Summary

Driving a vehicle may seem to be a fairly simple task. After some initial training many people are able to handle a car safely. Nevertheless, accidents do occur and the majority of these accidents can be attributed to human failure. At present there are factors that may even lead to increased human failure in traffic. Firstly, owing in part to increased welfare, the number of vehicles on the road is increasing. Increased road intensity leads to higher demands on the human information processing system and an increased likelihood of vehicles colliding. Secondly, people continue to drive well into old age. Elderly people suffer from specific problems in terms of divided attention performance, a task that is more and more required in traffic. One of the causes of these increased demands is the introduction of new technology into the vehicle. It began with a car radio, was followed by car-phones and route guidance systems, and will soon be followed by collision avoidance systems, intelligent cruise controls and so on. All these systems require drivers' attention to be divided between the system and the primary task of longitudinal and lateral vehicle control. Thirdly, drivers in a diminished state endanger safety on the road. Longer journeys are planned and night time driving increases for economic purposes and/or to avoid congestions. Driver fatigue is currently an important factor in accident causation. But not only lengthy driving affects driver state, a diminished driver state can also be the result of the use of alcohol or (medicinal) sedative drugs.

The above-mentioned examples have in common that in all cases driver workload is affected. An increase in traffic density increases the complexity of the driving task. Additional systems in the vehicle add to task complexity. A reduced driver state affects the ability to deal with these demands. How to assess this, i.e. how to assess driver mental workload is the main theme of this thesis.

In chapter 1, the theoretical aspects of mental workload are introduced. The difference between task demand, i.e. the external demand, the goals that have to be reached, and (work)load, i.e. the individual reaction to these demands, receive attention in this chapter. Mental workload is defined as a relative concept; it is the ratio of demand to allocated resources. Task difficulty is explicitly separated from task complexity. Task complexity would have been an objective property of the task that is related to demand on computational processes, were it not dependent upon individual goal setting. Task difficulty is very much dependent upon the context and the individual. Applied strategies may affect resource allocation or task complexity and thus difficulty and mental workload.

In chapter 2, a model of mental workload, task performance and demands is presented. In the model, performance and workload are related to task demands in 'regions of performance'. Two regions receive specific attention; namely those in which performance remains

unaffected at the cost of increased effort. A division between state-related effort and task-related effort is made. State-related effort is exerted in the case that the operator's state deteriorates but performance remains unaffected, while task-related effort is exerted to maintain performance in the case of increased task complexity. It is argued that both processes indicate increases in mental workload. Here, a key question arises: is it possible that different measures are differentially sensitive to these two kinds of effort?

In chapter 3, an overview of general characteristics of measures is given, while in chapter 4, specific measures of mental workload are presented. The often-used division between self-report measures, measures of task-performance and physiological measures is conserved. Different measures are presented and evaluated on their potential use as indicator of workload in traffic research. The issue of so-called dissociation of measures is weakened by the effort principle. The determination of a critical level of unacceptably high workload, the workload redline, is discussed and it is concluded that determination of a general valid level in terms of absolute values or scores on a measure is unattainable owing to individual differences in workload and the relativeness of the concept of mental workload. Performance margins are considered to be more useful in workload research than a workload redline.

In chapter 5, seven studies in which mental workload differed between conditions are presented. The studies are divided into two groups; studies in which the driver's state was affected and studies that included an increase in task complexity. The latter group was further subdivided into studies that involved an increase in complexity of the environment as opposed to studies in which a task was added. Two self-report scales, two primary-task performance parameters and three ECG-parameters as physiological measures were selected to assess sensitivity to mental workload. Differential measure sensitivity to mental workload associated with non-optimal driver state opposed to mental workload caused by increased task complexity receive specific attention. It seems that the evaluated subjective effort scale is sensitive to both kinds of effort, while the 0.10 Hz component of heart rate variability is more sensitive to task-related effort than to state-related effort. Task conception, task interpretation in terms of goal setting, is an important factor for the primary task measures. The need to perform at an optimal level on the primary task of lane keeping is absent, and most people allow for inaccuracies in steering. As a result, under some of the 'load-conditions' improvement in primary task performance measures was found. This unexpected effect may be related to increased effort.

In chapter 6, the conclusions are summarized and the different measures are linked to the model of mental workload, task performance and task demands. Recommendations for the measurement of mental workload in applied settings are given in this chapter and the different

concepts that are related to mental workload are evaluated on the basis of the results of applied (traffic) psychological experiments.

Finally, as appendix, detailed reports on five of the seven experimental studies are included.