Car driving
The present thesis addresses the topic of ‘the failure to apprehend’. In the previous chapters we discussed potential underlying mechanisms for ‘the failure to apprehend’, such as a failure to select (Chapter 2) and a failure to respond (Chapter 3). In Chapter 4 we discussed four situations that are often associated with the occurrence of ‘the failure to apprehend’.

In addition, this thesis focuses on driving to demonstrate the effects of ‘the failure to apprehend’ in daily life. This chapter discusses ‘the failure to apprehend’ in the particular context of driving, using Rasmussen’s three stage task performance model (Rasmussen, 1986) as a basis. 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 the original model.

The driving task is often analysed 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 (e.g. Hoedemaeker, 1999; Kuge, Yamamura, Shimoyama & Liu, 1998; Hollnagel, Nåbo & Lau, 2003). The three levels of behaviour that Rasmussen distinguishes are the knowledge-based, rule-based and skill-based level.

1. 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. With knowledge-based behaviour, new knowledge has to be applied to the situation at every moment, so it is a very conscious way of handling information and responding to that information. Since it is very demanding, there is a risk of task overload.

2. 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. Rule-based behaviour applies to interpreting everyday situations and scenarios as well as applying traffic rules and regulations. Problems at the rule-based level may occur if people apply the wrong rule to the situation or misinterpret the situation and therefore select the rule that applies to another situation.
3. 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. Skill-based performance is highly related to automatic task performance. 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.

When applying this model to the driving task, it is not possible to take a subtask (steering, shifting gear, braking, etc.) and exclusively fit it to one single level. Where the subtask 'shifting gear' is at the knowledge-based level for a novice driver, it is skill-based for an experienced driver. Since the full description of skill-based, rule-based and knowledge-based behaviour applies to experienced drivers only, we focus on experienced drivers.

As discussed in Chapter 4, the four situations in which ‘the failure to apprehend’ is most likely to occur are; situations in which people have strong expectations, situations in which people show automatic task performance, situations that induce vigilance, and situations that have a high task load. We will now illustrate these situations on the basis of Rasmussen’s model.

5.1 Skill-based and automatic task performance

Skill-based behaviour corresponds best to what we refer to as automatic task performance. In case of automatic performance, there is a direct link between presented information and the response. Information is processed completely bottom-up, with information directly triggering a response. In case of automatic task performance, there is not much room for top-down control.

An example in the driving context is lane keeping. An experienced driver has practised the task of lane keeping so often that he performs this task at an automatic level. Getting too close to a road marking on the right side automatically triggers a steering response to the left. This is done without any top-down control. Godthelp [1988] found that car drivers make corrective steering actions at a constant Time-to-Line Crossing (TLC) irrespective of vehicle speed. TLC represents the time it takes, with unchanged heading and speed, before a car will reach the lane boundary or road marking. Apparently, the driver uses the TLC as a safety margin. If a certain minimum TLC value is reached, a corrective steering action is automatically triggered.
This was confirmed by Van Winsum and Godthelp (1996) in negotiating curves. The TLC minima to the inner lane boundary were constant over different curve radii. Normally, this completely bottom-up way of processing is very efficient and lane keeping is done in a safe way without occupying many attentional resources. Another example is braking in response to activated braking lights from a lead vehicle. This response is automatic that there is no top-down control. As soon as a car in front brakes very abruptly, the driver automatically releases the gas pedal and brakes. It is almost impossible to ignore the red braking lights of a lead vehicle and not hit the brake. This automatic link is strong and guarantees a fast response.

Although automatic performance does have its advantages (response is fast and does not require many attentional resources), there are also problems associated with an automatic response. The presentation of information that automatically triggers a response is so strong that all other information will be ignored. There is hardly any room for top-down control in automatic task performance. That means that it is almost impossible to affect the response by the driver. This may lead to ‘the failure to apprehend’ in driving. Again, consider the example of lane keeping. Under normal circumstances, this automatic task performance leads to safe behaviour, that is keeping the car in between the road markings. However, in case of road works, accidents may arise due to this automatic response without any top-down control. For example in the Netherlands, in situations in which there are road works, drivers have to attend to the yellow (temporary) road markings and ignore the regular white markings. This task is very difficult to perform since the presence of road marking (regardless of its colour) will trigger automatic lane keeping. What typically is observed in road works situations in the Netherlands is that drivers start to drive in between one white and one yellow line. Even though drivers may know that they should only attend to the yellow lines, there is no cognitive control that allows them to selectively respond to the yellow lines. In other words, they cannot help it that they respond to the two lines that are closest to the vehicle. Obviously, the result of this is that drivers try to negotiate the vehicle within the boundary of a much too narrow lane, which increases task load. In case that a driver automatically follows the white markings instead of the yellow ones, this may even cause side collisions since this will result in two drivers driving too close together. Following the white road marking may even lead to a direct collision with for instance a barrier. There have been real accidents from road users following the track of the old road marking, thereby colliding with a road work barrier. Because of these types of accidents in road work situations, it is more and more common to actually erase the white markings when the new yellow lines are introduced. By erasing the white road markings, ‘the failure to apprehend’ in automatic task performance is avoided since it takes away the information that automatically triggers the (in this case incorrect) response. It is not
always sufficiently checked if there are any misleading road markings that may lead to dangerous situations.

Another example of accidents resulting from automatic responses is the case of responding to a braking vehicle in front. As an automatic response, the bright red braking lights from the car in front may lead to a road user hitting the brake fully. This response is so automatic that experienced drivers do this even if it were better to steer to the right to avoid the object in front. Even though any driver knows that fully hitting the brake may cause the wheels to lock, possibly resulting in a collision, it is almost impossible not to perform this action. Since this response is known to be fully automatic without much top-down control, anti-lock braking systems (ABS) were invented.

5.2 Rule-based behaviour and schemata

Rule-based behaviour in Rasmussen’s model is similar to the situation in which strong expectations trigger specific schemata. In this case, a specific context i.e. the presentation of specific information activates a schema. Schemata are characterised by a very strong top-down control. In case of activated schemata, a specific sequence of perceptual, cognitive and behavioural actions is carried out. For example a road user that approaches an intersection that he passes every day will have specific activated schemata. Based on familiarity with the intersection a specific set of actions (schema) is triggered: first the driver looks to his right and then to his left in order to check for any approaching vehicles before turning right.

The problem with this type of behaviour is that a schema may activate such a strong top-down component that there is hardly any room for bottom-up selection of information. In case that new (bottom-up) information needs to be selected that does not fit the schemata ‘the failure to apprehend’ may occur. Consider the example of the driver approaching the intersection: if the driver does not expect cars approaching from the left side, then cars approaching from the left side may not be part of the schema. Even if traffic is approaching, the driver may not respond. This is exactly what has been found in accident data. 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, described in Chapter 1, are also related to activated schemata. In many cases, the driver looked in the appropriate direction (according to the activated schema) but failed to give priority to the other vehicle, most likely since they did not expect any vehicle to be
present. Apparently, the presence of another road user did not have strong enough bottom-up features to actually result in a response. Also Rumar (1990) explains these types of accidents by the road user having a partly incorrect expectation. This is confirmed by Brown (2005) who claims 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 may develop fixed routines for searching information. For example, drivers only scan the expected location of traffic signs, showing the strong top-down control (Theeuwes, 1991c, 1992c). If information is presented at a location that does not fit the activated schema, it will not be selected. But even if the information is selected e.g. because it is presented at a location that is part of the schema, it may still be insufficiently processed to break through this strong top-down control.

Chapter 4 also described vigilance as one of the four situations in which ‘the failure to apprehend’ can occur. This holds for classic vigilance tasks. However we do not consider the driving task to be a classic vigilance task, even though literature has described vigilance as ‘a human factors concern in driving’ (Mackie, 1977; Harris, 1977). The term ‘vigilance’ in the context of driving is only used to indicate a situation in which a driver is passively monitoring the outside scene rather than actively scanning the environment. In this sense, this type of behaviour can be characterised as being rule-based and strongly depending on schemata. Note however, that vigilance tasks are different than more common rule-based tasks because targets are very infrequent.

5.3 Knowledge-based behaviour and new tasks
Knowledge-based behaviour is found in new situations. For experienced drivers this can be driving in a new city or interpreting new traffic signs. An illustrative example is a Dutch driver who has to switch to driving on the left side of the road in the UK. The Dutch driver cannot rely on automatic task performance, nor on schemata or top-down control. Only by allocating all attentional resources to this new driving situation, the driver is able to perform this task.

However there is a severe risk in trying to change an automatic task to a knowledge-based task. In case of sudden and imminent situations that require an immediate response, things go wrong. Consider the Dutch road user, who has been driving on an empty rural road in the UK for an hour. If a car suddenly approaches from the front, automatic task performance takes over again; the mere presence of the car on collision course immediately makes the driver turn the steering wheel to the right hand side in order to avoid the vehicle. In the UK, the driver should have done the opposite, which may result in a frontal collision.
In case of knowledge-based behaviour, all information is basically new and not much top-down knowledge is available for selecting and processing this information. One could argue that most processing is done in a bottom-up manner. Performing a new task (or at a knowledge-based level) requires a high level of attention and is therefore very demanding. A driver receives a lot of visual input since all information needs to be processed basically in a bottom-up manner. Because top-down knowledge cannot guide the selection and processing of information, it is expected that knowledge-based behaviour is relatively slow. Because processing is relatively slow, not all information can be processed. There is too much competing information in the visual field, causing ‘the failure to apprehend’ simply because relevant information may not get selected. For instance, when driving in a new city, a driver has to find his way, look at directional signs, choose the right lane in time, pay attention to other cars, watch for zebra crossings, interpret the priority situation etc. All these tasks together increase workload and result in a large competition between different task elements. Since the driver has no prior expectations of where important information is located (top-down control), he has to actively scan all information elements. Therefore the driver may be able to only select a limited amount of information, leading to a failure to select an important sign telling him or her that it is not allowed to enter that road. This may result in a frontal collision with a car coming from the other direction.

Knowledge-based task performance is most severely impaired by adding another (sub)task, since the extra task may divert attentional resources from the primary task of driving. An example is making a telephone call while driving (e.g. Strayer, Drews & Crouch, 2003; Strayer, Crouch & Drews, 2004; Burns, Parkes, Burton, Smith & Burch, 2002; Consiglio, Driscoll, Witte & Berg, 2003; Patten, Kircher, Östlund & Nilsson, 2004). In the Netherlands there is considerable debate about the need to further regulate hands free calling and driving at the same time. Some companies have decided not to wait for legislative measures and forbid their employees to make even hands free calls whilst driving (Intermediair, 2006).

In order to comprehensively illustrate the effect of ‘the failure to apprehend’ we elaborated Rasmussen’s original model. The model is shown in Figure 5.1.

According to the elaborated model, the difference between the three levels of performance is explained by the level of bottom-up and top-down control, the level of practice, the level of attention and time that a task requires, the level of arousal, and the level of task load.

At each level, the risk for ‘the failure to apprehend’ results from a different cause.
In case of knowledge-based performance, there is a high task load, but if the task load does not exceed the available attentional resources, performance may still be fairly good. Because the task is new and is hardly practised, performing the task takes quite some time, arousal is relatively high and selection and processing basically occurs in a bottom-up manner. In this case ‘the failure to apprehend’ is a result of failure to select the right information at the right time because of a limited processing capacity.

In case of rule-based performance, drivers have a strong top-down control and depend on the activated schema to select and process information. The task is fairly well practised, the level of arousal is not so high, nor is attention, task load and the time required for performing the task. ‘The failure to apprehend’ is the result of the strong top-down control, which is so strong that it does not allow the bottom-up input of signals that do not fit the top-down schemata.

Finally, in case of skill-based behaviour or automatic task performance, there is a direct link between a stimulus and a response. Information processing and responding is carried out entirely bottom-up, without any room for top-down control. The task is highly practised and the required level of attention is low; these tasks are not very demanding, arousal is normally very low and the time needed for performing the task is minimal. Therefore, in skill based behaviour ‘the failure to apprehend’ is explained by the lack of top-down control.