The influence of structural salience and verbalisation on finding the return path

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Abstract

Are some landmark positions at intersections better for finding a return path than others? This study investigated whether there is a variation in the influence of a landmark on performance and decision times when finding a return path depending on its position at an intersection. A variation of this influence is expected depending on the type of verbalisation of spatial directions used. First, participants learned a path either with direction specific *(turn left at* or *turn right at*) or direction unspecific material (*turn into direction of* or *turn in the opposite direction of*). In this path the positions of the landmarks were varied systematically. Secondly, participants had to find the return path of the learned route and their third task was to write down verbal route descriptions. An effect of the landmark position on finding the return path can be suggested, although it was barely insignificant, for direction specific and direction unspecific material. A significant influence on the accuracy of the information in the route descriptions depending on the position of a landmark and on the specificity of the spatial directions could be shown. The results are discussed in the context of current wayfinding and landmark research.

Keywords: return path; structural salience; landmarks; verbalisation; mental transformation; route descriptions

Introduction

In a previous work we introduced some theoretical assumptions concerning the return path (CogSci 2013; Hamburger, Dienelt, Strickrodt, & Röser, 2013) which shall be experimentally addressed in the following study. Before going into detail, let us start with an initial example taken from the just mentioned work: "Imagine that you are on a vacation in an unknown foreign city. After your arrival at the hotel you want to explore the surroundings and maybe visit a place of interest or a touristic feature (e.g., a famous building such as the Eiffel Tower in Paris). You may base your search on different means for successfully reaching your goal" (Hamburger et al., 2013, p. 537). Let us assume that we are not in possession of any of these means (e.g., a city map or a smart phone with a GPS tracking function). Besides of just walking around, including the risk of getting lost, we could ask a pedestrian or the receptionist at the hotel desk for verbal route directions. It has been shown that the use of so-called landmarks in route descriptions plays an important role in finding ones way successfully (e.g., Denis, 1997). Landmarks are commonly described as reference points for navigation (e.g., buildings) which stick out of their environment (e.g., Lynch, 1960; Presson & Montello, 1988; Caduff & Timpf, 2008; Hamburger & Knauff, 2011). Now let us assume that with the help of such a verbal route description we successfully reached our goal (here, point of interest). In many cases, like in our hotel scenario, we want to get back to where we came from. This confronts us with a new problem: We have to find our way back. To manage this task the probably easiest way would be to retrace the initial path and therefore use the same landmarks provided in the initial route description. One question of interest is now: Are certain landmarks and landmark positions more suitable than others for finding the return path?

Several theories of landmark suitability have been suggested (e.g., Klippel & Winter, 2005; Caduff & Timpf, 2008; Röser, Krumnack, Hamburger, & Knauff, 2012). One important term in this context is *landmark salience*, which is often described as a pop-out effect or how much an object stands out from its immediate surroundings. Klippel and Winter (2005) differentiate between three forms of landmark salience based on the assumptions by Sorrows and Hirtle (1999). These are *visual* (how much an object stands out from its surroundings, referring to colour, size, shape, etc.; Caduff & Timpf, 2008; Hamburger & Knauff, 2011), *semantic* or *cognitive* (knowledge-related features of a landmark like its meaning, function and name; Caduff & Timpf, 2008; Hamburger & Knauff, 2011), and *structural salience* (e.g., the location of a landmark at an intersection; Klippel & Winter, 2005). As we assumed in our previous work, the structural salience might be the most important of these three kinds of saliencies for finding the return path (Hamburger et al., 2013). Therefore, in the current study we try to control for the visual and semantic saliences.

At a prototypical cross intersection four landmark positions –the four corners of the intersection– are possible (Röser, Krumnack, & Hamburger, 2013). Since the direction of turn seems to play a critical role for choosing landmarks (e.g., Röser, Hamburger, Krumnack, & Knauff, 2012), positions may be defined in dependence of the direction of turn: *behind the intersection opposite to the direction of turn* (A), *behind the intersection in direction of turn* (B), *before the intersection opposite to the direction of turn* (C), and *before the intersection in direction of turn* (D) (Hamburger et al., 2013). To keep it simple, the defined position labels for the return path remain in the perspective of the initial path.

As pointed out by Hamburger et al. (2013) the optimal landmark positions for the return path might differ from the ones of the initial path (see figure 1). For the latter, the ideal positions for an egocentric perspective seem to be the positions B and D (Röser, Hamburger, et al., 2012). For the return path, however, it might be important that a landmark is located either at position A or D. This might be because of the invariance of these positions, i.e. they remain unchanged for the return path and may lead to an advantage in a wayfinding task. This does not apply for the landmark positions B and C. These positions are variant and have to be mentally/verbally transformed on the return path (see Hamburger et al., 2013 for further details).

One important restriction concerning the advantages of variant positions is that it only holds for the use of unspecific spatial information. Compared to direction specific information, where *left* has to be transformed into *right* on the return path, direction unspecific information used with the invariant positions (e.g., "*turn into direction of"* or "*turn in the opposite direction of*") remains unchanged. This could lead to less cognitive load since no verbal and mental transformation and therefore one processing step less would be required. Note that for the variant positions mental and verbal transformations have to be conducted independent of the type of verbalisation on the return path (Hamburger et al., 2013).

When spatial directions are verbalised in a specific way, different positions might be optimal for the return path (see figure 1 right). Based on the findings of Röser, Hamburger, et al. (2012) it seems to be important that in such a case the landmark is located somewhere *in the direction of turn*. This is the case for landmarks on position D in both travel perspectives (overlapping feature). Therefore, we conclude, that with direction specific route information position D is the optimal position.

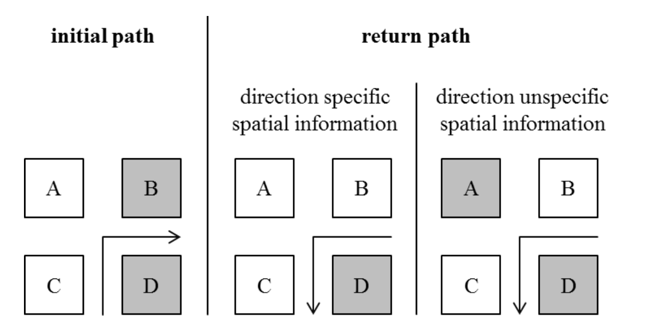

Figure 1. Possible optimal landmark positions (grey) for the initial and the return path. For the return path, optimal positions differ with respect to the specificity of the used route information (direction specific or unspecific). Please see text for further details.

According to the concept of "visibility" (Winter, 2003; Röser, Krumnack, et al., 2012) another premise for landmarks located *before the intersection* comes into play (figure 2). If the facades of such a landmark differ in a way that makes them unrecognizable as belonging to the same landmark (not visually similar), it (the landmark) becomes useless for the return path (for direction specific *and* unspecific route directions).

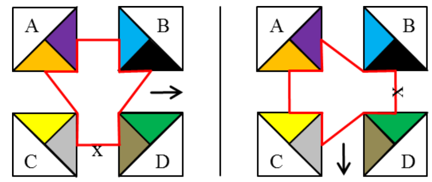

Figure 2. Visibility for the forward run (left) and the return path (right). "X" indicates the position of an individual, "→" the walking direction. If, for example, the brown facade of D or the blue of B is initially used as a landmark this becomes critical on the return path because both memorized facades are not visible anymore (before a decision has to be made).

The landmark's visibility can have further implications. As can be seen in figure 2, the facades of position A are visible from both travel perspectives. One could argue that due to this position A might be optimal for finding the return path. Nevertheless, whether landmark visibility has such an impact or not is beyond the scope of this work. Here we try to control for the described potential issues of visibility by using landmarks which can be easily recognized again on the return path (identical facades).

According to the above logic the hypotheses are: in an experiment where participants first have to learn an initial path and find the return path afterwards, the optimal landmark positions differ with respect to the provided route information: either direction specific or unspecific. For the latter, positions A and D might be the most suitable (due to their invariant location). With direction specific material position D could be optimal (because it is in direction of turn on the initial and return path).

Method

Participants

A total of 34 students from the University of Giessen participated in this experiment (21 females). They had a mean age of 25.15 years (*SD*=4.16). All participants provided informed written consent and some received course credits for participation. They were naïve with respect to this study and had normal or corrected-to-normal visual acuity, as well as normal colour vision. Epileptics were excluded in order to prevent health risks caused by photosensitive epilepsy.

Material

For this experiment we used the virtual environment SQUARELAND (Hamburger & Knauff, 2011). It was designed using the freeware Google Sketchup 6.0© and consists of a maze made of 10x10 cuboids, representing regular orthogonal intersections. This environment has repeatedly been used successfully for this kind of research (e.g., Hamburger & Röser, 2011; Röser, Hamburger, & Knauff, 2011; Röser, Hamburger, et al., 2012; Röser, Krumnack, et al., 2012; Bucher, Röser, Nejasmic, & Hamburger, 2014). We created 34 routes in an egocentric perspective. The directions left and right were used. At each intersection one cuboid stood out from the background representing a landmark. Therefore, the cuboid was coloured (figure 3) with one of the following colours or luminances: red, green, blue, yellow, purple, brown, black, and white[1]. Within each route, every colour was used only once resulting in eight distinct intersections within the route. The sequence of the colours was pseudo-randomized, considering every sequence had to be used only once. In order to prevent the participants from seeing the whole maze, a virtual haze (light grey) was used. To indicate the turning direction at a decision point for the initial path an instruction (white letters on black background; floating at the same position in midair) was presented at each intersection. In half of the 34 routes direction specific route directions were presented, in the other half direction unspecific route directions, respectively. In the direction specific cases sentences like “Red facade turn left” (originally in German: “Rote Fassade links abbiegen”) were presented. In the direction unspecific trials, messages like “Turn in direction of the red facade” or “Turn in the opposite direction of the red facade” (original: “Richtung roter Fassade abbiegen” or “Entgegen roter Fassade abbiegen”) were shown. For the return path, the perspectives at the intersections were adjusted and the route directions were removed.

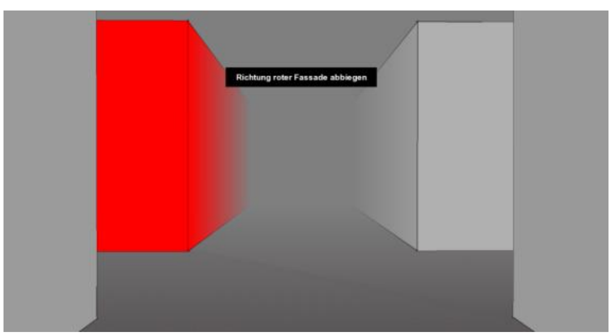

Figure 3. Screenshot of an intersection in the virtual environment (decision point) including the route direction (“Turn in direction of the red facade”). The red cuboid represents the landmark.

To control for direction or landmark effects, the number of right/left turns and the position of the landmark at an intersection (before or after the intersection, in or against the moving direction) were balanced for single routes (within-subject factor).

The routes were presented by a custom 19” monitor (DELL©) attached to a Personal Computer (DELL© Optiplex 745). For presentation and data recording the software SuperLab 4.5 (Cedrus Corporation©) was used.

Procedure

Each participant was pseudo-randomly assigned to either a route with direction specific or unspecific route directions (between-subject factor). The participants were instructed to memorize a path for the purpose to eventually find the return path. After a pause of five seconds the assigned route consisting of eight intersections was presented successively via screenshots. The picture presentation duration time was self-paced. When pressing the space bar the next intersection was presented. Between the pictures a fixation cross was shown for a period of one second. After this learning phase the participants had to find the return path for the given route. Hence, the intersections were presented in reverse travel direction. At each intersection it was the task to decide whether the correct travel direction is left or right, using the arrow keys of the keyboard. No feedback about the accuracy of decisions was given. After the return path test phase two randomly chosen intersections in perspective of the return path were shown (in order to control for sequence effects). Again, the participants had to indicate the memorized travel direction. After completing this wayfinding phase, the next task was to write down a verbal route description for the return path of the presented route. Therefore, pen and paper were provided. Eventually, the participants had to answer exploratory questions (demographic data, learning strategies, etc.).

Results

Prior to descriptive or inferential statistics, three participants (two from the group with specific route directions) were excluded from the analysis due to rapid progress from one intersection to the next (quicker than 500ms) in the learning phase. It can be doubted that the participant was able to memorize the route appropriately in such a short amount of time.

The results for mean correct decisions at an intersection depending on learning condition and landmark position are visualized in figure 4. It shows the highest amount of correct decisions if a landmark was located on positions B and D on the initial path with respect to direction specific route information. With direction unspecific information landmark position A and D obtained the highest percentage values.

Analyses of variance with repeated measures were performed for each of the dependent variables correct decisions and response times. The *learning conditions* (direction specific or direction unspecific route information) represented the between-subject factor. The within-subject factor consisted of the four possible *positions of a landmark* at a decision point (A, B, C, or D). For the amount of correct decisions no main effects for the factors learning condition

[1] Colours were chosen with the help of the webpage *http://www.colorschemedesigner.com*. The whole spectrum was used periodically to create differentiable colours.

(F(1,29)=.149; p=.702) and landmark position (F(3,87)=.914; p=.438) could be found. Further, the interaction of learning condition and landmark position was barely insignificant F(3,87)=2.659; p=.053. Concerning the response times no main effect for the factors landmark position (F(3,87)=.855; p=.468) and learning condition (F(1, 29)=.341; p=.564), as well as no interaction between these factors could be found (F(3,87)=.680; p=.567).

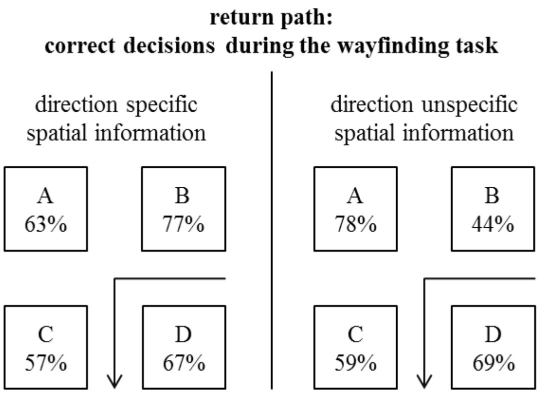

Figure 4. Mean correct turning decisions (in %) for the wayfinding task with respect to the specificity of the provided spatial information and the landmark position.

Unilateral one sample t-tests were performed in order to establish if choices were significantly higher than 50% (chance level). For direction specific information this was the case for positions B and D, but not for A and C (A: t(14) = 1.468; p = .164; B: t(14) = 2.779; p = .015; C: t(14) = .619; p = .546; D: t(14) = 1.784; p = .096). With direction unspecific the positions A and D were significantly higher than 50%, while position C and B were not (A: t(15) = 4.392; p = .001; B: t(15) = -.620; p = .544; C: t(15) = .764; p = .456; D: t(15) = 1.861; p = .083).

The used landmark colours did not lead to significant differences in performance (correct decisions: χ^2(7, N=31)=1.453; p=.984; response times: F(7,210)=.344; p=.933).

Mean correct decisions for the additionally shown crossings were 43% for direction specific and 69% for direction unspecific route information. Tests did not reveal significant differences between the learning conditions with respect to correct decisions (t(29)=-1.726; p=.095) and response times (t(29)=-.194; p=.847).

In the condition with direction unspecific spatial information, six (38%) of the participants used unspecific spatial directions for describing a return path. In the condition with direction specific material, one participant (7%) wrote a direction unspecific route direction.

Results for mean correct directions provided within the written route descriptions (evaluated in segments) are shown in figure 5. Those route descriptions that did not refer to landmarks were excluded from the analysis (62% or 21 route descriptions remaining). For direction specific route information highest mean correct directions were provided if a landmark was located at positions B and D. Landmark position A and D obtained the highest percentage values with respect to direction unspecific route information.

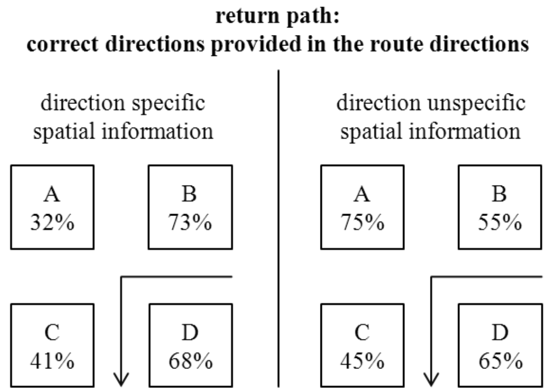

Figure 5. Mean correct directions (in %) provided in the written route descriptions with respect to the specificity of the provided spatial information and landmark position.

Analyses of variance with repeated measures were performed for the dependent variable correct directions provided in the written route description. The *learning conditions* (direction specific or direction unspecific route information) represented the between-subject factor. The within-subject factor consisted of the four possible *positions of a landmark* at a decision point (A, B, C or D). A significant main effect for the factor landmark position (F(3, 57)=3.191; p=.030) but not for learning condition, (F(3,19)=.243; p=.628) could be found. According to these results, post-hoc tests were performed, showing a significant difference between position C and D (t(20) = -2.911; p = .009) independent of the learning condition. Further, the analysis of variance revealed an interaction between the factors landmark position and learning conditions (F(3,57)=4.647; p=.006). Subsequent post-hoc tests showed a trend to a difference of the mean values of the two learning conditions for position A (t(19) = -2.592; p = .018).

Discussion

In this experiment direction specific and unspecific spatial information was presented on a forward run of a route. Participants had to reproduce the return path in two different ways: in a wayfinding task and in a verbalisation task (route descriptions). We expected that the variation in the specificity of the spatial information leads to different optimal landmark positions for reproducing the return path (position D for direction specific, positions A and D for direction unspecific material).

Concerning the results of the wayfinding task an interaction trend between the landmark position and the specificity of the provided route directions could be revealed. As the descriptive statistics suggest, there might be an advantage for positions A and D in finding the return path if the route directions were verbalised in an unspecific way (see figure

4). As already mentioned this might be because it is not necessary to conduct mental or verbal transformations for these two positions (Hamburger et al., 2013). With specific route directions positions B and D seem to have an advantage. This differs from the assumption of position D being the only optimal position for finding the return path in such a case. An explanation for these findings could be the following: the words *left* and *right* in the provided route directions on the initial path may cause attentional shifts in the indicated direction, as shown, for example, by Hommel, Pratt, Colzato, and Godijn (2001). This could lead to a better memorability for landmarks at positions *in the direction of turn*, resulting in a better recall on the return path. With direction unspecific spatial information this change in visual attention might be missing as such kind of information is relatively uncommon and new. Nevertheless, the findings are in line with the assumptions made by Klippel and Winter (2005), where the best location for a landmark is in front of an intersection (on the return path this is the case for landmarks on position B and D).

However, the mentioned interaction trend may be seen as somehow unsatisfying. Besides the possibility that a larger sample size might remedy this, further reasons for the absence of clearer results can be found if we compare this study to two experiments conducted by Hamburger et al. (2013). In their first experiment, no landmark position effect could be revealed (only in the group of low performers an impact of structural salience was indicated). In the second experiment, however, the landmark position led to significant differences in the wayfinding performance. Better decisions were made if landmarks were located at the assumed optimal positions (*before the intersection in the direction of turn* and *behind the intersection opposite the direction of turn*, respectively). The authors suggested that the absence of position effects in the first experiment was due to the rather unrealistic setup that was used (sequence of screenshots) and, therefore, suppressed the originally pursued route learning strategies. A serial learning strategy (e.g., Buchner & Jansen-Osmann, 2008) of combining different items in a sequence (e.g., red, left; blue, right) is not quite comparable to learning a route. The second experiment used a more realistic setup (videos) and could be seen as closer to a wayfinding task in the real world (Hamburger et al., 2013). Since in this study we used sequences of screenshots rather than videos the same explanation for the absence of clear significant results could be taken into account.

When it comes to the additionally shown crossings, direction unspecific route information seems to lead to higher mean correct decisions than direction specific material. This allows the suggestion that a deeper processing of the route knowledge is obtained when learning a route according to spatial information like "in direction of" and "opposite to". Landmarks and directions can be remembered more easily leading to an advantage for direction unspecific verbalisation.

Regarding the results for the written route descriptions, the factor landmark position led to significant differences in correct direction information. Moreover, these differences varied as a function of the specificity of the presented spatial information. As further tests revealed position D led to significantly more correct directions than position C independent of the spatial directions, while position A led to a better performance if direction unspecific route information was presented on the initial path. These findings are in line with the assumptions.

As figure 5 shows positions A and D seem to be the optimal ones if a return path has to be verbalised for a route direction in the condition with direction unspecific spatial information. For direction specific information this seems to account for positions B and D. Although writing a verbal route direction is not perfectly comparable with a wayfinding task the data imply that structural salience has an effect on finding ones way and that this effect varies according to whether an initial path was learned with direction specific or unspecific spatial directions. Interestingly the results (optimal positions) for the route descriptions are in line with the results of the wayfinding task.

Further, it can be seen that with specific route directions only 32% correct direction information was provided in the written route descriptions for landmarks on position A (see figure 4). However, in the same learning condition the results concerning the wayfinding task revealed a relatively good outcome for position A (63%, see figure 5), what might be due to its good visibility (see figure 3). Such a discrepancy, however, can not be reported for the remaining landmark positions, but could be expected between a cued (wayfinding) and a free recall task (creating a verbal route direction). Since these findings are somehow ambiguous, future systematic investigations should be considered.

Concerning direction unspecific spatial information, one important question is whether people are able to encode route and/or spatial information in such a way or not (Hamburger et al., 2013). This study's results suggest that the given route information indeed effects the retrieval. So it seems that wayfinders are able to encode unspecific route information and therefore they can make use of the advantage of the invariance of a landmark's location on position A or D. However, it seems that even if this is the case, people prefer to provide direction specific information in route descriptions. Only six (38%) out of 16 participants learning the route with unspecific instructions used this type of verbalisation in their own route description. This could be because under everyday conditions wayfinders are used to verbalise spatial directions in the more common specific way (probably due to socialization).

In summary, this study presented further empirical data on the influence of structural salience on finding the return path and first evidence that the type of verbalisation interacts with the landmark position, leading to different optimal landmark positions for the return path. However, the found optimal positions differed from the expected ones if direction specific route information was shown originally. According to this, a new model of the possible optimal landmark position for finding the return path (figure 6) could be established, but further research is needed for validation.

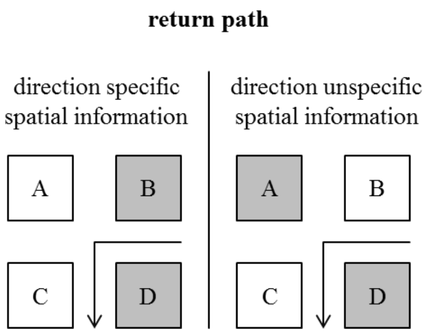

Figure 6. Possible optimal landmark positions (grey) for the return path with respect to the specificity of the used route information (direction specific or unspecific) based on the findings of this study. Please see text for further details.

Open questions concerning the differences between males and females, as well as people with poor or good spatial abilities and learning strategies (wayfinding performance vs. sense-of-direction; e.g. Kato & Takeuchi, 2003; cognitive styles and mental imagery; e.g., Pazzaglia & Moè, 2013) still remain. A systematic investigation of whether videos rather than a sequence of screenshots result in clearer position effects and whether the visibility affects the structural salience of a landmark is yet to be implemented.

Acknowledgments

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References

Bucher, L., Röser, F., Nejasmic, J., & Hamburger, K. (2014). Belief revision and way-finding. *Cognitive Processing, 15*, 99-106.

Buchner, A., & Jansen-Osmann, P. (2008). Is route learning more than serial learning? *Spatial Cognition & Computation, 8*, 289-305.

Caduff, D., & Timpf, S. (2008). On the assessment of landmark salience for human wayfinding. *Cognitive Processing, 9*(4), 249-267.

Denis, M. (1997). The description of routes: A cognitive approach to the production of spatial discourse. *Cahiers Psychologie Cognitive, 16*(4), 40-458.

Hamburger, K., & Knauff, M. (2011). SQUARELAND: A virtual environment for investigating cognitive processes in human wayfinding. *PsychNology Journal, 9*(2), 137-163.

Hamburger, K., & Röser, F. (2011). The meaning of Gestalt for human wayfinding – How much does it cost to switch modalities? *Gestalt Theory, 33*(3/4), 363-382.

Hamburger, K., Dienelt, L. E., Strickrodt, M., & Röser, F. (2013). Spatial cognition: the return path. In M. Knauff, M. Pauen, N. Sebanz & I. Wachsmuth (Eds.), *Proceedings of the 35th Annual Conference of the Cognitive Science Society* (p. 537-542). Austin, TX: Cognitive Science Society.

Hommel, B., Pratt, J., Colzato, L., & Godijn, R. (2001). Symbolic control of visual attention. *Psychological Science, 12*, 360–365.

Kato, Y., & Takeuchi, Y. (2003). Individual differences in wayfinding strategies. *Journal of Environmental Psychology, 23*(2), 171-188.

Klippel, A., & Winter, S. (2005). Structural salience of landmarks for route discrimination. In A. G. Cohn & D. Mark (Eds.), *Spatial Information Theory. International Conference COSIT* (pp. 347-362). Berlin: Springer.

Lynch, K. (1960). *The image of the city*. Cambridge, MA: MIT Press.

Pazzaglia, F., & Moè, A. (2013). Cognitive styles and mental rotation ability in map learning. *Cognitive Processing, 14*, 391-399.

Presson, C. C., & Montello, D. R. (1988). Points of reference in spatial cognition: Stalking the elusive landmark. *British Journal of Developmental Psychology, 6*(4), 378-381.

Röser, F., Hamburger, K., & Knauff, M. (2011). The Giessen virtual environment laboratory: Human wayfinding and landmark salience. *Cognitive Processing, 12*, 209-214.

Röser, F., Hamburger, K., Krumnack, A., & Knauff, M. (2012). The structural salience of landmarks: Results from an on-line study and a virtual environment experiment. *Journal of Spatial Science, 57*(1), 37-50.

Röser, F., Krumnack, A., Hamburger, K., & Knauff, M. (2012). A four factor model of landmark salience – A new approach. In N. Rußwinkel, U. Drewitz & H van Rijn (Eds.), *Proceedings of the 11th International Conference on Cognitive Modeling (ICCM)* (pp. 82-87). Berlin.

Röser, F., Krumnack, A., Hamburger, K. (2013). The influence of perceptual and structural salience. In M. Knauff, M. Pauen, N. Sebanz & I. Wachsmuth (Eds.), *Proceedings of the 35th Annual Conference of the Cognitive Science Society* (p. 3315-3320). Austin, TX: Cognitive Science Society.

Sorrows, M. E., & Hirtle, S. C. (1999). The nature of landmarks for real and electronic spaces. In C. Freksa & D. M. Mark (Eds.). *Spatial Information Theory: Cognitive and Computational Foundations of Geographic Information Science, International Conference COSIT 1999* (pp. 37-50). Stade: Springer.

Winter, S. (2003). Route adaptive selection of salient features. In W. Kuhn, M.F. Worboys & S. Timpf (Eds.), *Spatial Information Theory: Cognitive and Computational Foundations of Geographic Information Science, International Conference COSIT* (pp. 37-50). Berlin: Springer.