The Effects of Landmark Presentation on Driver Performance and Uncertainty in a Navigation Task
A Field study

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Abstract (background, aims, methods, results) max 200 words:

The effects of landmark presentation on driver performance and uncertainty in a navigation task - a field study. In order to study if there are positive effects of using landmarks in a route guidance system, a field study was carried out.

Two groups of drivers had to drive to an unknown destination, following the directives from a simulated route guidance system that presented visual and verbal information. In the control group the subjects received left-right and straight ahead directives. In the experimental group the subjects received the same information plus information about landmarks on a total of six occasions. The landmarks were chosen to define more clearly directions, distances, and where to stop.

The results showed some positive effects of landmarks presentation. The subjects in the experimental group were more satisfied with the content of the visual information, and were less unsure where to turn. Most important, they did not make any navigational errors. A number of suggestions for the improvement of the system was also obtained.
INTRODUCTION

A safe, efficient, and user-friendly route guidance system must be able to communicate effectively with the driver. Among other things this means that such a system must be adapted to drivers' mental models of the environment. It must be able to perceive the environment in the same way as the driver does. Research within environmental and cognitive psychology has given us some valuable input. It seems that when people learn to find their way in a new environment first of all they learn some reference points or landmarks. That is, from a very complex and rich environment people seem to start by taking some samples, mainly from features that are easy to see and remember. In connection with the learning of some landmarks it is possible to develop relations between them, for instance, the order of landmarks along a route. To increase knowledge of an environment would thus mean to learn more and more landmarks, and more and more relations between them. Research by Alm (1990) has specifically focused upon the landmarks drivers are using in their mental models of routes. With the help of this knowledge it should be possible to adapt the information from a route guidance system to drivers' mental models of the environment.

The use of landmarks in route guidance

An extremely simple route guidance system can probably help a driver to travel from A to B by simply giving the driver left/right, and straight ahead directives before each choice point. This will, however, leave the driver with some uncertainties. First of all, the driver might wonder if the system really is working properly, and s/he has few chances to check that before the destination is reached (or not reached). Second, in some cases it does not give the driver a chance to anticipate where to turn, or if s/he is on the right track, or where s/he is supposed to stop. It seems reasonable to assume that information about these topics may help the driver.
This information, (where to turn, if the driver is on the right track, where to stop) can be given to the driver in many ways. One possible way is to use landmarks. Since we know what landmarks most drivers have in their mental models of routes, we also have a common language to be used for communication. For instance, to inform the driver about how far s/he is supposed to drive it is possible to use a landmark ("drive until you reach landmark X"). To help the driver to take the correct exit, and show that s/he is on the right track it is also possible to use landmarks ("take to the right after landmark X," or "straight ahead passing landmark X"). To give information about where to stop it is possible to have a landmark as a reference ("stop beside or close to landmark Z"). The driver will also have a chance to see if the system really works. If the system gives information about items that the driver can see with his or her own eyes, then it is rather obvious that the system works. Naturally, it is of utmost importance to use landmarks that are easily seen under all driving conditions.

It is assumed that using landmarks to give this type of information will make route guidance more effective, and reduce drivers' uncertainty during a trip. To test this assumption, two groups of subjects were given the task to drive to an unknown destination, guided by a simulated route guidance system. The system presented landmarks to one group at certain positions along the route, but not to the other group.

2 METHOD

Subjects. Twenty subjects, 10 men and 10 women, aged 23 to 51 years (mean=33.3, SD=8.4) participated in the study. They all had a driver's licence. Their mean distance driven was 12,500 km per year, SD=5,300 km. The subjects were paid 99 SEK for their participation in the study. The subjects were randomly assigned to two experimental groups, with the restriction of an equal number of male and female subjects in each group.
2.1 Material

Instruction. Before starting the experiment the subjects studied a written instruction. The instruction explained the purpose of the study (to find a good way to present route guidance information to drivers). It also explained the subject’s task in the experiment (to drive to an unknown destination, following the instructions from the route guidance system). When arriving at the destination they were told that their task was to answer some questions concerning the quality of the information they received. They were asked to respect the speed limits while driving.

Test car. The test car was a SAAB 9000 Turbo, with a manual gear box. The car was equipped with a simulated route guidance system that could present verbal and visual messages. Visual messages were presented on a display mounted on top of the dashboard, to the right of the steering wheel. The size of the display was 13,7 by 7 cm. The display was a colour LCD screen from Auto-display. It has eight colours, and a resolution of 200 by 640 pixels. In this experiment it presented black pictures against a light green background. Verbal messages were presented with natural speech of telephone quality via two loudspeakers mounted in the dashboard. Both types of messages were generated by an Apple Macintosh II, with the program supercard. The computer was located in the trunk of the car, and controlled via a keyboard.

Test route. The route used in the experiment started in a city centre of Linköping, a middle-sized Swedish city with a population of roughly 100,000 people, and ended in another city center. The route was 5,950 metres long, and contained 15 choice points. The choice points were fourway intersections (11), two T-junctions, one roundabout with four exits, and one large roundabout with six exits. The route also contained straight sections, and curves with different radii. Table 1 shows the approximate time it takes to drive between the choice points (in normal traffic conditions and respecting the speed limits), and also the distance.
Table 1. Description of the experimental route in terms of time (excluding waiting time at traffic lights) and distance between the choice points.

<table>
<thead>
<tr>
<th>Point</th>
<th>Time (s)</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td>30</td>
<td>200</td>
</tr>
<tr>
<td>1-2</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>2-3</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>3-4</td>
<td>12</td>
<td>150</td>
</tr>
<tr>
<td>4-5</td>
<td>67</td>
<td>850</td>
</tr>
<tr>
<td>5-6</td>
<td>28</td>
<td>350</td>
</tr>
<tr>
<td>6-7</td>
<td>94</td>
<td>1,450</td>
</tr>
<tr>
<td>7-8</td>
<td>70</td>
<td>1,100</td>
</tr>
<tr>
<td>8-9</td>
<td>10</td>
<td>250</td>
</tr>
<tr>
<td>9-10</td>
<td>24</td>
<td>450</td>
</tr>
<tr>
<td>10-11</td>
<td>20</td>
<td>450</td>
</tr>
<tr>
<td>11-12</td>
<td>25</td>
<td>350</td>
</tr>
<tr>
<td>12-13</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>13-14</td>
<td>7</td>
<td>25</td>
</tr>
<tr>
<td>14-15</td>
<td>16</td>
<td>75</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>438</strong></td>
<td><strong>5,950</strong></td>
</tr>
</tbody>
</table>

As can be seen from Table 1, the driving time between the choice points varied between 7 and 94 seconds, corresponding to 25 and 1,450 metres. The effective driving time was approximately 438 seconds, given that the posted speed limits were respected. In order to drive the route correctly, the driver had to make nine turns (five right, and four left turns) at different choice points. The posted speed limits on the route were 30, 50, and 70 km/h.

**Questionnaire.** After the task had been completed each subject had to fill in two questionnaires. The first had to do with the quality of the information they received from the navigation system. To be able to use any system a driver must be able to: a) perceive the messages, b) understand the messages, c) remem-
ber the messages, d) be able to follow the recommendations from the messages. A good system should also keep a driver's stress level within reasonable bounds. It is also of great importance that the system does not have a negative impact upon the driver's ability to drive safely.

The first questionnaire aimed at covering most of these different topics. The drivers were asked to state how pleased they were with the information they received (global evaluation of the information), how easy it was to hear the spoken and see the visual information (perceptual evaluation), if they missed some kind of information of visual or spoken form, respectively (completeness of information), how easy it was to remember the information (memory load), how often they had to look at the screen for repetition (memory load), how easy it was to follow the instructions (ease of translating messages into actions), if they sometimes were uncertain about: a) if they were on the right track, b) where to turn. They were also asked if they were distracted by the information on the display, and by the spoken information. All these questions were answered using a seven-point scale. The questions concerning the completeness of the visual and verbal information also gave the subjects an opportunity to say in their own words what they missed in the information presented. Finally, they were asked some general questions concerning age, sex, driving licence, distance driven each year.

The other questionnaire was a slightly modified version of the NASA-TLX (Hart and Staveland, 1988). The aim was to measure the subjects' workload. The subjects had to rate six different workload factors (mental demand, physical demand, time pressure, performance, effort, and frustration level) on a continuous scale ranging from very low to very high. They also had to rate the relative weights of the different factors.

Experimental conditions. In the control condition, subjects received left, right, and straight ahead directives before each choice point. The left and right messages were always preceded
by an alerting sound (a two-tone signal), followed by presentation of visual and verbal information. When straight ahead was presented no alerting signal preceded it, and it was only presented visually. The visual information consisted of black arrows on a green background (see Appendix for a detailed description) showing the different directions of travel. Besides these arrows, schematic descriptions of the two roundabouts were included, where the direction of travel was indicated using a black arrow. The verbal information consisted of the directives "left", "right", "right in the roundabout", and "straight ahead in the roundabout". A natural male voice was used to read the messages.

In the experimental condition, subjects received the same information with the addition of landmarks on a total of six occasions. The landmarks were used to indicate more clearly one right turn (right at traffic lights), to clarify the direction of travel in two fourway intersections (straight ahead at traffic lights), to specify one exit from a roundabout (straight ahead towards X), one rather long straight ahead part of the road (straight ahead until traffic lights), and to clarify the final destination (right, enter parking place).

Procedure. Each subject was randomly assigned to one of the two experimental conditions, thus giving a between-subject design with 10 subjects in each group. Before starting the experiment all subjects were familiarized with the test car. They drove it for a distance of approximately 3 km, to the starting point of the test route. At the starting point they read a written instruction, explaining that they were supposed to drive according to the instructions they would receive from the route guidance system. It was explained that both visual and verbal information would be presented, and that the absence of new information meant "go straight ahead". When they had to change direction of travel, an alerting signal would always precede the message. They were also told that they were supposed to answer some questions after arriving at the destination.
When the instruction was completed, the test trial started, and the subjects drove to the final destination, guided by the instructions from the route guidance system. The route guidance system was controlled via a keyboard by the experiment leader (sitting in the backseat). The presentation of information occurred at predetermined places along the route. The experiment leader also had the task to count the number of navigational errors during the trip.

At the final destination the subjects answered the two questionnaires, and could give free comments about anything of relevance to the experiment. Finally each subject received 99 SEK for their participation in the study.

3 RESULTS AND DISCUSSION

At first, we will present the results from the questionnaire intended to cover different aspects of the information quality and then the results from the questionnaire covering drivers' mental workload. Finally, the results from the subjects' free comments about the respective system will be presented.

Questionnaire 1, Quality of information.

Question 1. How pleased are you with the information you received to reach the destination? (1= not at all, 7= very pleased).

It was found that the subjects were quite pleased (mean rating landmark condition= 6.30, control condition= 5.70) with the information they received. There was a tendency for the subjects in the landmark condition to be more pleased with their information, but the difference was not significant.

Question 2 and 3. How easy was it to hear/see the verbal/visual information? (1= not at all, 7= very easy).
It was found that the messages were quite easy to hear and see, respectively, (mean rating verbal info= 6.6, visual info= 6.0). There was a tendency that the verbal information was easier to apprehend, but the difference was not significant. A possible explanation of the small difference in favour of the verbal information was probably that the lighting conditions were sometimes unfavourable for the visual display. On some stretches of the road the sun was shining from behind, and made the use of the visual display rather tricky.

**Question 4. Did you miss something in the display information?** (1= not at all, 7= to a high degree).

Generally, the ratings were rather low (1.4 for the landmark condition, and 2.5 for the control condition). The difference between groups was significant, $t(18) = 2.286, p<.05$, indicating that the subjects in the control condition were missing information to a higher degree than the subjects in the experimental condition.

**Question 5. Did you miss something in the verbal information?** (1=not at all, 7=to a high degree).

The answers to this question indicate that the subjects were rather pleased with the verbal information (mean rating landmark condition= 1.6, control condition= 1.95). Again we have a tendency of the subjects in the landmark condition to be more positive, but the difference is small, and does not reach statistical significance.

Looking at the answers to the open question concerning what they were missing, it was clear that the major problem was caused by a large roundabout with six arms. In the control condition the subjects received the direction to travel in it ("straight ahead in the roundabout") and shortly before the exit they also received a "turn right" instruction. In the experimental condition the subjects received the same information, and a reference to a landmark ("straight ahead, towards X").
Looking at the number of navigational errors also confirms this result. Three subjects in the control condition made navigational errors in the roundabout, compared to none in the experimental condition. From this we can draw some conclusions. First of all, it is not possible to base a navigation system on only left-right, and straight ahead messages, if there are complex roundabouts (more than four arms) in the driving environment. Second, one way to guide drivers through a roundabout is to use a landmark. Third, if a picture of a roundabout is presented, then that picture must have a close resemble of the roundabout. It is not recommended to use one stereotype picture for all roundabouts.

Question 6. How easy was it to remember the information from the system? (1= not easy at all, 7= very easy).

From the answers it is obvious that it was very easy to remember the information (mean rating landmark condition= 6.65, control condition= 6.75). No significant difference between the conditions.

Question 7. How often did you have to look at the display to get the message repeated? (1= never, 7= after every message).

The subjects' answers indicate that about half of the subjects used the visual display as a memory aid, and the other half did not. There was no significant difference between the conditions (mean rating landmark condition= 2.35, control condition= 3.10). A conclusion from this is that a route guidance system obviously needs some kind of memory back-up. In this case the visual display served as a memory back-up. The advantage of this solution is that the information on the visual display can be picked up when the driver chooses to do so, and it can be made quickly. This is probably an advantage over a repeat button for the verbal message.

Question 8. How easy was it to follow the instructions you received? (1= not easy at all, 7= very easy).
As expected there seems to be no problems to follow instructions of this kind (mean rating landmark condition= 6.35, control condition= 6.20). No significant difference between conditions.

**Question 9.** Did you at any time wonder if you were on the right track? (1= not at all, 7= to a high degree).

There was a difference in the ratings for the respective groups (landmark condition= 1.25, control condition= 2.85). The difference was only significant on the .10 level, $t$ (18)= 1.734, $p$= .10. Again the difference is in favour of the landmark condition.

**Question 10.** Were you at any time uncertain about where to turn?

In this case we have a significant difference, $t$ (18)= 2.295, $p$= .05, in favour for the landmark condition. Thus, landmarks can obviously be used to indicate more clearly where to turn. This is, of course, only necessary when the driving environment is complex. If the driving environment is simple, meaning that left and right can not be misunderstood, then there is probably no need at all to use landmarks.

The next two questions have to do with possible negative safety related aspects. If a driver’s attention is diverted from the traffic environment for a prolonged time, or in a critical moment, then there is a risk of an accident. The next two questions concern the driver’s subjective assessment of being distracted by the system.

**Question 11.** In your own opinion, did the information on the display distract your attention? (1= not at all, 7= to a high degree).

Judging from the driver’s answers, this was not the case (mean rating landmark condition= 1.55, control condition= 1.40). No significant difference between the two conditions was obtained.

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In this case we must emphasize that this is the driver’s subjective experience of being distracted, and this does not necessarily reflect the actual distraction during the trip. In order to be able to draw safe conclusions we need to perform studies where we actually record the number of glances, and time length of glances at the visual display, and the increase in mental workload caused by the verbal message.

**Question 12.** In your own opinion, did the verbal information distract your attention? (1 = not at all, 7 = to a high degree).

As in the previous question this seems not to be the case (mean rating landmark condition = 1.25, control condition = 1.40).

**Questionnaire 2, Drivers’ subjective workload**

Each subject’s rating (except for two subjects in the landmark condition, who left incomplete answers) on each factor was used for the analysis of the NASA-TLX. Table 2 shows the results of the landmark and control conditions.

**Table 2.** Mean ratings of subjective workload as a function of experimental condition.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Landmark</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mental load</td>
<td>0.74</td>
<td>1.21</td>
</tr>
<tr>
<td>Physical load</td>
<td>0.74</td>
<td>1.67</td>
</tr>
<tr>
<td>Time pressure</td>
<td>1.17</td>
<td>1.87</td>
</tr>
<tr>
<td>Achievement</td>
<td>8.94</td>
<td>7.50</td>
</tr>
<tr>
<td>Effort</td>
<td>1.52</td>
<td>1.58</td>
</tr>
<tr>
<td>Frustration</td>
<td>0.90</td>
<td>2.22</td>
</tr>
</tbody>
</table>

As can be seen from Table 2 the ratings of mental, physical load, time pressure, effort, and frustration were lower in the
landmark condition. The rating of achievement is also higher in the landmark condition. We can also see that the differences are rather small, and statistical testing showed a borderline significant difference of mental load, \( t (17) = 1.747, p = .10 \).

### 3.1 Free comments about the systems

The subjects' free comments about the systems can be grouped in basically five categories.

1. The system should not give more information than necessary. If a system gives too much and detailed information there is a risk that the driver is treated as totally incompetent. For instance, in the large roundabout subjects were shown a picture of the roundabout with the driving direction indicated, and given a verbal directive before entering it, and a "right" directive just before the exit. This was commented upon by a number of subjects (three) who considered this to be too much and too detailed information. This is, of course, a question of achieving a good balance between completeness of information and respect for the driver's ability to think by him or herself.

2. The tone of the voice may be of importance. A suggestion was that the tone of the voice should not be monotonous and neutral (like an artificially generated voice). Instead it could very well be more full of life.

3. In some instances subjects would have liked more information than only the next choice point. Especially, when the driving time between choice points is short. This result was also obtained by Alm (1991), and these results give the same indication. A user-adapted navigation system should be able to vary the amount of information depending upon the structure of the driving environment. When the driving time between choice points is less than, for instance 7-10 seconds, then information about the next two choice points can be given.
4. It was found that the timing of the navigation information is important. In the experiment, the presentation of messages was made at some predetermined places along the route. This resulted in a timing that was not ideal for all subjects. Obviously, this is an important question for future research.

5. There seem to be individual differences between subjects in the preference for verbal versus visual information for route guidance. Most subjects stated that they preferred verbal information, since they did not have to look away from the road scene to pick up the information. Some subjects stated that they preferred the visual information, because they could look at it when there was time to do so. Thus it seems reasonable to conclude that a navigation system should give drivers both opportunities. This will give the driver an opportunity to choose between verbal and visual information, and thus get the information source s/he prefers. It will also give a driver an opportunity to use the visual display as a memory aid, which can be looked on when the traffic situation allows it. It is, of course, of great importance that the information on the visual display is simple and easy to understand.

4 GENERAL DISCUSSION

Some general conclusions can be drawn from this study. First of all, the route guidance system used in the study apparently worked well. Judging from the subjects' answers they were quite pleased with the information they received. The information was also easy to see, hear, remember, and follow. The improvements that can be made have to do with readability of the visual display under some conditions and the content of the visual message but also with the timing of the information.

Another conclusion is that a safe and efficient route guidance system should be based on both verbal and visual information. At least one of the information sources should be self-paced, meaning that the driver can attend to it when s/he considers it safe.
to do so. A recommendation is to use the verbal message as the primary information source, and the visual as the memory back up. This also means that a repeat button for the verbal message is not necessary. The visual display is given that function.

There seem to be positive effects of the use of landmarks. Most results pointed in that direction, although many of them did not reach statistical significance. Looking at the tendencies in the study it seems as if the effects of landmark use were to make the drivers certain they were on the right track, and that they were more sure about where to turn. There was also a tendency of landmarks to produce a lower level of mental demands on the driver. We must, however, be a bit careful with the interpretation of these results. Time pressure and some technical problems during the running of the study justify this carefulness. Consequently, the results from this study are promising, but before jumping to any safe conclusions a cross validation of the results would be recommended.

In this context it must be pointed out that the route to be driven was not very complex, so the relative effect of landmark use may have been limited. The use of landmarks along the route was also rather limited. This was made in order to make a hard testing of the landmark idea possible. It would be of great interest to run a slightly larger study, in a more demanding driving environment.
REFERENCES


Alm, H. (1991). What is the optimal amount of information from a verbally based navigation system? In Deliverable NAV 4 - DRIVE GIDS.

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