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Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 37(0)

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Publication Date
2015

Peer reviewed

Landmarks in motion: Unstable entities in route directions

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Abstract

In the present study, we investigate if and when speakers refer to moving entities in route directions (RDs). On the one hand, there is a general agreement that landmarks should be perceptually salient and stable objects. On the other hand, animated movement attracts visual attention, making entities intrinsically salient. In two experiments, we tested to what extent people are prepared to use moving entities. Our results show that participants mention moving entities when the communicative setting affords such references (route directions in a joint communicative setting) and when the movement is informative for the place where a turn should be taken.

Keywords: stability; animated movement; moving landmarks; visual attention; route directions.

In the last decade, GPS-based pedestrian navigation systems and augmented reality have become increasingly popular. Cutting edge technology can redefine the capabilities of navigation systems, by grounding route directions (RDs) into the visual context. For example, devices such as Google Glass can capture visual surroundings (via videos) in real time and this could enable pedestrian navigation systems to become spatially aware and generate live instructions making use of both stable database information (e.g., streets) and variable visual information captured by the camera (e.g., cyclists or pedestrians). References to entities in the environment (or landmarks) are considered key ingredients for good RDs (Allen, 2000). However, the urban space is under continuous transformation: as we walk events take place at each step and people and cars are moving on the streets. We know little about how the dynamic character of the environment can influence RD production and landmark selection. In a co-presence situation it might be common to hear an instruction such as: “Turn left where that man turns now”. It is yet unclear under which circumstances people refer to such moving entities and to what extent these references are useful in navigation.

In this study, by RDs we refer to a set of instructions on how to (incrementally) follow a route (Richter & Klippel, 2005) and we focus on references to landmarks, traditionally defined as environmental features that function as points of reference (Allen, 2000). In RD studies, landmarks are defined as route-relevant, stable entities, such as buildings. One likely reason for this could be that the communicative situation used in these studies includes some type of delay or asymmetry between producing directions and navigating with them. For example, instructions are communicated over distance (e.g., telephone) or asynchronously (based on previous experience of the environment or maps, one participant produces instructions, to be later used by another one). In such situations, links to here-and-now motion do not exist and their communication is useless. In this study we focus on a novel situation in which this delay is absent: in-situ turn-by-turn RDs. Particularly, the request for assistance is formulated and followed on the spot. While experiencing a shared dynamic environment, speakers can refer to any entity that could improve the instructions.

The most important characteristic of a landmark is its distinctiveness. Objects can be distinctive on different dimensions (for example due to familiarity or functional relevance). In this study, we focus on unfamiliar navigation contexts in which perceptual salience is more important than other (e.g., knowledge-based) information. It has been theorized that, the more visually noticeable or attention-grabbing an object is, relative to neighboring entities, the more likely it is to be used as a landmark (Sorrows & Hirtle, 1999). For example, color and size seem to influence landmark selection (Sorrows & Hirtle, 1999; Allen, Siegel, & Rosinski, 1978) as confirmed by previous experimental work in natural environments (Nothegger, Winter, & Raubal, 2004; Raubal & Winter, 2002). However, in early processing stages of attention, other simple visual attributes come into play, such as the direction and velocity of motion (Itti & Koch, 2001). It is generally accepted that, if relevant, moving entities grab and guide visual attention. If they grab attention it seems intuitive that people would mention them, especially when this motion is task-informative. Thus, to what extent do people refer in a direction giving task to dynamic entities?

Stable vs. dynamic objects

In navigation literature, there is high agreement that landmark objects should be stable / permanent entities. Previous studies suggest that good reference objects are large, geometrically complex and stable (Talmy, 1983). The perceived stability of objects seems to influence rodent and toddler’s use of landmarks for orientation. For example, rats can search for a location defined by visual landmarks, but will not do so if the landmark’s position has varied from trial-to-trial (for a review, see Burgess, Spiers, & Paleologou, 2004). In addition, studies on toddler's reorientation behavior speculate that stability and scale are important factors in landmark use, with smaller or more portable objects having less navigational significance attached to them (Learmonth, Newcombe, & Huttenlocher, 2001; Smith, Gilchrist, Cater, Ikram, Nott, & Hood, 2008). Recent human fMRI evidence suggests that stable objects elicit greater activity in regions of the brain involved in navigation and landmark assignment (see Chan, Baumann, Bellgrove & Mattingley, 2012). Most of these experimental studies start with the default assumption that objects have to be stable in order to be used as landmarks and with the exception of the rodent experiments, the studies mentioned above were not designed to test this assumption. In none of them the object's movement is directly witnessed by the participants and movement is never used as a clue that could potentially help with solving the task. Moreover, in most communicative situations used in the RD studies, stable landmarks are the only available entities, a reason for which the scholarly attention is mainly focused on these entities. For example, in map-based RDs or RDs produced for later use (e.g., Denis, Pazzaglia, Cornoldi, & Bertolo, 1999), the most frequently mentioned landmarks are two dimensional, mostly related to the path to be followed (e.g., streets), as well as three dimensional, such as shops and pubs (see also May, Ross, Bayer & Tarkiainen, 2003). In sum, in all cases in which landmarks play a role (orientation studies; RD production), these entities are always stable.

However, this does not mean that, in situations in which both producer and addressee are co-present, moving entities are not referred to. Humans have a rich repertoire of landmarks and to our knowledge there are no studies analyzing the conditions under which producers are ready to mention moving entities in RDs. If moving entities would be available would speakers refer to them? Moving entities are notably attention grabbing, a prerequisite for landmarks. Movement is processed effortlessly by the visual system and an object's motion can efficiently grab and guide attention when the movement is informative about the location of a target (Hillstrom & Yantis, 1994). In an outdoor environment there can be different types of movement (self-produced / induced) of different entities (e.g., humans, cars). In this study, we focus on self-produced, animated motion which was empirically proven to (automatically) capture attention.

Animate entities seem to intrinsically capture visual attention. They are conceptually highly accessible, retrieved and processed more easily than inanimate entities (Prat-Sala & Branigan, 2000). Visual representations of the face and the human body have the ability to capture the focus of attention even when visual attention is occupied by other tasks (see Downing, Bray, Rogers, & Childs, 2004). Studies using static images have shown that humans prioritize the visual processing of animate objects over inanimate ones. Kirchner and Thorpe (2006) found that people initiate saccades more quickly to pictures of animals than to pictures of other objects, and New, Cosmides, and Tooby (2007) showed that changes in animals were detected more rapidly than changes in objects. In addition, several studies using picture description tasks presented evidence that attention and animacy are linked and bias language production (for a review, see Henderson & Ferreira, 2013).

Moreover, it was shown that the onset of motion (a feature that contributes to the impression that movement is self-produced) captures attention better than objects that are static, continuously moving, or that have stopped suddenly (Abrams & Christ, 2003). Allocation of attention and linguistic reference are closely related and, given these results, we would expect moving entities to be mentioned in RDs. When other factors such as animacy and motion onset times are kept under control, it seems that animate motion per se captures attention (Pratt, Radulescu, Guo, & Abrams, 2010), thus contributing to the object's perceptual salience.

Previous experiences may, however, hinder the use of moving landmarks. People might be much more used to stable landmarks, so that in direction giving, perceptual salience alone might not suffice for eliciting this type of reference. For example, Miller and Carlson (2011) manipulated the objects' perceptual salience (size and color) and spatial position (decision versus non-decision point). Their findings showed that perceptual salience positively affected object memory, yet it was only the spatial position that determined whether objects were included in the RDs. This suggests that motion should be more than attention grabbing. It should be relevant for both producer and listener. This relevance stems both from the type of movement witnessed (it seems unlikely to mention something that takes place elsewhere than where the turn should be made) and the communicative setting (it is useless to mention motion for an addressee that cannot observe it, as in the asynchronous communicative settings).

The current study

Given that referring to landmarks can maximize the helpfulness of the instructions (Allen, 2000) and research has shown that people nearly always refer to landmarks (Tom & Denis 2003), we wonder if people refer to moving entities as a function of motion relevance and if this referential behavior is modelled by the communicative situation. We suggest two crucial conditions for moving landmarks to be used in RDs.

First, references to moving objects depend on the communicative context. As mentioned before, landmarks are by default stable, but this might be due to the asynchronous communication setting, which imposes several spatial and temporal constraints. But, it might well be that this bias in navigation studies hides the possibility that producers use both types of landmarks, provided the communication situation allows for. In this study, direction giving is a joint activity and a situated communicative act. In order to test the extent to which co-presence might influence reference to (dynamic) landmarks we select two situations: one in which producers are asked to imagine giving instructions to a fictitious traveler who is seeing the same scenes (see Experiment 1) as opposed to engaging in direction giving with a real person (see Experiment 2).

In the first communicative situation, instructions are framed to emphasize a co-presence context. Bringing people in a particular mindset by asking them to imagine a situation is a method successfully used to influence task performance. For example, Anderson & Pichert (1978) found that participants remember different details from a story after they were told to imagine themselves in a specific role (homebuyers or burglars). Asking participants to think about the task in a specific way was also shown to influence language production. Arts, Maes, Noordman, & Jansen (2011) report more overspecified references when participants were asked to imagine that the description they had to produce was an instruction in long-distance medical surgery, compared to a simple object description.

In the second setting, the joint situation is translated as physical co-presence of producers and addressees. In general, we expect producers to mention moving entities when they believe that such references are beneficial for the listener. When the addressee is not present, the producer has to decide alone how much communicative effort to undertake to ensure that the instructions are correctly understood. While, in the second communicative situation, the producer can directly evaluate the usefulness of the references by receiving feedback from the listener.

Second, the type of movement perceived by the producer might influence his referential behavior. To our knowledge there are no studies to have manipulated movement as a crucial variable in their design. If an entity attracts attention, we expect it will be mentioned, especially when it is relevant for the navigation task. By task relevant we mean that moving landmarks (just like other landmarks) should be located and timed near the navigation action. Thus, in this study there are three conditions depicting moving entities that might be of different relevance for the navigation situation (persons moving towards the intersection or taking a turn in the direction in which the addressee should also turn).

Lastly, we do not expect this type of dynamic landmarks to replace stable objects that afford long-term orientation, as they might be mentioned together (e.g., "turn right at the shop, follow that person"). In such case, the moving entity would help in disambiguating the stable landmark out of a series of possible distractors (other shops in the scene).

Experiment 1

Methods

Participants 54 native English speakers (20 women, mean age 42 years) were paid to take part in the experiment via a crowdsourcing service similar to Amazon Mechanical Turk.

Materials The materials consisted of 144 street view HD videos recorded in 72 intersections of Rotterdam downtown. The critical trial videos depicted 36 low traffic, +- shaped intersections. These intersections have a simple geometric shape, in which just saying "go left" would discriminate the target street from the other branches of the intersection. Each intersection was recorded three times illustrating a different movement manipulation (see Figure 1): (a) no pedestrians / cyclists moving towards / coming from the intersection (no movement condition (NM), 36 videos); (b) a person walking / cycling towards the intersection up to a point very close to where the turn should be taken (irrelevant movement condition (IM), 36 videos); (c) the same person recorded some seconds later, while taking a turn in the required direction (relevant movement condition (RM), 36 videos). As all entities may be relevant, due to their proximity to the intersection, the terms "irrelevant / relevant movement" are used for labelling purposes only. The people recorded were casually walking / cycling down the street, without paying attention to the camera. These people were different from one intersection to another. The filler videos captured a different set of intersections from crowded pedestrianized areas or intersections with complex geometric structures (36 videos) in which passers-by did not turn in the indicated direction. A semitransparent red arrow depicted the route and the direction to be followed. Each video lasts 3 seconds.

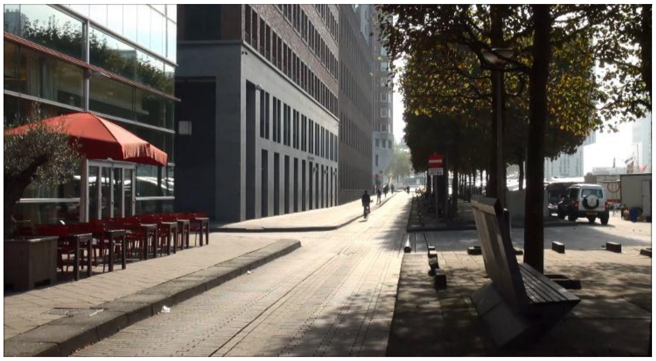
Procedure Participants were presented with instructions stating that we are developing software that can generate real time/live pedestrian route descriptions based on the visual input coming from the Google Glass video camera and realized in audio format via a smartphone. The participant task was to provide route instructions for a fictitious addressee who would be attending the same videos. Participants were explicitly told to be as informative as possible and that they could take advantage of everything that was visible on the streets, as they shared exactly the same view with the addressee. Participants saw one video at a time and filled in the RD in the input field provided under the video. At the end of each video, the last frame would be displayed until the participant moved to the next item, by pressing a button. The videos could be replayed. Each intersection was presented only once to each participant, thus the critical trials were divided across three presentation lists, to which participants were randomly assigned.

Design This study had Movement type (levels: NM, IM, and RM) as within participants factor and Presentation List (levels: 1, 2 and 3) as between participants factor. The dependent variable was the number of landmarks mentioned.

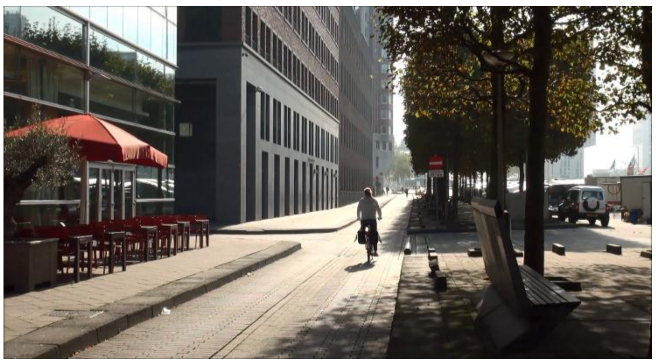
Results

There were 1944 RDs (54 participants x 36 videos) produced in this test and 964 landmarks mentioned. In each condition, approx. half of the instructions contained landmarks (M = 0.53 in NM; M = 0.47 in IM; M = 0.51 in RM). In general, there were few references to moving landmarks (2 references in NM; 6 in IM and 13 in RM). In addition, there were some references to movable objects (objects that could potentially move, such as parked cars and bikes: 15 references in NM; 20 in IM and 15 in RM). Overall, these results strongly suggest that participants prefer stable landmarks irrespective of the types of movement seen. Next, we will assess if moving objects are mentioned in a co-presence situation.

a) No movement – the street up to the junction is free



b) Irrelevant movement – a cyclist moves towards the junction



c) Relevant movement – the cyclist turns left

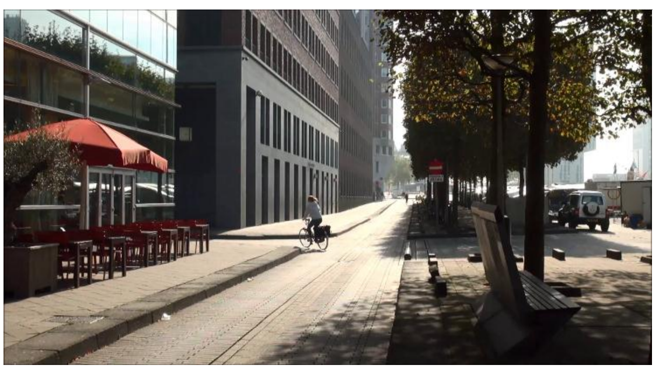


Figure 1: snapshots from critical trial in three versions

Experiment 2

Methods

Participants 48 dyads of Dutch-speaking students of Tilburg University (52 women, mean age 21 years and 5 months) participated in exchange for partial course credits. Participants were randomly assigned to speaker roles (30 women).

Materials the same as in Experiment 1, with the difference that the videos did not contain arrows. Videos were projected on a white wall, at size of approx. 170x120cm. In addition, two paper booklets with line drawing maps of the intersection's shape were prepared (the speaker booklet included an arrow showing the direction to be taken in each intersection).

Procedure Dyads of participants were presented with the same Google Glass scenario as in Experiment 1. The task for the speaker was to provide route instructions, while the listener had to mark in his booklet the indicated street. The speaker had to look first at the map, then play the video projection and start giving instructions as soon as possible, while watching the video. The listener had to watch the video and afterwards mark the intended street on the map. The listener was allowed to ask questions only if the instructions were unclear. The videos could not be replayed, but the last frame was displayed until the addressee announced he had finished. Pointing was discouraged by installing a screen between participants up to shoulder level. Each intersection was shown only once to each participant pair, and participants were randomly assigned to one of the three presentation lists. The task started with 2 warm-up trials, then 72 experimental trials (36 critical trials) were presented in randomized order. There were no time constraints.

Design and statistical analysis This study had Movement Type (levels: NM, IM, and RM) as within participants factor and Presentation List (levels: 1, 2 and 3) as between participants factor. For the first analysis, the dependent variable was the number of (different types of) landmarks mentioned by the producer in the first instruction (moving / stable entities) and, for the second analysis, if moving objects are mentioned together with a stable object. Statistical analysis was performed using logit mixed model analysis (Movement type and Presentation List as fixed factors; speakers and videos as random factors). Random intercepts and random slopes for speakers and videos were included to account for between-subject and between-item variation. First, a model with a full random effect structure was constructed (Barr, Levy, Scheepers, & Tily, 2013). In case the model did not converge, we excluded random slopes with the lowest variance. The first converging model is reported. This model contained random slopes for list in speakers and movement in videos (p - values were estimated via parametric bootstrapping over 100 iterations).

Results

In total there were 1728 RDs (48 speakers * 36 videos) produced. In all the three conditions, participants mentioned landmarks (N = 998) of various stability. In each condition, landmarks were mentioned in approximately half of the instructions (M = 0.51 in NM; M = 0.56 in IM; M = 0.69 in RM). In the NM condition, participants rarely referred to moving landmarks (6 references to people walking on the other side of the street or crossing in a different direction). Thus, statistical analysis was performed only on data from the other two conditions.

Table 1. Number of landmarks (moving, stable and combinations) produced per condition.

	NM	IM	RM
total no. landmarks	291 (100%)	317 (100%)	390 (100%)
stable landmarks	271 (93.12%)	237 (74.76%)	170 (43.59%)
moving landmarks	6 (2.06%)	54 (17.03%)	184 (47.18%)
moving & stable	14 (4.81%)	26 (8.20%)	36 (9.23%)

There was no significant effect of Presentation List ($p > .05$). There was a main effect of Movement Type ($\beta = 1.97$; $SE = .30$; $p < .001$). In the relevant movement condition participants referred more often to the moving person taking a turn ($M = 0.39$), than in the irrelevant movement condition ($M = 0.14$)[1]. Moving entities were present in instructions alone (e.g., "go left where the man is also going"; "follow that man, go left") or in combination with stable landmarks (e.g., "at the pub turn left, where the man is going").

In order to see if, in these RDs, moving landmarks are considered sufficient, we analyzed to what extent moving landmarks combine with stable ones across conditions. A smaller data-set was created by selecting only the instructions which mention moving persons. There was a main effect of Movement Type ($\beta = -1.41$; $SE = .51$; $p < .01$). In IM condition, the moving person is mentioned more often together with other landmarks ($M = 0.25$), than in the RM condition ($M = 0.12$).

Discussion

In this study, we have investigated the circumstances under which people refer to moving landmarks. Specifically, we focused on the type of movement and on the communicative setting that might influence RD production.

The collected RDs included a fairly large amount of references to unstable landmarks when producers were giving instructions to a real addressee. When movement is task informative more than half of the landmarks mentioned are moving landmarks and often, these moving entities are the only ones mentioned in the instructions, which highlights the producer's preference for this heuristic in the here-and-now setting. The results suggest that factors contributing to object salience in RDs depend largely upon context and producer's goals. The main role of these moving entities was to provide short-term orientation for the listener, by marking with their presence the street where a turn should be made. Thus, a moving entity may function as a point of reference and have navigational importance in a joint communicative situation. In addition, moving landmarks were mentioned even when their trajectory was not task-informative. However, references to pedestrians that were just heading towards the intersection without taking a turn were significantly often mentioned in combination with other (stable) landmarks from the environment. Despite the fact that their motion is not task-informative, they might have been referred to because they are perceptually salient (due to their movement), but also because they are walking very close to the turning point. Based on this stimuli design we cannot evaluate to what degree proximity had influenced the perceived usefulness of these entities. Further analysis is also needed to understand the role of these references: as landmarks due to their position or as attributes used to disambiguate a stable landmark out of a series of similar entities (e.g., "turn left at the shop where the man turns", where the scene shows a couple of shops placed nearby the intersection).

A couple of questions remain unanswered. For example, how efficient are references to moving landmarks for the addressee. A first analysis of the listeners' data showed that the task was simple and addressees rarely asked clarification questions, subsequently, their drawings were mostly correct. In addition, in an ongoing experiment, we try to determine the navigational value of moving landmarks. In a future study, we would like to further define the conditions under which participants refer to moving landmarks (e.g., to what extent the amount of movement or the complexity of the intersection affect this type of references).

Despite several differences (such as cultural differences between participant samples, familiarity with the Glass concept), the data collected in the two experiments suggests that references to moving landmarks were influenced by the communicative context. Apparently without a joint communicative situation, respondents preferred stable landmarks. When conversation partners are distant in time and space and no feedback is possible, the speakers have to adapt to the situation and ensure that the message is well understood (the principle of mutual responsibility, Clark & Wilkes-Gibbs, 1986). Referring to moving landmarks when no feedback and further correction is possible could result in an unsuccessful instruction. In contrast, when the producer was asked to address a real listener, participants referred to moving entities quite often. Referring to a moving item might be a faster heuristic to refer to the place where the turn should be taken.

Finally, cutting edge technology enables machines with a rich sensory input. Our results suggest that movement detected in the nearby environment can be informative in a landmark selection task. Of interest for real-time navigation services, our results highlight that not only the stable landmarks, but also the moving entities play a role in the production of turn-by-turn route directions.

Acknowledgments

The first author received financial support from the Netherlands Organization for Scientific Research, via NWO Promoties in de Geesteswetenschappen (322-89-008), which is greatly acknowledged.

[1] Means are calculated over all RDs from IM and RM conditions, including the cases without landmarks.

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