Discussion and conclusions
The phenomenon, central to this thesis is ‘the failure to apprehend’. The phenomenon describes the situation in which information is clearly visible in a scene, but the observer does not act upon the presented information even though the information is relevant for the task.

The thesis started by discussing literature that is related to this phenomenon. In Change Blindness and Inattentional Blindness studies, numerous examples are available of observers not acting upon apparently clearly visible information. This may be the result of either a failure to select the information or a failure to respond. If information is not selected (for instance someone does not glance at the information), it cannot generate a response. However, even in case of selection, it is possible that the selected information is not sufficiently processed to generate a response.

After assessing the type of situations in which ‘the failure to apprehend’ occurs [e.g. high task load or in case of expectations], an elaborated task performance model was introduced. This elaborated task model was mainly introduced as a framework to explain ‘the failure to apprehend’ in driving and to link the concept of expectations to Rasmussen’s task performance model. Rasmussen’s model is elaborated by introducing the main factors of top-down and bottom-up control. Also, factors that are influenced by the various task levels, such as attention, arousal, task load and required time are included.

This thesis focuses on the mid level of the elaborated task performance model. This mid level is called rule-based behaviour, with a link to schemata and expectations. In the remaining chapter, we discuss the results of the studies in the light of this model and discuss what can be done to avoid ‘the failure to apprehend’ at this task level.

13.1 Top-down versus bottom-up in normal conditions

One of the assumptions of the model is that knowledge-based tasks (or new tasks) are characterised by bottom-up processing and lack of top-down control. Even though this thesis did not focus on this task level, the lab tasks in this thesis were initially performed at a knowledge-based performance level. None of the participants had any experience with this task. However, by allowing half of the participants to develop expectations about the occurrence of targets, we manipulated the level at which the task presumably was performed. We expected that by training half of the participants with this task, their performance would be executed at a rule-based or schemata level.

With knowledge-based performance, glance duration to all stimuli was equal. However, expectations (schemata-based performance) changed the way that people scanned their environment. Expectations introduced top-down control, illustrated
by a change in glances to the presented stimuli. In case of expectations, people spend more time glancing at information they expect to be relevant for the task. Even though the bottom-up features at both task performance levels were exactly the same, it was top-down control that determined how long people glanced at specific items.

But how does this relate to real world tasks such as driving? Since we used experienced car drivers as participants, and people did not have to find their route, people did not perform all aspects of the task at a knowledge-based level. However, we could still manipulate expectations, as we did in the lab tasks, by having road users drive the same road several times. This manipulation did affect expectations as shown by the observation that after several drives, road users had stronger expectations about what information was presented at what location. That this also introduced top-down control was shown by the observation that also in this task, expectations changed drivers' scanning strategy. With increased familiarity with the road, drivers spent less time glancing at traffic signs. Again, the bottom-up features remained the same (since the traffic signs are the same from drive to drive), but glance duration decreased, showing the effect of top-down control.

Together the results of the lab and the driving tasks show that with stronger expectations, less active information processing takes place. Glance duration to irrelevant information decreases (lab tests), but also in case of relevant information (e.g. traffic signs in the driving tasks), familiarity with a road decreases glance duration. This shows the difference between bottom-up and top-down control.

13.2 Top-down versus bottom-up in case of incorrect expectations

The elaborated task performance model assumes that in case of rule-based performance, top-down control is so strong that there is not much room for bottom-up features. This strong top-down control may lead to 'the failure to apprehend'.

In order to study the strength of expectations and top-down control, we introduced a change in the tasks. In those cases in which the presented information was not similar to what was previously presented, or so to say did not correspond with the expectations, 'the failure to apprehend' was found. Apparently the top-down control was indeed so strong that the bottom-up features were not strong enough to overcome this. Given the model that we outlined, this was exactly what was expected. Even though in many cases, the changed information was selected, with people actually looking at the information, the response often corresponded to the old situation rather than to the newly presented information. In many cases, there was no response at all and even if there was a response, response times were long or
the response was not strong enough. In case of the driving task, there were instances in which the new sign indeed seemed to affect driving speed, but only to a rather small extent. An interesting phenomenon in this is that ‘the failure to apprehend’ also occurred in situations without familiarity with the road. In these cases drivers drove the road for the first time. This shows that top-down control is not only linked to familiarity with the road, but also to the design of the road in itself. Apparently, experience with various roads in the past has also generated schemata of what to expect in similar road environments. These schemata have a similarly strong top-down component as being familiar with one specific type of road.

In a Change Blindness task, one cannot really speak about incorrect expectations in case of a change. People were instructed that there would be a change, which probably kept the arousal and attention level at a relatively high level. The main result was that people who noticed the change had longer glances at the traffic sign in all ‘drives’ (even in drives without any change) than people who did not notice the change. This shows the close link between glance duration and level of processing. Longer glances allow deeper processing and therefore resulted in less occurrence of ‘the failure to apprehend’. In case of the actual change, glance duration was even longer for those who noticed.

Together these results show that when a change or unexpected information is presented, the new information is often not selected or selected but insufficiently processed. In these cases, responses are absent or inadequate (e.g. slow response). ‘The failure to apprehend’ in driving is also present without familiarity with the specific road. This shows that expectations do not always have to be the result of experience or familiarity with that exact road. A road may also elicit expectations by the way it is designed, with strong top-down control even if the road has not been driven before. The longer the glance at the changed information, the higher the chance of a response.

13.3 Top-down versus bottom-up: the balance

The elaborated task model describes ‘the failure to apprehend’ at all task levels as the result of the inbalance between top-down and bottom-up selection and processing. In case of expectations or schemata – i.e., at the rule-based level –, the top-down influence is so strong that there is not much room for bottom-up features. At this level, ‘the failure to apprehend’ is the result of this too strong top-down control in case of incorrect expectations.

In order to avoid ‘the failure to apprehend’ under those circumstances, there are three possible approaches.
The first approach is to only design roads that perfectly match driver expectations and fit the schemata. An attempt to do this has been the Dutch road design concept of Sustainable Safety. The concept of Sustainable Safety was introduced in order to decrease the number of injuries and fatalities in road traffic in the Netherlands. The idea is that all roads should be designed in such a way that road users know what type of behaviour is expected of them (in terms of speed, having priority, overtaking etc.) and what type of other users they will encounter (cars, cyclists, mopeds and slow agricultural vehicles etc.) just by looking at the road. Sustainable Safety acknowledges that this self-expaining character of roads can only be realised if there is a limited number of road categories and if they are designed according to specific rules. This means that within one road category, design characteristics have to be similar and between road categories they need to be different. Although in itself, the idea is excellent (since it allows road users to develop schemata that are linked to specific road categories) the problem is its implementation. The implementation of Sustainable Safety in the Netherlands is decentralised. This means that different local road authorities are responsible for implementing Sustainable Safety in their own region. Since the implementation also has to fit the local budget, there still may be quite some variation within one road category. Also, several examples are shown in which road authorities do not implement the right design characteristics for the road category. For instance, there are already examples in the Netherlands in which a characteristic that belongs to the design characteristics of road category A is used in case of road category B. This real-life example shows that it is not so easy to perfectly harmonise road categories throughout an entire country, let alone harmonise them over country borders.

A second approach would be the opposite: Avoiding any top-down control by preventing any driver expectations, thereby avoiding schemata. The problem with this approach is twofold. On the one hand, it requires a rather complicated co-ordination between road authorities. This co-ordination is even more difficult than the co-ordination required for implementing Sustainable Safety. In order to avoid the development of schemata, there should be quite large differences and variation between roads of the same category. Only by making the design within one type of road very different from one road to the other, expectations and schemata will not develop. This is a very complicated design process and the risk of developing schemata and expectations is still there if drivers get familiar with a specific road. The second problem is that this would bring the driving task back to the task level of a novice driver, that is, to the knowledge-based or new task level. This poses a rather high task load and there are many visual elements competing for selection. This may also result in ‘the failure to apprehend’, even though here it is caused by too strong bottom-up control. The advantage of top-down control is completely lost, with an increase in workload. Since novice drivers are known to have a high accident
risk, probably due to this high workload, the fact that many more visual elements compete for selection, and that they are not able to handle complex situations since they have to rely on bottom-up processing, one may question if this approach really improves safety.

The third approach is to increase the strength of the bottom-up features of new or unexpected information in order to get more balance between top-down and bottom-up. By strengthening bottom-up features, a balance may be found without losing the advantages of top-down control. As previously discussed, a first requirement for a response is the selection of the relevant information. Although it is possible to attract the gaze by means of highly conspicuous items such as a flashing light, this is not the proper way to proceed. We want to avoid creating a road environment with many flashing lights to attract attention, since this will decrease the attentional value in general if they are used very often. Also, they imminently warn all drivers whereas the warning is not necessarily relevant for all drivers. Moreover, they may attract attention away from other imminent items such as the activation of braking lights of the car in front or a child that crosses the street. Therefore, it seems more appropriate to suggest another measure. What we can learn from the experiments is that in case of an auditory warning, there were no cases of 'the failure to apprehend' in driving. The most likely assumption is that the auditory warning changed drivers' scanning behaviour to a more active one. This most probably resulted in more drivers selecting the new traffic sign and taking longer glances than without this message, bringing task performance more towards a knowledge-based level of a novice driver. However, we have to keep in mind that in knowledge-based or new tasks, there is much competition between presented elements in the environment. A disadvantage of a warning – bringing the task performance to a bottom-up level of processing – could therefore be that a driver selects as many items from the visual surroundings as possible, whereas the purpose of the warning is that the driver selects the specific critical item. Therefore, an auditory warning is only effective if it leads to the selection of the right information, and not just of any information. In order to make sure that the relevant information is selected if the auditory message is provided, there should not be other items competing for selection. It is therefore important to limit the amount of other signs and signals. This also accounts for other conspicuous visual elements in the vicinity of the changed or deviant situation. Limiting the amount of visual information increases the chance of selecting the right items. But how will this auditory message be implemented? In a future scenario, a driver always carries a personal driver card. This card contains all sorts of personalised information such as the preferred position of the mirrors and the chair, the favorite radio station and information about where the road user has been driving and what road situations have been changed since the last time he or she drove there. This personal card will be inserted into the car at each drive and will activate a system that warns the driver for a changed traffic situation or for black spots where
accidents often occur. The big advantage of these systems is that they are personal, so they will only be activated if drivers previously encountered a different situation. This has advantages to flashing lights that will also warn drivers that drive the route for the first time.

Now, if the item is selected, a second requirement for a response is sufficiently deep processing. This can be done by making the difference with the former or the expected situation as large as possible. The larger the difference between the changed situation and the original one, the higher the chance of a response. The difference can be the location of a sign (not replacing the old sign with a new sign but also changing its location), the form of the sign (triangle, square, round), the colour of the sign, the size of the sign (enlarging it), the type of sign (warning sign, information sign, etc) and most importantly the pictogram or text shown on the sign. Also, additional measures have to be taken to increase the strength of bottom-up control, like road markings (timely in order to allow the information to be processed) and additional traffic signs. This does not only hold for road situations that are changed, but also holds for situations in which there is an exception compared to similar roads. An example in this case may be that there is a side road that has priority whereas other similar side roads do not have priority. The more different the road design is compared to previous designs, the stronger the bottom-up features and the higher the chance of the proper response. The effectivity of this approach is directly derived from this thesis. Very subtle implicit additional cues do not have any effects, bottom-up features really have to be strong.

The idea that information with strong bottom-up features that is not in line with expectations will lead to selection and deep processing is exactly what is used to attract attention to advertisements along the road. The purpose of the advertisement agency is to attract as many and as long glances as possible. The purpose of the road authorities is that advertisements attract as little and as short glances as possible. Therefore, the question is what type of advertisements are too distracting for the driving task and what type of advertisement can still be allowed by the road authorities. Based on this thesis, we claim that only for advertisements that present a very limited number of items (e.g. one short word together with one slogan or one pictogram or logo) and present items that are well-known (for instance a well-known logo or a non-ambiguous picture), glances will be sufficiently short to not adversely affect road safety. Advertisements that are very large, are dynamic, flash, present several items, have long text, are ambiguous or show logos or symbols or pictures that need more than some seconds to be fully processed need to be forbidden along the side of the road. This is also the case for information shown on advertisements that have a large subjective relevance, such as advertisements showing people in their underwear or shocking images like the results of road accidents. These advertisements should not be allowed along the side of the road.