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LABORATORY NOTE

# The Giessen virtual environment laboratory: human wayfinding and landmark salience

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**Abstract** In our virtual environment laboratory, we focus on different topics in human spatial cognition with projects on landmark salience, route knowledge, and survey knowledge. Within this laboratory note, we provide an overview of previous, current, and future work with our virtual environment SQUARELAND.

**Keywords** Landmarks · Landmark salience · Wayfinding · Virtual environment · Spatial cognition · Cognitive psychology · SQUARELAND

## The virtual environment SQUARELAND

The Giessen virtual environment laboratory (Experimental Psychology and Cognitive Science) is currently equipped with a high-resolution projecting system and a 238 ×171 cm projection screen for wayfinding and recognition experiments within virtual reality settings. For this purpose, we have designed a 3D virtual environment with the freeware Google SketchUp® by Google® which we refer to as SQUARELAND. It will be briefly described in the following. Basically, SQUARELAND consists of a 10 × 10 block maze, which allows for all kinds of investigations in human wayfinding (Fig. 1). Therefore, the maze provides a simple square-shaped structure. This is similar to the common design of northern American cities, and it is also close to the layout of indoor environments such as office or administration buildings. Thus, it should be familiar to most of the participants. This basic layout can be changed in many different ways: blocking the "streets" to limit the possible decisions concerning turns (e.g., making a T-junction from a regular intersection), inserting additional walls to elongate single segments, blocking the paths to create dead ends, and so on. In the basic version, each block has a size of 5.5 × 5.5 × 2.75 m (L × W × H) (small version) and 11 × 11 × 2.75 m (large version), and each path between the blocks is 2.75 m wide. Since each segment has the same length, a full control of path lengths, number of turns, etc., is ensured. The intersections serve as decision points while objects along the path can be placed at non-decision points. In addition, the visibility from an intersection in all other directions (streets) is identical.

A more detailed description, downloads, and further information are provided in Hamburger and Knauff (in press).

The eye-height within the virtual maze was set to 1.70 m, which is close to an average eye-height in the population (but it can easily be manipulated in order to correspond to the physical eye-height of each participant). Therefore, the complete setup is a good approximation to the physical world outside the laboratory (of course, virtual environments are not identical to the real environment, but they allow for good control). In order to prevent the participants from seeing two objects simultaneously, a haze was implemented within the maze. Thus, in the basic version, the participants cannot see any further intersection and landmark when they are standing right at an intersection where a decision (turn) has to be made. The next intersection comes into sight when the participant is about half-way through a path, but the visibility of this haze (transparency and distance) can be varied to manipulate the quantity of information provided to the participants. Additionally, this haze—when presented in black, white, or any other luminance or chromaticity—also allows for

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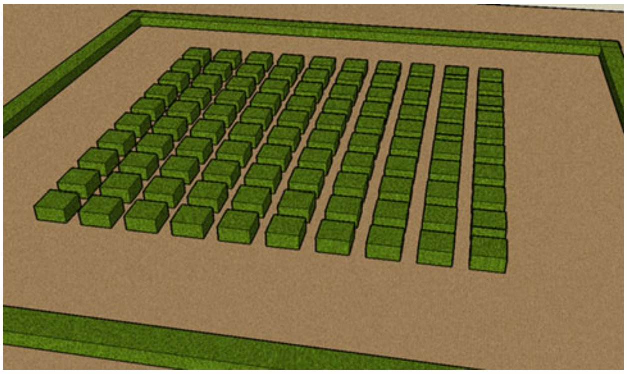

**Fig. 1** The virtual environment SQUARELAND from an aerial perspective (Google SketchUp 6.4). It consists of 100 blocks that have a dimension of 5.5 × 5.5 × 2.75 (LxWxH), and each path between the blocks has a width of 2.75 meters

examinations of different luminance or color contrasts of landmarks compared with the surround (context).

Shapes, color objects, or photorealistic images can be implemented as landmarks at any place in the maze. The size of these landmarks can easily be varied, and each landmark may be placed at the same position with references to the intersections. Furthermore, it is also possible to implement 3D models into the maze or use them as obstructions of the path. Currently, we are using two implementation variations for the landmarks: First, a central position above the participant in mid-air (perception: luminance and color contrast) and secondly, a position along the path at the walls in the form of "pictures" (cognition: visual, semantic, and structural salience).

The main advantage of the combination of SQUARELAND and Google SketchUp® is that it is very economic: a cost-saving and hands-on tool (e.g., ideal for Bachelor or Master students in Psychology).

## Investigating landmarks and landmark salience

Our above-introduced "lattice" construction is actually used to investigate the different concepts of landmarks.

A literature review on landmarks reveals that there are currently three major concepts to define landmark salience: visual salience (e.g., Klippel and Winter 2005), semantic salience (Daniel and Denis 1998; Klippel and Winter 2005), and structural salience (Klippel and Winter 2005; Raubal and Winter 2002; Sorrows and Hirtle 1999):

- *Visual salience* refers to all visual features of an object such as size, shape, color, texture, etc.
- *Semantic salience* refers to all knowledge-related features such as famousness of a building (e.g., Statue of Liberty) or its function (e.g., city hall, church). Semantic salience is often related to how well a building can be named (language and knowledge components).
- *Structural salience* refers to features that are primarily (directly) related to navigation. For example, it contains the number of intersections that need to be passed (surround context) and the exact location of a landmark along a route (close to it—local; further away—global; decision point versus non-decision point). "Such features are of great importance if there is no possibility to revert to any visual or semantic features for successful wayfinding." (Hamburger and Knauff in press, p. 5).

Other concepts such as "cognitive salience" (Caduff and Timpf 2008) have recently been introduced, but for now, the three (most) detailed saliencies described earlier seem to play the most important role.

In our experiments, we want to unveil the visual, semantic, and structural characteristics of (helpful) landmarks within a single setup to allow for the comparison of the different findings. This should enable us to draw inferences about human wayfinding and navigation processes and the underlying neural structures. Our main aim is to establish a neurocognitive theory of landmark salience for human navigation based on the results of empirical (behavioral) data collected in reality (built or urban surrounds), in our virtual environment, future brain-imaging studies, and finally augmented by computational modeling.

## Experiments

In the following section, we will briefly present a few of our diverse experiments. Here, we want to outline the various approaches and the possibilities of SQUARELAND. The current experiments primarily focus on the investigation into the three well-established saliencies of landmarks: visual, semantic, and structural. Furthermore, we also want to offer valuable insights into wayfinding and navigation processes with our experiments.

### Experiments on visual salience

These experiments are a first step toward finding empirical evidence for the visual salience of landmarks, which may easily be estimated (matched) with computational or mathematical models (e.g., Galler 2002; Klippel and Winter 2005). However, do such models really represent how the human brain processes such information? Another, related question is which features define a helpful landmark and are visual landmarks always helpful (Hamburger, Trillmich, Weinberg, Röser, and Knauff in revision) as is generally assumed?

In several experiments, we wanted to find the optimal shape and optimal color for a landmark, respectively. For this, we compared 24 shapes differing with respect to their geometrical shape and six colors with two different saturations and two different background fogs (black and white; to control for luminance contrast) (Fig. 2). This latter condition is the reason why it is also good to show the stimuli "floating" in the air; at first glance, this seems unrealistic but it allows for the investigations into contrasts.

As a central result of these experiments, we may assert that there is no ideal shape or color that seems to represent excellent "landmark" characteristics in comparison with other shapes or colors. This is equally true for a recognition task in which the participants must differentiate between stimuli they had seen in a learning phase and distractors as well as for a wayfinding task in which the participants had to find the way they had learned before, containing the different landmarks. Thus, we could not find any evidence for the classical assumption so far that landmarks must have a great (visual) contrast to their background/surround (e.g., Presson and Montello 1988). By contrast, we found a better performance in the navigation task for unsaturated stimuli (low contrast) compared with saturated ones (high contrast). Additionally, our participants were confronted with the between-subjects factor instruction (remembering objects, remembering route, or just to watch the movie). No performance differences or differences in decision times could be found, no matter whether the instruction was congruent with the test phase (e.g., learn objects + recognition task) or incongruent (e.g., learn objects + navigation task). Thus, we may assume that humans encode landmarks in multiple ways, so that they do not just rely on single characteristics (visual, semantic, or structural).

In a further step, it should be verified that there are no differences with regard to the background on which the material is presented. For this experiment, two different backgrounds ("hedge aisle," "street with houses") with three different levels of brightness were used, showing again different shapes and colors. In this simple detection experiment, it did not matter whether the objects were shown on a light, dark, or medium brightness background. Additionally, an urban surround compared with the hedge maze background did not play a significant role. Performance (detection of objects at certain places) and detection times were quite similar. Thus, different visual features (color, shape, and contrast) did not show to be of great importance and neither did the structure of the street scene (location of the objects within the scenes).

Taken together, with this experimental series, we tried to identify shapes or colors that could be referred to as good landmark features in order to create an "ideal" landmark. What we instead found so far with this series of experiments was that performance and decision times were slightly better for the shapes than for the colors, nothing more. Our results thus challenge the classical landmark definitions. They assume a high (visual) contrast of the landmark to the background is required for high landmark salience (e.g., Lynch 1960; Presson and Montello 1988). However, we could not find any evidence for this assumption. Our results were obtained with virtual designs and also need to be evaluated in a more realistic setting in the future.

The question about an "ideal landmark" is of interest for the applied sciences. However, for the basic research here,

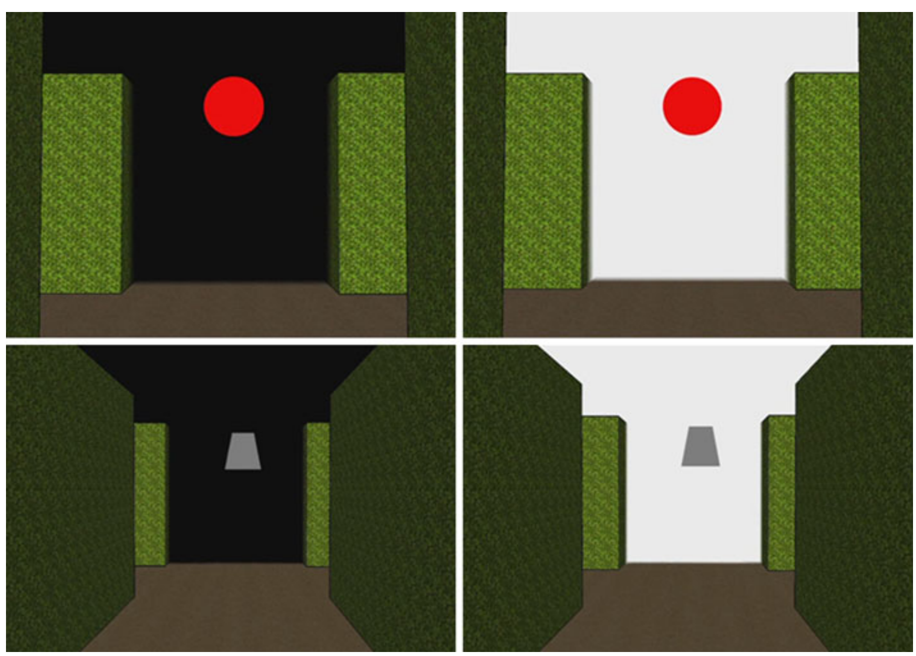

**Fig. 2** Four examples for colors and shapes with two different backgrounds (in this case, white (*high luminance*) and black haze (*low luminance*)) in the virtual environment SQUARELAND

it might be more appropriate to rather focus on qualitative differences such as strategy changes from landmark-based to geometry-based wayfinding. We therefore need to differentiate between physical properties (e.g., visual features) and more cognitive psychological properties and mechanisms (global vs local position, surround structure, semantics, experience, etc.). For example, physiological mechanisms (parvocellular and magnocellular pathways) influence our perception of color and contrast in different ways (e.g., Okubo and Nicholls 2005), which may also have an influence on global and local feature processing. Thus, physical and psychological issues clearly need to be addressed which will indirectly also be part of the remaining sections.

## Experiments on different encoding and retrieval modalities of landmarks

A second series of experiments was focused on a part of the visual/semantic salience: the question whether acoustic and verbal (text) landmarks could also be used for orientation and wayfinding as realized and assumed for visual (pictorial) landmarks (Fig. 3).

First results show that verbal (landmark) information is better recognized than the visual information. The same accounts for acoustic landmarks compared with visual ones. However, this superiority effect of verbal and acoustic landmarks disappears when it comes to a wayfinding task. Thus, again, for the wayfinding process, landmarks and routes seem to be encoded in multiple ways (modalities).

This provides further evidence that classical theories on landmarks and wayfinding/navigation need to be revised, since they make no claims about modality differences (encoding/retrieval) between various landmarks. Furthermore, this experimental series further demonstrates the flexibility of our virtual environment SQUARELAND.

## Experiments on cross-modality

A further section is concerned with the question whether there are cross-modality (switching) costs when the stimuli are presented in a different modality during encoding of information than at retrieval of this information (e.g., visual presentation during the learning phase, acoustic or verbal presentation at test, and vice versa) (Fig. 4). Another question was whether the modality of a landmark has any influence on the cognitive processes in the navigator.

In this experimental series, no differences between congruent material (same modality) and incongruent material (different modality at encoding and retrieval) occurred. Again, the acoustic and verbal (text) material revealed better performance than the visual material in recognition. This effect disappeared during the navigation phase. This is consistent with the results already described and discussed above.

## Experiments on semantic salience

A second major issue in landmark theories is the semantic salience that can best be demonstrated with the famousness of buildings. This is something we have also found in our studies as famous buildings are better recognized than non-famous ones. The question that may not be answered herewith is what really makes a building famous. Is it the uniqueness of the architecture or is it the prominence for each person (personal relevance)? As a first step, we created an intercultural arrangement between German and Russian participants. In an evaluation task, Russian and German participants rated which buildings are famous to them and which not. For the subsequent behavioral experiment, these famous and non-famous buildings were implemented as (visual) landmarks in our virtual environment. In this case, we simply conducted a recognition task with these buildings together with other famous and non-famous buildings as distractors.

For the German sample, no differences occurred between famous and non-famous Russian buildings and for the Russian sample no differences between famous and non-famous German buildings (as expected). For the Russian sample, we obtained a trend for better remembering famous Russian buildings. Here, again, across all

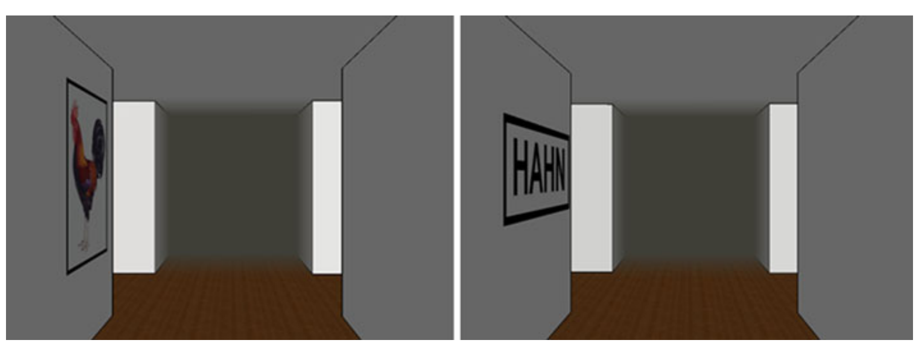


**Fig. 3** Example for a landmark in a visual (*left*) and verbal (*right*) version. Here, an indoor variant of the virtual environment SQUARELAND is displayed

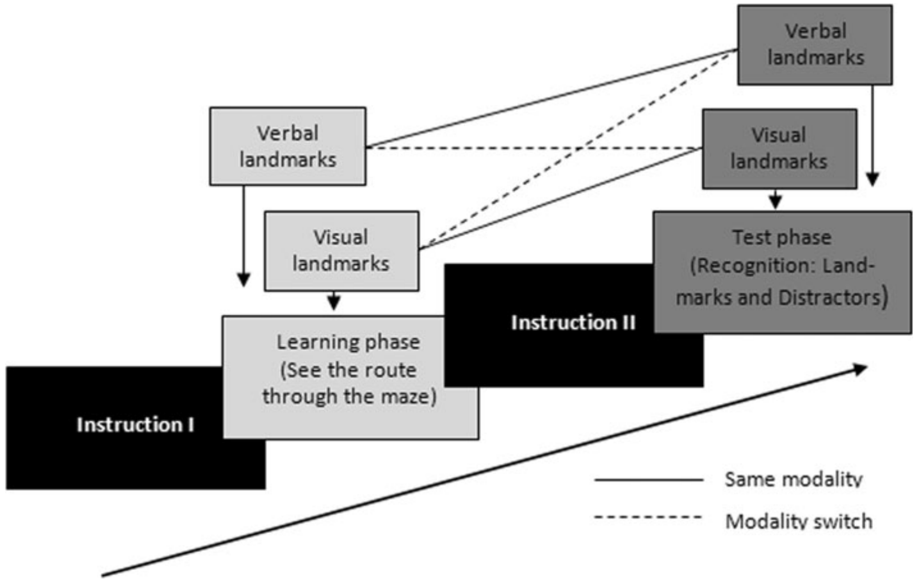


**Fig. 4** Procedure for the experiments on cross-modality processing. First, the participants saw an instruction, followed by a video with the route through the virtual environment SQUARELAND. At each intersection, landmarks were placed, and half of them were visual (*pictures*) and the other half verbal (*letters*). After the learning phase and a second instruction, the participants must decide whether the images they saw now represented landmarks they had seen in the learning phase (*visual* and *verbal* are partially interchanged) or represented new and therefore unknown ones (*distractors*, also *visual* and *verbal*). See text for more details

conditions and samples, the famous buildings produce a significantly better performance in the recognition task than non-famous buildings. This allows for the assumption that such objects become helpful landmarks due to our experience with and knowledge about them.

## Experiments on structural salience

Our current focus is on experiments investigating the crucial issue of structural salience. In a first field experiment, we wanted to examine whether landmarks may also have a negative influence on a wayfinding task. For this, we confronted the citizens of Giessen with a map containing (for them) a well-known start point and a well-known goal location in downtown Giessen. Their task was to draw the shortest possible (realistic) route between these two points, considering the topography of Giessen. In a second step, the same participants received a new map with the same start and goal, but now quite a few extra landmarks were shown. In this condition, a substantial part of the participants showed a worse performance than before. The landmarks seemed to have confused the participants (Hamburger et al. in revision) and distorted their mental representation of their survey knowledge. This result led us to the question of what effect the structural salience has for a wayfinding process. Concerning this question, Klippel and Winter (2005) developed a modulation theory in which they weight the specific points at an intersection. On the basis of this model, we are currently developing further studies. In a first step, we created an online test in which participants must learn a verbal route direction. Afterward, they saw individual intersections from a bird-view perspective and had to say at which point they ideally would like to see the specific landmark (the preferred location instead of a true location) (Fig. 5). We used a similar design in a further field experiment and repeated it in a modified way. Here, the participants must learn the road directions. Afterward, they saw a map of a city (downtown St. Louis, MO) in which the learned route was mapped onto the streets. Now, they must put small metal blocks at each intersection at the points where they think that the landmarks ideally should be located. The model proved to be partly correct. The results and the model showed that the landmarks should ideally be located before an intersection on the side at which a turn has to be made, but the model provides no clear assumptions about the other locations at an intersection and the behavioral results show that the points across the intersection were also of great importance to the participants.

To assess whether these results also apply in a test with egocentric perspective, we currently run an experiment in our virtual environment SQUARELAND. Here, the participants also learn a route description and subsequently they are guided through our virtual environment, and at each intersection, the participants must state at which ideal point they would like to perceive the specific landmarks.

These experiments just resemble the first steps to an empirical investigation into structural landmark salience,

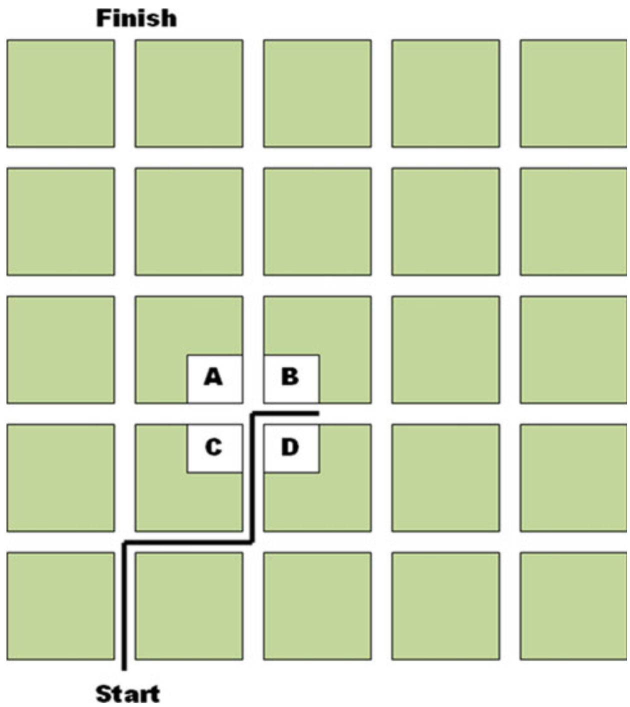


**Fig. 5** Screenshot of the questionnaire (LimeSurvey 1.85). In the learning phase, participants must learn a verbal route direction. Here, an intersection from a bird-view perspective is shown and participants have to decide at which point they ideally would like to place the specific landmark (in this case the church). See text for more details

which has seemingly been neglected in the recent past (at least from an empirical point of view).

## Outlook

Last but not least, we may state that we are currently on a promising way to provide empirical data for the currently widely accepted models of landmark salience and furthermore to develop a neurocognitively based theory of landmark salience for human wayfinding (empirically- and theoretically based).

To reach this goal, further research on these questions and topics is required in order to provide clear conclusions. In a next step, we want to find neurocognitive correlates for specific landmark information and wayfinding strategies using brain-imaging techniques (Janzen and van Turennout 2004). Thus, the Giessen virtual environment laboratory is well prepared for the upcoming challenges in the spatial cognition domain.

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