A four factor model of landmark salience – A new approach

Florian Röser (florian.roeser@psychol.uni-giessen.de)
Antje Krumnack (antje.krumnack@psychol.uni-giessen.de)
Kai Hamburger (kai.hamburger@psychol.uni-giessen.de)
Markus Knauff (markus.knauff@psychol.uni-giessen.de)

Justus Liebig University Giessen, Department of Psychology,
Experimental Psychology and Cognitive Science
Otto-Behaghel-Strasse 10 F
35394 Giessen, Germany

Abstract

Until today there exist few theoretical assumptions about the concept of landmark salience. They could be divided into two fields: a more physical view (inherent aspects of the landmarks) and a more cognitive/personal view (the validation of the specific landmark from the individual cognitive features). We here combine these two aspects and present first empirical evidence for the inter-dependence of visibility and structural salience.

Keywords: wayfinding; landmarks; perceptual, cognitive, structural salience; visibility

Introduction

What is a landmark and how can a landmark be defined? Today there exist several definitions of landmarks (e.g., Lynch, 1960; Presson & Montello, 1988), additionally models of landmark salience have been put up (e.g., Klippel & Winter, 2005; Caduff & Timpf, 2008).

While Lynch (1960) assumes objects to have inherent physical features that make them a landmark, Presson and Montello (1988) emphasized the importance of visual contrast of an object to its immediate surrounding. Thus, visual aspects seem to play a major role in landmark and wayfinding research. Within this context Caduff and Timpf (2008) proposed the importance of “relatively distinct, prominent or obvious features compared to other features” (p. 250). This leads to a competition between different objects to be chosen as landmarks. In other words, they need to draw our attention (extrinsically as well as intrinsically). Such competition will serve as basis for a) comparing different salience concepts and b) establishing our own salience model based on the previous concepts, empirical findings, and modeling.

Our first assumption is based on the approach by Gärling, Böök, and Lindberg (1986). It is defined in more detail by Caduff and Timpf (2008) and means that there is a trilateral relationship between the observer, the object (that is potential a landmark) and the environment (figure 1). This implies that the object cannot be assessed without the context.

Caduff and Timpf´s (2008) model includes the three concepts of salience: perceptual (the bottom-up perception), cognitive (top-down factor; wayfinders’ experience and knowledge), and contextual (measure of attention that the wayfinder can render). Furthermore, they focus on the personal and cognitive aspects of a wayfinder in the context of wayfinding and landmarks as highlighted in the trilateral relationship (figure 1).

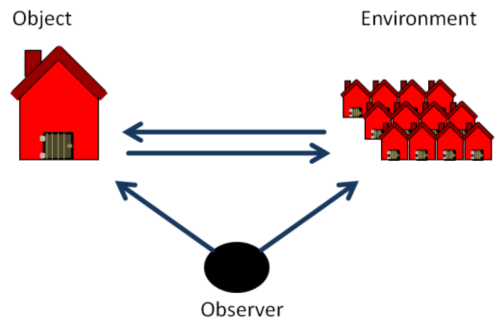

Figure 1: Observer, object, and environment have a trilateral relationship (based on Caduff & Timpf, 2008).

Sorrows and Hirtle (1999) proposed a concept which concentrates more on the physical aspects of the landmarks: visual (visual characteristics of the landmark), cognitive (meaning or prototypicality), and structural (location in space) salience. Based on this landmark salience concept, Klippel and Winter (2005) proposed a mathematical model and amended it with the concept of visibility (Winter, 2003). Each quality in their model is expressed by a normed measure of salience (with values in the interval $[0, 1] \subset \mathbb{R}$). These individual measures are combined to a joint salience of a landmark in a weighted sum (formula 1). This joint salience is moderated by the visibility (formula 2):

$$s_0 = w_v s_v + w_s s_s + w_u s_u \quad \text{with } w_v + w_s + w_u = 1 \qquad (1)$$

$$s_t = v * s_0 = v w_v s_v + v w_s s_s + v w_u s_u \quad (2)$$

s_0 = joint salience; s_v =visual salience;
s_s = semantic salience; s_u = structural salience,
w_v, w_s, w_u = weighting factors,
s_t = total salience; v = visibility

We use this formula as a starting point but adapt the definitions of the components. In our model we combine cognitive and personal aspects similar to Caduff and Timpf (2008) with physical aspects similar to Sorrows and Hirtle (1999). We think that the following four major aspects constitute the salience of a landmark:

1. perceptual salience (p),
2. cognitive salience (c),
3. structural salience (s), and
4. visibility (v).

Perceptual salience (p)

We define the perceptual salience as the physical aspects of the object (color, shape, texture, orientation, height, weight; these are not the only ones, see Hamburger & Röser, 2011). One inherent aspect is the contrast to the surroundings as described by Itti and Koch (2001). Objects need to be highly noticeable in order to pop out from the surroundings (Presson & Montello, 1988; Janzen & van Turennout, 2004).

Therefore, this salience type should reflect the setting at an intersection. A good landmark at one intersection can be a bad landmark at another intersection. A red house, for example, generally has a high perceptual salience but if it is located in a series of red houses, or if all houses at an intersection are red, than it has a low or insignificant perceptual salience.

We assume that there is an absolute perceptual salience, but that this property is moderated by the context to judge the suitability of a landmark. Therefore, we need a measure of how much the salience level of a landmark stands out from the salience values of other landmarks. To achieve this, we compare how much the perceptual salience differs from the average salience values at an intersection and only consider salience values to be relevant which are higher than the average at the intersection. To achieve this, we subtract the average salience value of the other landmarks at the intersection from the salience value of the landmark in question. We use a maximum function to ensure the resulting value is at least zero. This looks as follows for an landmark A with a absolute perceptual salience s_{p_A} at an intersection i with a set of landmarks (L) Λ:

$$s_{p_{A_i}} = max\left(s_{p_A} - \frac{\sum_{L \in \Lambda \setminus A} s_{pL}}{|\Lambda \setminus A|}, 0\right), \qquad (3)$$

where $s_{p_{A_i}}$ is the intersection specific perceptual salience for landmark A.

Cognitive salience (c)

The cognitive salience is based on the personal, intellectual, and cultural background of the wayfinder. Again, the manifestation of this can only be considered within the direct context of the landmark (see above for the similar description of the perceptual salience). Imagine there is a gas station at an intersection. For a common car driver it could serve as a landmark with a high cognitive meaning. But, if there are two or three gas stations at this same place every single one has a low or insignificant cognitive salience.

To express this, we used the same formula as for the perceptual salience. So for a landmark A with an absolute cognitive salience s_{c_A} at an intersection i with a set of landmarks (L) Λ we get:

$$s_{c_{A_i}} = max\left(s_{c_A} - \frac{\sum_{L \in \Lambda \setminus A} s_{cL}}{|\Lambda \setminus A|}, 0\right), \qquad (4)$$

where $s_{c_{A_i}}$ is the intersection specific cognitive salience for landmark A.

If no object perceptually or cognitively contrasts the other objects at an intersection (that means if all objects are equal with regard to perceptual or cognitive concepts) then by definition the perceptual and cognitive salience values are zero.

Structural salience (s)

We define the structural salience as a local salience (Klippel & Winter, 2003) which reflects the position of the landmark at an intersection, and thereby the structure of the intersection where it can be found. We assume that structural salience has the same distribution for every four-way, right-angled intersection (figure 2). Positions with a high structural salience can be viewed as places where people prefer to look for landmarks, which tend to be in the direction of the turn (see Röser, Hamburger, Krumnack & Knauff, in press). Or, in other words, the structural salience is based on the attention since it will be on the direction of the path.

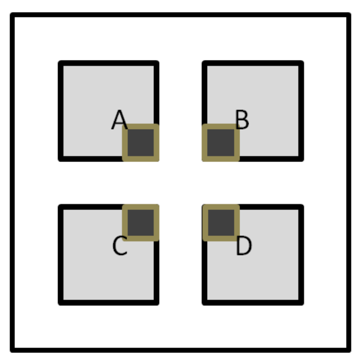

Figure 2: Four positions: two before and two after the intersection. Two directions: in direction of the turn or opposite to the direction of the turn (left, right).

Visibility (v)

Here, visibility is defined as a viewpoint based visibility which is based on the position at which the participant has to decide in which direction to move on (Röser, Hamburger, Krumnack & Knauff, in press). This is in contrast to the advanced visibility by Winter (2003).

First of all, we assume that there is a visibility threshold for the perceptual and cognitive salience: if the visibility is so low that you cannot recognize the quality of the landmark that induces the salience, then that type of salience does not contribute to the total salience of the landmark. If the visibility is high enough for the observer to recognize the quality of the landmark that induces the salience, then that type of salience is not limited by visibility. For example, consider the identification of a train station. First, the wayfinder will only see a large building but there will be one point at which he could identify it as a train station even if he cannot see it clearly. On the other hand, if there is a red house in a haze so that the wayfinder could not identify it (or perceive it) than it is not usable as a landmark.

Therefore we define specific visibility values v_p and v_c to be multiplied by the perceptual and cognitive salience:

$$v_p = \begin{cases} 1, \text{if percptual sal. of the landmark is noticible} \\ 0, \text{otherwise} \end{cases},$$

and accordingly

$$v_c = \begin{cases} 1, \text{if cognitive sal. of the landmark is noticible} \\ 0, \text{otherwise} \end{cases}.$$

However, visibility does not have this all or nothing effect on structural salience.

Now we have all the necessary components for defining our model. Substituting our definitions in formula (2) we get:

$$s_t = v_p w_p s_{p_{A_i}} + v_c w_c s_{c_{A_i}} + v w_s s_s. \qquad (5)$$

Experiments

In the following experiments we will examine the influence of the visibility on the structural salience by eliminating the influence of the perceptual and cognitive salience (thus, we only investigate two factors). For this we use the combination of four colors and four shapes as landmarks. We assume that these landmarks have an equal perceptual and cognitive characteristic. By definition (formula 3 and 4), we assume that these aspects do not influence the results, leading to the following formula:

$$s_t = v_p w_p * 0 + v_c w_c * 0 + v w_s s_s = v w_s s_s. \qquad (6)$$

For a variation of the influence of the visibility we used different perspectives within our virtual environment SQUARELAND (Hamburger & Knauff, 2011): an allocentric and egocentric point of view (figure 3). In the allocentric condition the visibility is identical for all possible landmark positions at an intersection, while in the egocentric condition different visibilities emerge (e.g., amount of occlusion), depending on the position of the landmark at the intersection.

Landmark material

As landmarks we used four shapes (triangle, square, hexagon, and circle) that could have one of four colors (yellow, green, blue, and red), resulting in 16 landmarks. Each of the 16 landmarks was randomly distributed to the four positions at the 16 intersections in the maze and at each intersection no shape or color were presented twice. Depending on the direction of the turn (see figures 3 and 6), each of the shapes and colors were presented four times at each position.

Experiment 1 – Allocentric perspective

Methods

A total of 26 participants (18 females; 21 students) completed the online questionnaire. Participant´s mean age was 22.88 years (range: 19-38). All participants provided informed written consent. The students received course credit for participation.

Material

A 2D maze consisting of 5 X 8 squares and orthogonal angles at each intersection was designed for this experiment (figure 2). For each decision there was a new map (image) with the route visualized up to the current position and decision point (figure 3). The maze with the paths and intersections was created in Word2007 (Microsoft Office) and LimeSurvey 1.85 was used to run the online questionnaire and for data recording.

Procedure

In the online questionnaire participants were presented with a short instruction to learn the given route with a map (16 intersections). Subsequently, they saw a short cover story ("imagine you must describe the learned route to someone who is unfamiliar with this route but needs to find the goal location of this route"). Then they were shown the path from the start point to the first intersection (allocentric perspective), and had to answer the question "which of the following descriptions (e.g., at the green hexagon to the right) appears to be most convenient for you". This procedure was repeated for all intersections.

Results

Results for colors, shapes, and position at the intersections are visualized in figure 4. They revealed no differences between the four shapes ($\chi^2(3)=0.201$, $p=.976$) and the four colors ($\chi^2(3)=.221$, $p=.974$). Clear preferences of the participants for landmark positions were obtained: on the right hand side of an intersection in case of a right turn (with 91.35%) and the left side in case of a left turn (88.91%). Such obvious preferences made any statistical analysis needless. Furthermore, for landmark positions in the direction of the turn, positions before the turn –the object has to be passed before the turn is executed– are selected 4.1 times more often than the position after (behind) the intersection –where the object is not physically passed.

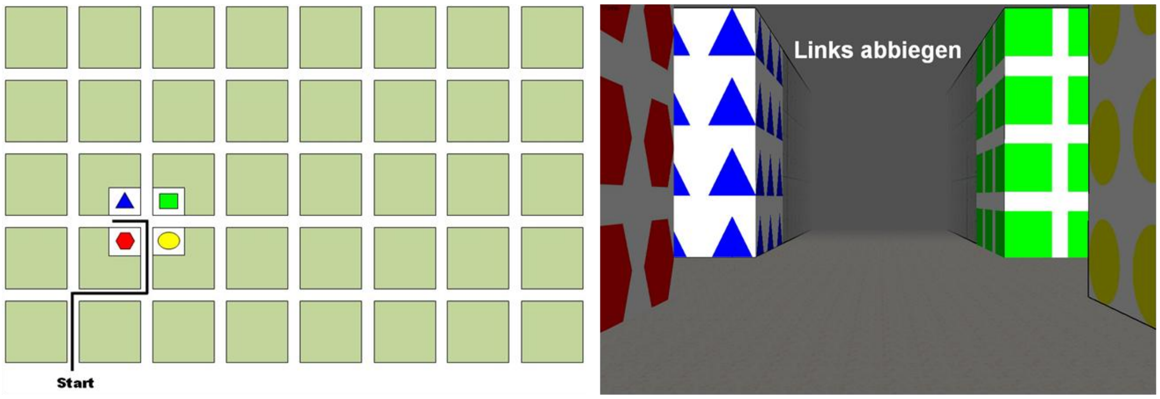

Figure 3: Allocentric view of the maze (SQUARELAND) on the left. Egocentric perspective on the right (instruction: "Links abbiegen" = "Left turn"). Landmarks are presented at the walls.

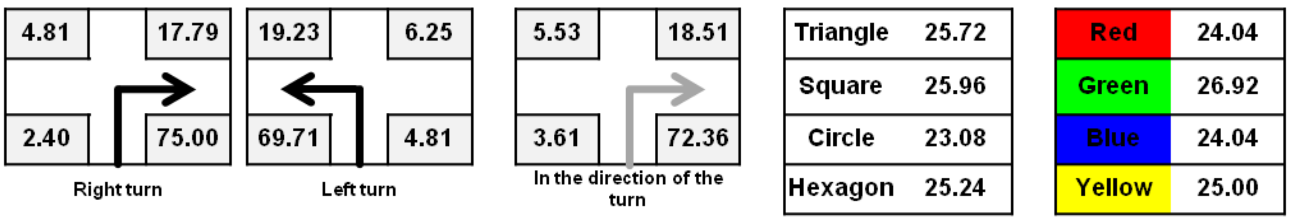

Figure 4: Relative choices of the single landmark positions over all intersections, shapes, and colors in the allocentric perspective (left). Relative choices for single shapes and colors over all intersections and landmark positions (right).

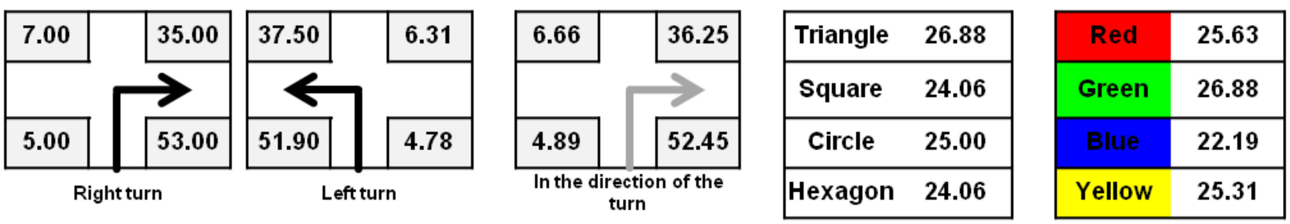

Figure 5: Relative choices of the single landmark positions over all intersections, shapes, and colors in the egocentric perspective (left). Relative choices for single shapes and colors over all intersections and landmark positions (right).

Discussion

For the allocentric perspective the visibility is the same for all intersections and positions and could therefore be ignored. Thus, we here only measured the inherent saliences of the landmarks, namely the structural salience (the other saliences assumed zero, see above).

In summary, we could determine that the position in the direction of the turn, before the intersection is the optimal one for wayfinding/route descriptions. This is in line with the assumption of Klippel and Winter (2005).

Experiment 2 – Egocentric perspective

We re-examined the structural salience of Experiment 1 with an egocentric perspective within a virtual maze. Again, we had a learning phase in which the participants had to learn a route direction and decide/imagine at which position the landmark could/should ideally be located.

Methods

A total of 20 students from the University of Giessen (11 females) participated in this experiment. They had a mean age of 22.9 years (range 19-29). They all had normal or corrected-to-normal visual acuity, provided informed written consent and received course credit for participation.

Material

For this experiment we used the 3D version of the virtual environment SQUARELAND (Hamburger & Knauff, 2011) as described above. The walls and floor were light and dark gray and a neutral gray haze was implemented in the background, so that participants could only see the next intersection but no additional landmark information.

A video led the participants passively along the path through the maze with 16 intersections. The route and positions of the landmarks (combinations of colors and shapes) were the same as in the allocentric experiment above; figure 3). The route direction and the video were presented by a Panasonic PT-F100NT projector. The full image subtended 67 deg in height and 85 deg in width of the observers' visual field. Superlab 4.0 (Cedrus Corporation 1991-2006) was used for running the experiment and for data recording (for more details see Röser et al., in press).

Procedure

The procedure was the same as for the allocentric experiment with the difference that the participants now saw a video (trail) (egocentric perspective) from the start point to the first intersection (where they had to decide which landmark they would prefer). Here the direction instruction was given in midair (figure 3). After each trial, the video started over until the next intersection was reached where participants again indicated the preferred landmark.

Results

The results for the colors, shapes, and positions at the intersections are visualized in figure 5. No differences between the four shapes ($\chi^2(3)=0.212$, $p=.976$) and the four colors ($\chi^2(3)=.477$, $p=.924$) were found. The participants preferred the positions in the direction of the turn with 88.70%.

Looking at the absolute frequency of the specific positions mentioned, we tested them for uniform distribution. Here we obtained a significant difference ($\chi^2(3)=209$, $p<.001$). If we take the relative frequency for how often each position was mentioned across all trials by a single participant and across all participants, we calculated a one-factorial analysis of variance (ANOVA). This analysis revealed a significant difference ($F(3)=9.72$, $p=.003$). The post hoc t-test revealed the following for the different positions:

Position	T-values	P-values
A ↔ B	-3.432	.003
A ↔ C	0.698	.494
A ↔ D	-4.276	<.001
B ↔ C	3.617	.002
B ↔ D	-0.941	.358
C ↔ D	-4.753	<.001

A = after intersection, opposite the direction of the turn
B = after intersection, in the direction of the turn
C = before intersection, opposite the direction of the turn
D= before intersection, in the direction of the turn
(compare to figure 6)

Discussion

There is no difference between the position before and after the intersection (independently, in the direction of the turn or opposite). This contradicts the general assumption that people prefer the position before an intersection (e.g, Klippel & Winter, 2005).

Since in this experiment the visual and semantic salience may also be assumed to be zero (see above), thus, we only measured the influence of the structural salience moderated by the visibility. The straightforward follow-up question then is: What is the influence of these factors and can we predict the results of the egocentric experiment with the values from the allocentric experiment and the visibility?

Modeling visibility measure

To measure the visibility we first regard the visible parts of the landmarks at each decision point that is which proportion of the facades facing the intersection is visible (figures 6).

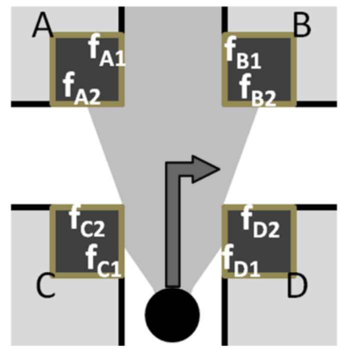

Figure 6: Intersection with the decision point and the visible parts of the landmarks from this position. The gray highlighted area on the path is the field of view. The arrow gives the direction of the turn (summarized for a left and a right turn).

Based on this we come to the following specific visibilities for the facades of the landmark: $f_{A1} = f_{B1} = 1$; $f_{A2} = f_{B2} = 0.48$; $f_{C1} = f_{D1} = 0.48$; and $f_{C2} = f_{D2} = 0$.

To calculate the visibility for one landmark we must average the visibilities of its two facades:

$$v = \frac{v_{f1}+v_{f1}}{2} \qquad (7)$$

This results in the following visibility values:

$v_A = 0.74$,
$v_B = 0.74$,
$v_C = 0.24$,
$v_D = 0.24$.

With formula (6), the visibility and the results of the allocentric Experiment 1 can be used to predict the results for the egocentric Experiment 2 (figure 7).

To do so, we multiply the results of Experiment 1 with the specific visibility. However, these calculated values cannot be compared directly to the results of Experiment 2 for the following reason: the measured structural salience of a single landmark position depends on the measured salience of the other landmark positions. Due to the fact that the participants always had to choose one position, the sum of all measured frequencies in our setups is always 1. The sum of our calculated values is less than 1. To adjust the prediction we divided each calculated value by the sum of all calculated values so that the resulting values add up to 1 (compare to figure 7). This operation does not change the ratio of the values for the different positions. The numbers obtained from these calculations indicate that the results from the allocentric experiment and the visibility are good predictors for the results of the egocentric experiment. Consequently, we may summarize that the interdependence between the visibility and the structural salience defined by Klippel and Winter (2005) and our new model could be empirically confirmed.

Conclusion and further experiments

Visibility seems to have the effect predicted by Klippel and Winter (2005) on structural salience. At the start we had five questions:

- What determines the salience of a landmark?
- What determines the distribution of landmarks chosen?
- What is the influence of the surroundings on the above issues? Is this fully expressed in structural salience?
- Is there an interaction between cognitive and structural salience or is the cognitive salience just influenced by the surrounding?
- If there is an interaction, what does it look like?

The first three questions can be answered with the model above. Currently we investigate the combination of the structural and cognitive salience. First results show that there is an interference between the four positions at an intersection and the influence of the cognitive characteristics. We hope to define this interaction and the weight factors in our formula (5) with this and further experiments.

With these experiments and model we found a first empirical answer to the question which position should be used for a landmark (especially in route descriptions or navigation systems) to be in accordance with human spatial abilities. The remaining two saliencies and their influence on human wayfinding will be subject to further experiments.

	Results of the allocentric experiment	Multiplicated with the specific visibility	Predicted values (divided by 0.36)		Results of the egocentric experiment
After the intersection, opposite the direction of the turn (A)	**0.06**	**0.04**	**0.12**		**0.07**
After the intersection, in the direction of the turn (B)	**0.18**	**0.13**	**0.37**		**0.36**
Before the intersection, opposite the direction of the turn (C)	**0.04**	**0.01**	**0.03**		**0.05**
Before the intersection, in the direction of the turn (D)	**0.73**	**0.18**	**0.48**		**0.52**
Sum	1	0.36	1		1

Figure 7: Calculation for the prediction of salience values for the egocentric experiment, based on the results of the allocentric experiment and the defined visibility.

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