‘The failure to apprehend’ in case of changes to the road environment: does familiarity make a difference?
11.1 Introduction

Traffic accidents are caused by many different factors. One of these factors is driver distraction. In many cases, driver distraction refers to distraction by something inside the vehicle. Examples are a driver who looks at an in-vehicle display or changes the radio station. When a driver takes his eyes off the road and looks inside the vehicle, it seems plausible that he can not respond to what happens outside on the road. The information on the road never enters the visual system, leading to a failure to respond. However, an interesting but dangerous phenomenon arises when drivers are looking at the road but still fail to select or respond to information relevant for the driving task. We refer to this phenomenon as ‘the failure to apprehend’; the information is clearly visible and relevant for the task at hand, but there is no response.

Examples of this phenomenon are described in Danish studies, that specifically look into traffic accidents at priority intersections [Herslund, 1993, 2001; Summala et al., 1996; Räsänen & Summala, 1998; Rumar, 1990]. They describe accidents in which drivers, after hitting a cyclist who had priority, claim that they did not see the cyclist even though they specifically looked for other traffic. These types of accidents are so called looked-but-failed-to-see accidents [Hills, 1980]. Although not scientifically proven, one of the explanations is that drivers only look for other cars. They do not detect cyclists or motor cyclists since they do not expect other road users but cars to be present.

In this respect, top-down visual search plays an important role. Top-down visual selection takes place when people select objects from a scene that share some features with the specific target object they are looking for [e.g. Treisman & Gelade, 1980; Wolfe et al., 1989; Findlay, 1997]. Top-down selection is also shown in the fact that when searching for an object in a scene, people first search at the likely locations for these objects. Search for an object at a non-predictable location is much slower than search for an object at a likely location [Meyers & Rhoades, 1978; Theeuwes, 1991c]. Research on expert performance clearly shows the strength of top-down selection. Because of their attentional set, experts primarily focus on domain-specific stimuli whereas non-experts may also pay attention to other stimuli [Werner & Thies, 2000; De Groot, 1978; Chase & Simon, 1973a, 1973b; Reingold, Charness, Pomplun & Stampe, 2001; Groff & Chaparro, 2003; Pearson & Schaefer, 2005]. These results suggest that intentions, goals and expectations guide selection and thereby perception. However, this top-down selection, ruled by intentions, goals and expectations may also introduce a fallacy. If road users are familiar with a road, they develop expectations about the presence of objects and how to behave. The fallacy may occur if these expectations are incorrect.
Martens and Fox (in press) already found that the visual glance duration to objects along the road decreases if people drive the same road several times. In a low-cost simulator, they had participants drive the same road several times over different days, thereby increasing the familiarity with the road. Only on the last day, a change was made in the lay-out of the road, in which a priority situation was changed into a give-way situation (with proper road markings and traffic sign). If people drove the same road numerous times they had more explicit expectations about what was represented on traffic signs than people who had driven the road only once. Besides decreasing glance duration, the effect of familiarity with the road was also reflected by an increase in average speed. Only 2 out of the 12 participants somehow noticed anything of the change. Of these 2, one participant only verbally responded to the change when actually crossing the intersection [so not in due time] and the other hardly responded and claimed to have noticed some change but did not remember what it was. Glance duration to the traffic sign that changed was as short as that of unchanged information. This suggests that even though the information is selected [glanced at], it is not processed to such a deep extent that it enables a response. These results support the idea that this is the fallacy of strong top-down information processing: With increased exposure to the same road, expectations are so strong that even though new information is selected, it does not result in a response since it does not fit the expectations. Although selected, it is not processed to a deeper extent that it allows a proper response.

Even though this previous study clearly showed that driving exactly the same road will result in this failure to respond to clearly visible stimuli, the question arises whether such an effect is more general in nature and can also occur when the road is not exactly the same. In other words, is it feasible that more general expectations that drivers have developed over time with a road lay-out in general may also induce ‘the failure to apprehend’. If such an effect occurs then one may ask how one can break through these expectations allowing an adequate response. These two questions were studied in a driving simulator experiment.

11.2 Method

The central question was whether familiarity with the road resulted in ‘the failure to apprehend’ and whether this ‘failure to apprehend’ mainly occurred if drivers drove the same road several times or whether it also occurred if the road environment partly varied from one drive to the other. In order to study ‘the failure to apprehend’, a change to the road lay-out was introduced from one drive to the next. In this study, a normal road was changed into a No-entry road.
In order to control familiarity with the road, a condition was included in which the road environment always varied from one drive to the next. In these cases, the same road was used as a basis (with the same curvature, the same number and location of intersections and the same priority situation) but there were variations from one drive to the next. These variations were:

1. separated or non-separated lanes,
2. the type of buildings next to the road (high flats, houses or trees only) and
3. the distance from the road to the buildings (close or further away).

Some examples of the type of variations from one drive to the next are provided in Figure 11.2 to 11.4.

11.2.1 Participants
Altogether, 78 participants completed the experiment. All participants were recruited from the TNO participant data-base. Participants drove more than 5,000 kilometers per year and had had their driver’s license for at least 5 years. Both men and women participated. All participants had normal or corrected to normal eye sight and were paid for their participation.

11.2.2 Apparatus
The experiment was conducted in the TNO driving simulator. During the experiment, a participant was seated in a fixed base mock-up of a BMW 318 (see Figure 11.1) and had all normal controls (steering wheel, accelerator, brake, car had automatic gear shift). Based on these controls, a mathematical vehicle model computed the momentaneous state of the vehicle model. Feedback of steering and gas pedal forces was given to the driver by means of electrical torque engines.

The momentaneous position and heading angle of the vehicle were transmitted via a supervisor computer to a SimFUSION Computer Generated Imaging (CGI) system, which computed the visual scene as seen from the position of the driver. This image was projected on a cylindrical screen in front of the mock-up with a forward angle view of 120 degrees. Participants also had a rearview mirror, a right mirror and a left mirror at their disposal.

Generating the visual images by the CGI takes about 66 msec, which yields a pure time delay in the simulated vehicle system that is not present in the real vehicle. A predictive algorithm has been added to the Vehicle Model (Hogema, 1992, 1993) to compensate for this delay. Thus, the output of the Vehicle Model consists of both the actual position and the CGI delay-compensated position.
The Sound System generated real-time sounds in the Mock Up of the driving simulator and provided the participant with sounds of the engine, tyres, driving wind and nearby other vehicles. The Sound System generated 3D-audio. The direction from which the participant in the mock up heard each sound component matched the location of the sound source in the simulated environment. For example, when a participant passed a car, the sound of that car first came from ahead, then gradually came closer and would finally end behind the mock-up.

The Motion Base PC received input from the Vehicle Model PC by means of an Ethernet communication link. The Motion Base PC transferred its input signals to commands for the Motion Base System. The Motion Base System was a 6 Degrees of Freedom [MOOG 2000 E] hexapod motion platform with the associated control equipment. The mock-up was placed on the platform; the RGB projectors and the projection screen were stationary.

11.2.3 Task
The task of the participants was to drive several drives on a road in the simulator. Participants were instructed to imagine that the drives were their daily drives home from work. They were instructed to drive as they normally would on such a road under these conditions. Participants were not instructed about what they would encounter, did not know that there would be a change in the last drive and they were not informed about the exact numbers of drives that they had to make.

11.2.4 Experimental conditions
Eight different conditions were used, with 9 or 10 participants per condition. For 6 out of the 8 conditions [Condition 1, 2, 3, 4, 5 and 8], participants made 19 drives, separated by 3 breaks. The first 18 drives were varied as indicated above (houses, flats, trees, separated driving lanes or not and distance of the objects along the road). Drive 19 included the change.

Examples of these varied drives are shown in Figure 11.2 through 11.4.

The road was always a 2-lane road with opposing traffic but on several drives the opposing traffic was physically separated by means of a wide mid section. There was no preceding traffic because this might affect the behaviour of the participant [speed, entering the No-Entry road]. The road was a 2 km long road with some wide curves. There were three intersections present and there were no speed limits posted.

The last drive that participants made was a scenario with houses nearby the road with separated driving lanes [see Figure 11.3]. At the second intersection, there was
a ‘No-Entry’ sign on the right side of the road [whereas there was no sign present at that location in any of the previous drives]. It was this last drive that made the distinction between Condition 1, 2, 3, 4 and 5. In Condition 6, participants made one drive in total and in Condition 7 two drives.

Figure 11.1 BMW mock-up in the TNO Driving Simulator.
Figure 11.2 No separated driving lanes, houses far away.

Figure 11.3 Separated driving lanes with grass in the middle, houses nearby.
Figure 11.4 Separated driving lanes with grass in the middle, trees far away.
Altogether the conditions were (see also Table 11.1):

1) **Condition 1** *control condition*
19 varied drives without a change at the end (There was not a No-Entry sign).

2) **Condition 2**
19 varied drives, the last drive showed the No-Entry sign.

3) **Condition 3**
19 varied drives, the last drive showed the No-Entry sign and 200m before the intersection, an in-vehicle voice warned the driver. The auditory message was: “Please note, traffic situation has changed” (In Dutch: “Let op, verkeerssituatie gewijzigd”).

4) **Condition 4**
19 varied drives, the last drive showed the No-Entry sign and 200m before the intersection, an in-vehicle voice warned the driver. The auditory message was: “Please note, traffic situation has changed, No entry” (In Dutch: “Let op, verkeerssituatie gewijzigd, verboden in te rijden”).

5) **Condition 5**
19 varied drives, the last drive showed the No-Entry sign and 200m before the intersection, a yellow traffic sign warned the driver reading: Please note, traffic situation has changed (In Dutch: Let op, verkeerssituatie gewijzigd).

6) **Condition 6**
1 drive, with the No-Entry sign.

7) **Condition 7**
2 drives, the second drive showed the No-Entry sign and a 200m before the intersection, a yellow traffic sign warned the driver reading: Please note, traffic situation has changed (In Dutch: Let op, verkeerssituatie gewijzigd).

8) **Condition 8**
19 similar drives (no varied environment), the last drive showed the No-Entry sign. Different from the other conditions, all 19 drives were exactly the same in their physical appearance, so the same type of buildings and the same road lay-out. All drives were driven in the road environment as shown in Figure 11.3. This condition was added in order to see whether the failure to respond would be stronger if people had driven the exact same road several times.

An overview of the conditions is shown in Table 11.1.
Table 11.1 Overview of the conditions.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Condition 1:</strong></td>
<td>Control condition, on drive 19, nothing was changed</td>
</tr>
<tr>
<td><strong>Condition 2:</strong></td>
<td>In drive 19, the last intersection showed the traffic sign: <img src="image1" alt="Traffic sign" /></td>
</tr>
<tr>
<td><strong>Condition 3:</strong></td>
<td>In drive 19, an in-vehicle voice was activated: “Let op, verkeerssituatie gewijzigd”* 200m before intersection. At the intersection itself, a traffic sign showed: <img src="image2" alt="Traffic sign" /></td>
</tr>
<tr>
<td><strong>Condition 4:</strong></td>
<td>In drive 19, an in-vehicle voice was activated: “Let op, verkeerssituatie gewijzigd, verboden in te rijden” ** 200m before the intersection. At the intersection itself, a traffic sign showed: <img src="image3" alt="Traffic sign" /></td>
</tr>
<tr>
<td><strong>Condition 5:</strong></td>
<td>In drive 19, 200m before the intersection, a sign similar to the following traffic sign was shown: <img src="image4" alt="Traffic sign" />  and at the intersection: <img src="image5" alt="Traffic sign" /></td>
</tr>
<tr>
<td><strong>Condition 6:</strong></td>
<td>In drive 1, the following traffic sign was shown at the intersection: <img src="image6" alt="Traffic sign" /></td>
</tr>
<tr>
<td><strong>Condition 7:</strong></td>
<td>In drive 2, 200m before the intersection, a sign similar to the following traffic sign was shown: <img src="image7" alt="Traffic sign" />  and at the intersection: <img src="image8" alt="Traffic sign" /></td>
</tr>
<tr>
<td><strong>Condition 8:</strong></td>
<td>In drive 19, the last intersection showed the sign: <img src="image9" alt="Traffic sign" /></td>
</tr>
</tbody>
</table>

This condition is the same as Condition 2, but here the 18 drives before had the same physical appearance in terms of road lay-out and type of buildings.

* In English: Please note, traffic situation has changed.

** In English: Please note, traffic situation has changed, No Entry.
11.2.5 Procedure
Participants took part in the experiment in pairs. After reading the instruction, they filled in an informed consent. One participant was driving the simulator while the other waited in the entrance room. The participant was seated in the simulator, and all controls were explained. After this, the experimenter left the simulator room and participants could get used to driving the simulator in a practice drive. After every drive, the system would start up a new drive automatically.

After 6 drives, the participants would get a break. During the break of one participant the other was driving. Participants with only 1 or 2 drives did not come in pairs but sequentially.

11.2.6 Statistical analysis
For most of the statistical analyses of the data, an analysis of variance (ANOVA) was used with the between-participant factor Condition (8 altogether) and the within-participant factor Drive (if participants made more than one drive) and Road Section (the 2 kilometers before the intersection in which the traffic situation was changed were divided into road sections of 100m). The dependent variables were speed [km/h], deceleration [m/s²] and number of entries into the ‘No Entry road’. For post-hoc tests, the Fisher Least Significant Difference (LSD) was used. For pairwise comparisons, Chi-square tests were used.

11.3 Results
Since it was a between-participant study, it was important to test whether there were no initial differences in behaviour between the different participant groups.

11.3.1 Driving speed in normal drives
There was no initial difference in driving speed between the conditions in the first drive. This means that the different participant groups were comparable. The data of Condition 7 could not be included in this analysis since they only made one drive in which they encountered the No-Entry sign. This made the speed data incomparable to begin with.

When including all conditions with 19 drives (condition 1 through 5 and condition 8), an increase in speed was found over the 18 drives [main effect of Drive \( F(17,918) = 1.97, p<0.01 \)]. Drive 19 was not included in this analysis since it included the drive with the No-Entry sign. Note that for condition 1 through 5, the road lay-out was varied from drive to drive. Over all 18 drives, the main effect of Condition \( F(5,54) = 2.58, p<0.04 \) showed speed differences between conditions. There was a 2-way interaction between Condition and Road section \( F(95,1026) = 2.33, p<0.0001 \),
indicating that the increase in speed during the drives was somewhat different for the different conditions. This interaction is shown in Figure 11.5. This figure shows that for Condition 1 and Condition 8, the increase in driving speed over all 18 drives was stronger than in other conditions.

11.3.2 Number of entries
Since the main goal of the traffic sign was to prohibit participants entering the road, it is interesting to assess the number of people who actually entered the road [which was forbidden] irrespective of their driving speed. These results are shown in Table 11.2.
Table 11.2 The number and percentage of entries of the No-Entry road for the different conditions.

<table>
<thead>
<tr>
<th>Condition</th>
<th># of participants</th>
<th># entering</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Condition 1</strong>: Control condition, in drive 19, nothing was changed</td>
<td>10</td>
<td>10 = 100%</td>
</tr>
<tr>
<td><strong>Condition 2</strong>: In drive 19, the last intersection showed the sign:</td>
<td>9</td>
<td>5 = 56%</td>
</tr>
<tr>
<td><strong>Condition 3</strong>: In drive 19, an in-vehicle voice was activated:</td>
<td>10</td>
<td>0 = 0%</td>
</tr>
<tr>
<td><em>Let op, verkeerssituatie gewijzigd</em> at 200m before intersection.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At intersection the following sign:</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Condition 4</strong>: In drive 19, an in-vehicle voice was activated:</td>
<td>9</td>
<td>0 = 0%</td>
</tr>
<tr>
<td><em>Let op, verkeerssituatie gewijzigd, verboden in te rijden</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>** at 200m before the intersection. At intersection the following sign:</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Condition 5</strong>: In drive 19, 200m before the intersection,</td>
<td>10</td>
<td>1 = 10%</td>
</tr>
<tr>
<td>a sign similar to the following sign was shown:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and at the intersection:</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Condition 6</strong>: In drive 1, the following sign was shown at the intersection:</td>
<td>10</td>
<td>4 = 40%</td>
</tr>
<tr>
<td><strong>Condition 7</strong>: In drive 2, 200m before the intersection,</td>
<td>10</td>
<td>1 = 10%</td>
</tr>
<tr>
<td>a sign similar to the following sign was shown:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and at the intersection:</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Condition 8</strong>: Participants encountered the same road 18 times in a row.</td>
<td>10</td>
<td>3 = 30%</td>
</tr>
<tr>
<td>In drive 19, at the last intersection, the following sign was shown:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* In English: Please note, traffic situation has changed.

** In English: Please note, traffic situation has changed, No Entry.
In the control condition, 100% entered the road, which was to be expected since the No-Entry sign was not present. In case of the No-Entry situation, there were several occasions of ‘the failure to apprehend’. When 19 varied drives were made, 56% of the participants still entered the road with the No-Entry sign only (Condition 2). This was 40% for the condition in which it was the first time people drove this road and were confronted with the No-Entry sign only (Condition 6). So even if people drove the road for the first time, there was a ‘failure to apprehend’. Altogether, quite some errors were made, entering the No-Entry road.

In Condition 8, participants encountered the exact same road 19 times. Here, 30% entered the No-Entry road. Although this percentage is still high, it is not higher than in the conditions with the varied drives. This indicates that the failure to respond is not the mere result of being familiar with that specific road. Apparently the road design itself leads to the failure to respond even when driving the road for the first time and irrespective of the exact appearance.

**Figure 11.6** Speed behaviour for Condition 1 (control condition) in drive 19. At road section 20, there was no No-Entry sign present.
In case of an additional road sign before the No-Entry sign (Please note, traffic situation has changed; Condition 5 and 7), 10% failed to respond and entered the road. Again, irrespective of whether they drove the road 18 varied drives before (Condition 5) or only once before (Condition 7). In case of an in-vehicle voice, 0% entered the No-Entry road. This was the case for the in-voice message that just told them that there was a change (Condition 3) or also pointed out what had been changed (Condition 4).

A Pearson Chi-square non-parametric test showed a main effect of condition on number of participants that entered the road \( \chi^2 (7) = 37.99, p < 0.0001 \). Most errors are made in Condition 2 (Just No-Entry sign after 19 drives with variation), Condition 6 (first drive No-Entry sign) and Condition 8 (Just No-Entry sign after 19 drives without variation). No errors were made in the conditions with the voice-messages (Condition 3 and 4) and one error was made in Condition 5 (‘No-Entry sign’ and additional sign after 19 drives) and Condition 7 (‘No Entry sign’ and additional sign after 2 drives).

Figure 11.7 Speed behaviour for Condition 2 in drive 19. At road section 20, there was a No-Entry sign present.
These data clearly shown that there is no indication that ‘the failure to apprehend’ occurs more frequently after more drives, so expectations built with familiarity cannot explain this. Also, the occurrence of ‘the failure to apprehend’ is comparable between the condition with the variation in the lay-out of the road and the condition without any variation.

11.3.3 Driving speed in the last drive (No-Entry sign)
In terms of speed behaviour, drive 19 was the most interesting drive in the experiment since it included the change in the No-Entry road. For Condition 6, the drive with the No-Entry road was their first drive (simulating people who did not have any experience with this road yet but did encounter the No-Entry sign). For Condition 7, this was their second drive (simulating people who did have some expectations based on the drive before, but familiarity is much weaker). In Condition 1, the control condition, people were not confronted with a No-Entry situation.

Figure 11.8 Speed behaviour for Condition 5 in drive 19 (yellow additional sign and a No-Entry sign).
Therefore, the speed behaviour of participants in Condition 1 can be taken as the behavioural baseline for participants that do not select or do select but do not deeply process the No-Entry information, leading to ‘the failure to apprehend’.

The adequate response to the No-Entry sign would either be to come to a complete stop (speed 0 km/h), or to turn left or right on the intersection. In order to make a left or a right turn, participants had to drastically reduce their speed but did not have to come to a complete stop. In order to make a fair comparison between adequate and inadequate responses, the speed on road section 20 (at the No-Entry sign) was manually replaced with the value 0 (speed 0 km/h) if one turned left or right.

When analysing the speed data, it is most useful to make a distinction between participants that showed the correct behaviour (stopped or made a turn) and those who did not (entered the No-Entry road). For those participants that did not

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**Figure 11.9** Speed behaviour for Condition 6 in drive 1 (No-Entry sign already on the first drive).
show the correct behaviour, it is interesting to investigate whether there was any change in speed. A decrease in speed may indicate that there was at least some response.

Since the number of participants that did not show the correct behaviour varied from condition to condition, it is not possible to statistically analyse the data. Therefore, the data are plotted in graphs for a qualitative analysis.

First of all, Figure 11.6 shows the data for the control condition. These data are illustrative for participants who did not see the No-Entry sign at all (since in this condition there was no such sign).

What can be seen from Figure 11.6 is that there are some participants that do seem to show some decrease in speed at the last road section[s]. This may be the result of participants paying attention to the intersection. This is primarily the case for

Figure 11.10 Speed behaviour for Condition 7 in drive 2 (yellow additional sign and a No-Entry sign on the second drive).
participant 2, 3 and 8. The decrease in speed is similar to the decrease in speed in response to the first intersection (road section 7).

As we have already seen, in Condition 2 (just the No-Entry sign after 19 drives), there were five participants that did not show the correct behaviour. The speed data for the last drive for those participants that did not stop or turn are plotted in Figure 11.7.

What is shown in Figure 11.7 is that there are at least two out of the five participants (participant 12 and 15) that do show a strong decrease in speed. Participant 18 already showed a similar decrease at the other intersection (road section 7) so this is not the result of the No-Entry sign.

Condition 3 and 4 only included participants that showed the correct behaviour.

Figure 11.11 Speed behaviour for Condition 8 in drive 19 (a No-Entry sign and no variation from drive to drive).
Figure 11.8 shows the results for Condition 5. There was only one participant that did not show the correct behaviour.

Figure 11.8 shows that there is some form of response in terms of a small decrease in speed that is stronger than speed changes found on the first intersection.

Figure 11.9 shows the results for Condition 6. There is no effect of the No-Entry sign. Participant 53 does not show any response, and participant 54, 57 and 58 may show some effect, but the speed is not lower than on any of the preceding road sections. Therefore this is most likely not the result of the presentation of the traffic sign.

Figure 11.10 shows the results for Condition 7. Condition 7 only contains one participant that does not show the correct behaviour. There does not seem to be any effect on the speed.

Figure 11.12 Maximum deceleration for Condition 1 [control condition] in drive 19. At road section 20, there was no No-Entry sign present.
Figure 11.11 shown the results for Condition 8. Two participants (participant 71 and 73) seem to show some effect on speed. Although this could also be claimed for participant 78, the decrease in speed is not much higher than has been found on previous road sections.

11.3.4 Maximum deceleration
Besides the driving speed just before the No-Entry sign and actual access of the No-Entry road it is interesting to study the decelerations that were shown. It might have been that in some conditions, participants decelerated more than in other conditions. The stronger the deceleration level, the higher the chance that this is the result of drivers noticing the sign at the last moment. The higher the deceleration the stronger one was braking.

Figure 11.13 Maximum deceleration for Condition 2 in drive 19. At road section 20, there was a No-Entry sign present.
The maximum deceleration levels are provided for all participants that entered the No-Entry road.

Figure 11.12 shows that in the control condition, the maximum deceleration at road section 12 does not exceed any maximum deceleration on prior road sections. Therefore this will also be a criterion for 'the failure to apprehend'.

Figure 11.13 presents the data for the five participants in Condition 2 that do not show the correct behaviour. In this condition, with only the No-Entry sign in drive 19, there are some indications of a deceleration response despite the fact that they did not come to a stop or made a turn. Participant 15 showed a maximum deceleration that was far stronger than any of the maximum deceleration levels on previous sections. For the other participants, the effects are not so clear.

**Figure 11.14** Maximum deceleration for Condition 5 in drive 19 (yellow additional sign and a No-Entry sign).
In Condition 3 and 4, all participants showed the correct behaviour. Figure 11.14 presents the results for Condition 5 (No-Entry sign and an additional yellow sign pointing to the change). Participant 41 did not show a maximum deceleration level on road section 20 that was higher than on the previous road sections.

Figure 11.15 shows the maximum deceleration levels for the four participants in Condition 6. In Condition 6, participants were confronted with the No-Entry sign at drive 1. There are no clear deceleration patterns for any of the four participants. Therefore there are no indications that there was a response to the traffic sign.

Figure 11.16 shows the results for participant 62 in Condition 7, the one participant that did not show the correct behaviour. In Condition 7, participants were confronted with the No-Entry sign and the additional yellow sign on drive 2.
There is no indication of any strong deceleration response of the participant as a response to the signs that were shown.

Figure 11.17 presents the data for the three participants of Condition 8 that did not show the correct behaviour. For participant 73, there seems to be an indication that there is a maximum deceleration that points to a response to the traffic signs that are shown. The maximum deceleration levels for participant 71 and 78 do not exceed the levels that are also shown at previous road sections.

11.4 Conclusions

11.4.1 Effect of familiarity

In the beginning of this report, we assumed that people who drive the same road several times will become so familiar with the road environment that they respond less adequately to a change due to the expectations they have built up.
In order to test this, the behaviour as found in Condition 8 (19 drives on exactly the same road, No-Entry sign only) was compared to the behaviour shown in Condition 6 (1 drive only, No-Entry sign only). The mean driving speed in Condition 6 (first drive) was lower than the mean speed of Condition 8 in drive 19, but this was the result of an increase in driving speed over numerous drives as was found in this experiment. The current study showed that this increase in driving speed with more drives is found irrespective of whether it is the exact same road that people drive or whether there are some variations in its appearance.

In the last part of the drive (just before the No-Entry sign), there was no difference in driving speed between these two conditions. In both conditions, the number of errors of people entering the road was fairly high (40% for first drive and 30% for the 19th drive). Based on this information, we claim that it is not the familiarity with the road per se that leads to the failure to adequately respond to the No-Entry situation. Even if people did not drive the road before, quite some participants failed

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**Figure 11.17** Maximum deceleration for Condition 8 in drive 19 (a No-Entry sign and no variation from drive to drive).
to respond adequately. Apparently the road design is so prototypical that strong expectations are triggered and even drivers unfamiliar with the road do not expect a No-Entry road. This is confirmed by the speed behaviour data and the maximum deceleration levels of participants that entered the road. For the four participants that drove the road for the first time (no familiarity), the speed at this intersection was not lower than the speed on any preceding road section in drive 19. Therefore the assumption is that there really was no response at all to the No-Entry sign. For the three participants that drove the same road 18 times before (familiarity), two participants seem to show some reduction in speed. The maximum deceleration levels generally seem to confirm these findings. There clearly is no worse response when participants are familiar with the road compared to participants that drive the road for the first time.

11.4.2 Effect of variation in the road environment

The question was whether there would be a difference in response to the No-Entry road if people have driven the exact same road numerous times or if they have driven a similar road but with variations in its appearance (same traffic rules but with different buildings, trees, different road widths and different distance to the buildings and trees).

In the last drive, the driving speed for Condition 8 (exact same road lay-out every drive) was not significantly higher than that of Condition 2 (variation in road lay-out from drive to drive). For the 19 varied drives with only one No-Entry sign on drive 19, 56% of the participants entered the No-Entry road. This was 30% of the participants for the condition with 19 exact same drives and only one No-Entry sign on drive 19. This indicates that even though the level of errors was high in both conditions, people responded even less adequately to a road change if the road lay-out was varied from one drive to the other. The number of participants that entered the road but did show some response in terms of a decrease in speed or a clear deceleration was equal in both conditions. Both conditions included one participant that showed a decrease in speed despite the fact that their response was not adequate.

The results indicate that there are some differences in behaviour. With the varied drives, people even tend to show less adequate behaviour compared to the people who drive the exact same road numerous times.

11.4.3 Countermeasures

Now the question is what can be done to break through this failure to respond. In order to investigate this, extra countermeasures were included into the experiment in order to assess the effects.
One of the countermeasures was placing an additional yellow traffic sign ("Traffic situation changed"), a measure that is often taken in the Netherlands in case of changed situations. In order to assess the effect of this additional sign, we compared Condition 5 (19 varied drives, the No-Entry sign and the yellow additional traffic sign) to Condition 2 (19 varied drives and the No-Entry sign only). With the additional sign, 10% entered the road whereas this was 56% for just the No-Entry sign. So there is better performance with the additional sign, although ‘the failure to apprehend’ is still found.

If we assess the effect of the in-vehicle systems, we compare Condition 3 (voice warning about changed situation) and Condition 4 (specific voice warning about changed situation AND not entering the road) with Condition 2 (only the No-Entry sign). The in-vehicle messages were the only conditions in the experiment that resulted in 100% adequate responses. The number of people that entered the road in the condition with the No-Entry sign only was 56%. This was 0% in the conditions with the voice messages.

These results indicate that there is indeed a better response with additional countermeasures. Best results are obtained with in-vehicle auditory messages. Interestingly, there is no difference between the non-specific in-vehicle message and the specific one. Apparently, the non-specific auditory message warns the driver sufficiently in order for him/her to pay attention to visual information in the environment (the No-Entry sign). It is not necessary to specifically tell the driver what the new situation is.

11.5 Discussion

In a previous study (Martens & Fox, in press) we found that there are risks involved in driving the exact same road several times. That study showed that familiarity with the road makes road users develop expectations and in case of incorrect expectations (a change in the priority situation) there were strong negative consequences due to the failure to respond to relevant information, also called ‘the failure to apprehend’. However, the current study reveals that these negative consequences of driving the same road several times are not the direct result of road familiarity.

In the current study, we found that ‘the failure to apprehend’ is also found in case of driving a varied road or even when driving the road for the first time. This indicates that there are situations in which ‘the failure to apprehend’ is not the mere result of prior exposure to that particular road. Even though it was shown that quite some errors were made in case of a change to a previously encountered traffic situation,
the errors seemed to be the result of incorrect expectations induced by the road design itself rather than the result of expectations that people developed while driving this road several times (road familiarity). When the road appearance was varied from drive to drive, behaviour was similar to the condition in which one encountered the exact same road numerous times.

Apparently a road lay-out may activate specific schemata without having driven that specific road before. By having encountered similar roads in the past, drivers have developed schemata that dictate what to expect on these types of roads and how one should behave. Since schemata are characterised by strong top-down control there is not much room for bottom-up selection of information. Information that does not fit the schema will either not be selected or it will not be sufficiently processed. This explains why there was no response to the No-Entry sign: the bottom-up features were not strong enough to break through this strong top-down control. For some participants, there were behavioural indications that there was some (although not the correct) response. A slight decrease in speed for instance indicated that the information was selected and processed to some degree. Presumably, there was no correct response since the top-down control by means of schemata was stronger.

In order to increase the chance of a response in these circumstances, two approaches can be chosen. One approach lies in increasing the bottom-up control, the other in decreasing the top-down control.

The first approach is to increase the strength of the bottom-up features of in this case the No-Entry information. This is done in the experiment by placing an additional sign. The colour of the additional sign was rather conspicuous in its surroundings (yellow sign) and by having two new elements in the surroundings instead of just one, bottom-up control was increased. The idea behind such an additional sign, that is often used for indicating a changed traffic situation in the Netherlands, is that people will pay more attention to monitor what has changed. The additional sign is supposed to be able to change the way drivers scan their surroundings. However this assumes that the information from this additional sign is actually selected and sufficiently processed. The current experiment showed that although the additional sign did improve behaviour, there were still cases of ‘the failure to apprehend’. Only by means of an auditory message, there were no cases of ‘the failure to apprehend’. It may very well be that the additional sign was not selected or not sufficiently processed in all cases, whereas the auditory message with strong bottom-up features was always selected and fully processed.

A second option for reducing ‘the failure to apprehend’ is to decrease the top-down control. This can be done by avoiding that schemata are developed. As long
as a specific road-layout is always accompanied by specific rules or prototypical behaviour, schemata will develop. In order to avoid the development of schemata with strong top-down control, roads should be designed very differently than is currently being done. Much more variation would need to be used, for instance by varying the priority situation within one type of road, by applying different rules to the same type of road, and by using the same type of road lay-out for different types of roads and behaviour. Simply applying some variation in the road surroundings is not sufficient, as the present experiment has shown.

Even though both options offer the possibility to reduce the occurrence of ‘the failure to apprehend’, the consequences of applying either one are quite different. The consequence of strengthening the bottom-up features to indicate a unique, changed or deviant situation would be to design the situation in a way that is most different from the former or normal situation (different markings, traffic signs, pavement, etc). The consequence of decreasing the top-down control would be that a completely new way of designing roads would need to be applied. In order to guarantee sufficient variation, all road authorities would need to co-operate and agree upon where to implement what type of situation. By avoiding top-down control, driving would be brought back completely to a knowledge-based type of behaviour, requiring a lot of attentional resources. The efficiency of task performance based on activated schemata will thereby be lost. Also, expectations will also develop if a driver becomes familiar with a specific road. Therefore, the most plausible and efficient option would be to strengthen the bottom-up features of the information that points to the changed or deviant situation.