Responding to relevant visual information is of crucial importance in almost any task. This thesis studies the mechanisms that underlie 'the failure to apprehend'; the phenomenon of not acting upon clearly visible and relevant information.

Chapter 1 through 6 describe the literature in the field and provide a theoretical framework for the thesis. Chapter 7 through 12 describe the experimental work that has been done. Chapter 13 ends this thesis with the discussion and conclusions.

Chapter 1 describes the 'failure to apprehend' in the context of Inattentional Blindness and Change Blindness. Inattentional Blindness refers to the phenomenon that people do not notice unattended objects or events, even though they may be relevant for their task. In case of Change Blindness, observers are not aware of a change that took place, even though the change is clearly visible.
In order to respond to information, it needs to be processed first. In order for information to enter the information processing cycle, it needs to be selected from all available information. 'The failure to apprehend' may be the result of information not being selected. **Chapter 2** describes this role of visual selection in the ability to respond to information. An important role in selection is played by attention. Attention is the mechanism that selects stimuli for further (higher-level) processing. Under normal conditions, with people performing real life tasks, selection takes place overtly by directing the eye to the visual information. The role of eye movements in information processing is explained, with a strong link between attention and glance direction in natural task performance.

Chapter 3 provides evidence that there may also be cases of 'the failure to apprehend' even though the appropriate information is selected. There may even be indications that the information was processed to some extent, without the information leading to a response. This may be the result of not sufficiently deep processing, with insufficient cues to lead to a response or a failure in memory. Therefore, explicit performance measures (e.g. asking whether people noticed the information) are not always the best performance measures. Implicit measures, such as glance duration, response times or the possibility to implicitly use this information for the task at hand should also be taken into account to get a better insight in the underlying mechanisms of 'the failure to apprehend'.
Situations in which 'the failure to apprehend' is most likely to occur are provided in **Chapter 4**. These situations are conditions in which people have strong expectations, show automated task performance, have a vigilance tasks type of character or induce a high workload.

Chapter 5 discusses the 'failure to apprehend' in the context of driving. To explain the underlying causes of 'the failure to apprehend' at each of the three task performance levels of Rasmussen, we propose an elaboration of his original model.

The elaborated model links automated task performance to skill-based behaviour, with a low level of arousal, attention, and task load. It requires little time to perform and the task is normally well-practised. The problem with this task level is that there is hardly any room for top-down control. Rule-based behaviour is linked to expectations and activated schemata, with an intermediate level of attention, arousal and workload. It requires more time to perform the task and it is less practised than tasks at the skill-based level. This level of performance is characterised by a strong top-down control, leaving little room for bottom-up features. The knowledge-based level is linked to new tasks, with a high level of attention, arousal and workload. Performing the task requires relatively much time and the task is hardly practised. Information processing takes place in a bottom-up manner, with almost no top-down control. Even though 'the failure to apprehend' may take place at any of these levels, the causes may occur at different levels. At the new task level, 'the failure to apprehend' is most likely the result of the failure to select the right information at the right time because of a limited processing capacity and no top-down control, resulting in competition between all displayed items. At the schemata level, 'the failure to apprehend' is the result of too strong top-down control; top-down control that is so strong that it does not allow the bottom-up input of signals that do not fit the top-down schemata. In case of automated behaviour, 'the failure to apprehend' is also explained by the lack of top-down control; the presentation of an item automatically triggers the response, even if in this case it is not the correct response.

Chapter 6 addresses the focus of this thesis. It explains the difference between the driving task and some classic Change Blindness and Inattentional Blindness tasks. In most Change Blindness and Inattentional Blindness tasks, participants are instructed what to attend to or what to search for, whereas this is not the case in normal driving. Also, the information of interest is not always relevant for the observer, whereas this thesis focuses on task relevant items. A third difference with Change Blindness tasks is that they specifically focus on detecting the change, whether our main focus is on responding to information that is currently there (irrespective of whether it was different before). The main research questions of this thesis are: What is the effect of developing expectations on eye movement behaviour and the occurrence of 'the failure to apprehend', what type of information results in 'the failure to apprehend' and what type does not, and what type of information can help break through incorrect expectations, resulting in 'the failure to apprehend'? The main focus is the driving context.

Chapter 7 investigates the effects of expectations on eye glance duration and on 'the failure to apprehend' in two laboratory experiments. Glance duration and manual responses to predefined targets amongst distractors were measured in a dynamic and abstract environment shown on a computer monitor. Participants received a continuous flow of stimuli with either a predictable sequence of targets and distractors or with a random sequence. In the predictable sequence, participants were able to develop expectations about the order of targets and distractors. Under those conditions, glance duration for targets was longer than for distractors. In the random condition, participants were not able to develop expectations about the presentation of targets and distractors, which resulted in similar glance duration for targets and distractors. Responses to targets were much faster in the predictable than in the random condition. The problem with these expectations, that in normal cases decreased response times, was 'the failure to apprehend' in case of incorrect expectations. Information that did not meet the expectations was either missed (no response) or responses were extremely slow, substantially slower than in the random condition. These results clearly show the downside of having expectations and the strong impact of top-down control. The chapter concludes by stating that these results have major implications for all tasks that have strong top-down control over visual selection and information processing, like operator monitoring tasks or driving. In these types of task, the consequence of 'the failure to apprehend' and strongly delayed responses may be dramatic.

Chapter 8 assesses the effect of expectations on response time, response accuracy and glance duration, again in a lab type setting. In a dynamic and abstract computer simulated environment, participants responded to predefined targets amongst distractors that were again presented in a continuous flow. The character of the stimuli was different than that in the previous study decribed in Chapter 7. Infrequently, participants had to respond to targets that were not expected to appear at that moment or they had to refrain from responding when a target was not presented even though expected. Again we found that participants' glance duration to targets was longer than for distractors. Response times to unexpected targets were much longer than response times to expected ones. Many errors were made when unexpected information was presented, with most errors being made when a response needed to be inhibited. There was no difference in glance duration between participants with correct and those with incorrect responses in case of unexpected information. Interestingly, the presence of unexpected information did not change the glance strategy of observers. Again, these results show the strong negative impact that expectations and top-down control may have for real life tasks such as assembly line workers or air traffic controllers.

Chapter 9 investigates the effect of expectations on glance duration and responding to unexpected information in the driving context. Participants drove a low-cost simulator while their eye movements were recorded. In some conditions, participants got familiar with a particular road by driving this road several times during various days. The study showed that repeated exposure to the same road indeed increased familiarity with this road and it changed eye movement behaviour.

With repeated exposure participants spent less time glancing at traffic signs along the route while having a better recollection of the traffic signs along the route. When the road situation was changed (a priority road changed into a yield situation) without any specific instruction, drivers did glance at the sign indicating the new situation but did not process the information sufficiently to show an adequate response. Repeated exposure to the same road resulted in many inadequate responses to the change in priority, even though there was a new sign and there were priority road markings that were not present before. The current finding that incorrect expectations may cause drivers to miss important information even though they look at it is relevant to other monitoring tasks.

Chapter 10 assesses glance duration after multiple exposures to the same road in real driving conditions and when watching videos. Since it was already demonstrated that the duration of glances at traffic signs decreases in simulated environments, this study investigates whether this also holds in real driving and in a video condition. In the video condition, a video was taped during driving from the driver's point of view. While watching this video, participants had to pretend they were driving the car while simulating steering and braking. One of the main outcomes of the study was that the decrease in glance duration for traffic related objects with increased exposure that has been found in simulated environments was also found in real driving. A second important outcome is that this decrease has also been found in the video condition. This means that over all objects, the two methods lead to comparable results when investigating the duration of glances at objects. For glance frequency, people have slightly more glances at object when watching a video compared to real driving and the decrease with increased exposure is not as gradual as it is with glance duration.
The decrease in glance duration over days was quite comparable between watching a video and actual driving. However, there were also some differences in glance duration between the two conditions with respect to specific objects. This means that the video configuration is not useful for identifying objects that would receive longest and shortest glances under real driving conditions. Although there are objects that have long glances in the video condition that also have long glances in the real driving condition, there is no exclusive overlap. Therefore, great care is needed when using video instead of real driving to investigate glance durations and frequencies to traffic related objects. The video method is suitable for exploratory research, looking into glance duration at road objects and to assess the effect of multiple exposures or familiarity with the road environment on glance duration without being interested in exact glance duration in real life situations.

In **Chapter 11**, a driving simulator study is described that assesses the effects of familiarity with a road on 'the failure to apprehend'. The central question was whether familiarity with the road results in 'the failure to apprehend' and whether 'the failure to apprehend' mainly occurs if drivers drive the same road several times or whether it also occurs if the road environment partly varies from one drive to the next. 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. Participants were warned for this change in various ways, from just putting up the No-Entry sign to additional signs warning for a change via auditory in-vehicle messages. The driving simulator study showed that there was no difference in the occurrence of 'the failure to apprehend' between the same drives and drives that were varied. Even more so, 'the failure to apprehend' was not a consequence of driving the same or a similar road numerous times, but rather the result of expectations that the drivers already had on the first drive. This indicates that there are situations in which 'the failure to apprehend' is not the mere result of prior exposure to that particular road, but rather the result of the wrong expectations induced by the road design itself. Even on the first drive, one did not expect the No-Entry situation, leading to drivers entering this road. Adding information to point the driver to the changed situation does decrease 'the failure to apprehend'. Although fewer errors were made in case of an additional yellow sign indicating a change in the traffic situation, there were still cases of 'the failure to apprehend'. Only by means of an auditory in-vehicle message, there were no cases of 'the failure to apprehend'.

Chapter 12 used a Change Blindness task to assess 'the failure to apprehend' in a driving related context. The purpose of the experiment was to study how large the problem of Change Blindness actually is in case of task relevant changes. With task relevant changes we refer to changes related to the task people are performing. In this case, drivers were instructed to detect a change in a traffic related item, which in this case was a change to a traffic sign. Another purpose was to study how the type of change affects Change Blindness and to study the role of glance duration in Change Blindness. The study was performed by having car drivers watch video films, taped from the driver's point of view showing 6 drives around a block. Participants were instructed to pay close attention to traffic related issues and to imagine they were the driver of the car. They were also instructed that they had to look for a traffic related change. Glance duration to traffic signs was measured as well as Change Blindness (are participants able to explicitly detect the change). In drive 6, one of the traffic signs was changed into a different traffic sign. There were five different conditions, including one control condition without any change to the traffic sign. In the four experimental conditions, the original sign was replaced by a different official traffic sign. Implicit processing of the change was measured by studying glance duration and by having participants perform a traffic sign identification test after watching the video. Of those participants not looking at the traffic sign, no one was able to detect the change. Of those participants that did glance at the changed traffic sign, participants who detected the change had overall longer glances than the participants who did not detect the change. In case of the actual change, the glances for the Change Aware participants were even longer than in other drives. Even in case of task related changes, in this case traffic related changes, Change Blindness was still high. However, Change Blindness was lower if the image presented on the traffic sign was more deviant from the original one, when it did not fit the driving scene and when attention was raised by means of an auditory warning. Under those circumstances, all participants that glanced at the critical sign were Change Aware. However, even under those conditions, there were still people who did not glance at the critical traffic sign and were therefore Change Blind. There were no indications of implicit change detection for the Change Blind.

Chapter 13 relates the experimental results to the literature and to the elaborated task performance model. This thesis focuses on the rule-based or schemata task level, with strong top-down control. The 'failure to apprehend' at this task level is the result of a too strong top-down control, hardly leaving any room for bottom-up features. There are several approaches to avoid this. One approach would be to design roads that perfectly match the driver's expectations and fit the schemata. However, this does not seem a realistic option since the introduction of Sustainable Safety has already shown that it is not possible to implement roads that perfectly match throughout the country. Another approach would do the opposite, that is, to avoid any development of schemata or expectations by designing every road in a very different way. This approach does not seem plausible since this asks for an even stricter coordination throughout the entire country, since sufficient variation needs to be implemented from one road to the next. Also, road users would still develop expectations if they drive the same road various times. Another reason why this approach is not suitable is that it brings the driving task to the knowledge-based level of novice drivers, with an increase in task load on all roads. Novice drivers are known to have a relatively high involvement in accidents and do not have the advantages of top-down control that experienced drivers have.

A third approach would be to increase the bottom-up features in order to receive some balance with the strong top-down control. One basic measure would be to present an auditory in-vehicle warning. This most probably results in more drivers selecting the new information and taking longer glances than without this message. This would temporarily bring task performance more to the knowledge-based level of a novice driver, with the possible disadvantage of strong competition between all different visible objects. An auditory warning will only be effective if the amount of non-change related traffic signs and conspicuous visual elements in the vicinity of the changed or deviant situation is severely limited. Otherwise the disadvantage of knowledge-based performance, or competition between all items presented, may lead to other problems. In a future scenario, a driver always carries his or her personal driver card. This card holds 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 that is inserted into the car at every drive, activates a system that warns the driver for a changed traffic situation or for black spots where accidents often happen. The driver will then actively look for visual information, and if the item is then selected, it is important that the item contains sufficiently strong bottom-up features to allow deeper 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. This means that as many things as possible should be changed, for instance location of a sign, its form, colour, size, type of sign and most importantly the pictogram or text shown on the sign. Also, additional measures such as road markings and additional traffic signs need to be provided. The more deviant the road situation is compared to the old situation, the stronger the bottom-up features.