Do familiarity and expectations change perception?
Drivers' glances and response to changes

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9.1 Introduction

If a task is well practised, only a small part of the available attentional resources has to be directed to that task. This is also the case for the driving task in which novice drivers have to invest a lot of effort into driving, but after some experience less attention has to be paid to the task itself. The driving task is often described in terms of the three different performance levels distinguished by Rasmussen (1986). Although Rasmussen’s model is a general task performance model, applicable to different sorts of tasks, it fits the driving task well (a.o. Hoedemaeker, 1999; Kuge, Yamamura, Shimoyama & Liu, 1998; Hollnagel, Nåbo & Lau, 2003). The three levels of behaviour that Rasmussen distinguishes are knowledge-based, rule-based and skill-based. Knowledge-based behaviour is applied in novel situations or at new locations and it represents a more advanced level of reasoning. It is the most demanding level of the three. An example in the driving context is a novice driver who still has to think about how to shift gear or an experienced driver who is driving in a city centre he has never been before. Rule-based behaviour is characterised by the use of rules and procedures to select a course of action in a familiar situation. The rules can be a set of instructions, e.g. if..... than....., acquired by a person through experience or provided by another person. An example in the driving context is giving priority to other road users, where drivers have learned that in the presence of specific traffic signs and road markings they have to give priority. Skill-based behaviour represents a type of behaviour that requires very little attention and does not allow conscious control to perform or execute an action. An example is an experienced driver steering the car between the road markings. The driver does not have to think about his task and small deviations in lateral position automatically trigger a steering response. Skill-based behaviour is shown when a task is highly trained.

In case of skill-based behaviour, for instance in case of experienced drivers, there is strong top-down control, with expectations of the driver guiding the gaze direction. In static non-driving surroundings Meyers and Rhoades (1978) investigated the effect of expectancy on visual scan patterns and showed that searching for an object at an unexpected location was much slower than searching for an object at a likely location. This implies that participants look where they expect relevant information to be, resulting in an effective search if these expectations are correct. In abstract laboratory experiments, Martens (2004) and Martens and Slegers (2002) showed that people fail to notice unexpected information or show increased response times to unexpected information. In the driving context, several studies point to expectation as a crucial factor influencing reaction times (Green, 2000; Evans, 2004; Rumar, 1990). Theeuwes (1992c) investigated the balance between top-down (active) visual search (ruled by expectations) and data-driven search (ruled by the object properties) in the driving context. In the Theeuwes study (1992c), participants watched a video.
of an approach of an intersection while searching for a specific traffic sign that was either located at an expected or an unexpected location. The results showed that eye movements of experienced drivers were first directed at expected locations, leading to a delay in response time for targets at unexpected locations. The major advantage of using eye movements as a dependent variable is that they are fairly involuntary if participants are not instructed to search for specific items in the environment (Bhise & Rockwell, 1973) and they indicate the goals of the observer and possibly the area of interest (Liu, 1999; Stark & Ellis, 1981). This makes it a valuable tool for exploring the effect of expectation on visual information perception. Martens (2004) controlled expectations by designing an experiment in which expectations were built up inside the experiment. She showed in an abstract dynamic environment that people spend more time fixating targets they expect to be relevant. This fixation pattern results from sufficient practice with the task (skill-based behaviour). Unexpected information is either missed or responses are slow (even slower than when one does not have any expectations).

This means that especially in a road environment that is highly predictable (for instance because he or she has driven the road numerous times) the experienced driver will have strong expectations about what will happen, which will guide his visual scanning. The expectations are assumed to guide visual search, with strong top-down control.

This scanning according to expectations may appear to be a very efficient process. However, it may also bear risks. What if something unexpected happens that does not correspond to the expectations? It could be that the driver either notices this information since the unexpected is conspicuous, or would the driver miss this crucial information because it was not expected?

Most visual search experiments use predefined search targets, whereas in driving there are no specific predefined search targets. Few studies have examined visual search in a dynamic familiar environment without predefined search targets while controlling the expectations. The questions addressed in this study relate specifically to the driving task and to visual search without predefined targets while controlling expectations. The first hypothesis of the study is that drivers spend less time glancing at traffic signs if they are being exposed to the same route numerous times due to developed expectations. The second hypothesis is that after driving a road numerous times, drivers respond less adequately to a change in the traffic situation than people that did not encounter this road before.
9.2 Method

A virtual driving task in a low-cost driving simulator was used since this allowed changing the road environment rather easily compared to a field experiment. The virtual road consisted of an 11 km long combined rural (9 km) and urban (2 km) road. Participants were seated in front of a computer monitor and were asked to drive a simulated road, using a steering wheel, gas and braking pedal (see Figure 9.1).

![Figure 9.1](image)

**Figure 9.1** The task environment of the experiment, with a participant driving through the virtual environment, wearing the eye movement equipment.

The road contained two intersections, 3 curves and 10 traffic signs along the route (see Appendix 9.2 for a list of the traffic signs displayed). Trees, houses, opposing traffic and parked cars were included in the database to make it more realistic. While people were driving the route, their glance direction was recorded and recorded in the overall scene. This allowed the analysis of glance duration and glance frequency to the traffic signs.

9.2.1 Participants

Thirty-six participants took part in the experiment. Their ages varied from 21 to 46 and both male and female Dutch drivers were included. Participants had their driving licence for at least 3 years and drove over 5000 km/year.
9.2.2 Conditions
The thirty-six participants were randomly assigned to one of 3 conditions. The 3 conditions are also explained in Table 9.1.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Day 1</th>
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<th>Day 3</th>
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<td>drives</td>
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0 = practice drive
1 = driving road 1 [last intersection: having priority]
2 = driving road 2 [last intersection: having to yield]
3 = road recognition test while driving road 1
4 = road recognition test while driving road 2

In the experimental condition 12 participants drove the same road 24 times on 5 successive days. Monday through Thursday, 5 successive drives were made and on the fifth day, only four drives were made. Twenty-three drives were made with the participants having the right of way at both intersections. In drive 24 there was a change in priority situation at the second (and last) intersection. The changed situation was indicated by a different traffic sign (the Dutch priority ⬇️ was replaced by the Dutch yield sign ⬇️) and by priority road markings 🟢 on the road [see Figure 9.2].

The change was introduced in the 24th instead of the 25th drive since participants may have been expecting something on their last drive. After this 24th drive, participants had to perform the traffic sign recognition test. In this test, participants slowly drove the road one more time while the experimenter indicated the locations where traffic signs used to be present on the former 24 drives. Participants were asked to indicate what traffic sign had been present there by selecting the sign out of a list of 20 general Dutch traffic signs printed on a paper [see Appendix 9.1]. This test was included in order to test the level of expectations regarding the traffic signs shown along the route and to test whether participants could explicitly report the changed
sign. In a field and a laboratory experiment, MacDonald and Hoffman (1991) found that the most dominant influence on correctly reporting a road sign was the probability of drivers having to make an overt response related to the sign information, or the so called action potential. The action potential for the changed sign was clearly high. Although the normal recognition rate for passed signs is low (e.g. Shinar & Drory, 1983; Johansson & Rumar, 1966; Johansson & Backlund, 1970; Milosevis & Gajic, 1986) the traffic sign recognition test was expected to be sensitive since the experimental condition drove the road 24 times before performing the test.

In the first control condition 12 participants did not make any experimental drives, but just performed the traffic sign recognition test. The condition allowed us to test how predictable the traffic signs were even if people had not previously been exposed to the road environment.
In the second control condition 12 participants drove the road only once in order to record glances and driving speed of people that did not yet have any expectations based on prior experience. In this condition the last intersection was an intersection where they had to give the right-of-way (similar to drive 24 of the experimental condition). After this drive people also performed the traffic sign recognition test.

All participants reported to have good visual acuity and did not wear glasses or lenses during normal driving. They were paid for their participation.

9.2.3 Apparatus
A pupil/cornea reflection eye tracking system (ISCAN) was used to measure the glance direction of the participant. This was done by illuminating the left eye with an infrared source. A camera obtained a clear image of the eye by using an infrared pass filter to identify the dark image area of the pupil. Another camera mounted slightly below the left eye recorded the participant’s field of view. The eye’s pupil and corneal reflection positions were calculated with a sample frequency of 120 Hz. The camera that recorded the participant’s field of view was connected with a Panasonic VCR. The camera image with the super-imposed glances was recorded on VHS tapes for later analysis. The cameras and the infrared source were built into a specially designed cap (also see Figure 9.1). During the experiment participants could move their heads like they would normally do while driving.

The computer used for running the experiment was a dual Pentium 3 processor running at 866 MHz. This computer was also used for storing the data obtained during the experiment. The images were generated on an Evans and Sutherland SimFusion OpenSim 4000 and displayed on a 21” SVGA Monitor. The monitor’s resolution was 1280x1024 with high color palette (32 Bits) and a refresh rate of 60 Hz. A Logitech force feedback steering wheel and pedals were used as input devices. There was one braking pedal and one gas pedal (automatic gear). The speed of the car was shown on the lower part of the monitor for the participant and was saved to the computer’s hard disk. Participants were seated about 1m in front of the screen.

9.2.4 Task
The task of participants was to drive as they normally would on this type of road in real life. Participants in the experimental condition (24 drives over 5 days) were asked to pretend that this was their daily drive home. The official speed limit was 80 km/h with a speed limit of 50 km/h in the urban area (2 km of length). No mirrors were present, but this did not cause a limitation in driving since participants did not make any turns or did not overtake. Objects alongside the road were trees, different
types of houses, parked cars and traffic signs. While driving on the road participants encountered opposing traffic without any lead vehicles.

9.2.5 Procedure
Before the actual experiment started, participants received a written and a verbal instruction that explained their task and the procedure. After this participants were seated in front of the computer monitor (one participant at a time) and the controls (steering wheel, gas and braking pedal, simulating an automatic gearbox) were demonstrated. The eye movement equipment was calibrated by the experimenter with the participants’ heads on a chin rest. After the system had been calibrated participants were allowed to freely move their heads and made a practice drive on an empty road during 2 minutes to get used to the controls.

After every drive participants received a 30-second break. The last task for all participants was the traffic sign recognition task.

9.2.6 Statistical analysis
The calibration of the eye movement equipment before the start of the experiment allowed the calculation of the actual glance direction within a scene. Video images, showing the dynamic road scene, were recorded via the camera attached to the baseball cap and a cross, superimposed in the scene, indicated the glance direction. In this study, the term ‘glance’ indicates what someone gazes at, irrespective of whether this is fixated, fixated interrupted with saccades while gazing at the same object or whether the gaze is following a moving object. The analysis of these glance data was done by slow-playing the video with a reduction factor of 5 (5 times slower than normal playing speed). Every time the cross (glance) was within a range of 0.5 cm around a traffic sign within the area between 250 and 0 meter in front of the traffic sign (at this distance the traffic signs was clearly visible and readable) this was recorded to be a glance. The acquisition of glances was done manually. Other experiments (see Chapter 10) were already performed in real life traffic without the possibility to automatically acquire these data (due to the lack of control over the environment it had to be done from video). In order to compare results between this lab task and the real life experiments, the data acquisition was also done manually. For the assessment of glance duration, 10 traffic signs were selected and are listed in Appendix 9.2.

An analysis of variance (ANOVA) was used to analyse the total glance duration (which was a summation of the glance duration for all glances) per traffic sign and the mean driving speed per selected road section (the selected road sections are listed in Appendix 9.3). Fisher (1992) claimed that the true measure of sign
effectiveness is not sign recall, recognition or naming per se but rather the extent to which, in operational terms, sign content affects drivers’ preparedness for action and subsequent responsiveness to events. Also, Håkkinen (1965), Scremec (1973) and Summala and Hietamäki (1984) assessed the effect of traffic signs on driver behaviour by measuring vehicle speed changes at predetermined locations close to the road sign. Since the results of glance frequency were similar to the results of total glance duration these results will not be discussed separately.

In order to analyse whether the duration of glances at traffic signs changed with exposure, only data from the experimental condition were analysed (this was the only group with numerous exposure). Since on the last day participants only drove 4 drives instead of 5 (a change in the very last drive might be too obvious, so the drive before that was chosen to be changed) no straightforward analysis with the factors Day (5 levels) and Drive (5 levels) could be performed. Therefore, data with 10 Traffic Signs, 4 Days and 5 Drives, or with 10 Traffic Signs, 5 Days and 4 Drives will be taken together in the analyses. Days and Drives were maintained as separate factors (instead of 24 drives) since it was speculated that the first drive on the next day would again lead to somewhat longer glances than the last drive on the day before. The probability of a Type I error was maintained at 0.05 for all subsequent analyses.

9.3 Results

9.3.1 Glance duration

Effect of familiarity

In order to analyse the effect of familiarity, glance duration was analysed for the first 4 Days and 5 Drives. A main effect was found for Day \[F(3, 33) = 5.61, p < 0.01\] indicating a decrease in glance duration at traffic signs with increasing number of days. The interaction between Day and Drive \[F(12, 132) = 2.50, p < 0.01\] showed that the largest decrease per drive was found on Day 1. This interaction is shown in Figure 9.3.

The interaction between Day and Traffic Sign \[F(27, 297) = 1.73, p < 0.05\] is shown in Figure 9.4, showing that the decrease in glance duration over days may differ from sign to sign.

The results also hold if 4 Drives and 5 Days are included in the analysis. There was no initial difference in traffic sign glance duration between the second control condition and the first drive of the experimental condition \[F(1,22) = 0.12, p<0.73\].
Figure 9.3 Mean glance duration as a function of day of testing [4] and drive number within each day [5].

Note that traffic sign 10 was different between these conditions, indicating ‘Yield’ in the second control condition and indicating ‘Priority’ in the experimental condition. When comparing glance duration on the last drive of the experimental condition (with the changed traffic sign but after numerous exposure to the road) with glance duration on the first drive of the second control condition (the same traffic sign but here it was the first time people drove the road), a main effect of Condition \( F(1,22) = 25.75, p<0.01 \) showed that the experimental condition had significantly shorter traffic sign glances than the second control condition (0.72s compared to 1.32s). This indicates that familiarity leads to shorter glances at traffic signs (not only within participants as was shown within one group but also between participants).
Effect of change in priority situation

In the last drive of the experimental condition, the priority situation was changed. This included a change in traffic sign 10 and the presence of priority road markings. In order to assess possible effects on glance duration, glance duration for traffic sign 10 was compared to glance duration for traffic sign 1 (being the same traffic sign on 23 drives but being different on drive 24 (drive 4 day 5). One may assume that if participants noticed the change in traffic sign the glance would be longer. Literature has shown that first pass glance durations are longer for semantically informative (i.e. inconsistent) objects (Loftus & Mackworth, 1978) and that first pass glance duration is correlated with the rated likelihood of that object in the scene, with longer glances at objects that were less likely to be found in a particular scene (Friedman, 1979).

Figure 9.4 Mean glance duration per traffic sign as a function of day of testing [4].

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Henderson, Weeks and Hollingworth (1999) found that total fixation duration was longer for semantically informative than for uninformative objects and in reading it is widely reported that unfamiliar words require longer fixation durations than common words (Rayner and Pollatsek, 1989). The explanation for this is that an unfamiliar word requires more processing and within certain limitations, the measure of fixation duration is considered to reflect object identification time (Henderson, Pollatsek & Rayner, 1987; Underwood & Everatt, 1992).

A t-test for dependent samples did not show a significant difference between glance duration in Drive 3 (Day 5) and Drive 4 (Day 5) for the changed traffic sign \( t(11) = 0.25, p<0.81 \). There was also no significant difference between the glance

![Figure 9.5](image_url)  

**Figure 9.5** Mean glance duration for traffic sign 1 and traffic sign 10 as a function of drive number within the last two days (day 4 and 5). Traffic sign 1 was the same as traffic sign 10, with the only difference that traffic sign 10 changed on day 5 on drive 4. The bars indicate the standard error.
duration in Drive 3 (Day 5) and Drive 4 (Day 5) for traffic sign 1 \( t_{11} = 0.24, p < 0.81 \), being the same traffic sign as traffic sign 10 during 23 drives. In drive 24, traffic sign 1 and traffic sign 10 were different since traffic sign 10 changed into a yield sign. Figure 9.5 shows the glance duration for those two signs on the last 2 days. The figure shows that even though the traffic sign changed people did not spend more time glancing at that sign.

As an illustration, glance duration for the 10 traffic signs in drive 1 for the second control condition, in drive 1 for the experimental condition and in drive 24 for the experimental condition are presented in Figure 9.6.

![Figure 9.6](image)

**Figure 9.6** Mean glance duration at traffic signs for the first drive of the experimental condition, the first drive of the second control condition and the 24th drive of the experimental condition. Note that traffic sign 10 is different between ‘experimental condition drive 1’ (participants have priority) and ‘2nd control condition drive 1’ and ‘experimental condition drive 24’ (participants have to give priority).
Twenty-five percent of the participants in the experimental condition (3 out of 12) did not glance at traffic sign 10 whereas this was 8% (1 out of 12) for the 2nd control condition. Note however that even if participants did not glance at the sign, they still might have seen the priority road markings. It seems plausible that the shorter glances for the experimental condition, found in general in drive 24, also led to the increased occurrence of ‘the failure to apprehend’. Compared to drive 1 in the experimental condition, the curve follows that same pattern in drive 24 as in drive 1. However, in drive 24, traffic sign 10 was changed. In the 2nd experimental condition (drive 1), there are relatively long glances at traffic sign 10.

### 9.3.2 Driving speed

**Effect of familiarity**

Besides glance duration, driving speed was also analysed over different drives and days. For driving speed, 7 different locations on the virtual road were selected.

![Image](image_url)

**Figure 9.7** Mean driving speed over all locations as a function of Day (4) and Drive number within each day (5).
beforehand. These locations were interesting for assessing effects of familiarity and responses to changes, e.g. just before and just after the intersection that changed, just before and just after the intersection that did not change, and at a control location outside the built up area. The 7 locations are listed in Appendix 9.3. An increase in driving speed was found over days \[ F(3, 33) = 10.30, p<0.01 \] and over drives \[ F(4, 44) = 3.94, p<0.01 \]. The interaction between Day and Drive \[ F(12,132) = 3.50, p<0.01 \] showed the largest increase per drive for Day 1 (see Figure 9.7).

**Effect of change in priority situation**
To assess the effect of the change in priority situation in driving speed, two types of analysis were performed. First, the mean driving speeds between the first drive of the second control condition and the last drive of the experimental condition were compared. The road layout for these two drives is exactly the same, but for the experimental condition, the last intersection was different (no priority) than all prior drives.

![Figure 9.8](image)

**Figure 9.8** Mean driving speed on the 7 locations for drive 1 of the second control condition and drive 24 of the experimental condition. Note that participants of both groups encountered the same road environment, but on location 6, the experimental condition had encountered a priority intersection on the 23 prior drives. The bars indicate standard error.
drives (having priority). Since there was a general increase in driving speed over the drives in the experimental condition, it is not expected that the driving speeds between these two conditions are comparable per se. However, if the shape of the curve of driving speed on the 7 locations is similar for the two conditions with the exception of location 6, this may indicate that this difference is caused by the lack of perception of the changed situation (even though the intersections are the same, the participants do not respond the same). Also, a comparison of driving speeds on location 1 and 6 is made since here the traffic sign on location 1 indicates the same situation as was shown in the 23 prior drives on location 6. The data in Figure 9.8 show the driving speeds for the 7 locations.

What we can see is that in the second control condition, driving speeds for location 6 are lower than they are for location 1. This can be explained by the difference in priority situation (location 1 having priority and location 6 having to yield). This difference can not be found for the experimental condition (drive 24) with driving

![Figure 9.9](image-url)  
**Figure 9.9** Mean driving speed on location 1 and location 6 as a function of day of testing and drive number within each day. Note that location 1 and 6 were the same, except for drive 4 on day 5. Here the intersection changed from having priority to having to yield. The bars indicate standard error.
speeds on location 6 being comparable to the driving speeds on location 1. The absence of a decrease in driving speed in the experimental condition is therefore interpreted as a lack of response to the change in priority situation.

Second, the driving speed over the last 2 days for location 1 was compared with that for location 6. If there is an increase in driving speed on location 1 that continues to be present in drive 4 on day 5, and this increase is absent for location 6 in drive 4 on day 5, this indicates that there was at least some response to the changed traffic situation (being the absence of an increase in driving speed). A Fisher LSD post-hoc test showed that for location 1, there was no significant difference in speed between drives 3 and 4 on day 5 ($p < 0.32$). This is also not the case for location 6 ($p < 0.45$), which is shown in Figure 9.9.

The absence of a difference in driving speed may again be interpreted as the absence of a response to the changed priority situation. Just after crossing the intersection, the experiment stopped and participants were asked if they noticed anything specific in this last drive. Ten out of the 12 participants claimed that they did not see anything remarkable. One participant said that she noticed something had changed when approaching the intersection (even though she could not specifically indicate what had changed). Another participant spontaneously reported a change when crossing the intersection at a high speed (therefore not showing an adequate response). He claimed that it was mean that we changed something since this was not previously indicated (apparently he had not seen the sign and just responded to crossing the road markings).

9.3.3 Traffic sign recognition test
In order to analyse whether participants actually had expectations in the different conditions, a traffic sign recognition test was performed. At the end of the experiment (at specific locations), participants had to select a traffic sign from a list of 20 traffic signs (see Appendix 9.1) of which they thought it had been present there during the previous drives (for the second control condition and the experimental condition) or that they considered likely there (for the first control condition that was exposed to the road for the first time). While participants slowly drove the road, the experimenter indicated these locations (identified by poles without a traffic sign) and participants had to select the traffic sign they considered to be the correct one at that specific location. The number of errors on the traffic sign recognition test was compared between the three conditions (the experimental condition and the two control conditions). The experimental condition had completed 24 drives in the same environment (with in the last drive a different traffic sign at the last intersection), while the first control condition had not been exposed to the road before and the second control condition only once. The number of correct responses was compared
using a Kruskal-Wallis test. There was a significant difference between the three conditions \( \chi^2(2, 36) = 28.99, p < 0.01 \) The experimental condition scored better (5% mistakes) than the second control condition (24% mistakes) and both conditions scored better than the first control condition (50% mistakes). This means that exposure or familiarity indeed increases the expectations that subjects have about the content of traffic signs at certain locations (including the one at the last intersection). After 1 drive, participants scored better than guessing, but the expectations are even higher after being exposed to the same road numerous times. When focusing on traffic sign 10 (the sign that changed for the experimental condition in the last drive on day 5), we see that for the experimental condition, 11 out of 12 participants said that the △ sign was shown there, whereas on the second control condition, 11 out of 12 participants said that the ▼ sign was shown. This suggests that expectations were controlling participants’ perception.

9.4 Discussion

The present results are clear: When people drive a road, they develop expectations regarding the traffic signs. The traffic sign recognition test resulted in better performance for those who drove the road several times compared to people who drove the road only once. However, when having to report the last traffic sign that was changed in the last drive, people report the traffic sign that had been present there on previous drives, and not the one that had actually been presented to them in the last drive.

In addition the results show that the more often people drive a specific road the less time they spend glancing at traffic signs. This is in line with the results of Martens and Fox [2007] who found that under real driving conditions, drivers glance duration for objects along the road decreases if they drive a road numerous times. This effect is strongest on the first day. Apparently familiarity with the road increases rapidly on the first day and only slightly more on successive days. Presumably, the driver workload also decreases with increasing familiarity with the road, with drivers spending less time attending information they already know. This leaves more time for attending other items. Furthermore the expectations people developed during the course of the experiment were reflected the increase in average speed on various locations.

Finally our prediction that people that encounter one type of traffic situation several times will respond less adequately to a changed situation than participants that encounter this situation for the first time could not be rejected. Driving speeds for the yield situation were lower (and therefore more adequate) for people who drove the road for the first time compared to people who had driven the road several
times. Only 2 out of the 12 participants showed any response to the change, but only after crossing the priority road markings (shark teeth, see Figure 9.2) and not as a response to the changed traffic sign or in anticipation to the shark teeth. Glances at the changed traffic sign were as short as the glances at unchanged information suggesting that even though road users glanced at the sign they did not process it sufficiently to respond to it appropriately.

These results support the idea that with stronger expectations, less active information processing takes place (glance duration decreases, even if things change). When unexpected changes are introduced, the new information is not sufficiently processed thereby resulting in less adequate or even absent responses. Although participants did glance at the changed traffic sign [as they did with all other traffic signs that were familiar] they did not respond to it accordingly. In this case, driver perception seems to be the direct result of driver expectation with corresponding behaviour.

9.5 General discussion and practical implications

When reading the literature, one could assume that the greater the significance of the information for the driver, the more or the longer the glances it will receive. Several studies show that objects of central significance are fixated more than incidental objects and that hazardous objects are fixated more than the equivalent object in a non-hazardous situation (e.g. Hillstrom & Yantis, 1994; Loftus et al., 1987; Chapman & Underwood, 1998; Underwood, Chapman, Berger & Crundall, 2003). Underwood (1974) even states that with developing [driving] skill, it gets easier to divide attention without any impairment in processing the information relevant for the primary task [in this case driving]. This is in correspondence with later findings (Underwood et al., 2003) that experienced drivers were better in recalling information about objects that were incidental to the main sequence of events without worse performance on task-relevant items. In case of our experiment, this would mean that participants would have more resources and time available for detecting new objects (such as the shark teeth that were introduced) if participants have shorter glances at the familiar signs. Groff and Chaparro (2003) hypothesise that changes to task relevant items are detected faster than changes to non-relevant items and that the ability to detect changes should increase with the viewers task experience, but only to the extent that the type of change is meaningful to both the object and the task. They found that responses to driving task relevant items (a.o. traffic signs) were faster than to changes not relevant for the driving task. Furthermore, more driving experience led to a better detection of changes to traffic signs. Groff and Chaparro (2003) state that individuals use a schema along with their own experience to guide the allocation of attention to both the objects and features they consider most relevant to the task. They specifically state that individuals learn through repeated encounters which
information is most important and allocate their attention accordingly. Based on prior experience with a given task, an individual may employ specific search strategies in the absence of bottom-up saliency features to guide attention. However, again this does not explain the drawback of the system, referring to the current results of not adequately responding (or maybe not even noticing) changes.

Crundall, Chapman, Phelps and Underwood (2003) measured eye scanning patterns while watching driving videos with more and less experienced drivers. They found that with more experience, the fixation durations to items were shorter. This resulted in an increase in the sample rate, leaving more time to also fixate other locations. This increase in sample rate is assumed to illustrate a decrease in workload. Recarte and Nunes (2000) found that increasing workload resulted in less variability in the horizontal and vertical gaze positions, so in a reduced glance activity. Again, the literature mentioned here indicates that our participants would have had more time to detect the shark teeth.

The decrease in glance duration may be part of the problem. De Graef, Christiaens and d’Ydewalle (1990) and Henderson, Weeks and Hollingworth (1999) claim that the observer’s eyes remain on each region until processing is completed. Glance duration under those conditions will depend both upon the complexity of stimulus features and upon the observer’s task. However, in case of strong expectations, it may be that there is a top-down control over glance duration instead of bottom-up control. In that case it may be that glance duration reflects the processing time that the observers expects to need. Rensink, O’Regan and Clark (1997) claim that the allocation of visual attention is driven by a task-related schema, leading to the conclusion that more experience with a task should result in a more detailed schema and a more efficient allocation of attention. For our task this means that more experience with the road resulted in more efficient allocation of attention, illustrated by drivers taking shorter glances at objects they are already familiar with. However, Rensink et al. also state this would result in improved change-detection ability for objects more relevant to the task. In our experiment, the change in priority situation was not detected by the participants. Apparently the top-down control was far stronger than the bottom-up features from the presented information. Information that is highly relevant for the driving task is most likely not being perceived or at least not responded to if it does not fit the expectations.

There are some differences between the type of experiments cited and the current experiment. For example, in the Underwood et al. study, all hazardous situations had abrupt onsets as opposed to the current experiment with a gradual onset (the recognition of some object initially in the distance and as the participant gets nearer...
it can be recognised as something that presents a danger). Also, in the Underwood et al. study, participants were told that they would need to answer questions, creating a specific mind-set probably with a more active visual information intake. This is definitely also the case for the Groff and Chaparro study, where subjects were even informed about upcoming changes, leading to active visual information processing. If people look but fail to sufficiently process changes in the traffic situation in case they are not warned for possible changes, this has serious consequences if adequate adaptation of behaviour to the changed situation remains to be absent.

Van Elslande and Faucher-Alberton (1997) refer to accident data that show that road users who are familiar with a site tend to perform their normal sequence of actions despite new or contradictory information. This clearly points to the strong top-down control, with little room for bottom-up features. The look-but-fail-to-see accidents (e.g. see Staughton & Storie, 1977; Herslund, 1993, 2001; Jørgensen & Jørgensen, 1994) are also assumed to be related to expectations. In look-but-fail-to-see accidents, drivers claim that they did not see the other vehicle until they were so close that a collision was unavoidable. In many cases, the driver looked in the appropriate direction (top-down control) but failed to give priority to the other vehicle, most likely since they did not expect any vehicle to be present (e.g. Rumar, 1990; Brown, 2005). Apparently, the presence of another road user did not have strong enough bottom-up features to actually result in a response. Brown (2005) even claims that these accidents are particularly likely when driving on very familiar roads, with drivers using stereotyped search patterns. Herslund and Jørgensen (2003) confirm that experienced drivers develop fixed routines for searching information.

The results of the current study have major implications for the real traffic environment where changes to local traffic situations can have a large safety impact if drivers do not notice this. In that sense, the effects in real life are expected to be at least as large for two reasons. One, the experimental set-up (where they know they are being watched) normally has participants pay attention to good performance, whereas this may not always be the case in real driving. Second, a simulated environment in an experimental set-up may be more likely to change than a real environment that never changed in the last 2 years that someone has driven that route.

The question that remains is what type of information would bring the driver to a state of active information processing, increasing the changes of appropriate responses? Would adding instead of just changing a road sign help? The next step in research would be to find out what type of information would be able to break though this passive information processing state. With timely warnings that something actually changed in the driving environment, an adequate action is likely to result.
Appendix 9.1

The traffic sign recognition test, using general Dutch signs (second sign in the first row indicates ‘Yield’, third sign in the third row means ‘End forbidden to overtake’).
Appendix 9.2
Traffic signs as used in the analyses of the experiment.

Traffic sign 1: Priority crossing
Traffic sign 2: Loose gravel
Traffic sign 3: No overtaking
Traffic sign 4: Curve to the left
Traffic sign 5: Curve to the right
Traffic sign 6: Curve to the right
Traffic sign 7: Maximum speed limit
Traffic sign 8: Children
Traffic sign 9: End speed limit
Traffic sign 10: Priority Crossing

Appendix 9.3
The selected road locations for analysing speed

1) 200 meters before the first intersection
2) 200 meters after the first intersection
3) 200 meters on a control location
4) 200 meters before the start of the urban area
5) 200 meters after the start of the urban area
6) 200 meters before the last intersection
7) 200 meters after the last intersection
Does road familiarity change glances?  
A comparison between watching a video and real driving

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