	138,32°	1.2234	not rejected	not rejected
Holzmarkt Day: from Hirschgasse	325,11°	0.1599	not rejected	rejected
Holzmarkt Night: from Hafengasse	310,96°	1.4660	not rejected	rejected
Holzmarkt Night: from Hirschgasse	194,44°	0.9215	not rejected	not rejected
Hirschgasse Day: from Hospizberg	272,72°	1.0818	not rejected	not rejected
Hirschgasse Day: from Marktplatz	276,71°	1.7465	rejected	rejected
Hirschgasse Night: from Hospizberg	243,40°	1.5156	not rejected	rejected

Hospizberg Day: from Hirschgasse	344,14°	1.7324	rejected	rejected
Hospizberg Day: from Marktplatz	344,80°	1.4786	not rejected	rejected
Hospizberg Night: from Hirschgasse	115,36°	-0.3528	not rejected	not rejected
Hospizberg Night: from Marktplatz	106,01°	-0.2316	not rejected	not rejected
Neckargasse Day: from Hospizberg	357,76°	1.0317	not rejected	not rejected
Neckargasse Night: from Hospizberg	5,17°	0.9709	not rejected	not rejected

As an additional means of testing whether there is any effect of the location where imagination takes place on the view of the location imagined, a method similar to the one deployed by Röhrich, Hardiess and Mallot in their study explained in chapter 1.4 was used. For each of the 30 variations of place connections for both day and night, mean vectors were calculated from all of the imagined view angles in turning condition of the 20 participants. These are identical to the "pair-means" inserted into the compass plots in chapter 3.2 above. Then, in the same manner, mean vectors of all the perspectives imagined in turning condition for one place from all places were produced, and then subtracted from all pair-means pertaining to the according places. This last step was undertaken to erase an eventual influence of a canonical view for a place from the pair-mean vectors. The corrected pair-means were then plotted into compass plots using MATLAB (For the code, see appendix chapter 5.2, figure A4). Then, for each location, a map was overlaid with the plots for the imaginations of said location from the other 5 places. It was checked for each of the plots if the corrected pair-means within point into the correct 180° range of the plot (the correct "half" of the circular plot), i.e., if the imagination of the place while somewhere else is roughly oriented as if coming from the point where imagination took place. The plots where then each marked accordingly. The 6 maps can be found in figure 12 below. Since the plots were scaled down to fit on the maps and the corrected pair-mean vectors within are sometimes small and hard to find the proper direction of, the full-sized plots can be provided electronically if requested so. As seen below, in 33 of the 60 cases of pair-means, the vector directions were deemed correct, in 27 cases incorrect. For imagination at daytime, a total of 13 pair-mean vectors showed a roughly correct orientation, at nighttime 20, out of 30 each. A one-tailed Fisher-Yates-Test revealed no significance of the pair-means to be oriented correctly at both α=0.05 and 0.10 for all pair-means combined, but a significant effect for the pair-means of the nighttime imaginations at both α-levels.


Kichererbse
Neue Str.
Wilhelmsstift
Dauth Spielwaren
Biwakschachtel Tübingen
Collegium
Mensa Prinz Karl
Lammhofpassage
Collegiumsgasse
Mokka
Marktgasse
Hirschgasse
Lange G.
Alte Kunst
Boulanger
Marktschenke
Fielmann
Polizeiposten Tübingen-Innenst
Am Markt
Kirchgasse
Rathaus
Haaggasse
Volksbank Tübingen
RANITZKY | Kaffeehaus Bar
Kronenstraße
Weinstube Forelle
Cafe Tangente
Münzgasse
Clinicumsgasse
o2 Shop
Alte Aula
Pfleghofstraße

a)


Kornhausstraße
Kichererbse
Neue Str.
Wilhelmsstift
Dauth Spielwaren
BUTLERS
Biwakschachtel Tübingen
Collegium
Mensa Prinz Karl
nimmersatt
Lammhofpassage
Collegiumsgasse
Mokka
Marktgasse
Hirschgasse
Lange G.
Alte Kunst
Boulanger
H&M
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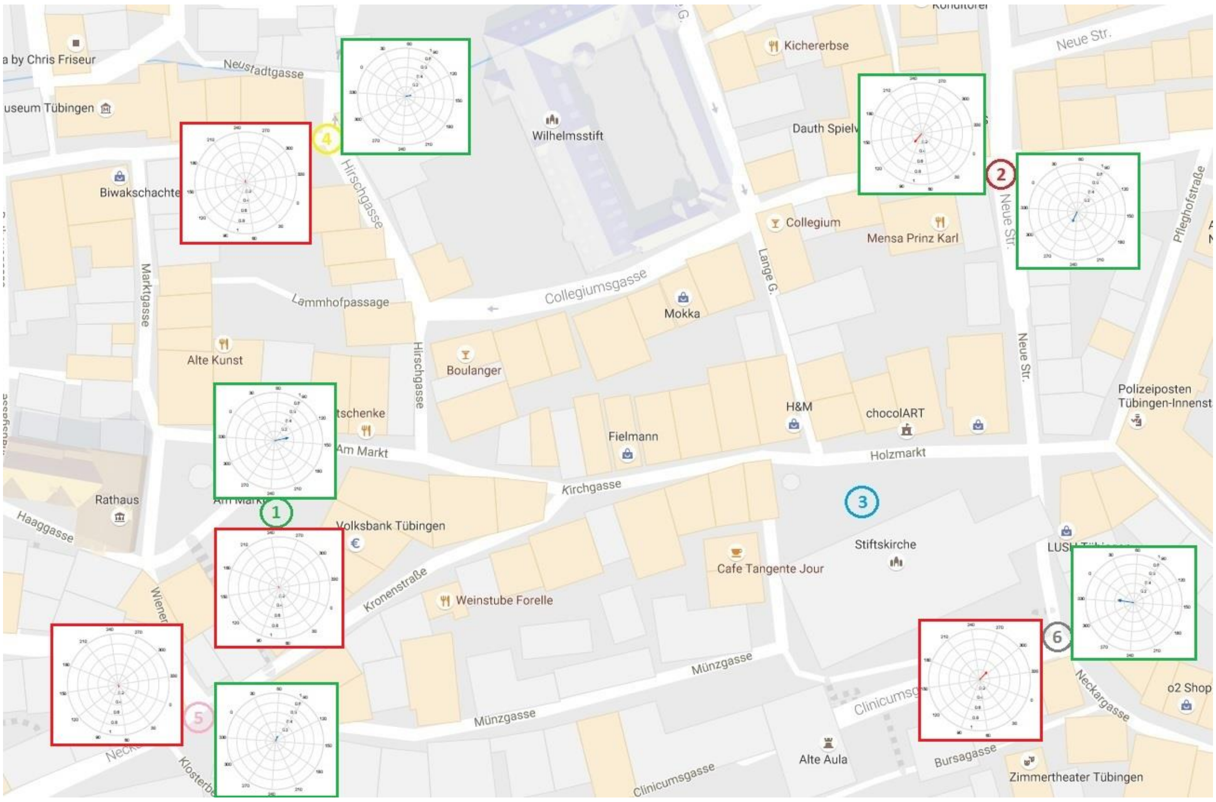
Marktschenke
Fielmann
Polizeiposten Tübingen-Innenst
Am Markt
Kirchgasse
Rathaus
Haaggasse
LUSH Tübingen
Cafe Tangente Jour
Weinstube Forelle
Münzgasse
Alte Aula
Bursagasse
Zimmertheater Tübingen
Clinicumsgasse
Pfleghofstraße

b)



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Biwakschachte
Hirschgasse
Collegium
Mensa Prinz Karl
Lange G.
Pfleghofstraße
Lammhofpassage
Collegiumsgasse
Marktgasse
Mokka
Alte Kunst
Boulanger
Polizeiposten
Tübingen-Innenst
H&M
chocolART
Fielmann
Am Markt
Holzmarkt
Kirchgasse
Rathaus
Haaggasse
Volksbank Tübingen
Stiftskirche
Cafe Tangente Jour
Kronenstraße
Weinstube Forelle
Neckargasse
o2 Shop
Münzgasse
Alte Aula
Bursagasse
Clinicumsgasse
Zimmertheater Tübingen
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c)

Kichererbse
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Wilhelmsstift
Dauth Spielwaren
Kornhausstraße
Hirschgasse
Biwakschachtel Tübingen
nimmersatt
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Pfleghofstraße
Lammhofpassage
Collegiumsgasse
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Figure 12: Plots of corrected pair-mean vectors for imagination in turning condition for each of the places. The plots, separated for day and night, are connected to the locations where the imagination took place, with number 1 (green) being the Marktplatz, number 2 (red) being the Hafengasse, number 3 (blue) being the Holzmarkt, number 4 (yellow) being the

Hirschgasse, number 5 (pink) being the Hospizberg and number 6 (grey) being the Neckargasse. The location without plots attached shows the place imagined. Plots with red vectors show the pair-means for daytime, those with blue vectors for nighttime. The cases where the pair-mean vectors point into the correct range of the plot are framed green, the incorrect ones red. a) Imagination of Marktplatz. b) Imagination of Hafengasse. c) Imagination of Holzmarkt. d) Imagination of Hirschgasse. e) Imagination of Hospizberg. f) Imagination of Neckargasse.

4. Discussion

4.1 Priming of Imagination

The main analysis done to determine whether in a virtual environment, being in a proximate location and getting an indirect cue pertaining to the location to be imagined, will prime the mental representation of the other location to become egocentric, was the V-Test. Looking at the test results for the V-Tests with undivided means for the walking condition, they seem to give a somewhat clear picture. At level u(α)=0.05, which is commonly used and accepted for statistical tests because it gives the result a fairly high significance while not sacrificing too much of the tests power, only in 22 of the 60 tests (30 combinations for day and night each) the Null Hypothesis is rejected and thus a significant trend for the views imagined in turning condition to be directed towards the view expected in case of an effect found. This is hardly more than one third of all the cases, and even when raising u(α) to 0.10, which already lowers the significance strongly, only 26 of 60 tests reject the Null Hypothesis, still less than half of the total amount. Since it would have been theoretically possible for this low proportion of positive results to be due to some places having multiple valid directions for imagination, a second run of V-Tests was done with the angles, and therefore their means, from walking condition being divided into groups along the correct views from the valid entry points, as explained at the end of chapter 3.3 above. As can be seen from tables 9 and 10, out of 42 tests conducted (one for each of the 2 valid different entry views for each of the 21 place combinations affected), at significance level 0.05 less than a quarter, namely 9 reject the Null Hypothesis and thus show a significant orientation of the views in turning condition in the expected direction. At level 0.10, the number of positive results is a bit higher with 16 out of 42 tests rejecting the Null Hypothesis, but the percentage here is still lower than that of the tests with undivided means at the same level, and, as stated above, the significance here is rather small.

When comparing the amount of times the Null Hypothesis at u(α)=0.05 is rejected (in the tests for undivided means) for each location, it is conspicuous that while in the other places, a rejection occurs only between 1 and 4 times, at the Marktplatz for 8 out of the 10 connections the Null Hypothesis is rejected. Though this might be interpreted as the process of priming being effective for that particular location, there would be no known plausible explanation for this kind of special influence held by this particular place. In addition, a more convincing explanation exists: From 4 of the 5 other locations, the one or one of the valid paths to Marktplatz and therefore views when entering there will show the town hall, a strongly salient building. The participants, instead of being primed by the place located in while imagining, might just have brought to mind the most memorable view of the Marktplatz. This interpretation is reinforced by the fact that the tests for the imagination from Hospizberg, the only place coming from which no valid view faces the town hall, were the only ones to show no significance, since the imagined views here are also mostly directed at the town hall. When taking all this into account, it leads to the conclusion that salient buildings or other landmarks, or memorable views of the place in general might have also influenced the subjects' representations of the other locations, even though this is not observable through the results of the V-Tests. Therefore, the amount of clustering in the imagined views in turning condition was searched out, as can be found in table 7 in chapter 3.2. It can be seen there that for 7 of the 20 subjects whose data was analyzed, a very strong tendency for their views to cluster (i.e. 10 or more out of 12 possible cases). Even when subtracting the cases where the clustering could be explained by an influence of the place imagined in on the imagination, which count between a maximum of 3 and a minimum of 0 for the subjects with strong tendency to cluster, the rate still stays well above half of all cases for each of them. Additionally, as counted here were only the cases with an almost absolute tendency for clustering, there are still cases of clustered views not explainable by priming of the imagination in 6 of the 13 other participants. Furthermore, counted as clusters here were only the occasions where all 5 of the possible views for a location were directed the same way. If the number of cases in which, for instance, 4 out of 5 imagined views point in the same direction, it would be much higher still. All in all, this points out that a significant amount of the participants mostly or at least partially imagine a certain landmark when thinking of a place, rather than a perspective influenced by their (virtual) position at the time of imagination.

The second method to test if a priming of the imagination, and therefore of the representation of a location, occurs, was the comparison of the direction of the pair-means, the vector means of the imaginations in turning condition of all participants, to a map, to see if the pair-means point roughly in a direction as if coming from the place of imagination. Though this method is strictly speaking not a statistical analysis, it can certainly indicate a tendency of priming, if one exists. As explained in chapter 3.3, the overall mean vector of a location was subtracted from the corresponding pair-mean vectors before comparing them to the map, to rule out the possible influence of a canonical view of the location on the pair-means. The results, also to be seen in chapter 3.3 above, are mixed. Out of the total of 60 pair-means plots, 33 show an alignment at least roughly in the direction to be seen when entering a place from another location, while 27 do not. This, though being slightly more than half of the cases, displays by no means a significant overall tendency, as was tested via a one-tailed Fisher-Yates-Test for both significance levels α=0.05 and 0.10. Interestingly, when the pair-means are split into day and night, while for daytime only 13 of the 30 vectors show an alignment in the right direction, for nighttime 20 out of 30 do so. Calculated again by means of a one-tailed Fisher-Yates-Test, this shows to be a statistical significant proportion of the pair-means here, even at α=0.05. Though this certainly indicates an effect of priming, at least in the nighttime imagination, there are 2 things to be considered: Firstly, since this kind of significant effect only showed for this means of analysis, and only for the nighttime cases, it would be way too far-fetched to speak of a general effect. Even a general effect on the priming of imagination at nighttime could be contradicted by the results of the V-Tests for the night trials, since there, no such significance could be observed. Secondly, in this analysis of the pair-means, only the direction of the pair-means vectors was interpreted, not the length. When looking at the plots, for both day and night and for both correct and incorrect directions, the vectors are mostly short, sometimes extremely so. This indicates that there is generally no strong orientation into one particular direction, be it one consistent with the idea of priming or not, at least not after subtraction of the grand mean of each place. This phenomenon could be explained both by the participants mainly imagining a different, random perspective each time they imagine a certain location, or always imagining the same one (e.g. an especially salient landmark), but differing from subject to subject.

In conclusion, these results indicate that there is no general effect of the place a person is located in in virtual reality on the mental representation of another place, at least in this paradigm. While there exists a certain percentage of cases in which the general view direction is mostly aligned with the direction one would expect in case of successful priming, it ranges from a very minor proportion to about half of the cases depending on the method of analysis, never being the significant majority of cases, safe for one occasion, which in and on itself is not enough to speak of a general effect. Of course, the results of this experiment do not completely rule out the existence of the searched effect in general, as will be discussed in chapter 4.3.

4.2 Difference between Day and Night

On several occasions while analyzing the data, it was checked what variations exist between the imaginations at day- and nighttime. One instance of this was already given in chapter 4.1 above, as for the corrected pair-means, at nighttime a significant amount of the vectors (20 out of 30) pointed in the approximately right direction for the possibility to be primed by the location imagining from. Leaving aside this account, while there are of course scattered differences between day and night, the general picture shows no significant or systematic variations.

At the beginning of the data analysis, the errors in the recorded turning angles of the turning condition were tested for significant differences for day and night. Even though the sums over all test subjects show a difference, with a total of 37 errors at daytime and a total of 44 errors at nighttime, a two-tailed Fisher-Yates-Test revealed this difference to not be statistically significant. Thus, it can be said that the possibly more obscure views of the places at nighttime do not influence the susceptibility to errors in a relevant way. Not only the turning errors were analyzed for variation of day- and nighttime data, the same procedure was also applied to the errors of the subjects for the imagination in walking condition. With an error count of 95 at daytime and 97 at night, it might be obvious that the Fisher-Yates-Test applied to the data shows no significant difference on either $\alpha=0.05$ or 0.10. Here, the same conclusion as for the turning condition can be drawn: No possible influence of unfamiliarity, lighting or other factors at neither day nor night appears to significantly alter the error rate between the two conditions. What can be observed for the errors of the walking condition view angles though, is that there are strong variations between the total sums of the locations, with as low as 22 total errors at the Holzmarkt and as high as 66 at the Marktplatz. One additional analysis' results, from the comparison of the number of errors with the distance of the several place connections (shown in table 4 and visualized in figure 10 of chapter 3.2), show the same phenomenon: The distance of a route doesn't seem to systematically influence the error rate either positively or negatively, with e.g. one 80 meter route showing a total of 29 errors in both directions and a 300 meter connection sporting only 5 errors, and on the other hand a 210 and a 90 meter connection with 27 and 3 errors, respectively. On the other hand here, too, can be found a strong influx of the imagined place on the error count, to be seen easily in form of the imbalance between the error numbers of both directions of one route. There are several possible interpretations for this influence of the location, such as differing familiarity or geometrical layout or varying knowledge about the shortest route leading to each location. To discern the effects possible here might be an interesting topic for further research.

As there was, in some cases in the imagination in walking condition, the possibility for subjects to choose between two different, equally short routes from one place to another, and therefore two equally valid view directions when imagining the target place, it was inquired whether at day and night different or similar perspectives out of these correct ones were chosen by the subjects. Out of 184 total times where a different perspective might have been chosen between the day- and nighttime trials, only in 23 cases this actually occurred. That being only hardly more than 10 percent, there was no need to conduct a Fisher-Yates-Test or any other form of statistical test here to clearly see no significant difference between the two conditions.

Even though these previous results speak strongly for no systematic difference existing, the result of the Fisher-Yates-Test for the cases of view clustering in turning condition between day and night does not fully support this conclusion. While in the one-tailed test, no significant difference between the number of cases with similarly oriented clusters and differently oriented clusters can be found at the 0.05 level, it shows significance at $\alpha=0.10$. This is, of course, not a strong significance since the chance for an α-error here is rather high, but it still sets a (albeit small) contrast to the previous findings of no general variations between day and night. A possible reason for the in this case stronger variations might be found when explaining the clusters per se as being directed at a salient view. The salience of at least some of the places and buildings might change at night by means of different lighting conditions resulting in a change of imagined views. While this might initially be thought of as making the result of the whole difference analysis unclear, it must be understood that rather than having analyzed the influence of day and night on a single phenomenon, the tests discussed in this chapter all investigate this influence for different kinds of behavior, and are thus not necessarily connected.

When summarizing the analysis results discussed in this chapter, it can be said that there are, for the data and kinds of behavior tested here, practically none significant general differences between day and night, be it for errors in turning or imagination or for choosing different views in the walking condition. Even for the orientations of clustered views, where a significant difference between the day and night cases on level $\alpha=0.10$ could be determined, this difference could possibly be caused by chance, since on this level, α-errors are more prevalent than on the commonly accepted 0.05. On the other hand, accounted for must always be the possibility that there indeed could be a significant difference for day and night contrary to these results, be it the case that said difference manifests in other tasks and behaviors or that the data are not representative due to a flawed test paradigm, as will also be discussed in the following chapter.

4.3 Problems, Summary and Future Prospects

In practically all forms of studies, there are problems to be accounted for when interpreting the results, regarding the paradigm of the experiment. Some of these problems stem from the technical, temporal, or other limits given, other from improvable parts of the paradigm not realized until after the experiments had been conducted, among other things. This study is not an exception. Here, mainly three factors which could have led to faulty and/or incomplete conclusion about the effects investigated must be accounted for:

Firstly, the realism of the virtual environment the experiments were conducted in. Although it is the explicit aim of this study to check if the effects on the imagination of places previously reported from reality-based experiments by Basten, Meilinger and Mallot and Röhrich, Hardiess and Mallot also apply in virtual reality, this does not presuppose said virtual reality to be specifically abstract. If, for instance, a location is portrayed in an overly abstracted way, one could well argue that this at least would influence, if not negate, the effect of the place the imagination is conducted in on the perspective of the imagination. Specifically, two measures could be undertaken to make the virtual environment more immersive: To use complete spherical panoramas instead of the simple 360° ones utilized, and to allow the participants some degree of movement freedom besides turning, that is, translational movement within the locations.

Secondly, the task to show if priming of the representation of the locations did occur. While having the participants show the first perspective that comes to mind when imagining themselves in a place is a fast way to record data for the question at hand, it appears to be less intuitive than drawing maps, as was done in the studies by Basten, Meilinger and Mallot and Röhrich, Hardiess and Mallot predating this one. On several occasions, it was asked by the participants during the task of imagination in turning condition whether locations should be imagined in a certain way or direction, in which cases it always had to be reinforced that only the first perspective coming to mind should be remembered. It is possible that despite this, the perspectives remembered by the subjects were altered by conscious thought and thus not identical with the representation, be it primed or not, active in working memory.

Lastly, the extent of both the experiment and the analysis of the data. While both were certainly on a scope big enough to provide useful results, with more time at hand, data on a wider range could have both been collected through additional experimental tasks and analyzed by more different means. Thinkable here could have been the study of the times taken of the participants' actions, further comparisons between day and night data, and investigation for a possible gender effect, as well as additional, different methods in the experiment itself, e.g. the data recording (map drawing etc.). Doing this could certainly have provided a deeper insight into the subject matter. Thankfully, this problem can still easily be addressed by conduction of future studies with a similar paradigm or at least similar aim, or by additional analysis of the data of this study.

To conclude, in this study, with the given paradigm and means of analysis, no general effect of priming of the mental representation of a virtually close location while being given an indirect cue pertaining to the location could be observed. It can thus be assumed, that under these circumstances, no mental activation of the spatial memory of the included locations took place. Additionally, no systematic variations between the results of the tests at day- and nighttime were found in the data analyzed for this purpose. However, neither of these results wholly rule out a general existence of the pertaining effects under circumstances similar to this experiment. The amount of research on these phenomena in virtual reality is still rudimentary, and as the results of the studies by Basten, Meilinger and Mallot and Röhrich, Hardiess and Mallot from the recent years strongly suggest an effect of activation of place memory to be present in real life, it is still thinkable for this to also be the case in virtual reality. To assuredly rule out (or prove) such, a far greater amount of research will have to be undertaken in this area. Possibilities for this are manifold, ranging from further, more in-depth analysis of the data from this study, to additional experiments with a partially altered paradigm, to substantially different approaches to the same question. Whatever the approach, further research in this area will be vital not only for understanding the phenomenon of mental activation of spatial memory, but also for the important knowledge about the limits and chances in the use of virtual reality in the field of cognitive neuroscience.

5. Appendix

5.1 Tables of the Angular Data

Table A1: Angles of turning in turning condition.

	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15	Test 16	Test 17	Test 18	Test 19	Test 20	Test 21	Test 22
Marktplatz Day: to Hafengasse	123,99	129,91	130,39	130,89	135,55	135,13	127,93	123,33	132,13	126,00	124,02	122,58	129,74	124,64	137,60	126,04	135,14	127,20	147,82	131,66	131,95	129,85
Marktplatz Day: to Hospizberg	306,54	305,04	317,58	317,64	316,22	313,46	321,98	310,14	301,43	310,60	127,67	127,41	308,55	312,23	308,03	309,39	314,15	131,81	307,01	309,97	268,88	129,43
Marktplatz Day: to Neckargasse	132,36	131,95	132,57	135,53	140,96	130,97	125,73	140,70	130,78	128,17	130,99	129,27	132,57	140,68	127,58	126,55	131,41	166,62	132,18	125,38	135,47	136,17
Marktplatz Day: to Hirschgasse	132,46	123,42	136,14	122,28	129,15	17,97	17,64	116,17	131,68	22,58	131,15	129,34	16,00	121,13	47,35	126,00	121,07	129,46	22,08	120,87	130,42	135,30
Marktplatz Day: to Holzmarkt	121,91	131,26	139,01	128,95	148,83	137,05	130,88	128,14	137,88	131,20	133,80	136,28	146,64	128,53	130,33	136,72	131,75	263,75	134,83	136,53	139,86	137,61
Marktplatz Night: to Hafengasse	310,54	301,37	313,78	306,20	133,91	306,61	303,53	311,66	307,76	304,03	314,73	307,79	310,75	302,11	308,61	306,41	301,98	307,73	312,81	303,77	311,71	305,53
Marktplatz Night: to Hospizberg	94,55	129,30	136,65	136,35	133,07	88,22	134,21	109,35	128,47	133,86	309,64	195,34	129,75	87,02	135,41	132,16	130,44	72,74	132,25	123,88	87,93	312,63
Marktplatz Night: to Neckargasse	313,02	307,59	312,44	316,56	309,43	312,77	305,07	317,96	310,93	305,10	308,43	306,32	321,39	309,15	308,63	294,41	315,59	310,08	308,41	298,96	316,35	313,56
Marktplatz Night: to Hirschgasse	299,87	304,17	138,35	309,60	299,53	236,71	193,88	306,96	311,58	200,19	305,13	308,29	203,70	300,28	297,09	304,26	310,05	306,04	203,55	307,11	201,56	311,70
Marktplatz Night: to Holzmarkt	323,34	307,00	310,99	307,16	319,20	305,77	305,62	310,20	316,49	305,37	311,32	305,95	312,82	310,99	312,88	305,73	317,90	321,51	311,11	299,75	309,60	305,06
Hafengasse Day: to Holzmarkt	285,32	292,28	293,63	300,91	138,48	296,76	297,32	75,74	298,19	300,78	28,52	289,13	298,54	301,77	299,45	299,90	301,35	285,48	299,86	293,70	293,42	296,20
Hafengasse Day: to Neckargasse	292,86	287,02	294,49	285,74	121,18	298,99	287,63	298,92	294,19	289,65	293,13	198,54	294,52	292,01	295,91	205,81	301,25	286,73	298,64	291,29	295,99	295,38
Hafengasse Day: to Hospizberg	292,24	291,88	27,76	41,74	122,13	302,13	27,21	292,13	297,62	303,80	294,49	31,28	304,27	294,98	299,52	293,68	300,79	295,90	24,91	305,90	38,72	293,64
Hafengasse Day: to Hirschgasse	28,59	37,84	27,10	33,82	118,34	33,92	28,75	38,67	29,72	30,95	25,41	121,81	23,62	30,65	22,31	50,42	32,82	33,95	31,20	24,19	34,71	31,03
Hafengasse Day: to Marktplatz	299,64	298,23	306,64	299,15	115,79	294,10	29,57	287,91	30,07	300,18	289,20	287,88	359,93	300,78	289,16	300,48	32,36	28,63	36,63	293,53	294,85	297,31
Hafengasse Night: to Holzmarkt	273,61	284,21	286,47	280,02	113,93	293,77	287,07	285,00	280,28	291,15	284,83	276,25	290,62	286,05	285,12	284,44	289,41	287,39	292,37	288,52	287,77	285,28
Hafengasse Night: to Neckargasse	270,38	282,13	286,28	277,36	21,98	288,57	284,36	286,35	280,86	285,77	284,69	276,42	281,83	285,21	286,37	281,41	288,64	287,64	284,89	275,15	284,99	286,61
Hafengasse Night: to Hospizberg	287,23	280,81	21,58	279,63	280,11	291,59	16,43	282,85	288,68	295,84	285,32	114,33	285,71	285,10	287,80	295,43	286,49	288,63	290,72	284,86	287,21	285,41
Hafengasse Night: to Hirschgasse	22,50	33,73	28,40	296,02	23,68	31,48	17,88	25,85	20,04	20,51	15,86	110,68	20,05	24,54	18,75	117,53	23,56	21,15	29,07	18,04	23,33	18,57
Hafengasse Night: to Marktplatz	295,38	292,63	284,65	289,63	18,79	23,06	18,19	265,09	18,51	291,23	10,08	190,91	328,41	280,04	284,84	291,00	15,55	19,65	292,60	285,06	292,05	22,41
Holzmarkt Day: to Hirschgasse	163,78	197,95	158,14	207,91	198,97	152,71	199,52	156,44	198,09	204,11	201,15	201,93	202,08	199,47	205,10	199,93	164,31	103,94	155,49	155,59	202,56	202,41
Holzmarkt Day: to Hafengasse	318,67	203,42	156,40	320,33	193,10	318,15	318,29	194,44	316,75	317,55	310,67	204,88	318,15	205,33	318,80	315,46	313,34	205,68	219,09	315,46	315,55	318,58
Holzmarkt Day: to Neckargasse	320,14	320,19	325,76	310,05	82,98	319,99	325,40	329,74	323,30	324,82	324,24	320,83	325,25	320,36	321,25	323,04	311,40	325,86	323,71	320,67	327,50	324,53
Holzmarkt Day: to Hospizberg	99,00	97,69	153,47	105,14	93,96	97,60	156,60	95,46	91,62	154,28	329,00	157,48	99,85	102,58	147,63	149,70	96,67	96,89	153,92	96,99	105,37	150,92
Holzmarkt Day: to Marktplatz	150,96	152,47	151,45	160,16	149,09	154,03	152,97	145,54	154,92	154,48	153,49	154,04	151,92	158,93	154,90	152,83	161,07	154,39	162,07	152,17	150,90	146,70
Holzmarkt Night: to Hirschgasse	350,42	14,26	21,33	18,59	23,62	336,00	11,63	319,54	5,41	13,84	15,35	121,02	10,31	7,84	19,35	18,21	329,98	319,40	330,62	320,24	22,60	17,16
Holzmarkt Night: to Hafengasse	14,77	119,56	102,20	117,08	282,27	124,36	122,79	324,83	13,58	121,89	14,67	7,64	119,13	14,07	125,26	123,09	123,88	112,83	8,64	117,78	120,47	125,44
Holzmarkt Night: to Neckargasse	132,14	127,53	131,48	130,58	127,72	129,25	128,48	115,81	132,65	131,27	130,12	119,81	129,51	21,41	134,49	134,09	137,20	139,80	123,79	126,67	130,91	134,03
Holzmarkt Night: to Hospizberg	265,24	316,05	264,13	274,33	271,41	261,62	326,00	318,19	263,89	324,83	132,66	329,73	263,67	261,60	313,73	336,43	273,48	274,18	326,87	269,78	264,82	279,24
Holzmarkt Night: to Marktplatz	311,98	322,88	321,72	332,74	316,34	329,53	326,41	325,82	330,94	325,69	320,14	327,90	319,54	328,97	323,60	329,23	322,41	318,73	326,24	310,54	319,86	316,00
Hirschgasse Day: to Hospizberg	48,97	48,72	208,28	63,17	54,29	53,19	56,82	51,83	60,56	55,58	48,66	208,63	67,52	57,98	67,86	59,22	47,02	55,22	60,87	48,78	55,26	51,27
Hirschgasse Day: to Hafengasse	50,38	53,28	56,11	52,05	206,91	55,19	51,15	61,30	56,56	51,01	50,06	208,28	60,29	49,53	55,57	50,57	55,61	54,10	297,14	55,13	60,09	56,56
Hirschgasse Day: to Marktplatz	57,80	53,83	55,43	60,39	205,94	209,55	59,52	50,49	68,70	61,55	65,08	54,07	84,37	65,06	62,74	59,13	193,27	48,10	58,21	56,96	60,28	61,98
Hirschgasse Day: to Holzmarkt	60,82	55,25	60,06	51,39	197,12	50,91	52,07	48,72	64,83	58,87	63,61	51,81	65,91	62,63	62,82	55,71	50,18	46,97	62,20	49,76	59,06	73,72
Hirschgasse Day: to Neckargasse	48,19	53,01	57,32	48,14	54,48	56,18	57,21	59,83	59,63	54,32	53,17	51,22	66,69	58,61	53,26	53,05	58,06	46,18	62,33	58,86	59,95	57,57
Hirschgasse Night: to Hospizberg	26,33	16,65	161,91	22,62	18,40	22,62	16,05	38,44	21,28	22,48	19,90	166,70	42,15	35,61	38,29	33,07	173,46	37,95	24,39	14,57	25,38	23,77
Hirschgasse Night: to Hafengasse	25,42	255,06	29,09	15,76	175,08	16,35	13,25	28,69	26,40	25,31	38,70	15,08	36,33	24,42	28,74	35,09	13,38	12,43	25,78	20,22	24,72	25,79
Hirschgasse Night: to Marktplatz	18,15	21,55	22,81	22,43	168,38	170,08	25,71	31,28	29,30	169,85	38,43	17,02	45,05	29,36	34,13	33,47	171,33	42,65	17,68	17,75	24,40	21,44
Hirschgasse Night: to Holzmarkt	36,49	8,12	20,98	19,74	167,06	26,67	14,63	29,44	61,27	24,42	23,70	11,66	38,37	25,46	27,48	21,84	170,13	18,99	25,18	13,96	21,13	26,97
Hirschgasse Night: to Neckargasse	34,50	13,62	24,29	22,28	17,95	11,69	21,55	31,75	29,33	20,97	23,11	17,08	23,25	23,29	20,87	18,70	16,91	14,58	23,13	16,90	21,18	30,25
Hospizberg Day: to Neckargasse	175,77	187,37	180,39	108,74	343,98	192,60	173,17	222,30	176,23	173,01	176,48	176,16	167,69	174,50	181,08	174,89	166,72	175,03	172,83	191,87	172,75	171,79
Hospizberg Day: to Hirschgasse	103,02	119,71	175,67	110,04	325,63	103,19	167,08	168,34	94,27	110,72	168,74	172,14	103,98	171,70	104,89	174,57	173,11	166,83	174,28	164,68	170,51	170,97
Hospizberg Day: to Holzmarkt	170,88	106,19	177,08	154,51	193,86	173,93	167,67	173,10	99,56	173,86	92,21	172,05	166,53	170,48	177,05	171,14	173,29	164,12	173,49	186,55	171,77	169,18
Hospizberg Day: to Marktplatz	100,39	102,05	170,51	102,38	104,40	181,83	102,55	97,58	92,42	107,14	87,31	171,19	165,51	169,13	104,80	173,18	110,90	76,33	177,30	99,30	172,59	167,64
Hospizberg Day: to Hafengasse	92,24	103,09	171,67	112,67	197,11	175,74	167,45	110,02	97,50	169,86	94,89	176,78	167,52	174,28	113,81	170,34	177,16	168,40	175,10	174,53	173,35	169,41
Hospizberg Night: to Neckargasse	358,10	348,17	351,19	302,35	162,96	0,08	344,40	340,02	353,67	349,33	285,03	355,18	344,69	350,94	353,96	353,12	22,34	63,11	351,51	86,21	350,70	349,74
Hospizberg Night: to Hirschgasse	283,87	286,98	170,44	272,74	349,78	287,40	284,40	343,09	281,09	293,02	283,44	273,94	344,50	344,02	292,06	339,79	349,44	165,82	349,63	352,22	344,07	345,81
Hospizberg Night: to Holzmarkt	9,12	281,00	346,14	283,25	266,29	348,27	340,34	343,66	280,19	350,81	288,89	349,12	343,76	346,51	344,58	352,35	346,09	352,22	349,20	347,18	345,28	346,78
Hospizberg Night: to Marktplatz	281,81	283,85	345,27	278,88	277,84	277,60	284,37	279,45	275,01	281,16	279,63	350,53	343,36	281,82	291,50	332,22	288,83	297,53	349,16	283,81	344,08	346,55
Hospizberg Night: to Hafengasse	272,72	284,18	350,18	300,23	347,94	7,71	345,28	349,18	279,18	355,26	280,48	348,85	342,34	346,32	293,36	353,26	343,29	350,28	350,86	350,14	353,65	348,43
Neckargasse Day: to Holzmarkt	207,68	201,23	203,97	195,87	196,85	202,09	201,53	181,17	198,00	198,26	203,64	200,91	198,41	208,29	203,38	197,97	194,36	198,66	202,85	197,46	204,21	197,53
Neckargasse Day: to Marktplatz	208,59	197,59	199,02	202,72	198,36	200,69	199,59	189,39	117,62	198,95	199,95	98,78	198,53	201,66	205,46	202,77	202,26	195,70	201,95	196,97	200,41	198,03
Neckargasse Day: to Hirschgasse	208,23	196,70	198,79	206,08	201,31	197,18	199,33	197,43	122,49	201,73	205,03	201,81	203,55	206,50	200,65	198,53	204,56	197,07	202,46	190,68	204,00	199,15
Neckargasse Day: to Hafengasse	200,31	197,61	200,69	210,51	193,09	208,45	203,17	180,71	200,90	200,12	203,93	202,32	201,22	203,48	202,66	197,96	201,33	199,71	201,60	192,35	204,82	203,56
Neckargasse Day: to Hospizberg	114,35	198,65	102,53	195,13	186,52	118,81	199,34	195,10	133,78	199,06	103,16	95,71	201,31	144,78	193,25	204,49	101,08	97,93	204,59	98,45	197,30	200,53
Neckargasse Night: to Holzmarkt	231,99	214,83	211,37	213,09	206,04	212,88	208,18	204,20	209,36	213,26	211,36	215,78	212,57	217,67	217,10	216,68	211,50	210,55	216,68	211,17	213,02	211,93
Neckargasse Night: to Marktplatz	138,68	210,53	211,13	210,34	207,83	208,80	212,16	191,85	127,79	213,02	210,34	215,02	210,37	214,78	209,86	216,71	212,58	117,28	212,73	211,07	216,59	211,91
Neckargasse Night: to Hirschgasse	194,00	215,17	212,11	222,61	215,32	211,27	209,22	206,79	126,00	211,67	208,21	214,10	212,31	217,09	212,98	214,82	217,15	206,76	213,72	207,16	210,76	210,56
Neckargasse Night: to Hafengasse	219,29	219,42	209,27	217,44	223,61	220,40	211,09	217,75	216,34	212,14	204,13	216,42	209,18	217,58	213,25	218,05	211,01	213,09	215,14	208,94	217,26	209,91
Neckargasse Night: to Hospizberg	139,04	215,56	115,85	218,23	198,15	135,78	214,44	209,46	135,42	214,12	120,99	212,44	200,28	136,29	216,12	218,08	209,14	117,56	213,18	210,15	145,76	211,09

Table A2: Angles of imagination in turning condition. Data marked in red is not included in the analysis.

	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15	Test 16	Test 17	Test 18	Test 19	Test 20	Test 21	Test 22
Marktplatz Day: from Neckargasse	6,84	340,65	293,55	342,59	330,14	43,72	342,80	339,86	211,38	350,08	2,19	14,00	344,60	356,11	324,75	355,20	351,06	285,31	2,25	350,65	343,03	4,62
Marktplatz Day: from Hirschgasse	25,46	328,86	231,03	289,83	107,21	40,71	345,10	2,35	2,39	349,17	356,92	19,09	345,23	353,78	329,65	7,90	130,04	352,93	7,91	124,84	268,36	16,31
Marktplatz Day: from Hospizberg	110,19	331,55	315,87	307,36	84,04	294,50	338,86	12,99	345,76	336,33	352,34	15,52	343,87	6,10	126,06	9,54	25,13	29,55	8,08	337,23	48,21	107,34
Marktplatz Day: from Hafengasse	345,59	339,51	109,97	306,03	333,85	323,46	341,07	79,67	73,77	344,24	349,60	273,13	342,05	13,52	317,25	11,55	345,09	347,44	11,08	104,93	327,85	7,91
Marktplatz Day: from Holzmarkt	346,01	334,57	69,21	324,75	340,23	36,13	343,37	257,52	355,45	346,16	347,16	13,07	339,62	8,93	335,17	352,54	36,27	343,02	2,53	120,60	344,64	359,76
Marktplatz Night: from Neckargasse	174,71	34,60	256,60	34,95	157,37	110,47	157,90	190,15	20,48	179,73	172,61	163,00	160,40	186,97	135,34	190,50	132,25	113,83	187,73	170,83	171,12	191,13
Marktplatz Night: from Hirschgasse	93,04	27,74	162,50	43,17	123,68	200,67	164,77	155,00	54,42	176,31	159,08	162,50	158,59	179,32	133,72	145,24	198,31	118,94	180,80	297,51	123,24	182,86
Marktplatz Night: from Hospizberg	280,31	31,69	176,21	312,10	275,33		159,89	136,91	165,27	198,08	169,64	161,76	157,67	190,69	302,68	234,93	304,50	183,67	184,10	110,56	273,32	184,08
Marktplatz Night: from Hafengasse	132,90	29,57	303,19	293,97	284,79	321,11	161,51	189,92	64,05	189,47	159,69	161,12	167,15	172,73	125,67	185,33	281,81	113,78	185,25	299,50	157,14	117,33
Marktplatz Night: from Holzmarkt	193,08	21,55	164,59	293,13	160,33	18,85	162,68	342,00	17,59	184,60	170,31	164,71	162,25	176,95	136,52	175,36	86,59	116,86	182,80	301,78	150,52	184,03
Hafengasse Day: from Marktplatz	53,98	74,02	130,48	82,60	97,95	107,84	87,25	81,26	102,33	84,80	291,80	119,81	331,92	42,44	124,89	89,32	30,43	104,14	29,25	81,66	198,02	81,66
Hafengasse Day: from Holzmarkt	53,51	68,82	66,35	87,23	93,14	210,21	91,40	29,42	85,51	87,96	292,62	121,57	331,95	26,28	115,42	43,16	122,94	79,78	26,96	88,37	118,48	161,33
Hafengasse Day: from Hirschgasse	191,13	89,06	94,25	79,98		269,88	85,85	118,71	29,81	92,97	296,86	123,30	347,69	27,64	206,42	158,79	203,87	114,04	33,74	49,41	193,80	232,50
Hafengasse Day: from Neckargasse	118,93	76,85	5,81	83,77	120,72	307,74	87,73	335,08	21,57	78,29	297,48	26,23	337,29	36,61	121,24	110,50	33,79	102,88	33,79	285,07	130,69	105,02
Hafengasse Day: from Hospizberg	48,36	85,47	195,92	79,17	14,69	297,31	94,96	78,13	11,16	82,34	290,96	121,97	332,87	35,66	121,80	124,35	34,09	56,76	28,07	308,40	112,43	130,35
Hafengasse Night: from Marktplatz	187,15	320,45	180,39	186,31	107,43	92,78	334,47	100,57	92,42	54,54	284,33	113,13	313,74	29,47	117,92	63,63	30,71	75,44	21,97	22,41	116,94	74,23
Hafengasse Night: from Holzmarkt	192,85	60,74	70,64	221,72	279,88	168,50	81,93	68,43	50,61	71,87	285,30	114,30	325,65	40,25	108,33	80,44	195,20	74,14	25,25	279,08	115,12	82,92
Hafengasse Night: from Hirschgasse	190,38	59,29	141,05	192,77	116,94	266,35	80,96	327,85	328,72	60,33	286,34	19,51	319,07	24,70	191,35	322,10	195,27	89,65	27,56	8,85	277,52	192,31
Hafengasse Night: from Neckargasse	109,92	76,22	74,04	183,46		300,94	338,64	29,56	334,54	49,41	285,73	112,48	335,34	26,42	25,31	22,94	33,68	93,75	33,72	282,26	117,72	114,66
Hafengasse Night: from Hospizberg	22,26	84,27	16,98	185,60	106,71	38,54	338,30	19,54	151,53	53,16	291,17	33,10	324,60	26,49	116,41	115,01	49,69	82,55	23,50	291,44	114,52	112,49
Holzmarkt Day: from Hafengasse	345,75	23,09	41,45	243,61	235,94	215,57	17,82	101,77	128,84	38,89	32,38	36,69	239,00	319,42	144,47	41,98	106,17	104,56	154,70	70,49	137,36	124,80
Holzmarkt Day: from Neckargasse	283,48	18,09	326,76	244,38	118,94	342,14	241,46	236,98	19,52	41,10	59,47	35,26	241,54	319,80	140,32	355,76	308,00	106,62	148,65	320,63	84,55	129,32
Holzmarkt Day: from Hospizberg	284,54	354,10	102,93	225,48		111,03	26,12	131,11	8,40	41,00	47,53	238,46	229,90	322,21	317,07	335,02	116,14	85,62	146,05	99,17	331,66	177,23
Holzmarkt Day: from Hirschgasse	351,02	331,86	56,41	213,06	48,57	185,33	58,21	117,52	125,68	43,19	44,12	239,27	238,73	323,24	325,01	19,91	204,18	318,75	146,62	186,98	352,98	140,00
Holzmarkt Day: from Marktplatz	329,76	350,48	138,62	214,36	337,35	159,56	133,86	174,91	130,39	45,47	46,04	36,72	243,05	320,28	326,92	344,17	90,08	25,08	132,96	125,15	328,15	330,33
Holzmarkt Night: from Hafengasse	146,40	46,31	105,11	323,85	107,43	259,34	230,72	318,62	231,77	209,14	201,40	240,52	42,10	315,67	318,18	209,90	290,10	222,00	208,78	225,63	284,44	309,75
Holzmarkt Night: from Neckargasse	336,00	54,25	105,73	320,37	299,53	310,03	305,48	323,47	186,40	230,04	222,49	302,18	51,51	316,84	310,76	299,98	139,62	318,31	312,91	114,16	278,76	307,42
Holzmarkt Night: from Hospizberg	127,23		138,65	315,99	69,62	358,32	220,16	53,57	306,53	231,76	225,52	247,52	37,05	129,74	136,64	169,48	22,79	228,05	302,38	318,89	354,28	164,02
Holzmarkt Night: from Hirschgasse	216,71	44,75	132,35	299,00	206,62		193,03	282,60	44,87	181,82	235,45	294,67	43,97	123,06	225,59	206,57	106,74	62,80	306,63	352,66	264,99	201,63
Holzmarkt Night: from Marktplatz	134,71	49,70	132,35	307,38	156,58	155,46	199,61	275,91	312,74	246,43	236,87	121,23	36,48	128,37	121,14	136,64	188,56	157,52	307,25	309,01	138,11	123,19
Hirschgasse Day: from Holzmarkt	218,03	338,62	42,17	215,36	281,02	347,78	80,89	65,21	287,41	213,23	216,95	286,17	119,85	77,12	285,84	212,58	47,47	270,04	201,58	81,58	264,65	160,62
Hirschgasse Day: from Hospizberg	220,60	313,29	350,43	315,65	296,84	59,81	85,84	327,02	198,73	90,31	213,23	285,76	125,02	76,05	260,97	265,45	297,83	204,93	206,57	57,80	283,64	327,15
Hirschgasse Day: from Neckargasse	56,67	325,83	19,21	316,98	274,13	74,22	83,30	69,61	339,91	210,39	209,41	288,32	121,10	68,86	279,24	258,53	61,49	271,22	205,19	57,24	259,53	261,31
Hirschgasse Day: from Hafengasse	214,64	324,07	313,15	321,90	243,19	41,81	76,55	93,53	331,59	205,06	213,61	287,97	115,37	65,28	265,52	228,06	133,36	204,97	200,34	50,67	262,60	274,28
Hirschgasse Day: from Marktplatz	207,68	321,71	277,09	327,14	283,09	264,38	85,36	33,33	288,94	200,70	219,02	285,62	118,01	68,10	310,73	326,88	261,65	193,65	210,41	60,83	237,59	333,56
Hirschgasse Night: from Holzmarkt	259,27	293,12	239,93	299,59	329,78	281,45	287,90	154,33	86,95	167,89	176,27	251,09	82,89	179,44	240,00	202,00	175,71	236,26	170,82	17,04	249,34	302,04
Hirschgasse Night: from Hospizberg	258,00	285,14	283,42	279,14	243,47	18,77	45,16	10,93	283,23	170,40	173,15	175,15	80,47	158,16	238,46	259,96	62,40	170,02	167,10	148,85	220,12	232,47
Hirschgasse Night: from Neckargasse	260,57	293,60	58,13	300,33	215,08	37,47	47,67	41,46	88,05	183,49	182,64	248,62	97,20	171,31	250,00	241,82	163,75	297,86	185,95	21,43	171,30	164,04
Hirschgasse Night: from Hafengasse	173,71	292,37	56,09	291,68	215,86	116,26	46,06	324,11	89,46	169,55	180,46	16,40	80,95	174,06	244,65	18,07	16,64	152,06	179,24	15,13	293,37	241,05
Hirschgasse Night: from Marktplatz	170,72	295,54	243,58	303,71	286,77	239,10	34,34	238,68	296,52	175,27	176,54	250,82	81,33	170,19	242,33	254,71	260,13	230,26	170,75	18,98	263,67	300,92
Hospizberg Day: from Hirschgasse	96,72	346,29	315,27	8,27	320,12		23,94	19,26	16,30	87,13	322,11	337,54	82,27	176,42	354,86	308,73	98,59	339,12	98,86	99,69	74,04	92,04
Hospizberg Day: from Marktplatz	97,89	336,43	293,77	12,32	152,87	186,42	10,46	97,49	7,90	92,01	319,77	338,94	87,64	174,10	93,53	331,85	313,83	339,92	92,70	96,11	3,40	72,37
Hospizberg Day: from Hafengasse	97,18	346,56	74,14	13,57	316,76	191,69	13,94	180,75	359,28	87,48	313,37	338,20	98,43	178,59	81,78	335,73	108,38	349,74	90,11	165,04	344,11	320,53
Hospizberg Day: from Holzmarkt	342,98	350,48	204,45	356,24	116,13	283,27	92,19	198,69	310,76	102,31	321,87	337,88	92,39	187,07	3,80	338,69	354,57	338,36	91,57	175,34	78,01	320,41
Hospizberg Day: from Neckargasse	341,69	335,94	171,31	354,53	335,41	351,70	13,09	180,64	28,56	83,66	314,20	338,35	92,32	185,95	13,68	71,20	328,92	346,50	92,99	276,61	348,90	327,37
Hospizberg Night: from Hirschgasse	97,32	346,91	143,23	206,50	147,38	36,04	189,29	272,41	192,94	297,31	143,83	162,02	282,02	287,12	192,50	139,19	147,21	177,73	265,67	185,70	273,28	275,99
Hospizberg Night: from Marktplatz	114,53	359,26	128,42	189,26	156,37	186,22	264,52	7,51	105,39	297,63	123,51	163,54	277,06	282,97	233,83	149,22	125,07	166,44	278,55	302,58	271,98	140,77
Hospizberg Night: from Hafengasse	158,58	348,39	119,51	178,80	132,66	156,78	265,11	12,92	313,19	309,98	131,89	282,02	276,41	285,40	211,92	131,01	192,03	180,17	273,06	344,82	262,11	144,32
Hospizberg Night: from Holzmarkt	178,87	357,02	133,08	177,77	141,51	331,46	279,63	355,57	198,31	303,18	130,98	354,46	275,66	281,68	207,94	162,61	299,24	180,43	281,05	357,97	253,24	141,84
Hospizberg Night: from Neckargasse	256,50	356,10	143,51	192,97	300,65	15,93	267,25	272,88	192,86	309,31	149,22	157,65	272,29	283,20	201,95	285,90	146,07	173,06	275,63	350,52	284,13	149,79
Neckargasse Day: from Hospizberg	348,91	342,02	334,23	0,25	168,72	203,89	135,00	26,34	203,96	193,20	205,76	346,64	146,03	343,27	358,90	111,13	342,78	109,43	206,16	350,16	351,52	57,70
Neckargasse Day: from Hafengasse	208,16	353,89	107,01	336,31	202,01	263,06	146,48	351,31	318,15	198,04	196,95	203,55	163,45	354,87	0,87	353,51	196,06	91,58	203,45	199,85	1,39	68,86
Neckargasse Day: from Holzmarkt	351,55	332,86	337,33	330,13	209,94	208,45	128,35	11,07	26,90	202,61	205,37	352,37	145,18	357,98	351,96	0,63	357,21	352,66	200,02	188,53	0,44	350,57
Neckargasse Day: from Marktplatz	352,00	336,82	341,60	338,48	196,50	116,81	133,01	345,62	53,07	200,07	201,25	349,45	158,73	354,42	0,41	350,98	91,76	342,78	203,73	189,99	355,26	0,86
Neckargasse Day: from Hirschgasse	356,10	339,45	118,69	345,73	2,62	211,29	137,96	134,71	134,23	204,25	200,31	352,97	135,24	348,16	352,31	354,30	343,82	353,92	203,72	199,27	359,93	349,81
Neckargasse Night: from Hospizberg	352,44	341,46	182,22	248,49	14,22	209,87	153,33	14,81	331,03	221,85	212,01	0,96	173,30	353,77	353,70	9,49	262,36	355,51	216,34	345,94	5,26	67,53
Neckargasse Night: from Hafengasse	339,77	13,25	351,40	237,22	350,82	203,48	154,02	245,03	15,62	225,53	210,10	3,16	156,26	5,74	10,16	210,44	209,75	0,48	4,75	212,67	8,87	3,39
Neckargasse Night: from Holzmarkt	354,08	344,38	2,19	251,24	7,95	7,28	146,38	69,97	36,66	220,19	207,56	355,22	163,79	6,65	352,87	22,84	358,07	8,00	206,12	208,97	354,87	44,02
Neckargasse Night: from Marktplatz	344,73	348,49	8,99	263,01	354,91	23,90	153,27	358,12	60,82	210,87	206,10	359,17	179,88	5,05	359,88	5,71	358,33	107,00	216,06	212,63	1,12	358,00
Neckargasse Night: from Hirschgasse	214,40	355,85	204,84	247,14	8,66	201,17	154,85	29,27	145,47	217,50	217,70	354,84	150,21	1,73	355,07	0,39	104,52	1,07	212,98	214,11	1,16	1,95

Table A3: Angles of imagination in walking condition. Data marked in red is not included in the analysis.

	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15	Test 16	Test 17	Test 18	Test 19	Test 20	Test 21	Test 22
Marktplatz Day: from Neckargasse	32,60	325,75	341,92	347,40	348,65	336,33	320,94	336,30	339,69	4,32	355,30	343,92	340,84	0,33	332,69	350,36	344,11	351,32	330,17	339,44	337,58	6,46
Marktplatz Day: from Hirschgasse	273,14	273,35	335,87	1,17	297,21	211,15	287,89	286,60	291,19	289,98	268,61	272,40	339,38	320,99	326,59	347,63	345,60	336,16	253,94	313,96	310,50	7,21
Marktplatz Day: from Hospizberg	12,49	100,15	270,76	63,99	109,26	80,71	132,31	109,40	47,92	104,14	356,58	150,27	122,31	78,66	131,13	69,52	63,70	292,60	117,46	114,65	21,10	6,29
Marktplatz Day: from Hafengasse	304,16	313,68	341,36	5,78	297,56	11,72	291,29	21,00	345,27	359,04	323,16	340,34	340,10	357,48	314,99	332,46	336,38	315,35	328,98	319,99	340,35	288,79
Marktplatz Day: from Holzmarkt	13,99	335,99	340,31	20,90	347,72	20,32	339,01	336,82	334,35	353,08	350,50	354,84	341,81	344,37	320,16	340,26	339,65	355,24	320,58	337,20	329,08	3,85
Marktplatz Night: from Neckargasse	200,91	168,97	163,13	191,01	162,01	193,62	171,81	176,39	174,74	169,73	169,55	170,38	160,27	170,62	137,83	155,14	171,06	166,00	153,36	167,09	163,17	184,26
Marktplatz Night: from Hirschgasse	86,30	107,46	151,99	97,44	146,06	313,94	95,89	62,05	116,01	77,58	126,88	165,09	124,63	172,24	153,51	157,92	6,50	162,55	83,95	146,21	85,05	187,45
Marktplatz Night: from Hospizberg	191,19	239,17	243,14	197,35	295,85	234,97	311,61	275,02	181,79	274,15	165,81	86,94	304,25	273,51	300,50	316,94	225,90	240,05	306,36	313,21	81,62	176,79
Marktplatz Night: from Hafengasse	103,02	156,16	150,67	184,88	304,34	193,28	177,87	157,32	170,46	179,41	160,46	165,63	109,45	170,05	140,86	188,73	142,79	172,19	137,05	165,90	171,20	175,09
Marktplatz Night: from Holzmarkt	179,84	161,26	158,82	204,72	165,94	201,15	171,88	173,82	172,94	178,68	158,13	166,41	157,09	176,31	146,65	180,90	170,49	177,58	153,51	151,64	151,05	179,03
Hafengasse Day: from Marktplatz	121,32	127,09	121,91	117,00	283,29	127,25	199,41	55,84	109,92	125,08	128,21	91,32	110,85	197,73	122,37	113,50	209,74	106,93	203,27	117,35	121,87	94,36
Hafengasse Day: from Holzmarkt	140,86	124,24	119,90	109,31	284,12	107,61	119,72	105,89	113,99	125,99	124,49	87,97	121,19	47,11	124,25	116,52	207,64	112,35	198,78	117,57	116,12	131,87
Hafengasse Day: from Hirschgasse	205,69	119,87	295,79	194,99	292,24	210,35	194,82	211,87	195,45	206,28	135,65	295,82	196,52	191,60	122,25	204,59	198,56	92,41	192,70	198,57	203,20	201,48
Hafengasse Day: from Neckargasse	135,20	125,50	118,52	131,00	98,16	101,71	114,53	114,05	124,55	115,35	122,39	120,24	114,99	117,74	129,30	125,12	124,02	103,41	36,16	114,46	117,75	106,99
Hafengasse Day: from Hospizberg	93,76	126,57	202,09	44,01	285,91	123,29	201,82	111,22	200,12	122,99	117,79	206,59	118,81	204,18	125,63	123,42	196,77	108,01	194,05	121,57	27,55	123,78
Hafengasse Night: from Marktplatz	193,09	104,47	115,29	114,22	265,18	104,59	190,46	196,92	153,81	102,90	109,34	191,35	115,44	192,04	121,52	110,88	197,65	89,56	199,13	279,37	113,37	111,40
Hafengasse Night: from Holzmarkt	195,14	111,73	110,30	112,00	130,34	97,69	110,28	108,41	108,58	106,23	112,71	112,89	106,90	200,45	107,90	103,75	114,54	91,20	190,81	109,09	113,30	109,16
Hafengasse Night: from Hirschgasse	188,97	104,62	278,72	178,44	275,44	201,55	193,12	196,64	190,63	183,03	132,81	283,64	105,07	190,13	119,83	102,83	195,43	88,64	192,22	186,81	194,63	195,45
Hafengasse Night: from Neckargasse	108,28	112,05	111,57	33,26	105,44	124,76	115,31	117,60	113,45	101,05	115,65	289,50	108,24	112,84	42,87	26,60	105,67	88,21	121,46	105,74	114,70	111,91
Hafengasse Night: from Hospizberg	130,06	118,66	193,92	15,97	281,23	119,42	186,66	118,45	114,65	120,57	18,10	192,27	107,40	194,10	117,61	128,51	195,92	94,12	199,49	101,83	113,22	117,64
Holzmarkt Day: from Hafengasse	116,08	137,33	139,18	136,38	60,77	133,66	133,77	133,80	35,88	155,14	331,04	135,36	148,34	152,86	134,61	40,78	141,58	329,65	140,32	136,98	138,50	134,59
Holzmarkt Day: from Neckargasse	114,07	139,18	143,47	107,83	116,14	138,19	130,83	109,13	137,17	150,17	169,39	130,15	124,40	153,33	135,15	132,78	143,26	318,58	134,97	133,81	111,51	135,75
Holzmarkt Day: from Hospizberg	325,49	290,23	327,73	264,65	322,38	312,43	313,21	305,31	323,21	313,64	159,30	128,50	317,17	313,21	326,77	320,16	318,15	230,10	324,33	299,67	292,80	317,95
Holzmarkt Day: from Hirschgasse	332,64	161,39	321,33	44,61	94,86	336,41	304,24	341,10	27,21	81,14	15,09	137,57	316,75	323,90	41,83	33,90	28,21	312,00	13,86	358,02	341,37	321,33
Holzmarkt Day: from Marktplatz	318,39	328,56	320,79	176,14	338,20	325,77	322,36	315,31	323,74	323,39	324,69	325,92	315,01	328,88	327,14	325,21	325,05	53,39	338,27	321,30	321,27	325,60
Holzmarkt Night: from Hafengasse	276,98	324,00	200,69	319,55	308,80	329,91	314,60	321,06	195,70	312,41	307,08	303,24	320,56	216,91	296,88	204,13	313,62	163,73	317,57	303,83	296,68	309,66
Holzmarkt Night: from Neckargasse	328,02	299,80	211,74	330,76	286,31	323,93	298,71	302,01	316,26	321,83	321,75	315,44	310,92	313,82	306,18	305,43	315,03	310,32	309,26	316,25	306,90	307,80
Holzmarkt Night: from Hospizberg	97,18	134,99	128,17	116,89	65,44	133,11	134,80	127,69	127,75	123,08	286,38	129,87	127,05	128,09	139,32	133,40	135,24	220,70	136,34	106,43	127,02	123,61
Holzmarkt Night: from Hirschgasse	213,08	258,53	295,08	232,47	196,76	130,80	134,44	240,79	158,86	138,21	240,88	291,67	246,40	132,60	257,95	213,38	208,66	138,70	179,66	188,10	140,60	199,35
Holzmarkt Night: from Marktplatz	136,81	105,75	133,93	111,04		134,41	122,86	129,67	158,63	117,13	128,69	121,38	127,07	130,55	124,69	127,60	127,06	122,60	138,31	126,70	125,91	127,59
Hirschgasse Day: from Holzmarkt	296,71	273,80	272,99	287,63	356,64	240,25	269,22	283,30	289,92	281,12	296,16	282,94	116,26	292,80	284,53	290,23	288,55	184,90	276,09	284,58	282,99	336,18
Hirschgasse Day: from Hospizberg	224,87	268,11	350,82	270,09	282,83	24,52	272,85	264,44	285,07	345,98	272,96	291,87	280,20	287,00	275,47	279,44	282,89	278,74	270,80	284,03	271,50	267,80
Hirschgasse Day: from Neckargasse	293,47		72,46	285,59	359,14	268,05	277,85	264,36	284,04	282,28	275,98	287,35	281,66	286,25	279,89	273,11	52,64	274,86	260,70	224,86	240,23	248,85
Hirschgasse Day: from Hafengasse	212,51	50,89	268,66	290,20	294,77	207,28	276,53	265,88	281,65	276,67	263,36	291,29	196,18	283,91	265,81	214,14	278,41	192,06	194,27	269,32	318,50	280,88
Hirschgasse Day: from Marktplatz	310,25	272,59	263,51	294,80	257,71	275,19	279,86	264,39	284,66	283,34	296,75	61,45	275,75	275,76	288,53	299,47	286,58	273,11	279,77	278,25	269,33	335,24
Hirschgasse Night: from Holzmarkt	189,48	231,82	233,42	234,78	342,24	235,12	226,84	232,71	266,33	237,52	238,34	251,22	242,27	256,03	239,03	242,77	240,25	232,64	241,19	243,80	249,18	313,85
Hirschgasse Night: from Hospizberg	256,40	251,09	319,05	184,07	23,35	234,89	230,44	309,08	252,29	321,89	246,28	161,81	245,22	262,13	251,46	246,46	315,41	163,90	212,27	246,27	242,71	229,69
Hirschgasse Night: from Neckargasse	177,46	254,44	234,34	235,24	214,84	254,03	242,90	260,09	253,65	248,62	257,76	252,29	171,85	248,01	239,73	244,62	243,49	233,22	193,62	198,72	199,93	231,34
Hirschgasse Night: from Hafengasse	179,25	272,19	320,52	250,22	204,79	161,71	245,62	246,88	253,68	247,40	229,68	254,25	243,68	252,57	249,85	257,21	242,78	156,82	153,61	185,89	193,00	250,97
Hirschgasse Night: from Marktplatz	238,07	271,17	233,21	229,23	326,37	235,93	240,60	263,82	258,52	262,32	252,75	252,66	240,00	247,34	253,00	253,79	254,02	221,20	232,53	38,03	204,15	299,77
Hospizberg Day: from Hirschgasse	283,94	263,63	301,04	278,22	339,74	341,53	346,95	330,15	341,98	252,47	280,23	335,62	349,60	53,10	12,07	356,66	336,97	337,83	18,25	307,52	74,88	327,61
Hospizberg Day: from Marktplatz	193,90	266,60	307,62	329,36	93,15	279,11	248,09	239,53	343,95	272,12	282,05	338,82	357,89	14,41	355,56	357,97	274,32	342,53	351,52	314,24	257,20	350,21
Hospizberg Day: from Hafengasse	332,27	344,69	297,38	343,67	324,16	345,35	331,90	343,00	345,20	279,81	312,38	341,49	341,46	16,26	7,96	359,12	40,11	342,08	356,18	29,75	69,63	350,34
Hospizberg Day: from Holzmarkt	331,19	243,19	310,49	338,20	325,01	355,28	334,69	0,76	342,44	275,68	317,97	335,45	348,42	74,29	358,57	351,03	42,56	343,06	10,15	25,81	55,08	337,36
Hospizberg Day: from Neckargasse	80,58	337,36	344,46	295,49	177,34	347,93	336,04	343,04	344,26	0,78	338,17	340,96	346,42	75,77	352,06	337,56	50,30	335,46	11,70	40,54	63,06	334,15
Hospizberg Night: from Hirschgasse	280,91	125,68	127,53	119,27	143,42	84,63	135,34	167,53	162,50	106,85	129,29	161,64	163,08	262,37	194,86	207,15	94,33	164,80	184,49	154,37	177,79	159,08
Hospizberg Night: from Marktplatz	173,61	137,28	169,94	83,77	296,10	94,28	51,44	161,38	96,42	116,84	119,54	164,11	168,47	65,56	198,56	174,70	81,41	150,38	194,03	118,59	143,97	208,62
Hospizberg Night: from Hafengasse	157,27	150,66	165,56	143,83	322,88	154,32	158,54	183,52	164,32	143,53	130,67	162,90	155,23	269,10	173,50	156,13	165,43	158,22	181,40	177,06	170,85	164,51
Hospizberg Night: from Holzmarkt	273,83	146,54	155,05	143,49	95,82	171,15	150,50	158,50	111,74	135,77	129,63	162,93	169,60	267,57	188,91	163,75	214,01	148,98	182,05	232,36	170,79	170,20
Hospizberg Night: from Neckargasse	162,22	152,64	144,39	145,40	336,08	174,49	148,09	159,98	160,14	191,42	165,09	154,74	169,71	273,46	182,90	160,21	224,65	166,45	178,24	170,61	168,69	173,36
Neckargasse Day: from Hospizberg	359,67	358,97	359,75	353,99	1,66	351,96	353,42	353,41	6,52	359,03	311,06	351,39	2,79	3,80	356,97	354,58	296,44	102,06	0,10	350,19	0,30	356,54
Neckargasse Day: from Hafengasse	341,62	356,88	358,37	354,85	357,33	7,59	9,46	11,48	4,66	354,02	356,34	354,20	0,76	353,84	3,23	4,34	358,43	355,70	355,94	0,66	5,38	31,20
Neckargasse Day: from Holzmarkt	352,79	355,73	2,32	352,25	353,86	354,70	356,81	347,06	352,54	6,91	347,94	350,16	18,77	355,88	352,38	4,57	355,29	343,07	352,87	352,08	338,23	355,16
Neckargasse Day: from Marktplatz	1,48	347,15	353,50	350,32	23,52	348,08	2,70	348,31	30,79	355,12	19,55	353,23	0,33	358,57	351,87	345,78	321,23	353,32	355,53	347,67	335,92	346,82
Neckargasse Day: from Hirschgasse	19,97	351,44	356,46	358,11	27,05	1,66	348,75	0,06	11,21	353,20	357,17	205,82	1,21	357,03	350,86	354,23	356,60	345,64	2,30	347,98	14,87	343,90
Neckargasse Night: from Hospizberg	352,03	6,18	295,06	351,74	3,39	13,21	4,68	4,61	307,38	19,27	328,10	213,22	1,97	8,21	8,60	9,32	4,91	348,44	13,58	0,80	11,78	8,56
Neckargasse Night: from Hafengasse	345,17	0,34	9,01	358,66	15,34	19,39	13,86	5,90	12,48	21,65	15,48	3,55	11,64	3,41	9,48	5,57	4,12	352,06	11,85	0,88	8,02	4,90
Neckargasse Night: from Holzmarkt	352,97	352,68	6,60	5,80	16,44	4,87	7,37	359,02	355,68	28,82	10,23	359,69	14,09	0,87	353,48	5,21	15,13	347,32	8,77	352,92	352,73	0,72
Neckargasse Night: from Marktplatz	348,00	358,49	8,72	351,36	32,11	6,73	5,07	359,35	5,50	17,86	352,60	223,68	358,67	359,28	4,09	351,69	1,46	353,90	9,27	355,27	3,17	359,12
Neckargasse Night: from Hirschgasse	349,92	346,91	4,41	347,49	25,90	5,03	2,88	4,35	7,35	35,35	9,44	213,35	12,62	0,68	356,68	357,91	10,91	6,79	3,37	2,71	6,77	357,86

5.2 MATLAB-Codes

Figure A1: MATLAB-Code for the creation of compass-plots of turning angles in turning condition (per subject, per location). Note that to get plots for different data, parts of the code has to be altered.

```
filename=xlsread('Final Test End Points Turning in walking
condition.xlsx','W57:W61');
[x y]=pol2cart(filename*pi/180,1);
Z = eig(randn(5));
clr = lines(numel(Z));
h = compass(x,y);
set(h, {'Color'},num2cell(clr,2), 'LineWidth',2);
legend('to Neckargasse','to Hirschgasse','to Holzmarkt','to Marktplatz','to
Hafengasse','Location','northeastoutside')
title('End Points of Turning in Walking Condition: Hospizberg Test 22 Night')
view([380 -90])
print('-bestfit','End Points of Turning in Walking Condition Hospizberg Test 22
Night','-dpdf')
```

Figure A2: MATLAB-Code for the creation of compass-plots of imagination angles in turning condition (per different place transition, all subjects, with vector means), and for the calculation of the u-values for the V-Tests. Note that to get results for different data, parts of the code has to be altered.

```
filename=xlsread('Final Test End Points Imagination in turning
condition.xlsx','B3:W3');
w=filename;
w(12)=[];
w(5)=[];
[x y]=pol2cart(w*pi/180,1);
h = compass(x,y);
hold on
q=deg2rad(w);
k=[cos(q);sin(q)];
k2=sum(k,2);
p21=atan(k2*(1/20));
compass(p21(1),p21(2),'r');
set(get(get(h(2),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(3),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(4),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(5),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(6),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(7),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(8),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(9),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(10),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(11),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(12),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(13),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(14),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(15),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(16),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(17),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(18),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(19),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(20),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
```

```
legend('Imagined Perspectives of Participants','Vector Mean of
Perspectives','Location','southoutside');
title('End Points of Imagination in Turning Condition: Marktplatz from Hafengasse
Day')
view([160 -90])
print('-bestfit','End Points of Imagination in Turning Condition Marktplatz from
Hafengasse Day','-dpdf')
[THETA,RHO]=cart2pol(p21(1),p21(2));
winkel=rad2deg(THETA);
a=deg2rad(winkel-339.38);
v=RHO*cos(a);
u=(sqrt(40))*v
```

Figure A3: MATLAB-Code for the creation of compass-plots of imagination angles in walking condition (per different place transition, all subjects, with vector means and determined correct directions). Note that to get results for different data, parts of the code has to be altered.

```
filename=xlsread('Final Test End Points Imagination in walking
condition.xlsx','B3:W3');
w=filename;
w(22)=[];
w(14)=[];
w(12)=[];
w(19)=[];
w(5)=[];
w(1)=[];
[x y]=pol2cart(w*pi/180,1);
h = compass(x,y);
hold on
q=deg2rad(w);
k=[cos(q);sin(q)];
k2=sum(k,2);
p21=atan(k2*(1/16));
compass(p21(1),p21(2),'r');
[a b]=pol2cart(320.49*pi/180,1);
compass(a,b,'g');
[c d]=pol2cart(91.24*pi/180,1);
compass(c,d,'g');
set(get(get(h(2),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(3),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(4),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(5),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(6),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(7),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(8),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(9),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(10),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(11),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(12),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(13),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(14),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(15),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
set(get(get(h(16),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
%set(get(get(h(17),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
%set(get(get(h(18),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
%set(get(get(h(19),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
%set(get(get(h(20),'Annotation'),'LegendInformation'),'IconDisplayStyle','off');
legend('Imagined Perspectives of Participants','Vector Mean of
Perspectives','Correct Perspectives','Location','southoutside');
title('End Points of Imagination in Walking Condition: Marktplatz from Neckargasse
Day')
view([160 -90])
print('-bestfit','End Points of Imagination in Walking Condition Marktplatz from
Neckargasse Day','-dpdf')
```

Figure A4: MATLAB-Code for the creation of compass-plots of corrected pair-means for imagination angles in turning condition (per different place transition, all subjects). Note that to get results for different data, parts of the code has to be altered.

```
filename1=xlsread('Final Test End Points Imagination in turning
condition.xlsx','B3:W3');
average1=xlsread('Final Test End Points Imagination in turning
condition.xlsx','B3:W12');
w1=filename1;
w1(12)=[];
w1(5)=[];
q1=deg2rad(w1);
k1=[cos(q1);sin(q1)];
k1sum=sum(k1,2);
p1=atan(k1sum*(1/20));
v=average1;
v(:,12)=[];
v(:,5)=[];
r=deg2rad(v);
g1=cos(r);
g2=sin(r);
g1(8,5)=0;
g2(8,5)=0;
g3=sum(g1,2);
g4=sum(g2,2);
g5=sum(g3);
g6=sum(g4);
g0=[g5;g6];
g=atan(g0*(1/298));
v1=p1-g;
h=compass(v1(1),v1(2));
set(h,'LineWidth',2);
view([160 -90])
print('-bestfit','Mean Vector of Imagination in Turning Condition Marktplatz from
Neckargasse Day','-dpdf')
```

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