Occlusion as a technique for measuring In-Vehicle Information System (IVIS) visual distraction: a research literature review

Prepared for Vehicle Technology and Standards Division 6, Department for Transport

A Stevens, S Bygrave, N Brook-Carter and T Luke

TRL Report TRL609
This report has been produced by TRL Limited, under/as part of a contract placed by the Department for Transport. Any views expressed in it are not necessarily those of the Department.

TRL is committed to optimising energy efficiency, reducing waste and promoting recycling and re-use. In support of these environmental goals, this report has been printed on recycled paper, comprising 100% post-consumer waste, manufactured using a TCF (totally chlorine free) process.
## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Executive Summary</td>
<td>1</td>
</tr>
<tr>
<td>1 Introduction</td>
<td>3</td>
</tr>
<tr>
<td>2 Background</td>
<td>3</td>
</tr>
<tr>
<td>3 Standards and guidelines</td>
<td>4</td>
</tr>
<tr>
<td>3.1 Statement of principles – European</td>
<td>4</td>
</tr>
<tr>
<td>3.1.1 Overview</td>
<td>4</td>
</tr>
<tr>
<td>3.1.2 Recommended criteria for single and total glance duration</td>
<td>4</td>
</tr>
<tr>
<td>3.2 Statement of principles – USA</td>
<td>5</td>
</tr>
<tr>
<td>3.2.1 Overview</td>
<td>5</td>
</tr>
<tr>
<td>3.2.2 Recommended criteria for single and total glance duration</td>
<td>5</td>
</tr>
<tr>
<td>3.2.3 Verification method</td>
<td>5</td>
</tr>
<tr>
<td>3.2.4 Other relevant issues</td>
<td>6</td>
</tr>
<tr>
<td>3.3 SAE recommended practice</td>
<td>6</td>
</tr>
<tr>
<td>3.3.1 Recommended criteria for total glance time</td>
<td>6</td>
</tr>
<tr>
<td>3.3.2 Verification procedure</td>
<td>6</td>
</tr>
<tr>
<td>3.3.3 Rationale</td>
<td>6</td>
</tr>
<tr>
<td>3.4 ISO</td>
<td>7</td>
</tr>
<tr>
<td>3.5 Japanese guidelines</td>
<td>7</td>
</tr>
<tr>
<td>4 Occlusion techniques</td>
<td>7</td>
</tr>
<tr>
<td>4.1 Means of occlusion</td>
<td>7</td>
</tr>
<tr>
<td>4.2 Test environment</td>
<td>8</td>
</tr>
<tr>
<td>4.3 Occlusion intervals</td>
<td>8</td>
</tr>
<tr>
<td>4.3.1 Interval pacing</td>
<td>8</td>
</tr>
<tr>
<td>4.3.2 Interval variability</td>
<td>8</td>
</tr>
<tr>
<td>4.3.3 Interval length</td>
<td>9</td>
</tr>
<tr>
<td>4.4 Handling of system response time</td>
<td>10</td>
</tr>
<tr>
<td>4.5 Participant selection</td>
<td>11</td>
</tr>
<tr>
<td>4.5.1 Age</td>
<td>12</td>
</tr>
<tr>
<td>4.5.2 Gender</td>
<td>12</td>
</tr>
<tr>
<td>4.5.3 Experience</td>
<td>12</td>
</tr>
<tr>
<td>4.5.4 Visual ability</td>
<td>13</td>
</tr>
<tr>
<td>4.6 Training</td>
<td>13</td>
</tr>
<tr>
<td>4.7 Experimental design</td>
<td>14</td>
</tr>
<tr>
<td>4.8 Number of tasks and repetitions</td>
<td>14</td>
</tr>
<tr>
<td>4.9 Sample size</td>
<td>14</td>
</tr>
<tr>
<td>4.10 IVIS tasks studies</td>
<td>14</td>
</tr>
<tr>
<td>4.11 Primary/loading tasks</td>
<td>15</td>
</tr>
</tbody>
</table>
5 Performance measures used in the literature

5.1 TSOT

5.1.1 Recommendations for TSOT or TGT

5.1.2 Investigating TSOTs to carry out IVIS tasks

5.2 TTT

5.2.1 TTT (occluded/dynamic/static) as a measure of task acceptability

5.2.2 Recommendations for TTT

5.2.3 Static TTT as a measure of task acceptability

5.2.4 Investigating dynamic TTT for IVIS tasks

5.2.5 Investigating occluded TTT for IVIS tasks

5.3 Resumption lag

5.4 Ratio TSOT/TTT

5.4.1 Recommendations for TSOT/TTT

5.4.2 TSOT/TTT as a measure of task acceptability

5.4.3 Investigating TSOT/TTT for IVIS tasks

5.5 Ratio $\text{TTT}_{\text{occluded}}/(\text{TTT}+\text{Ttclose})$ also written $\text{TTT}_{\text{occl}}<1.25(\text{Static}+\text{Ttoclu})$

5.6 Total number of glances

5.7 Task errors

6 The validity of the occlusion technique

6.1 Comparison with static task completion and eye glance measures

6.2 Comparison with driving performance and safety

7 Developing a protocol

8 Conclusion

9 References

10 Glossary of Terms

Appendix A: Occlusion research summaries

Appendix B: Table of research methods and conclusions

Abstract

Related publications
Occlusion is a technique that can be used to assess visual distraction. The technique is used for simulating the shift in visual attention associated with driving where a driver has to share visual resource between the driving scene and the in-vehicle information system (IVIS). This is done using a shutter to hide and expose the IVIS from view, or goggles that also block or reveal the visual scene (the IVIS). The amount of time (duration and frequency) that the IVIS is visible or occluded (blocked from view) is controlled during occlusion. The basic idea is to investigate whether in-vehicle tasks can be carried out in short bursts of visual attention towards a display screen (typically 1 to 2 seconds).

In-vehicle information systems (IVIS) can provide useful information to support the driving task, reduce stress and make a journey more comfortable. A few brief glances to an IVIS are not likely to have a significant effect on safety. However the visual distraction caused by some in-vehicle systems that require longer and more frequent glances is of concern.

This literature review highlights that previous work on occlusion is conclusive in several areas. From detailed examination of the research it is possible to identify some appropriate parameters for use in a standard occlusion protocol. A vision interval of 1.5 seconds and an occlusion interval of between 1 and 3 seconds appear to be most suitable. PLATO goggles that are system paced are most frequently used to obtain occlusion conditions and appear to be very effective.

However, it is evident that there are a number of important factors that have not been fully explored in the research, such as, training, sample demographics, test environment, number of trial repetitions, impact of primary distracter tasks and how to deal with system response delays. So there is a clear need to determine their effect. Inconsistencies between these factors are likely to increase the variability between measurements.

From the review it is evident that there is considerable debate over how visual distraction should be measured using the occlusion technique. In particular the variability of the link between occlusion measures and driving performance and safety have yet to be fully established.

Occlusion can provide measures that may help to determine the visual distraction caused by different IVIS tasks. These measures include; TSOT, TTT and the ratio of TSOT to TTT (TSOT/TTT). TSOT is the total time that vision is not occluded when using an occlusion procedure. TTT is the total time required to complete a task. If the task is the only or main task (i.e. not undertaken while driving as a primary task) then this is also referred to as the Static TTT. More specifically Static TTT is the total task time measured while not in motion and Dynamic TTT is the total task time measured while driving.

Static TTT and TSOT are not appropriate single measures because they do not take into account the chunkability of the task. Tasks that have a very long completion time have been shown to be easy to perform when they can be completed in small ‘chunks’. Ratio measures such as TSOT/TTT are promising, but are criticised because they are not independent of TTT and therefore are very sensitive to its value. The ratio is less consistent for tasks that are less than a few seconds in length, but more consistent for tasks which have a TTT of 5 or more seconds. TTT static may provide a useful measure in conjunction with other measures such as mean glance duration. However, TTT dynamic as a lone measure does not indicate the chunkability of a task.

Although TTT, TSOT and TSOT/TTT all provide some useful information about visual distraction, it can be proposed that the most suitable way to assess a system is by considering both the ratio of task complexity and the length of time required to complete the task. However more work is required to establish the influence of the factors described above and to determine reference values that may be used to assess IVIS.
1 Introduction

This literature review has been conducted by TRL on behalf of the UK Department for Transport, with the aim of bringing together all of the occlusion research to date investigating the visual load imposed by in-vehicle information systems (IVIS). The aim is to discuss common findings and arguments within the research, and to identify areas where research is still lacking if a common assessment protocol for occlusion is to be achieved.

An agreed method for measuring distraction would allow system manufacturers and road authorities to assess the level of visual load caused by using in-vehicle information systems. It is important to measure the visual attention associated with these devices so that they can be designed to minimise the amount of time drivers have their eyes off the road. Occlusion is a potentially useful method for assessing IVIS distraction and might offer a practical economic alternative to simulator studies or investigations of glance behaviour using eye trackers or video data. However, limited research has been carried out in this area to date and this research has not been co-ordinated or comprehensively reviewed.

Section 2 discusses the background to the occlusion technique and introduces this review. Section 10 provides a glossary of terms. Section 3 discusses current standards and guidelines for IVIS visual demand, specifically in relation to the occlusion technique. This includes the current Society of Automotive Engineers (SAE) (2000) 15-second rule, the USA and European Statement of Principles, the JAMA guidelines and the ISO working group on visual demand which are currently developing a standard using the occlusion technique as a measurement method.

The occlusion technique may at first glance appear simple. However, there are numerous factors and variables that need to be considered and controlled when applying the technique, in order to ensure that IVIS are assessed appropriately and fairly and that results across studies or assessments are comparable. For example, the level of training a participant receives before a study, the participant sample demographics involved in the study, the order in which participants are presented with tasks and the number of repetitions a participant carries out on each task (to name but a few) will all impact on the outcome of the assessment. A limited amount of research has been carried out to address such issues. The research to date on these factors and variables and the associated implications for the application of the occlusion technique are discussed in Section 4.

In order to successfully compare results between studies and to provide normative data, a standard occlusion protocol would be beneficial. This would assist in assessing the visual demand of a driver caused by IVIS and could be used by manufacturers and researchers. A standard protocol would be an appropriate first step towards developing guidelines for inspection time, total glance time and total task time. The current values suggested by guidelines differ and findings from the research base to date are not in full agreement. The findings from the research studies in relation to inspection times, total glance times, total task times and the ratio between total glance and total task times are presented and discussed in Section 5.

Section 6 presents findings from the research in terms of the validity of the occlusion technique. These findings are taken from comparison studies of occlusion, driving in a simulator or during real-road trials and the peripheral detection task, whilst interacting with IVIS.

In Section 7 the current ISO draft standard is compared to the wider research findings to highlight areas where the is consensus and aspects where issues remain unresolved. Gaps in the research, and areas where research questions remain, are highlighted.

2 Background

Driving is primarily a visual task; a large part of the information needed for driving is visually oriented. The cognitive element of driving (mainly concerned with navigation and interacting with the road and other traffic) relies on the acquisition of information from the vehicle and its surrounding environment. The vast majority of this information is received visually, and therefore vision is the largest and most important single resource available to the driver. Rockwell (1972) estimated that as much as 90% of all information drivers use is obtained visually. Attending the forward view is the drivers’ primary visual task (Wierwille, 1993). However, visual information is also provided to the driver from other sources within the vehicle such as in-vehicle information systems (IVIS) and drivers will allocate their attention between these systems and the driving scene.

In-vehicle information systems (IVIS) can provide useful information to support the driving task, reduce stress and make a journey more comfortable. A few brief glances to an IVIS are not likely to have a significant effect on driving acceptability. However the visual distraction caused by some in-vehicle systems that require longer and more frequent glances is of concern. Distracting the drivers visual attention away from the road scene has implications for safe driving. There have been concerns for many years about the quantity of information presented to drivers by IVIS and their ability to cope with this while driving, particularly as the IVIS market is expanding and the technology available within the vehicle is developing at an increasing rate. ‘How much is too much?’ however, is difficult to answer and there are no fully agreed acceptable limits.

An agreed method for measuring distraction would allow system manufacturers and road authorities to assess the level of visual load caused by using in-vehicle information systems. It is important to measure the visual attention associated with these devices so that they can be designed to minimise the amount of time drivers have their eyes off the road. An appropriate assessment method also needs to consider whether the dialogue sequences between the driver and the IVIS can be interrupted and resumed in order to minimise distraction.

An alternative to occlusion could be subjective measures, such as the DETR/TRL IVIS HMI Safety
Checklist (Stevens et al., 1999), which provide an approach to assess IVIS. However, even when carefully designed and applied there is an element of subjective judgement. Ideally a quantitative method is required which can be applied throughout the design and development process and to systems already on the market.

Previous quantitative techniques for assessing IVIS that could potentially be used as alternatives to occlusion have included the level of visual distraction imposed by analysing driver eye glance behaviour using video or eye tracking techniques, or investigating the impact of IVIS on driving performance measures, such as lateral position. These methods are limited in that they can be time consuming and/or expensive. This review will focus on occlusion and will not discuss the alternatives in depth, although they may potentially provide more ecologically valid data.

‘Occlusion’ is a more economical and practical option, to assess visual distraction, than full glance behaviour analysis. Occlusion has the advantage of tight control in terms of the conditions to which participants are exposed. The technique is used for simulating the shift in visual attention associated with driving where a driver has to share visual resources between the driving scene and the IVIS. This is done using a shutter to hide and expose the IVIS from view or goggles that also block or reveal the visual scene (the IVIS). The amount of time (duration and frequency) that the IVIS is visible or occluded (blocked from view) is controlled during occlusion. The basic idea is to investigate whether in-vehicle tasks can be carried out in short bursts of visual attention towards a display screen (typically 1 to 2 seconds).

If a task can be carried out this way it is regarded as ‘chunkable’ and it can be undertaken by the driver more easily than ‘non-chunkable tasks’. It is important to address how long an IVIS needs to be looked at during each separate glance in order to perform a task. The current SAE recommended practice (SAE J2364, 2000) uses a ‘15-second rule’ to assess visual distraction based on research conducted by Green et al. (1999). The 15-second rule suggests that IVIS tasks are acceptable if they can be completed within 15 seconds when parked. However, the current 15 second rule does not address how long an IVIS needs to be looked at during each separate glance and hence does not assess the ‘chunkability’ of the task. Therefore the 15-second rule may erroneously assess safety.

Occlusion is a potentially useful method for assessing IVIS distraction and might offer a practical economic alternative to simulator studies or investigations of glance behaviour using eye trackers or video data. However, limited research has been carried out in this area to date and this research has not been co-ordinated or comprehensively received.

There remain a number of unanswered research questions which need to be addressed if the technique is to be used to assess the suitability of IVIS tasks for operation whilst driving. Further, the protocol by which the method is applied in terms of participant size, the training provided, the number of task repetitions and so on, need to be agreed, as do the acceptable performance ranges, such as the maximum total task time.

3 Standards and guidelines

This section presents the current situation in terms of standards and guidelines for visual distraction and in particular for measuring visual distraction in terms of the occlusion technique or equivalent glance durations.

3.1 Statement of principles – European

3.1.1 Overview

The European Statement of Principles was produced by a consortium of experts representing both public organisations and industry. The document summarises essential safety aspects to be considered for the Human Machine Interface (HMI) for in-vehicle information and communication systems. The European Statement of Principles is intended to be of particular use to manufacturers who may be unaware of the safety implications to HMI and the importance of good design practice. The Statement of Principles explores the following issues:

- How to design and locate information and communication systems in such a way that their use is compatible with the driving task.
- How to present information so as not to impair the driver’s visual allocation to the road scene.
- How to design system interaction such that the driver maintains acceptable control of the vehicle, feels comfortable and confident with the system and is ready to respond to unexpected occurrences.

The main topics covered are overall design, installation, information presentation, interaction with displays and controls, system behaviour and information about the system.

The Statement of Principles is not intended to act as a barrier to innovative design and is therefore expressed in terms of the goals to be reached by the HMI.

3.1.2 Recommended criteria for single and total glance duration

The European Statement of Principles makes several recommendations that are potentially relevant to occlusion:

- ‘Visual displayed information should be such that the driver can assimilate it with a few glances which are brief enough not to adversely affect driving.’
- ‘The system should not require long and uninterruptible sequences of interactions.’

The final version of the Statement of Principles does not state specific values for the maximum duration of glances or a verification procedure. However, more detail is provided in a complementary document, expansion of principles, 2001. This document intends to explain the meaning of each principle in sufficient detail for work to begin on procedures to test if a specific system conforms to the principles.

The expansion document provides guidelines on the specific number of glances and glance durations that are acceptable to complete a task on an in-vehicle information or communication system. Typically, up to four glances should
be sufficient to assimilate visual information from a system. This is notably different from the American Statement of Principles that allows for up to 10 glances towards a system. These glances should be brief and the expansion of the European Statement of Principles states that the maximum single glance duration should be 2 seconds and single glances of approximately 1 second should be the normal case.

The expansion document defines an uninterruptible sequence as when ‘the driver does not have the possibility of restarting (within a ‘time-out’ period)’ after an interruption at the place where the interruption was made.’ A suitable time-out period of 1-2 minutes is suggested. ‘Long’ sequences are not defined, however, there are several suggestions and they may be defined by the complexity in terms of menu inputs, the number of control inputs or the time it takes to make the control inputs.

No verification procedure was defined for these recommendations, however, occlusion is clearly an option for the assessment of these criteria.

3.2 Statement of principles – USA

3.2.1 Overview

The USA Statement of Principles (AAM, 2002) is under development by the Alliance of Automotive Manufacturers in response to the request of NHTSA that the manufacturing industry address the rising safety concerns relating to in-vehicle information and communication systems. The Statement of Principles document sets out the ‘best practices’ for the design and assessment of such systems.

The guidelines focus on light vehicles and are intended for use by equipment manufacturers and the aftermarket. The topics covered in the statement of principles are overall design, installation, information presentation, interaction with displays and controls, system behaviour and information about the system. The guidelines are limited to safety aspects of human-machine interface (HMI) under the following conditions:

- ‘New’ information and communication technology and devices with visual and manual/visual interfaces.
- Features and functions designed for use by the driver while driving (vehicle speed ≥ 5mph).
- Under routine driving conditions.

The document is still under development, currently, only the eleven most significant sections of the document contain specific criteria, technical justification, verification procedures and illustrative examples on how to satisfy the principle.

This section will specifically focus on the section/sections relating to criteria or methods for establishing the minimum requirements for the presentation of visual information. In particular, those criteria that could be assessed using the occlusion technique.

3.2.2 Recommended criteria for single and total glance duration

AAM (2002) states the duration of single glances required to complete a task while the vehicle is in motion should not exceed 2 seconds. In addition, the task completion should not require more than a total of 20 seconds total glance time to the system display or controls. A task is defined as ‘a sequence of control operations (i.e. a specific method) leading to a goal at which the driver will normally persist until the goal is reached.’ A goal is defined as a system state sought by the driver.

The 2-second glance duration recommended by AAM (2002) is based on research conducted by Rockwell (1988) that examined the distribution of single glance durations. 1.9 seconds was the 85th percentile duration of single glances. This is rounded up to 2.0 seconds to give an engineering estimate for acceptable maximum single glance duration. However, the AAM also states that single glance duration is not a good predictor of safety-related driving performance, such as lane departures and that single glance duration is self-limiting, i.e. drivers are generally only willing to look away for a short period. Therefore, this criterion is included for completeness but is not a sufficient criterion in itself.

The 20-second maximum total glance time was derived from consideration of several factors. Several studies have found that the number of glances needed to complete a secondary task was predictive of lane exceedences (Green, 1999; Dingus, 1987). However, many tasks may require very short check glances, for example, to see whether certain information has arrived or not. This would result in a large number of glances to complete a task, but the majority of the glances would be very short and have little impact on the task or the driver performance. Therefore, limiting the number of glances was seen to be overly conservative.

Instead, a limit on total glance time is offered. This is based on the mean number of glances away from the road required for radio tuning (\(x = 6.91\), S.D. = 2.39 glances, Dingus, 1987). A normal distribution was assumed, giving an 85\(^{th}\) percentile figure of 9.40 glances required to tune a radio. This figure has been rounded up to 10 to produce a whole number engineering criterion. The total maximum recommended glance time is therefore, the mean number of glances multiplied by the recommended maximum duration of a single glance.

It is notable that both of these recommendations are based on what drivers will actually do in order to complete a task, rather than what may or may not adversely impact driver performance. However, the criterion is based on a driver-paced interaction and this may be more suitable as real-world interaction with the system will also be user-paced.

It is also notable that the radio-tuning task used to arrive at the total glance duration recommendation has not always been considered to be an acceptable task to complete with the vehicle in motion. However, the Statement of Principles does acknowledge the need to relate system use to measures of driver performance. Therefore, it also proposes an alternative assessment criterion that refers to the measurement of several driver performance factors such as lane keeping and headway while completing an IVIS task.

3.2.3 Verification method

The USA Statement of Principles defines a number of verification procedures for the presentation of visual information. These are all based on a methodology in which:
A sample is drawn to perform tasks with the system and the sample is of a sufficient size to control type 1 and type 2 errors. A type 1 error is where the null hypothesis is rejected when it was actually true. A type 2 error is where the null hypothesis is accepted, when it was actually false.

Test participants are not familiar with or knowledgeable about the systems, but they are interested, motivated and capable of learning and completing the test procedure.

Test participants are aged between 45 and 65 years old.

The sample is split evenly according to gender.

Each participant is familiarised with the system prior to testing and given practise trials.

Each participant is tested multiple times on the tasks.

However, only the visual occlusion method of verification will be discussed in detail in this review.

This method requires that the tasks are performed under a condition where visual occlusion is used. This may be by means of either occlusion goggles or an equivalent technique. Regardless of the technique chosen it should always be possible for the participants to maintain light adaptation during periods of occlusion.

The occlusion apparatus should be configured so that the vision/occluded cycles are fixed, with vision intervals of 1.5 seconds and occluded intervals of 1.0 second. These values are based on the justification provided by Hashimoto and Atsumi (2001). This is also the consensus from Japan and it was reached by the highest correlation between this cycle and empirical measurements of total glance time. Research (Dingus 1989; Rockwell, 1998) has indicated that with radio tuning as a reference task the glances to the roadway typically average less than 1 second in length and 1.5 seconds is the mean glance duration for this task.

This recommendation is made in the USA Statement of Principles pending further research and is not intended to preclude other applications of visual occlusion. This is primarily because research, such as Wierwille et al. (1988) has indicated that mean glance duration can vary considerably under different traffic conditions.

The USA Statement of Principles states that a task that can be reliably completed under conditions of occlusion with a total vision interval of ≤15 seconds can be considered to have met the requirements of a single glance duration of 2.0 seconds and the total glance time of 20 seconds.

3.3 SAE recommended practice

The SAE (Society of Automotive Engineers) has developed guidelines relating to the recommended level of visual distraction of navigation and route guidance system functions (i.e. not IVIS, more generally). It does not recommend occlusion, stating that total task time is a sufficient measure. SAE J2364 sets out a basic procedure for calculating total task time.

3.3.1 Recommended criteria for total glance time

SAE 2364 (2000) recommends that the total task time for navigation system functions accessible while driving does not exceed 15 seconds. This criterion must be verified using the following procedure:

3.3.2 Verification procedure

The system under investigation should be operational and fitted to a vehicle, buck or mock-up in the design intent location. Assessment should be conducted in a static situation, i.e. not while driving. Testing should be repeated for between 5 and 10 licensed drivers, who are capable of learning and completing the test procedure and aged between 45 and 65 years of age. Prior to testing all participants should be given a clear explanation of the task, in addition to 5 practice trials of the task to be assessed.

The timing of the task should begin when the driver’s hand begins to move towards a control and should end when the system provides confirmation that the last operation has been accepted. All tasks are timed from beginning to end without interruption, except for computationally interrupted tasks. Each task should be repeated three times by each participant to obtain a mean task completion time.

A computationally interrupted task is defined as ‘A task where the driver must wait 1.5 seconds or more for the driver interface to respond to driver input in order to complete a task such as when an off-board computer is queried.’ (SAE 2364, 2000). SAE 2364 (2000) provides specific guideline regarding when to include computational interruptions in the total task time. Interruptions lasting less than 1.5 seconds, or exceeding 1.5 seconds but with no feedback to the driver, should be included in the total task time. For interruptions exceeding 1.5 seconds where feedback indicating an interruption and estimated delay is provided then only the first 1.5 seconds of interruption can be included.

The exact details of SAE J2364 (2000) are currently being revised.

3.3.3 Rationale

The 15-second performance boundary was determined according to a number of factors including minimising risk to the driver, consistency with current design practice, consistency with existing standards and the results of research. It was also necessary for the time to represent a consensus of all committee members. Therefore, the literature suggested a maximum time of 9-12 seconds. However, some members of the committee opined that this was too short, therefore 15 seconds was adopted, allowing a reasonable margin for error (Green, 1999).
The total task time method is favoured for its simplicity and ease of administration. However, it has been criticised because it does not take into account task interruptibility or chunkability.

3.4 ISO
ISO (the International Organisation for Standardisation) is a worldwide federation of national standards bodies. ISO carries out the work of preparing international standards through the formation of technical committees.

The current (pre-CD) draft of the occlusion standard (ISO N3XX) proposes a method of occlusion for assessing the visual or visual manual interfaces accessible to the driver whilst the vehicle is in motion. The draft standard states that the vision interval shall be 1.5 seconds and the occlusion interval shall be 2.0 seconds.

The draft also defines several other aspects of the method. The system under investigation should be fitted to a vehicle, simulator buck or mock-up in the design intent location. Each participant should be given a minimum of two trials of training on the occlusion procedure and at least five practice tasks of equivalent difficulty to the task being evaluated. The participants should be licensed drivers not familiar with, or technically knowledgeable about, the specific driver interface under investigation and capable of operating the driver interface, learning and completing the test procedure. The characteristics of the participants such as age, gender and driving experience should be recorded. It is recommended that at least 10 participants are used.

The system should be judged not excessively visually distracting if 85% of trials achieve a TSOT less than an agreed Target Value, which has yet to be defined. The pre-CD draft also refers to a method of assessing whether the task is interruptible. This has also been referred to in the literature as a chunkability index (Noy et al. (in press)). The calculation is TSOT/TTT. This provides a ratio between the time taken to complete the task in a continuous sequence and the time taken to complete the task under conditions of occlusion, which can be employed as an estimate of the visual demand of a task. Section 5.4 provides a more comprehensive explanation of this measure. This standard is still in the development stage. The information given here was correct as of 1st August 2003.

3.5 Japanese guidelines
The JAMA (Japanese Automobile Manufacturers Association) guidelines apply to in-vehicle display systems, installed in a vehicle and visible to the driver. The document covers several topics relating to in-vehicle displays: display location, display requirements, operational requirements and software. The JAMA guidelines simply state that in-vehicle display systems shall be easy for the driver to handle and complex operations should be prohibited when the vehicle is in motion.

JAPAN MLIT was produced by MLIT (Ministry of Land, Infrastructure and Transport) and replaces and includes the previous JAMA Guidelines. The document covers similar topics to the JAMA guidelines and provides more specific guidelines relating to in-vehicle display systems. It states that ‘Information manipulation should not require keeping a close watch on the screen.’ This document recommends the occlusion method to ensure this requirement is met. It states that the total shutter opening time from the start to the end of the control, with vision intervals of 1.5 seconds and occluded intervals of 1.0 second, should be 7.5 seconds.

This guideline is based on a study by Hashimoto and Atsumi (2001) who measured total glance time required for tasks on several different in-vehicle navigation systems and related this to driver errors. A total task time of less than 8 seconds resulted in no driver errors. TGT was found to be very highly correlated with TSOT when the occlusion intervals of 1.5 seconds vision interval and 1.0 second occluded are employed. Occlusion is therefore proposed as a good criteria to evaluate interactions with an in-vehicle system. Hashimoto and Atsumi (2001) recommend a TSOT of < 7 seconds as a standard. See Appendix A for further details on this study.

4 Occlusion techniques
This section of the review presents the different occlusion techniques and study designs that have been used in previous research studies. It includes summaries of the different methods of occlusion, the test procedures used, the training provided, participant selection protocols and the tasks used to assess driver visual distraction. The aim of this section is to consider the advantages and limitations of the various study designs and methods used, and also to identify any outstanding issues that have currently not been addressed within the research in terms of study set-up and design.

4.1 Means of occlusion
The occlusion technique involves a period where a participant can complete the task (‘Vision interval’, ‘inspection interval’ or ‘shutter open time’) and the period where the task is interrupted (Occlusion interval). There are a number of different methods for obtaining the vision and occlusion intervals.

The majority of research studies have used goggles or spectacles to achieve the occluded intervals. Of these studies, six specified that they used the PLATO goggles (‘Baumann et al. (in press); ‘Baumann et al. (in press); Bengler and Rosler, 2001; Fichtenberg, 2001; Karlsson and Fichtenberg, 2001; Noy et al. (in press); Weir et al., 2003). The PLATO goggles are a spectacle-mounted shuttering device, with portable liquid-crystal apparatus for presenting visual stimuli for brief exposures. Two studies used spectacles with liquid crystal displays (Goujon, 2001; Hashimoto and Atsumi, 2001) but did not specify make or manufacturer. A further two studies used goggles/ spectacles but gave no description of their type (‘Baumann et al.; Niiya, 2000).

Goggles might be criticised for being an intrusive measure. However, a number of research studies have considered this issue. Goujon (2001) found that there was
no noticeable difference in task completion time with the goggles removed and goggles permanently open. They also found that elderly participants are not ‘more disturbed’ by the use of goggles than younger participants. Elderly people are often considered limiting users, experiencing more difficulties adapting to new technologies and suffering from degraded sensimotor abilities. However, it can be suggested that the goggles do not generate a bias for younger or elderly participants. Karlsson and Fichtenberg (2001) collected subjective ratings on how their participants felt when wearing the occlusion spectacles. The results showed that older participants find occlusion spectacles less frustrating than younger participants, probably due to the eagerness of young participants. One disadvantage that Goujon did find was some drivers noted the difference between a real driving scenario and wearing occlusion spectacles is that the spectacles do not allow peripheral vision to take place.

Another means of occlusion in a number of studies is a PC that has periodic screen blanking (Krems et al.; Monk et al., 2000). Weir et al., (2003) used a screen blanking method based within a vehicle environment to compare the screen blanking method with the PLATO vision goggles. They found that there was no clear subjective preference for the screen blanking or the occlusion goggle method. The literature suggests that PLATO goggles or screen blanking methods are equally preferred by participants (Weir et al., 2003). However, the PLATO goggles provide a more realistic environment for assessing the visual workload of IVIS as the driver is unable to view the vehicle display or IVIS controls whilst focusing on the road ahead. When using the screen blanking method, participants are still able to view the touch buttons, whereas during real driving both the screen and the manual controls are not visible when the driver is viewing the road scene.

4.2 Test environment

Studies may be undertaken in situ i.e. within a vehicle (Bengler and Rosler, 2001; Karlsson and Fichtenberg, 2001; Fichtenberg, 2001; Goujon, 2001; Niiya, 2000) or in a laboratory using a PC task (Krems et al., 2000; Noy et al., 2002). This means that the in-vehicle system will be in the correct position and the participant is more likely to behave and react in the same way as they would when driving. The advantage of a laboratory-based technique is that it is extremely cheap and requires little space. However, the participant is not placed in the environment for which the IVIS is designed. ISO states that components should be in design-intended locations to be as ‘real’ as possible. No studies have been found that directly compare results in a lab or ‘buck’ and a real vehicle.

4.3 Oclusion intervals

The occlusion technique involves a series of ‘vision’ and ‘occlusion’ intervals. The vision interval is the period of time in which a secondary task (i.e. IVIS task) can be completed, and is also referred to in the literature as the ‘goggle open’ ‘shutter open’ or ‘display on’ interval. The occlusion interval is the period of time in which it is assumed that the visual attention is focussed on the driving scene (i.e. when the goggles are closed or display is off), and is also referred to in the literature as the ‘goggle close’ or ‘display off’ interval. Research has investigated interval pacing, variability and length of these occlusion intervals.

4.3.1 Interval pacing

During the occlusion technique, the vision and occlusion intervals can either be ‘system paced’ or ‘user paced’. System paced means that a computer or external source controls the switch between intervals. User paced means that the participants can decide when the vision and occlusion intervals occur by using a control. All but one of the research studies reviewed used system paced occlusion methods (Baumann et al. (in press); Krems et al., 2001; Goujon, 2001; Hashimoto and Atsumi, 2001; Karlsson and Fichtenberg, 2001; Monk et al., 2002; Niiya, 2000; Noy et al. (in press); Weir et al., 2003).

System and user paced occlusion techniques have not been extensively compared in the literature. (Krems et al. (2000) used user-paced occlusion to distinguish between simple and complex stylised maps. User paced in this study meant that no user intervals were considered, but each map was visible until the participant finished the IVIS task. (Krems et al. (2000) concluded that both user and system paced occlusion techniques distinguish between complex and simple visual search tasks and hence are both valid techniques.

The advantage of a system paced occlusion technique to assess IVIS is that it is very simple and the participant is not required to control the shutter (and therefore has no additional tasks). Additionally the system paced occlusion can be designed to open for intervals that represent acceptable driving practice, i.e. acceptable eyes off time (Weir et al., 2003). When validating a system paced technique in a driving simulator, Weir et al. (2003) found that system paced occlusion does not decrease driving performance, as lane keeping performance is similar when the participant chooses when to complete the IVIS task and when the driver is forced to drive under occlusion intervals. Lansdown et al. (in press) suggested that glances to the road scene and IVIS are influenced by environmental demands, driver behaviour and other factors. They criticised system pacing and suggest that a system paced occlusion method does not resemble real interaction.

A user paced system may provide a more realistic test, because the driver is able to choose how frequently to look at the IVIS. However, although there has been little research into the driver paced occlusion technique, it would be expected to produce more variable results as the participants have an element of choice. This in turn would require a larger sample size and result in a more complex assessment.

Lansdown et al. (in press) discuss how user paced occlusion intervals might work, suggesting that users might initiate viewing times after an occlusion time of at least 2 seconds.

4.3.2 Interval variability

Intervals can be fixed, varied systematically or varied by the user (variable). Fixed intervals have the same duration throughout the experiment. Variable intervals are flexible
and the user/driver determines the length of the intervals according to the demands of the tasks. Intervals that are systemically varied (or fixed from a distribution) are varied in a repeated pattern. For example Krems et al. (2000) used a vision interval that was varied systematically between 0.2 and 1.2 seconds with a fixed occlusion interval.

The advantage of user interval variation is increased natural behaviour but at the expense of complexity and undertaking an additional task (see above). The argument for a fixed interval is based on simplicity and the arguments against it are:

- **a** A fixed interval may disfavour certain tasks, e.g. those that require individual operations of a length just more than half a vision interval. It will be possible to do one operation but not two and the remaining part of the vision interval, after the first task, is wasted.
- **b** There is a possibility of drivers engaging in rhythmic behaviours by anticipating the opening and closing of the shutter. No evidence for this has been found.
- **c** Certain in-vehicle displays with dynamic displays (e.g. Trafficmaster) provide information in rhythmic cycles. It is anticipated that occlusion results will be very sensitive to the vision interval and the system display cycle.

### 4.3.3 Interval length

The length of the occlusion and vision intervals can be varied according to the investigator's requirements. Several research studies have compared different interval lengths in order to find the most appropriate vision/occlusion intervals (Weir et al., 2003; Hashimoto and Atsumi, 2001; Karlsson and Fichtenberg, 2001; Fichtenberg, 2000).

#### 4.3.3.1 Vision interval

**Investigating inspection times to carry out IVIS tasks**

Resulting from driving studies, many guidelines recommend 1.5 or 2 seconds for inspection times. Chiang et al. (2001) conducted an on-road study (not using occlusion) measuring the eye movements of drivers when entering the destination into a navigation system. Display fixations were measured as below 2 seconds for 94% of the time. However the transition time needs to be added to this figure for it to be equivalent to shutter open times. So although the tasks in this study required a greater amount of time to complete than recommended, Chiang et al. (2001) claimed that they were suitable for driving as they did not take the drivers eye of the road for longer than 2 seconds. Chiang et al. (2001) supported this argument with the finding that the observed rate of lane exceedences was similar to that taken during a baseline study.

Tijerina et al. (1998) found that without occlusion but whilst driving, mean average glance durations were higher for dialling a number on a mobile phone (over 3 seconds) than destination entry on different navigation systems (above 2.5 seconds).

**Determining appropriate inspection times**

The ideal vision interval would be short enough to represent a time that would not interfere with normal driving but long enough to be able to perform an IVIS task.

Zwahlen et al. (1988) showed that for safety reasons drivers should not be distracted from their driving task for longer than two seconds. Therefore recommending that a single interaction time should not last longer than 1-2 seconds. Similarly, Hoedemaeker and Kopf (2001) found that drivers could tolerate an average occlusion time (eyes off the road/ IVIS inspection time) of 1.5 seconds during a normal car following situation. Further, Morita et al. (1998) found that when observers look at a display for a duration that they are comfortable with whilst driving, the average total time spent, from moving their vision to the display, looking at the display and returning their vision to the driving scene is 1.38 seconds.

Some occlusion studies have considered the most appropriate inspection or shutter open times to use when applying the occlusion technique, in relation to their reflection of actual driving. Hashimoto and Atsumi (2001) conducted a study investigating the visual distraction of four different types of navigation systems in a real road environment and using the occlusion technique. The study investigated a number of different occlusion shutter closed and open times. The shutter open time found to correlate most with actual glance times was reported as 1.5 seconds.

Weir et al. (2003) investigated time looking away from the road whilst driving in a driving simulator using occlusion goggles. Occluded periods, which transfer to inspection times using an IVIS, of above 2.5 seconds were found to degrade driving performance in terms of lane keeping. Similarly, the subjective ease of carrying out the driving task decreased above 2 seconds. Weir et al. (2003) suggested that visual intervals of 1.5 seconds or greater allow satisfactory secondary (i.e. driver interface) task performance.

MILT, AAM and ISO have converged on 1.5 seconds as a suitable vision interval. These results unanimously suggest that the occlusion vision interval should be between 1.5 and 2 seconds. Based on such research findings, Lansdown et al. (in press) state that the viewing time should be no longer than 1.5 seconds given that the test is intended to identify overly distracting tasks.

**Inspection times commonly used in past occlusion studies**

As a result of findings that inspection times exceeding 2 seconds impact on driving performance, many research studies have used inspection times of 1 to 2 seconds during occlusion studies. Noy et al. (in press) used inspection times of 1.5 seconds during their investigations of the occlusion technique. Weir et al. (2003) found that with inspection times or occlusion goggle open times of 1 second a high rate of no system entries, for a particular in-vehicle task, occurred. This no entry rate diminished to a negligible level for open times greater than 1.5 seconds. In line with this, the ease of doing the task was rated as significantly lower for 1s open times.

Keinath et al. (2001) used fixed presentation times ranging from 0.2 to 1.0 seconds during their occlusion experiments, claiming them to be acceptable times for taking the eyes off the road. Interestingly, inspection times were the same for tasks that were solved correctly and incorrectly. An explanation was given that participants reached a time threshold and stopped the inspection of a display even if the information was not gathered completely.
Not surprisingly, Krems et al. (2000) found that the probability of making a mistake on a task decreased as inspection times increased, when considering inspection times between 0.2 and 1.2 seconds. They also described a study in which inspection times of 0.2, 0.3 and 0.4 seconds were compared. The probability of errors was lower for simple compared to complex tasks, but for all tasks the probability of error increased as the inspection times decreased. In a further study described by Krems et al. (2000) it was found that even with inspection times chosen by participants, the occlusion technique can distinguish between simple and complex tasks.

Finally, Baumann, et al. (in press) (Experiment 1) conducted a study investigating destination entry tasks for a navigation system. Shutter open times of 1.5 seconds were used in this study. They reported that tasks were significantly degraded in performance when they were interrupted and some tasks that are not interruptible, may not be suitable for driving. The occlusion technique can distinguish between interruptible and non-interruptible tasks. However without comparing driving performance measures in a driving environment it is not possible to conclude, from these studies that distinguishing between tasks is the same as distinguishing between acceptable and unacceptable behaviour.

4.3.3.2 Occlusion interval

Frequently used occluded intervals (OCCLT)

OCCLT stands for the occlusion time or the time for which the scene is occluded in a single sequence. This can be a constant value, like 3 seconds, or it can follow a certain distribution, like a normal-distribution with a mean of a constant value, like 3 seconds, or it can follow a certain distribution, like a normal-distribution with a mean of 3 seconds and a standard deviation of 0.1 second.

Occlusion intervals between 1-6 seconds have been investigated in the literature. Baumann et al. (in press) conducted a study (experiment 1) investigating destination entry tasks for a navigation system during which occluded times of 3 seconds were used. Krems et al. (2000) used an OCCLT of 500ms during their study investigating the validity of the occlusion technique. Noy et al. (in press) used occlusion times of 3 seconds during their investigations of the occlusion technique. Finally, Monk et al. (2002) used occluded periods of 3, 8 and 13 seconds and during these interruption periods participants were required to carry out a primary task, providing them with cognitive loading (a tracking task).

The most recent ISO draft standard (ISO N3XX 2002) recommends an occlusion interval of 2 seconds, while AAM(2002) and Japan MLIT recommend 1 second.

Studies investigating varying occluded intervals

Some research studies have specifically investigated whether different occluded periods affect the findings of the occlusion studies. Karlsson and Fichtenberg (2001) investigated the effect of varying occlusion intervals on TSOT. They considered 4 OCCLTs: 1 second, 3 seconds, 4 seconds and 6 seconds, all with and INSPT (shutter open time) of 1.5 seconds. There was no significant difference between the TSOT for the different OCCLT suggesting that the length of OCCLT is not a significant factor that needs to be controlled during occlusion experiments. However it should be noted that the OCCLT will affect the total task time (TTT). There was a tendency for the TSOT to be higher with an OCCLT of 1.0 second. It is suggested that this could be a result of the reduction in thinking time and that with longer OCCLTs the operator has more time to think and act. A greater contributing factor was suggested to be the computational interruptions of the system (when the system is doing a calculation and it is not possible to operate it). With a short OCCLT the operator is more likely to encounter a computational interruption.

Karlsson and Fichtenberg (2001) noted that since the TSOT was always less than the static total task time (TTTstatic) (i.e. TTTstatic:TSOT is 1:<1), the tasks involved in the study were all chunkable. As a result there was no reason for the different OCCLT to affect TSOT. However, if tasks that were not chunkable were assessed using occlusion, variations in OCCLT may affect TSOTs. This was confirmed by a second study conducted by Fichtenberg (2001) in which less chunkable tasks were considered. The results of the study indicated that for tasks that are difficult to chunk, the ability for a person to perform these tasks is negatively affected by increasing the occlusion interval time. The TSOT increases with the increase in OCCLT while the accuracy decreases. It is easier to lose point of focus on the screen when the OCCLT is longer, therefore shorter OCCLTs are required for higher accuracy.

Weir et al. (2003) also investigated the effect of different occluded periods finding relatively little effect for varying occluded times. The error rate tended to increase a little with closed time and was largest for the 4 seconds closed time (the longest closed time). A broad range of closed times have been found to be acceptable, however in this study participants were shown to have a preference for occlusion intervals of 1 to 3 seconds.

4.4 Handling of system response time

An in-vehicle information system is often required to process information once the driver has added data. This processing may take some time. This is time where the driver cannot use the IVIS so would be expected to look back at the road and continue driving. If the IVIS does not indicate it is ‘busy’ or does not indicate when new data is available, then long driver glances and increased frustration can be expected. However, assuming that the IVIS is suitably designed with these features, the occlusion technique should account for ‘IVIS response times’ because the IVIS is not likely to be distracting during this time. Karlsson and Fichtenberg (2001) investigated the effect of changing the length of the occlusion interval on TSOT. Their results showed that the 1-second occlusion interval significantly increased TSOT compared to the 3, 4 and 6 second occlusion interval. They suggested that this was most likely to be due to ‘computational interruption’ (i.e. when the system is performing a calculation and unable to have data input). The authors suggested that when using the occlusion technique, it is much more likely that a driver will encounter a computational interruption.
during the vision interval, if the occluded interval is only 1 second. They found that the interruptions were rarely more than 2 or 3 seconds.

It must be remembered that TTT is (by definition) the Total Task Time. It is the actual time taken by the driver to complete the task (TTToccl similarly in occluded conditions). Also, TSOT is defined as the total shutter open time and so should be the value recorded by the measurement.

The literature does not conclusively agree on how to deal with system response delay. One way may be to subtract the total response time from the TSOT or TTT measure, as the driver was likely to be performing driving tasks during these periods. However as can be seen from the discussion below this is not necessarily a simple calculation (Figure 1).

Similarly the TSOT is ‘not really’ 4.5 seconds because during the second vision interval the subject couldn’t do anything.

So, in terms of assessing Visual Demand, these parameters are not quite right when the driver is ‘idle’ for part of the time – waiting for the system. Another solution could be to calculate new parameters relevant to the driver’s visual demand:

- (Net Total Task Time) \( NTT = TTT - \text{System Response Delay (SRD)} \)
- (Net Total Task Time) \( NTToccl = TTToccl - SRD \) (Occluded)
- (Net Shutter open time) \( NSOT = TSOT - SRD \)

Then, NSOT is the relevant parameters to be compared with reference data. However, even this correction is simplistic.

In fact, two different situations can arise when calculating NSOT (Net Shutter Open Time) (Figure 2).

In ‘Situation 1’ (Figure 2a), the system calculates during an occluded period and there is therefore no influence on visual demand. Both the TSOT and NSOT equal 3 seconds.

In ‘Situation 2’ (Figure 2b) the system calculates during a vision period, and the subject has only 1 vision period to complete the task. In this situation the TSOT is 3 seconds and the NSOT is 1.5 seconds (note that NSOT is not equal to TSOT-SRD because only 1.5s of the SRD occurs during an open period).

The main difficulty is to evaluate the part of system response delay occurring during a visual interval, because in reality a scenario similar to that presented in Figure 3 is likely to occur.

In this situation (Figure 3) the TSOT is 3 seconds but it is unclear what the NSOT should be, because it is difficult to practically measure the delay when the end of the delay is somewhere in the middle of the shutter open period.

It has also been suggested (within ISO WG) that a comparison with a baseline situation without occlusion solves these problems, as the system delay is the same with and without occlusion. See Section 5.4 for a discussion of the ratio parameter R.

4.5 Participant selection

Participant selection is an important aspect of any study because if the participant sample is not appropriate the results of a study are likely to be misleading. Therefore, when selecting participants for occlusion research factors likely to be important include age, gender, experience and visual ability of the sample. A large variety of samples have been used in occlusion research. However few studies explain the reasons for their choice of participants. The important factors for participant selection for the occlusion technique are discussed as follows.
4.5.1 Age

Age is a surrogate for a range of human capabilities. Older drivers have different sensory, physical and psychomotor abilities, which is likely to affect how they adapt to and interact with new IVIS. For example, the elderly require increased ‘thinking time’ to carry out a task due to a decreased short-term memory and information processing capacity (US Department of Transport Report, 1997). This may have implications in terms of how quickly the elderly learn to use in-vehicle information systems. Age also affects the accuracy and speed of precise physical movements. Elderly drivers are therefore likely to take longer to complete an IVIS task successfully. Further, the elderly have reduced perception and attention abilities. Elderly drivers may therefore be less likely to detect a dangerous situation if they are absorbed in an IVIS task. Age is also commonly known to have an affect on visual capabilities (Schieber, 1988-1994), which may effect their ability to use IVIS (refer to Section 4.5.4 for a more detailed discussion on visual ability). Age affects an individual’s ability to change focus (Schieber, 1988-1994). This is likely to have implications on the length of time a task takes due to a greater transition time.

A small number of occlusion studies have compared participants of different ages. Curty et al. (2002) investigated occlusion with two age groups (middle age: 45-55, older: 56-65). The results showed that older age groups used a greater number of glances to the IVIS to complete the task and took more time looking away from the road to complete the task. Therefore tasks that require several glances are even more difficult for elderly participants than for younger participants. Additionally for any one task, an older person is likely to spend more time looking away from the road when driving compared to a middle-aged or young person. Other research has shown that older participants (>40) reported greater subjective mental and physical demand than younger participants (<30) (Karlsson and Fichtenberg, 2001). On the contrary other research has suggested that there is no difference in navigation task completion time between older (mean 65) and younger (mean 22) participants while there is a difference for very brief tasks such as the answering the phone and tuning radio volume (Goujon et al. 2001).

The American Statement of Principles (AAM, 2002) and SAE Standard (SAE J2364, 2000) both only use participants aged between 45 and 65 years. This is possibly based on the assumption that if a system is found to be acceptable for this age range, who are not used to using new technology, it is likely to be acceptable for all other age-ranges. Therefore this is a near worst case scenario. However it can also be argued that the above age range are the safest drivers on the road per kilometre travelled and may be able to divide their attention, between the primary driving task and IVIS, better than younger or very elderly drivers. If this is the case, IVIS systems may be less acceptable for other users than 45-65 year olds. The accommodation/transition time problems with older drivers discussed above needs to be further researched (in the context of occlusion) because if older drivers are used as participants in standards and research it will have a significant effect on occlusion findings.

A complete range of ages would be expected to use in-vehicle information systems. The advantage of using a wide range of ages to assess an IVIS would be that the entire population was represented, including elderly participants. It is clear from the discussion above that elderly drivers are likely to respond to IVIS quite differently to younger drivers. Further, older drivers are less familiar with technology and have often been regarded as less accepting of technology changes. However the problem with using a wide range of ages is that there is likely to be a wider spread of responses so a larger sample size would be required to obtain valid results. So one ‘solution’ is to use a homogeneous group, such as 25-35 years, and set the acceptable distraction limit accordingly lower (to account for the more elderly drivers). However this idea would require research before such a method could be verified.

4.5.2 Gender

In a number of studies, driving and behaviour characteristics have been found to differ between male and female drivers, as well as factors like accident involvement, hospitalisation, traffic rule violations etc (e.g. Zhang, et al., 2000, Laapotti and Keskinen, 1998). This has implications for how males and females react to IVIS.

The majority of occlusion research has used a mixed gender sample. Some research has shown that when IVIS are used under occlusion, females report greater subjective physical demand than males (Karlsson and Fichtenberg, 2001). Karlsson and Fichtenberg (2001) suggested this may be because females have smaller hands and therefore find it more difficult to reach the in-vehicle information system controls. However, further research is required in order to understand fully the difference in visual distraction caused by IVIS between males and females.

The advantage of choosing a mixed gender participant group is that the sample is more representative of the population that will be using IVIS and currently it is difficult to predict which gender group is likely to be most distracted when using IVIS. However, using a mixed gender is likely to increase the variability of the results, which in turn would increase the sample size required to obtain valid results.

4.5.3 Experience

The driving experience of participants is not thought to be an important factor in participant selection for the occlusion technique, as it does not involve a driving task. However it is only the ‘driving’ population who will use IVIS, hence the occlusion technique should use participants who have a valid driving licence.

Noy et al. (in press) used participants with specific driving experience. They chose participants with greater than 1500 miles/year experience because their study aimed to investigate driver performance during occlusion rather than using the occlusion technique to assess IVIS. Chiang et al., 2001 found that drivers used in their study did an average of 13,400 miles/year (21,600 km/year).
The experience of participants in using IVIS is another aspect that needs to be considered in the sample selection. The majority of studies that specified this level of detail used participants with little experience of IVIS. The studies do not explain the reason for this choice and this review did not find any studies which have compared the occlusion technique for inexperienced and experienced users of IVIS. It is likely that participants with little IVIS experience have been chosen in these studies so that they learn the system and are not expecting the IVIS to work in a particular way, and all participants have a similar training and exposure. This helps the results to be more consistent.

However in the future as IVIS become increasingly popular the majority of drivers would be expected to have experience with IVIS. Therefore if selection criteria demand little or no experience of using systems then recruiting may be more difficult. In addition to this, the training participants are given should ideally be designed so that they are equally competent at using the IVIS in question.

### 4.5.4 Visual ability

Individuals’ visual abilities can be measured both by their visual acuity and contrast sensitivity. The level of visual acuity differs between individuals. Poor acuity results in a fuzzy appearance of objects. Acuity has an obvious relationship with vision quality and as it is fairly simple to measure, has been used as the criterion for measurement when applying for a driving licence. Acuity tests the optics of the eye (the ability of the eye to focus on an image) and is therefore a measure of quantity and not quality of vision. The standard driving test requires that drivers have 20/20 or corrected vision. Drivers who are short sighted (i.e. poor long vision) are required to correct their vision when driving. Drivers who are long sighted (i.e. poor near vision) are not always required to wear glasses when driving. This is because perfect near vision is not essential for driving tasks. However if IVIS have small text which appears on close screens, drivers with poor near vision may have problems reading the display. Refer to Section 4.5.1 for a discussion on the effect of age on visual performance.

Most of the occlusion research has not specified the visual ability of the participants so it is assumed that they used a sample with 20/20 or corrected vision. The participants selected by Morita et al. (1998) were required to have normal colour sense as the participants were required to react to brake lights. The participants selected by Goujon (2001) were required to have perfect vision. It is not realistic to expect that all people using IVIS will have perfect vision. But all users will have passed the driving test. Therefore it could be recommended that the occlusion technique uses participants with 20/20 or corrected vision.

### 4.6 Training

Training that is provided to participants before they begin a trial can significantly affect the results of a study. The training that should be provided to participants before a study will depend on the aims of the research. If occlusion is being used to assess the ease of learning an IVIS then limited training should be provided so that differences can be seen as the participants’ experience increases and the speed of learning can be ascertained. However, if the occlusion technique is used to assess the ease of use, the aim of training would be to familiarise the participants with the activities/task that will be undertaken throughout the study such that the participants do not have learning effects during the trial. If a participant is still learning how to complete a task/activity the results of the study may be unreliable and misleading. Several different types or combinations of training have been provided in the occlusion literature (as can be seen in Appendix B). To our knowledge no research studies have compared results when participants were trained differently. Therefore, the effects of differing levels of training currently remain unknown.

Several research studies provided the participants with instructions including:

- providing participants with the manual for the IVIS;
- providing verbal training (from experimenter) on handling the IVIS;
- providing a demonstration (from the experimenter);
- providing instructions on mini TV.

In a number of studies, after some form of instruction, participants were provided with practice trials of the tasks they would be performing during the study. Some research only provided practice trials and did not detail any prior instruction. The form of practice trials that have been used in the literature include:

- providing a certain number of practice trials (2, 3, 5, 12 trials);
- providing practice until a specified number of consecutive successful trials are complete (2);
- providing practice until a consistent rate of task completion is achieved.

Some research studies provide a range of training. For example Chiang et al. (2001) provided the training manual to be reviewed by participants. Following that they provided introductory verbal instructions and allowed 5 practice trials, 3 parked and 2 driving. Likewise Tijerina et al. (1998) provided time for the participants to familiarise themselves with the navigation system and then allowed 12 practice IVIS destination entry tasks. However, other research papers simply provided time for practice (Niiya, 2000) or do not detail any training (Krems et al., 1998; Morita et al., 1998; Curry et al., 2002).

It is clear that different individuals will have different training requirements, so a training process that tests consistency and allows for participants with different abilities to reach the same level is likely to lead to more consistent results. Therefore, the latter two practice trial methods bulleted above would be advantageous; however, they may require more time. The authors who have tried these methods have not commented on the time required. No research in this review assessed the number of times an IVIS task is required to be repeated by a range of participants until consistency is achieved. Research of this nature could be used to pick the number of repeat trials that is appropriate for different IVIS tasks.
4.7 Experimental design

A repeated measures study design has been used in much occlusion research (Fichtenberg, 2001; Goujon, 2001; Hashimoto and Atsumi, 2001; Krems et al., 2000; Monk et al., 2002; Niiya, 2000; Noy et al. (in press); Weir et al., 2003). In repeated measure designs each research participant provides data for all of the levels of the independent variable. These designs are characterised by having more than one measurement of at least one given variable for each participant. A repeated measures design assumes that since the participants are the same for all conditions, and all other variables are controlled, any difference in results will be due to the effect of the independent variables. This design can also be referred to as a ‘within subject’ or ‘within group’ design, since differences in participants have been eliminated as the source of difference.

The primary benefit of a repeated measure design is that order effects may result. This means the participants may improve or be less anxious on the second task. Several of the occlusion study designs documented accounted for this by counterbalancing or randomising the order of tasks in order to eliminate order effects (Baumann (in press); Chiang et al., 2001; Goujon, 2001).

Another disadvantage of the repeated measures design is that if each participant experiences all conditions, a slightly different task would have to be used for each condition so that they had not been exposed to the same task twice. For example, if the task was entering the destination into a navigation system, different destinations would need to be used for each condition. However, this creates a problem of choosing destination for each task which are equivalent.

Independent sample designs have also been used in the occlusion literature (Baumann et al. (in press); Curry et al., 2002; Tijerina et al., 1998). Under this experimental design an entirely different group of people are involved in each condition (there could be two conditions or more). This experimental design may also be referred to as ‘between subjects’, ‘between groups’ or ‘independent groups’. In occlusion research, independent sample designs have been used to compare different participant groups, such as the elderly versus the young.

The advantage of an independent samples design is that exactly the same task can be used for the two participant groups and no learning effects will be present. The disadvantage of an independent samples design is that variations among participants may be unevenly spread across the participant groups. However, it is possible to reduce the likelihood of participant variations. The participants can be randomly allocated to the conditions, a pre test can be conducted to see if both groups are similar before the conditions are applied and the investigator can ensure that each group has representative allocation (i.e. male versus female, young versus old etc.).

A typical occlusion study design may actually incorporate mixed measures where two independent groups repeat the same selection of IVIS tasks.

4.8 Number of tasks and repetitions

The number of tasks used in occlusion research studies depends largely on the aim of the research. The number of tasks used ranges from 1 to 15 in the studies that have been considered in this review. When assessing an IVIS, the advantage of using a large number of tasks is that the IVIS is fairly reviewed on several of its capabilities. The disadvantage of assessing a large number of tasks is the associated increased cost and time involved. However, to fully assess an IVIS, its whole functionality would need to be incorporated in the assessment.

The number of repetitions of a task under each condition is another important aspect of study design. In the occlusion literature the number of repetitions ranges from 1 to 10. The advantage of using a large number of repetitions for each task is that the results become more reliable and have greater statistical power. The disadvantage of using a large number of repetitions is that as the number increases, the time and cost involved also increase.

4.9 Sample size

The number of participants that are used in a study will usually vary depending on the number of conditions being tested and the expected variability in results. If results are expected to be variable a larger sample size needs to be used. From the occlusion research reviewed the sample size varied from 10 participants up to 60. However the majority of studies used a sample size of between 20 and 30 people. The advantage of using a large sample size is that a wide variety of the population can be assessed and the results have greater statistical power and reliability. However using a large sample increases costs.

4.10 IVIS tasks studies

A primary task is one that is of greater importance than a secondary task when a person is required to multi-task. For example when driving the primary task should be driving in a acceptable manner, while the secondary task may be using an IVIS. However in an occlusion study, the primary task would be completing IVIS tasks and a ‘distracter’ task or non-active period would represent the secondary task. See Figure 4 for a diagrammatic explanation.

<table>
<thead>
<tr>
<th>Normal driving</th>
<th>Occlusion measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Task</td>
<td>Driving</td>
</tr>
<tr>
<td>Secondary Task</td>
<td>IVIS</td>
</tr>
</tbody>
</table>

Figure 4 Diagrammatic explanation of primary and secondary tasks.
A large variety of primary and secondary tasks have been investigated in the occlusion literature depending on the aim of the research and choice of the researcher. The range of tasks are listed below:

- Navigation tasks – destination entry, data entry, visual search, understanding scrolling text.
- Telephone tasks.
- Air conditioning tasks.
- Radio tasks.
- Stylised maps – deciding routes linking two destinations.
- Stylised telephone lists – i.e. looking for numbers corresponding to names.
- Continuous tracking task.
- VCR task.
- HMI generic alphabet entry task.
- Tasks occasionally accomplished by drivers (e.g. unwrapping sweets).

Radio tasks have frequently been used in the literature as a ‘reference task’ because radios have been accepted within vehicles for many years. This suggests that if a radio task meets a certain assessment criteria then an equally distracting IVIS task should also meet it. However, some TRL research has shown that not all radio tasks are acceptable (Reeves and Stevens, 1993).

IVIS tasks are frequently categorised as either simple or complex. Tasks that involve visual searches, scrolling maps or reading scrolling text have been described as complex tasks (Baumann et al. (in press); Noy et al. (in press)) as they are not easily chunkable. Krems et al. (2000) compared simple and complex tasks using predefined presentation periods by screen blanking. They used stylised map displays (Figure 5a) where for the simple task the subject was required to indicate the shortest path that connected point A and point B, by pressing a button. In the complex version 3 paths were displayed starting at point A (Figure 2b). The participants were required to decide the shortest route to connect A with B, by pressing the associated direction key. The complex version of the task required the whole display to be completely searched followed by a cognitive comparison.

Krems et al. (2000) also used simple and complex stylised telephone lists to look at display continuation at different levels of complexity after the interruption. The stylised telephone lists contained a vertical list of 5 names each with corresponding telephone numbers (Figure 6a). One of the names had a box around it and the box changed position a total of 4 times. During the experiment the participants had to determine the name in the box and the corresponding telephone number. In the simple task the name to be found was predictable after every interruption, i.e. the change of position followed a clear pattern. In the complex task, the position of the name to be found varied between all positions at random.

<table>
<thead>
<tr>
<th>Name</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steffen Laufer</td>
<td>3092</td>
</tr>
<tr>
<td>Maja Lader</td>
<td>4803</td>
</tr>
<tr>
<td>Uwe Falke</td>
<td>2775</td>
</tr>
<tr>
<td>Olaf Pester</td>
<td>3201</td>
</tr>
<tr>
<td>Deiter Gerlich</td>
<td>3135</td>
</tr>
</tbody>
</table>

Figure 6 (a) Simple stylised telephone list, (b) complex stylised list, used by Krems et al. (2000)

4.11 Primary/loading tasks

In the majority of research participants do not undertake a task during the shutter close time. The authors of this review think that it is possible that, an occlusion technique that does not occupy a participant during the shutter close time might not reflect conflicting demands of the driving task. This is because in a real driving scenario, a driver is cognitively stimulated while looking at the road and analysing the ever changing road environment. The driver will have changed their focus and eye position from when they finished the last chunk of the IVIS, before returning to the IVIS at an appropriate time to complete the task. This also suggests that the driver may be unable to process the ‘secondary’ IVIS task whilst looking at the road. During occlusion, if the driver is not performing a task during the shutter close interval, the issue of eye position, fixation and focus may have some relevance (Lansdown et al. (in press)). This raises the question of whether a simulated driving task or ‘distracter task’ is necessary during the occlusion interval.

A simulated driving task performed during the occlusion interval would significantly increase the cost and complexity of the occlusion technique. This is not desirable as the technique is hoped to be suitable for testing IVIS at the design stage. Little research has been conducted looking specifically at distracter tasks. Monk et al. (2002) used a continuous tracking task in between the primary IVIS task. However Monk et al. were using a blanking occlusion technique where it was more feasible to conduct a secondary task. They used two tracking tasks, one easy and one difficult but commented that neither task seemed sufficiently difficult to distract the driver from processing on the IVIS task. It was found that the tracking task difficulty led to longer total task times. This has
implications for the cognitive loading of the driving task in comparison to doing nothing during occluded period. The issue of participant cognitive loading during occluded periods needs to be addressed. Without a valid and reliable benchmarking procedure or distracter task, it could be argued that occlusion can only be used for making relative judgements between completing systems.

5 Performance measures used in the literature

A number of different performance measures are used to ascertain the visual loading imposed by an in-vehicle information system, including both the occlusion technique, and also driving measures which can be taken in an instrumented vehicle, in a driving simulator. This section presents the measures used during occlusion research, including inspection times, occlusion times, total shutter open times, total shutter closed times, total task times, ratios between total shutter open times and total task times, the number of glances and task errors. Findings from the research are presented along with a discussion of possible appropriate reference values as a result of research. The implications of this research, in terms of the effectiveness of occlusion as a measure of visual distraction, are also considered.

5.1 TSOT

5.1.1 Recommendations for TSOT or TGT

TSOT stands for total shutter open time or the total amount of time (sum of all sequences), with the shutter open, taken to complete a task. TGT is the total glance time or the total amount of time spent glancing at the system while completing the task. TSOT has been shown to be almost equal to TGT while the vehicle is in motion (Niiya, 2000). This allows TSOT to be used as an alternative measure to TGT. This is beneficial as TSOT is much more economical to obtain. This finding indicates that a distracter task during the occlusion technique may not be as necessary as suggested in Section 4.11.

The MLIT guidelines state that the TSOT from start to end of control should be less than 7.5 s (ISO N366 JAPAN-MLIT), with an occlusion interval of 1.0 second and a vision interval of 1.5 seconds. Hashimoto and Atsumi (2001) made a recommendation based on their study that a TSOT of around 7 seconds is a good criteria for evaluating and extracting the interactions with IVIS visual displays that require long periods of visual attention or frequent glances.

The European Statement of Principles recommends that a task should take no more than 4 glances, with maximum glance duration of 2 seconds. The total glance time recommended is therefore implied as 8 seconds. The American Statement of Principles (AAM, 2002) recommends a mean average glance duration of less than 2 second for 85% of the sample and a total glance time of less than 20 second for 80% of the sample.

The above recommendations (JAPAN-MLIT, European Statement of Principles and AMM) can be criticised in that the TGT or TSOTs recommended would not allow certain tasks, that have been found not to adversely influence driving performance, pass their criteria. The problem with TSOT and TGT as measures for assessing IVIS is that they imply that if the values are high then the IVIS is not acceptable to use while driving. However, if the task is very chunkable it could be argued that the TGT is not important as long as each glance is only short. It must also be noted that the value of TSOT will vary when different vision/occlusion intervals are used. This highlights the importance of standardising interval length if the occlusion technique is to be used to assess the acceptability of IVIS. It should be noted that the risk of a ‘false alarm’ must be weighed up against the benefit of correct detection of a poorly designed driver interface.

5.1.2 Investigating TSOTs to carry out IVIS tasks

A number of occlusion studies have provided a set of data on the TSOTs for carrying out IVIS tasks. Baumann et al. (Experiment 1 (in press)) observed an average TSOT of 31.0 seconds over a number of destination entry tasks of differing lengths (5-8 inputs, 9 to 11 inputs and 12-13 inputs). This TSOT exceeds all the above recommendations.

Goujon (2001) conducted a study comparing IVIS tasks with and without occlusion goggles in a static vehicle environment. For some tasks such as answering the telephone and adjusting the radio volume TSOTs of less than 7.5 seconds were observed. For other tasks such as destination entry into a navigation system TSOTs greater than 7.5 seconds were observed. These results comply with the current MLIT guidelines and proposition that destination entry tasks are unsuitable to carry out whilst driving.

A number of studies have examined the TSOT required to complete IVIS tasks and found that they seriously exceed all or most of the recommendations that have been made (Baumann, et al. (in press); Fichtenberg, 2001; Hashimoto and Atsumi, 2001; Karlsson Fichtenberg, 2001; Niiya, 200; Noy et al. (in press)).

5.2 TTT

TTT stands for total task time or the total time taken to complete a task.

5.2.1 TTT (occluded/dynamic/static) as a measure of task acceptability

TTT(occluded) is the total amount of time it takes to complete a task under conditions of occlusion. It therefore includes the occluded intervals as well as the vision intervals when the user can interact with the system. TTT dynamic is the total task time measured while driving and TTT static is the total task time measured while not in motion. All three of these TTTs are potential candidate measures of task acceptability. This section describes research examining the relationship between these measures.

A number of studies have found occluded TTT to be correlated with static and dynamic TTT, suggesting that the occluded measure is valid as a surrogate for TTTdynamic. Baumann et al. (Experiment 1 (in press)) found that although more time was needed to complete the
task in the driving condition than in the occluded condition or the static condition where the task was carried out without occlusion or driving, there was a strong correlation between TTT static, TTT occlusion and TTT driving. The study states that using a scaling factor, the time to complete a task was more similar during occlusion and driving than during non-occluded static and driving.

Similarly, Farber et al. (2000) suggested that TTT measured statically is well correlated with dynamic TTT and that it can be used as a surrogate for total glance time (TGT), which is a much more time consuming, inconvenient and expensive measure. Similarly, Curry et al. (2002) found TTT as dynamic to be highly correlated with TGT. TGT is a widely used measure of visual demand. Curry et al. therefore claim that dynamic TTT is an appropriate surrogate of TGT.

Curry et al. (2002) compared TTT in dynamic, static and mock-up situations, finding that TTT measured in a static mock-up could be a valid predictor of driving performance. This was based on the finding that TTT was correlated with TGT and that TGT was correlated with the number of lane violations in the driving study.

5.2.2 Recommendations for TTT
Different authors have different opinions of when a task is ‘too long’ to carry out whilst driving. The majority of recommendations refer to the TTT static, which is the time taken to complete the task only, without driving or any other simultaneous task. The guidelines developed by Battelle for FHWA (Campbell et al. 1997) supported restricted functionality when static task times exceed 10 seconds.

SAE 2364 (Standard for navigation and route guidance function accessibility while driving, 2000) states a design limit for TTT static for the presentation of visual information and the manual control inputs associated with navigation functions accessible by the driver while the vehicle is in motion. The TTT recommended is less than 15 seconds when carrying out the task statically.

Manufacturers (or designers) of in-vehicle systems vary in opinion; for example, destination entry is not allowed whilst driving in some navigation systems, whilst others have all options accessible whilst driving.

5.2.3 Static TTT as a measure of task acceptability
A criticism of TTT static as a measure of distraction is that it does not address how the task is performed, especially how it is chunked or partitioned. The ‘15-second rule’ implies that any task which can be performed statically in less than 15 seconds is acceptable to complete while driving. However, if that happens to be a task that requires an uninterruptible sequence of 15 seconds, that also required continuous visual attention then it is likely to pose a threat to safety! The counter-argument to this is that drivers’ sense of self-preservation limits the length of a glance away from the road. Tijerina et al. (2000) assume total task time and single interaction time to be fairly independent. Some tasks that take 15 seconds to complete may only require 2 second glances, whereas other tasks that take 15 seconds to complete may require 4-5 second

5.2.4 Investigating dynamic TTT for IVIS tasks
A number of research studies have investigated the TTT for completing IVIS tasks during driving and on-road studies. Chiang et al. (2001) conducted an on-road study (not using occlusion) measuring the eye movements of drivers when entering destinations into a navigation system. Dynamic TTTs of between 27 and 49 seconds were observed. However, the authors claim that this TTT is acceptable due to the interruptible nature of the task and this was supported by the finding that the observed rate of lane exceedences was similar to that taken during a baseline study.

Tijerina et al. (1998) investigated TTT dynamic whilst carrying out a number of IVIS tasks in combination with driving. They found that TTT was higher for destination entry tasks (between 70 and 120 seconds) than dialling a number or tuning a radio. Voice input was found to have lower dynamic TTT. This suggests that dynamic TTT can distinguish between tasks that possess different amounts of visual demand.

5.2.5 Investigating occluded TTT for IVIS tasks
A number of studies have presented TTT for IVIS tasks with occlusion and found that TTT is increased as a result of the occluded periods in comparison to static TTT.

Goujon (2001) conducted a study comparing IVIS tasks with and without occlusion goggles in a static vehicle environment. For a number of the tasks, such as destination entry and telephone number dialling, the unoccluded TTT exceeded the AAM recommendation of 20 seconds. During the occluded conditions this TTT was found to increase.

Karlsson and Fitchenberg (2001) found that tasks of lesser complexity passed the 15-second rule, whilst those of higher complexity (destination entry) did not, suggesting that the occluded TTT is able to distinguish between task complexity. As would be expected, the time to complete a task increased with the length of input, when considering input destination tasks with different destination lengths.
5.3 Resumption lag

Monk et al. (2002) indicated that within the inspection time, or each separate glance time, is a resumption lag time. This lag is the additional time it takes users to resume the task after having switched back from the interruption. They state that by measuring the resumption lag a more accurate explanation of total task times will be possible. Further, appropriate characterisation of the interruptability or chunkability of tasks can be quantified in terms of resumption lags. During their experimental work the resumption lags averaged just over 1.6 seconds. There were no differences between easy and hard conditions in resumption lag. It was suggested that this might have been due to the limited cognitive loading provided by the tracking task used during the occluded period. This indicates that resumption lags would not be different during the occlusion technique without an additional task, but that they might be during real driving.

It was found that the length of the resumption lag is dependent on the point at which a task is interrupted. It is better to interrupt a task before a new task has begun, or during a repetitive task like scrolling through a list. On the other hand, interrupting a task during the middle or at the end will result in longer resumption lags.

Resumption lags need to be accounted for when applying the occlusion technique. The vision interval must include enough time to re-evaluate the task before continuing progress. The best IVIS designs will minimise resumption lag by developing appropriate sub tasks. Research determining the resumption lag associated with returning to an IVIS task following a period of driving may be beneficial.

5.4 Ratio TSOT/TTT

5.4.1 Recommendations for TSOT/TTT

In order to estimate the portion of total task time (TTT) that is combined with visual attention to the task, the ratio TSOT/TTT is calculated. This ratio can be viewed as a rough measure of the degree to which a task can be done without visual control. The smaller the deviation from 1 the more visual attention is necessary for performing the task. Ideally the ratio should be much lower than 1.0.

5.4.2 TSOT/TTT as a measure of task acceptability

Research findings differ with regard the acceptability of this ratio for measuring task acceptability. Noy (in press) described this ratio as a ratio to calculate the chunkability index of a task (R). Noy reported that the occlusion paradigm successfully differentiated among tasks, in the expected way. A scrolling task had a higher R ratio than the static task, which in turn had a higher ratio than the radio-tuning task. Tasks did not differ in TTT, but the differences in R indicated differences in the chunkability of tasks. This implies that the inherent characteristics of a task, and not TTT, affect the chunkability indices.

However, other studies have reported conflicting findings. Goujon (2001) and Karlsson and Fichtenberg (2001) found the ratio to be very sensitive to the TTT value, rather than task complexity, and therefore criticised it for not indicating task complexity. Goujon stated that the measure was therefore not appropriate to determine visual distraction induced by the use of a system. The reason for the criticism is because tasks with a very short TTT (such as answering the telephone) have been shown to have a high TSOT/TTT ratio (Goujon, 2001; Karlsson and Fichtenberg, 2001). A high ratio suggests an unsuitable task, which is not the case if the reason for the high ratio is due to a very short TTT.

The research of Karlsson and Fichtenberg (2001) and Fichtenberg (2001) raises an important issue in the relationship between TSOT and TTT. Their work shows that the ratio is quite different for visual task than for a visual-manual task and furthermore the ratio varies due to the subjects’ ability to manipulate the control(s) during the occluded periods.

5.4.3 Investigating TSOT/TTT for IVIS tasks

‘Baumann, et al. (Experiment 1 (in press)) observed a TSOT/TTT ratio of 0.63 over a number of destination entry tasks of differing lengths (5-8 inputs, 9 to 11 inputs and 12-13 inputs).

5.5 Ratio TTToccluded/(TTT+Ttclose) also written TTToccl<1.25(Static+Ttoccl)

It is possible to make a few recommendations for the ratio, TTToccl/(TTT+Ttclose), based on the literature. This ratio is also a measure of the degree to which task completion is dependant on visual attention as it compares the static TTT to the occluded TTT, taking into account the time the display was occluded. If the ratio is high then it indicates that all of the time spent with the display visible is needed to visually process the display in order to complete that task and that the task is difficult to split into chunks. If the ratio is lower then it indicates that the task did not always require visual attention and is therefore likely to be less distracting than a task with a higher ratio. Ttclose/Ttoccl is the total time during task completion that the display was hidden from the driver.

The one study investigating this finding was not supportive of it as a measure of IVIS distraction. Karlsson and Fichtenberg (2001) found all tasks that they tested to be below the 1.25 mark, with the highest values coming from the least complex tasks of adjusting the brightness and volume. Further, all the destination entry tasks had similar values regardless of their complexity. This suggests that the ratio is not a good indicator of task complexity and questions its usefulness as a measure of task acceptability.

The ratio has been investigated as a measure of task acceptability. Karlsson and Fichtenberg (2001) did not find a difference between TSOT/TTT and TTToccl/(TTT+Ttclose). This indicates that the two ratios are similar in their nature and implies that the choice of ratio used in any standard is not of significance.

5.6 Total number of glances

The total number of glances has often been used as one element in recommendations for visual demand (e.g.
Zwahlen et al., 1988) The argument is that the longer that is spent looking away from the road, the greater the potential for missing an unexpected event. The time spent looking away from the road increases with each additional glance, so minimising glances is one way to increase driver vigilance. Zwahlen (1988) suggested 4 glances (of 2 seconds) as a recommended limit. However, in the occlusion literature there is less support for this single measure.

Chiang et al. (2001) stated that the total number of glance durations is not important and that values greater than 10 are acceptable. They stated, as has been stated in many of these studies, that what is more important is whether the task is chunkable.

5.7 Task errors

Task errors are often referred to as measures of performance whilst applying the occlusion technique and during a number of studies, performance on the task in terms of task errors, using occlusion, has been found to separate complex and simple tasks. However, no studies have alluded to the level of number of acceptable errors.

Keinath et al. (2001) used task errors as their primary measure of performance. They found that increased viewing times (shutter open times) led to fewer task errors and that the more complex the task the more errors. They therefore stated that the occlusion technique separates simple and complex tasks with either pre-defined or subject-paced inspection times.

Krems et al. (2000) described studies that used task errors as a measure of assessing performance on a task when validating the occlusion technique. They concluded that the technique indicated the interruptability of different tasks, indicating which displays make it difficult to continue dialogue following an interruption.

Finally, Noy et al. (in press) found that an unpredictable task produced more errors under occlusion than a more predictable and less complex task.

6 The validity of the occlusion technique

Studies designed to validate the occlusion technique have compared in-vehicle tasks with and without occlusion, and compare glance duration under static, dynamic and occluded conditions. Other studies that validate the occlusion technique compare task completion measures such as total task time with driving performance measures.

6.1 Comparison with static task completion and eye glance measures

A number of the research studies provided evidence supporting the occlusion technique, claiming it to be closely transferable to the results of real driving studies. Hashimoto and Atsumi (2001) carried out a study on occlusion techniques. The subjective ratings of uneasiness from their study showed that there may be a need for an upper limit on the number of interactions. The study showed that the Total Shutter Open Time (TSOT) has strong correlation with the Total Glance Time (TGT) as well as the Total Task Time (TTT). They recommended using the occlusion technique on a test bench instead of using equipped vehicles.

A trial carried out by Toyota (Niiya, 2000) showed that the occlusion technique can simulate visual recognition behaviour. Therefore, they also concluded that the evaluation for Total Glance Duration could be carried out on a test bench with use of the occlusion technique.

The occlusion technique has been shown to produce very similar eye movement measures to a simulated drive (’Baumann et al. (in press)). The above research findings suggest that occlusion parameters measured in a static mock-up using the occlusion technique is a valid predictor of driver distraction and driver performance. Therefore the authors concluded that the occlusion technique is a valid method to assess the visual demand of driver assistance systems.

Work carried out by Curry et al. (2002) supports the above research in indicating that task completion time measured statically (or on a mock-up) is well correlated with dynamic task completion times, and therefore, can be used as a surrogate for total glance time.

’Baumann et al. (in press) Experiment 1 observed that the number of errors was associated with the length of destination to be entered. The study states that using a scaling factor, the number of errors was more similar during occlusion and driving conditions than during non-occluded static and driving. This finding is therefore supportive of the occlusion technique over TTTstatic. The Goujon study found a relatively good correlation between TSOT and TTT and suggested further research should be conducted.

A further study carried out by Krems et al. (2000) used a computer display which could be turned on and off to represent different occlusion intervals. Their results showed that the occlusion technique can make a distinction between display designs of varying complexity. Krems et al. (2000) suggested that their finding demonstrated that the occlusion technique is a valid procedure for evaluating displays, but they concluded that further investigation is necessary. They mention that the technique would need to be tested outside the experimental laboratory for comprehensive validation.

Several research studies have shown that the occlusion technique set-up is advantageous to the 15-second rule when assessing IVIS. This is because the 15-second rule does not assess the ‘chunkability’ of the task. A chunkable task is one that can be broken down into small parts. A task could be completed within 15 seconds but it may not be possible to split it into several smaller chunks. This will have implications in terms of whether a task can be completed acceptably whilst driving.

6.2 Comparison with driving performance and safety

The work carried out by Goujon (2001) concluded that an isolated measure based on the ratio of Total Shutter Open Time or Total Task Time with occlusion is not appropriate to determine the visual distraction induced by the use of a system by the driver.

Relatively few studies have investigated driving performance measures whilst using IVIS in depth. Some
studies have investigated driving performance during occlusion to give information on the appropriate length of time that it is acceptable for drivers to look away from the road. In these experiments the conditions are reversed compared to ‘occlusion to test acceptability of IVIS’. The occluded interval in the driving performance occlusion experiments represents the time that drivers would spend completing IVIS tasks and looking away from the road. The vision interval is the time in which the driver is performing real (or simulated) driving tasks. In studies that use occlusion to test the acceptability of IVIS (i.e. majority of occlusion research) the closed interval represents the time in which the driver would be driving and the vision interval is the period where IVIS tasks are completed. Therefore when the driving performance occlusion studies talk about the closed interval it is equivalent to an open interval in the occlusion technique to assess IVIS.

Weir et al. (2003) (experiment 4) measured lane keeping performance while driving in a simulator using occlusion. A vision interval (driving) of 1 second with an occluded interval of either 1, 1.5, 2, 2.5, 3 or 4 seconds was used. The authors found that the results showed little difference in lane keeping performance as the occlusion time increased up to 2 seconds, but performance decreased as occlusion time increased to 2.5 seconds and greater. The performance measures used by Weir et al. (2003) indicated that if IVIS tasks can be completed within an occlusion experiment which uses an occluded interval of 1 second and a vision interval of between 1 to 2 seconds driving performance will not be significantly effected. Weir also suggested that the standard deviation of lane position is a more sensitive and useful measure of lane keeping performance than lane exceedence.

Noy et al. (in press) conducted a study to derive lane-keeping measures under dual-task conditions. Participants drove under 4 scenarios in a simulator, 3 scenarios involved an in-vehicle task and one involved only driving (baseline). The direction of road curvature differed in the 4 scenarios. During each scenario, the in-vehicle task was repeated in 30 second intervals until complete, but the participants were instructed that driving was their primary concern and to perform the secondary task at their own pace. The driving performance measures included standard deviation of lane position, number of lane exceedences, duration of lane exceedences and 15% time-to-line crossing. A significant decrease in driving performance in terms of standard deviation lane performance and number of lane exceedences was observed in the dual-task conditions when compared with the baseline but there was no difference in the duration of lane exceedence. There was also no significant difference in lane keeping measures under the different dual-task conditions. Noy et al. suggested that the reason for the lack of differentiation may be because there was no way to partition the data according to dual-task and single task episodes. This meant that driving performance could not be compared to task chunkability. Further research is required to determine the effect of different tasks on driving performance.

Tijerina (1998) used lane exceedence duration and the number of lane exceedences to investigate the workload of different route guidance systems and concluded that voice systems are a viable alternative to visual-manual destination entry while driving. Occlusion was not used and no reference to the validity of the occlusion technique was made.

Curry et al. (2002) conducted a study to assess eye glance behaviour measures and their relationship to surrogate candidates such as driving performance (lane keeping) and task completion times (static and dynamic). They found that TGT is highly correlated with the number of lane violations committed during a task. Hashimoto and Atsumi (2001) also found a positive correlation between TGT and lateral deviation. Experiments of this nature are extremely useful for determining the validity of the occlusion technique.

7 Developing a protocol

Based on the research discussed within this review the consensus situation is summarised in the tables on page 21.

8 Conclusion

Although previous work on occlusion is conclusive in some areas, a number of research questions remain unanswered. From detailed examination of this research it is possible to identify some appropriate parameters for use in a standard occlusion protocol. For example, a vision interval of 1.5 seconds and an occlusion interval of between 1 and 3 seconds appear to be most suitable. However, it is evident that there are a number of important factors that have not been fully explored in previous research, such as training, sample demographics, impact of primary distracter tasks and how to deal with system response delays. No studies have been found that directly compare results in a lab or ‘buck’ and a real vehicle. A study of this nature would provide interesting information. Also, no research in this review assessed the number of times an IVIS task is required to be repeated by a range of participants until consistency is achieved. Research of this nature could be used to determine the number of repeat trials that is appropriate for different IVIS tasks.

There is a clear need to determine the effects of these factors and to decide upon the most appropriate strategies for an occlusion protocol. Inconsistencies between these factors are likely to increase the variability between measurements.

From the discussions within the research it is evident that there is a considerable debate over how visual distraction should be measured using the occlusion technique (if the technique is to be used at all). In particular it is unclear how occlusion measures relate to driving performance and safety. Static TTT and TSOT are not appropriate single measures because they do not take into account the chunkability of the task. Tasks that have a very long completion time have been shown to be easy to perform when they can be completed in small ‘chunks.’ Ratio measures such as TSOT/TTT are promising, but are criticised because they are not independent of TTT and
therefore are very sensitive to its value. The ratio is less consistent for tasks that are less than a few seconds in length, but more consistent for tasks which have a TTT of 5 or more seconds. Therefore tasks that take a long time to complete are more likely to have a favourable ratio than more simple tasks. For different tasks, the balance between manual, visual and cognitive tasks are all different, which has implications on the relationship between TSOT and TTT. TTT static may provide a useful measure in conjunction with other measures such as mean glance duration. However, TTT dynamic as a lone measure does not indicate the chunkability of a task.

Although TTT, TSOT and TSOT/TTT all provide some useful information about visual distraction, it can be suggested that the most suitable way to assess a system is by considering both the ratio of task complexity and the length of time required to complete the task. However more work is required to establish the influence of the factors described above and to determine reference values that may be used to assess IVIS. Future research (outside the remit of this project) should investigate the correlation between occlusion measures (e.g. TSOT, TTT and TSOT/TTT) and driving performance to determine if occlusion is a valid technique to assess safety while driving.

9 References


ISO N3XX (2002). Road vehicles – Ergonomic aspects of transport information and control systems – Occlusion method to assess visual distraction due to the use of in-vehicle information and communication systems. Pre-CD draft.


<table>
<thead>
<tr>
<th>Glossary of Terms</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chunkable task</strong></td>
<td>A task that can be broken down into small parts. If the task can be carried out in short bursts of visual attention then it is regarded as ‘chunkable’.</td>
</tr>
<tr>
<td><strong>Design</strong></td>
<td>Is the process of conceiving and recording an intended purpose and physical form for a system.</td>
</tr>
<tr>
<td><strong>Display</strong></td>
<td>A device that presents information to the driver. Examples include visual displays (such as LCD screens and control labels), auditory displays (such as tones), and tactile displays (such as a haptic display).</td>
</tr>
<tr>
<td><strong>Driver performance</strong></td>
<td>The ability of the driver to control their vehicle in an acceptable manner in terms of, for example, lane keeping, lane position, lane violation, headway etc.</td>
</tr>
<tr>
<td><strong>Glance</strong></td>
<td>Can be defined (ref.: ISO 15007, SAE J2396) as the time from the moment at which the direction of gaze moves to a target to the moment it moves away from that target. This includes the transition time to or from the target (but not both) and the dwell time on the target.</td>
</tr>
<tr>
<td><strong>Independent sample design</strong></td>
<td>Under this experimental design an entirely different group of people are involved in each condition (there could be two conditions or more). This experimental design may also be referred to as ‘between subjects’, ‘between groups’ or ‘independent groups’. In occlusion research, independent measures designs have been used to compare different participant groups, such as the elderly versus the young.</td>
</tr>
<tr>
<td><strong>IVIS</strong></td>
<td>In-vehicle Information system</td>
</tr>
<tr>
<td><strong>NSOT - Net Shutter Open Time.</strong></td>
<td>Total shutter open time minus the system response delay.</td>
</tr>
<tr>
<td><strong>NTT - Net Total Task Time</strong></td>
<td>Total task time minus the system response delay.</td>
</tr>
<tr>
<td><strong>NTToccl - Net Total Task Time Occluded</strong></td>
<td>Total occluded task time (TTToccl) minus the system response delay.</td>
</tr>
<tr>
<td><strong>OCCLT</strong></td>
<td>This stands for the occlusion time or the time for which the scene is occluded in a single sequence.</td>
</tr>
<tr>
<td><strong>Occlusion interval</strong></td>
<td>The time for which the driver interface is not visible when using an occlusion procedure. During this time it is assumed that the visual attention is focussed on the driving scene (i.e. when the goggles are closed or display is off), and is also referred to in the literature as the ‘goggle close’ or ‘display off’ interval. The driver interface includes the visual display and any relevant controls.</td>
</tr>
<tr>
<td><strong>Primary task</strong></td>
<td>A task that is of greater importance than a secondary task when a person is required to multi-task. For example when driving the primary task should be driving in an acceptable manner, while the secondary task may be using an IVIS.</td>
</tr>
<tr>
<td><strong>Primary driving task</strong></td>
<td>All those activities that the driver has to undertake while driving, navigating, manoeuvring, and controlling a vehicle, including steering, braking, shifting, and accelerating.</td>
</tr>
<tr>
<td><strong>Repeated measure design</strong></td>
<td>In this study design, each research participant provides data for all the levels of the independent variable. Repeated measures designs are characterised by having more than one measurement of at least one given variable for each participant. A repeated measures design assumes that since the participants are the same for all conditions, and all other variables are controlled, any difference in results will be due to the effect of the independent variables. This design can also be referred to as a ‘within subject’ or ‘within group’ design, since differences in participants have been eliminated as the source of difference.</td>
</tr>
<tr>
<td><strong>Resumption lag</strong></td>
<td>The additional time it takes users to resume the task after having switched back from the interruption. Within the inspection time, or each separate glance time, is a resumption lag time.</td>
</tr>
</tbody>
</table>
**Secondary task**
A task which is of lesser importance than the primary task but may be completed in conjunction with a primary task.

**System**
Includes all components with which the manufacturer intends the driver to interact whether stand-alone or integrated into another system.

**System Response Delay (SRD)**
Interval during which the driver must wait for the driver interface to respond in order to complete a task. For example, waiting for an off-board computer to be queried or waiting for a voice message to be generated.

**Task**
The process of achieving a specific goal using a definite and prescribed method. Example: Obtaining guidance by entering a street address using the scrolling list method until route guidance is initiated. A goal is defined as a system state sought by a driver.

**TGT – Total Glance Time**
The total amount of time spent glancing at the system while completing the task.

**Ttclose - Total Time closed**
The total time the shutters were closed during the task. It can also be referred to as Ttocclu.

**TSOT – Total Shutter Open Time**
Total time that vision is not occluded when using an occlusion procedure. TSOT is the sum of vision intervals required for the task of interest.

**TTTbase**
Total time required to complete a task under non-occluded conditions. This is the same as TTTstatic.

**TTT – Total task time**
Total time required to complete a task. If the task is the only or main task (i.e. not undertaken while driving as a primary task) then this is also referred to as the Static TTT.

**TTTdynamic**
Total task time measured while driving.

**TTTstatic**
Total task time measured while not in motion.

**TTToocl - Total Task Time occluded**
Total task time to complete the task of interest while using a visual occlusion procedure. It therefore includes the occluded intervals as well as the vision intervals when the user can interact with the system.

**Ttoccl - Total Time occluded**
Total time that vision is occluded when using an occlusion procedure. The total time occluded is the sum of occlusion intervals required for the task of interest, it can also be referred to as Ttclose.

**Vision interval**
The periods during the occlusion technique where a participant can complete the secondary task (i.e. IVIS task). It is also referred to in the literature as the ‘goggle open interval’ ‘shutter open time’, ‘display on’ or ‘inspection interval’.
Appendix A: Occlusion research summaries

A.1 Baumann et al. (2001)
This document is in the format of a presentation (from BMW) which has been circulated as an ISO paper. An experimental method was briefly explained but the written presentation is of limited use without the context of the verbal presentation (as it was not designed for this purpose).

A.2 Baumann et al. (in press)
The overall aim of this study was to report results from two experiments where the validity and usability of the occlusion technique was investigated. The first experiment was a field study designed to assess the validity of the occlusion method outside a laboratory environment. The second experiment aimed to compare the occlusion technique with alternative methods that used global measures to evaluate IVIS.

Experiment 1:
Forty-three subject with an average age of 23 were used in a 2 factor mixed design. The three input condition factors (no-occlusion, occlusion and driving) were varied between subjects and randomly assigned. The length of input factor (short, medium, long) was within subject. Each subject was given 15 address charts indicating destination to be entered and were required to enter the city and street. The subjects’ reactions were videotaped. Total Task Time (TTTnon-occl, TTToocl, TTTdriving) and the number of error rates were recorded. The results of the experiment showed that TTTdriving was greater than TTToocl and TTTnon-occl. As expected the time to complete a task increased with the length of input (destination). The results show that the input condition factor and input length have a significant main factor correlation. There were strong correlations between TTTnon-occl, TTToocl and TTTdriving (particularly between TTTnon-occl and TTTdriving) when TTT was calculated for every task within the three input conditions. The average TSOT was 31.9 seconds. The TSOT: TTTnon-occl ratio was 0.63. TTT under the driving condition was 1.27 times longer than the occlusion condition. The non-occlusion condition had the lowest number of errors while the driving condition had the largest number of errors. The number of errors increased with the length of entry. An analysis of the errors categorised into different levels of severity was made. This showed an unexpected decrease in the amount of errors for long inputs and driving conditions. This was possibly due to the increased probability of drivers being able to finish longer inputs under the driving condition while standing at traffic lights or in a traffic jam. The authors suggested that the especially high correlation between TTT non-occl and TTTdriving could be used to argue that measures obtained under non-occlusion conditions like a total task time or total glance time are suitable criterion for a system evaluation. However it must be noted that the correlation does not reflect the size of the absolute difference between the two variables and secondly TTT non-occl does not measure whether a task can be easily interrupted while driving. The second experiment supports this argument.

Experiment 2:
Twenty-six participants were used in an independent samples design to compare task completion under occlusion and no occlusion condition. The results show that the frequency of correct answers was significantly lower under the occlusion condition compared to the non-occlusion condition for both motorway questions and general content questions. Performance under the occlusion condition showed a significant drop in quality when participants were interrupted during task completion. Only about one-third of the trials were answered correctly under the occlusion condition for questions requiring pieces of information and questions on the general content of the text. The authors concluded that if the task used in this experiment was undertaken while driving it could lead to a deterioration of driving performance or to a situation where the task could not be completed at a satisfactory level. This was because the dynamic structure of the task makes it very difficult to chunk the task into small units. Therefore TTT alone cannot be used as the only criterion to evaluate whether an IVIS has suitable levels of driver distraction.

A.3 Baumann et al. (IN PRESS)
This study was completed within the ADAM-project and aimed to validate the occlusion procedure and the peripheral detection task (PDT) as techniques to assess IVIS. Twenty-four participants (half male and half female) were used in a repeated measures design to solve 12 tasks under baseline, occlusion and PDT conditions. The results were compared to eye movement data from a simulator study. The authors concluded that the visual occlusion technique is a practical and valid method to assess visual demand measurements of IVIS.

A.4 Bengler and Rosler (2001)
This document is in the format of a presentation (from the Turin Occlusion Workshop 2001). The aim of the presentation was to report on a BMW project which aimed to implement a ‘User Interface’ (UI, called ITSWAP) for service operation. They assessed the handwriting input, blind-operation ratio and chunkability of different task types. The authors used an occlusion technique with goggles to assess product design. They concluded that ITSWAP is an effective handwriting input and several inputs can be made without visual contact. The inputs are interruptible; however the selection of functions on the user interface needs improvement. This paper also demonstrates that BMW have used occlusion to assess product/design and presumably consider it a practical technique.
A.5 Chiang et al. (2001)

The aim of this study was to observe and measure the use of a contemporary navigation system by typical drivers in over-the-road conditions, with regard to destination entry. The results demonstrated that average total entry time was 34 seconds, with none of the tasks taking less than 25 seconds. On average 17.3 keystrokes were used to enter the 15 required keystrokes. For street entry 5-6 strokes were typically used, the majority of errors for street entry only involved one keystroke per chunk. The average fixation for one keystroke was 1 second, and for 2 keystrokes was 1.5 seconds. The overall average fixation was 1.2 seconds (95% <2seconds) and the average number of keystrokes per fixation was 1.3. The authors found that mean transition time was 0.15 seconds (transition time to display + fixation time = glance duration) while 95% were 0.25s. The navigation display was typically fixated for half the time, but there was a greater attention to display on city roads compared to freeway. Lane keeping performance while using the navigation system was deemed acceptable. The authors concluded that subjects can use a contemporary navigation system while operating in actual traffic conditions, with acceptable levels of secondary task loading, path performance and subjective lack of difficulty. Glance duration and eyes off road behaviour was within previous suggested rules of thumb and entry times of 30-40 seconds are acceptable to the drivers when there is no need to enter the destination quickly.

A.6 Chiang et al. (in press)

This paper presents the same information as Chiang et al. (2001) - to be published in ‘Applied Ergonomics’ special edition.

A.7 Curry et al. (2002)

The aim of this study was to assess eye glance behaviour measures and their relationship to surrogate candidates such as driving performance (lane keeping) and task completion times (static and dynamic). A 2 × 2 × 6 × 3 mixed factor design was used. Subjects of varying age and both genders completed six IVIS tasks within 3 environments (dynamic, static-vehicle, static mock-up). During each trial eye glance behaviour measures and driver performance measures were recorded. The results show that task completion time, measured in the simulator (TTTdynamic), is highly correlated with total glance time (TGT). TGT is a widely used measure of visual demand therefore dynamic task completion is an appropriate surrogate for visual demand. Total glance time (the most direct measure of visual demand) is highly correlated with the number of lane violations committed during a task (r² = 0.942). Previous research suggests that task completion time measured statically or in mock-up is well correlated with dynamic task completion time. The authors concluded that ‘mean task completion time’ measured in a static mock-up would be a valid predictor of driver performance (lane violations). This paper (along with Tijerina, 1998) was used as foundation for the SAE Recommended practice J2364.

A.8 Fichtenberg N (2001)

The aim of this experiment was to determine how different occlusion interval times affect the total shutter open time (TSOT) and accuracy of the subject, with tasks that are thought to be less chunkable than the tasks in the previous study by Karlsson & Fitchburg (2001). Fifteen subjects completed 6 tasks (3 of type 1 and 3 of type 2) under four occlusion conditions including no occlusion. The three occlusion conditions had goggle close times of 1 second, 3.5 seconds and 6 seconds with a goggle open time of 1.5 seconds. The two types of tasks were a string task (type 1) and matrix task (type 2). The string task was a series of the same alphabetical letters and the participant was required to count the number of letters in the ‘string’. The matrix task consisted of six lines of different letters without spaces and the volunteer was required to count the number of times a certain letter (e.g. ‘D’) occurred within the matrix. The results for the string task showed that the task was extremely difficult and possibly even not chunkable. The TSOT increased from the static condition compared to the occluded conditions, but the results showed no real correlation between TSOT and different occlusion conditions. The accuracy decreased from the static condition compared to be occluded conditions and continued to decrease as the occluded time increased. The matrix test results showed that the task was difficult but possible to achieve. Increasing the occlusion interval (from 1 second to 3.5 seconds) increased TSOT but drastically decreases accuracy.

The authors concluded that for tasks that are difficult to chunk, the ability of a person to perform the tasks is negatively affected by increasing the occlusion interval time. TSOT tends to increase with increasing occlusion time, while the accuracy decreases. For less chunkable tasks: Longer occlusion interval times decrease overall performance and ability to perform the task in terms of accuracy and time.

A.9 Gelau and Krems (in press)

This paper reviews the other research papers that will make up the special edition Applied Ergonomics journal.

A.10 Green (1999)

This paper discusses the rationale for ‘15 second rule’ proposal and is the basis for the SAE J2364 standard.

A.11 Goujon (2001)

The aim of this study was to implement the occlusion technique, and apply a criteria previously proposed in the ISO Task Force. Four different subject groups (different ages and gender) completed 10 IVIS tasks whilst wearing occlusion goggles with a shutter open time of 1.7 seconds and shutter close time of 5 seconds. The same tasks were also completed without occlusion goggles. The task completion time, accuracy (error rate) and number of open/close cycles were recorded. The Total Task Time without shutter [TTT (without shutter)], Total Task Time with shutter [TTTocc (with shutter)], Total Shutter Open
Time (TSOT), TSOT/TTT and TTToc/(TTT+Ttclose) were recorded (Ttclose is the total time the shutters were closed during the task). The results showed no noticeable difference in task completion time with goggles off and goggles open; therefore the goggles do not generate a bias or special behaviour. There is a correlation between TSOT and TTT. The results also show that TSOT/TTT is significantly correlated with age but TTToc/(TTT+Ttclose) is not. The correlation is thought to be due to brief tasks (answering phone/tuning radio) not navigation tasks. Elderly people are not ‘more disturbed’ by the use of goggles than younger ones. The authors applied the criterion TTToc < 1.25*(TTT+Ttclose) to the results. All tasks passed but the criterion appeared to be very sensitive to the absolute value of TTT rather than task complexity. The authors suggested that another possible criterion was ‘TSOT:TTT ratio’. This measure is also sensitive to TTT not complexity. The author concluded that a single criterion is not appropriate to determine visual distraction induced by the use of a system by the driver.

**A.12 Hashimoto and Atsumi (2001)**

The aim of this study was to obtain an upper limit of Total Glance Time (TGT) that does not interfere with uneasiness and lateral deviation when driving and to obtain a test bench based evaluation method. Subjects completed nine tasks on four different navigation systems in four different road environments. The volunteers completed the tasks under several different occlusion open/close patterns. In the results the visual distraction while the vehicle was in motion was directly evaluated by TGT. The authors suggested that total glance time should be less than eight seconds based on the results of TGTs that did not cause an ‘uneasy feeling’ to the subjects and that did not affect lateral control of the vehicle. Total glance time had a high correlation with uneasiness feeling of subjects and lateral deviation of the vehicle. The author suggested from their results that the upper limit of the TGT should be eight seconds (7.9 was the minimum TGT that could not cause uneasiness with any system in any vehicle). The results suggested that it is difficult to evaluate visual distraction by Single Glance Time only, because subjects feel more uneasy as Total Glance Time increases. Total Task Time (TTT) had a fairly close correlation with TGT. The author suggested that a static TTT measure could not evaluate visual distraction for tasks which require a continuous gaze (i.e. map scrolling). The TSOT had a very high correlation with TGT. The author suggested that TSOT is a good measure of visual distraction including map continuous scrolling. The results showed that an occlusion pattern where the goggle shutters are open for 1.5 seconds and closed for 1.0 second has the closest correlation with TGT. The authors additionally found that an increased number of interactions with the navigation system, resulted in increased uneasiness and increased lateral deviation. This suggests a necessity for an upper limit in the number of interactions with an IVIS. The authors concluded that the occlusion technique (TTT &TSOT) could be used as a Test Bench instead of using a fully equipped vehicle. TSOT had a stronger correlation with TGT than TTT. The analysis showed that a TSOT of 7.1 seconds was equivalent to TGT of eight seconds. Finally the authors suggested that a TSOT of 7 seconds while using occlusion technique is a good criteria to evaluate and extract interactions with visual equipment.

**A.13 Karlsson and Fichtenberg (2001)**

The aim of this study was to determine how different occlusion intervals affect the TSOT. This study also aimed to compare the results with the ISO proposed criteria (TTToc/(Static+Ttclosed)) and investigate the participants feelings towards occlusion goggles. Twenty-four subjects completed in-vehicle information systems tasks under five occlusion conditions (including a no occlusion condition). The four occlusion intervals were 1 second, 3 seconds, 4 seconds and 6 seconds, with a constant 1.5 second vision interval. Not all tasks were completed under every condition except for the no occlusion condition but the order was randomised. The results showed that there was a trend for greater TSOT in the 1 second occlusion condition but this was not significant. The authors suggested the trend might be because the 1-second occlusion interval gave did not give the test subjects sufficient time to perform the manual tasks, that the longer occlusion intervals permitted. In this particular experiment the manual task was move a cursor on the visual display to the vicinity of the next letter to be entered. The control for this particular navigation system was mounted on the forward facing side of the steering wheel and was out of sight of the driver. However, another possible explanation is that the subject was more likely to have a computational interruption (i.e. experience a situation where the navigation system is still processing) when the close interval was only 1 second, resulting in the subject not always being able to utilise the open shutter time. The TSOT/Static TT ratio tended to decrease as the occlusion interval increased. The overall (mean) TSOT/static ratio was similar to that found by Goujon (2001). The results also demonstrate that there is a high correlation between TSOT and static task completion time. The results showed no difference between different occlusion interval times for tasks that were easy to chunk into small parts (therefore there was no reason for a difference in TSOT).

All eight tasks met the proposed ISO criterion [TTToc < 1.25*(TTT+Ttclosed)]. However, the author noted that two of the least complex tasks obtained the highest values. All destination entry tasks had similar TTToc/(Static +Ttclose) ratio regardless of complexity. The authors concluded that it would be difficult for tasks with a very small static time to fail the ISO criterion. They suggested a better criterion to determine visual distraction would be based only on the occlusion experiment. They suggested Total Glance Time (TGT) needs to be further investigated.

The subjective results showed a difference in subjective physical demand between males and females. This result may be due to differences in hand size (reaching for controls). The results also showed that older people found the occlusion spectacles less frustrating than younger
people, probably due to young people’s eagerness. Some drivers noted that the difference between a real driving scenario and wearing occlusion spectacles is that the spectacles do not allow peripheral vision to take place.

A.14 Keinath et al. (2001)
This paper discusses the study conducted by Krems, Keinath, Baumann, Bengler and Gelau (2001) which is described in more detail in this review. The aim of this study was to present the occlusion technique for visual-system evaluation as a simple and valid method for assessing different aspects of the in-vehicle HMI. The authors concluded that their experiments (Keinath et al., 2001) confirm that the occlusion technique is a valid procedure to discriminate between simple and complex versions of visual display and is also suitable to investigate the impact of dialogue interruption on task performance.

A.15 Krems et al. (2000)
The aim of this study was to describe the occlusion technique as an evaluation instrument during the design process and to produce a summary of experimental results. This study used a computer with a display which could be turned on and off to represent different occlusion intervals. The study was carried out in four phases/conditions: (1) Simple vs. complex samples compared for pre-determined occlusion periods, (2) Comparison of simple vs. complex samples for presentation periods determined by the subject, (3) Dialog interruption without secondary task (graphic coding), (4) Dialog interruption with secondary task (semantic coding).

The results for experiment 1 showed that the probability of errors for the complex task was greater than the probability for the simple task for all presentation periods. The probability of mistakes in both conditions decreased when presentation time was increased. The results of experiment 2 showed that significantly fewer tasks were solved correctly during complex condition compared to the simple condition. Out of the correct tasks, the complex tasks took significantly longer to solve than the simple tasks. The results of experiment 3 showed that when a primary task is interrupted by a secondary task (that is interruptible), the complexity and duration of the secondary task had a significant effect on the probability of errors. The probability of errors in the simple condition was always lower than in the complex conditions. Generally as the length of the occlusion periods increase, fewer errors are made in the primary task. The results of experiment 4 showed that significantly more errors are made in a complex task compared with a simple task when the primary task is interrupted by a secondary task that is less interruptible. Significant differences between the probability of errors in secondary task were also found. In the complex task the probability of error in the secondary task was much higher than in the simple condition (i.e. complex conditions have negative effect on secondary tasks).

Overall the results of this study demonstrate that the occlusion technique is a valid procedure for evaluating displays when either system or user paced. It can make a distinction between display designs of varying complexity. The maximum separation of the displays was found with a one second visual interval. There was also a distinction between simple and complex displays when the subject chose the observation periods. The experiment concerning dialog interruptions or difficulty of continuing dialogue after interruptions also showed the occlusion technique as a suitable and simple evaluation tool. The authors suggested that the occlusion technique is a valid procedure for evaluating display concepts and dialog interruptions. However the technique needs to be tested outside the experimental laboratory.

A.16 Krems et al. (2000)
This paper presents the same experiments and findings as Krems et al. (2000).

A.17 Lansdown et al. (in press)
This paper discusses the limitations and potential of using an occlusion technique to assess the visual distraction and suitability of in-vehicle Information Systems (IVIS). This paper describes the history of research and foundations of occlusion. It describes the technology used in occlusion and the applications for the procedure. Issues concerning the method and timing of occlusion intervals are discussed. The paper suggests alternatives to the occlusion technique and future research needs. The authors concluded that the occlusion technique has some promise although the empirical basis for the technique is lacking.

A.18 Monk et al. (2002)
The aim of this study was to identify attentional switching costs for interruptions occurring at various task stages. The primary task was a VCR task and the secondary task was a tracking task. The primary task had a visual period of five seconds and was then interrupted by the secondary-tracking task for either 3 seconds, 8 seconds or 13 seconds alternating until the primary task was complete. Four VCR tasks were assessed with two continuous tracking tasks (easy/hard) in a 4 × 2 design. The order was randomised to account for order effects.

The results of the study show that there was no stable difference in resumption lag time between the easy and hard tracking tasks. This was likely to be because neither of the tracking tasks were hard enough. Therefore the subjects may have been able to rehearse the primary task whilst completing the secondary tracking task. However, TTT significantly increased with the hard tracking task because the subjects had less time to think. The average resumption lag was 1.6 seconds. The point at which a task is interrupted was shown to have an influence on the resumption lag. The results showed that it is better to interrupt a task before a new task has begun or during a repetitive task (like scrolling through a list). Interrupting a task in the middle or near the end of a task results in a longer resumption. A longer resumption lag provides less time on the task, which results in a greater TSOT and number of shutter intervals. The authors therefore suggest that designers should develop interfaces with discrete sub-
tasks. Resumption lag measures provide information on
one source of TTT variability. NOTE - These results are
based on a VCR task not IVIS tasks and would need to be
validated for IVIS through further research.

A.19 Morita et al. (1998)
The aim of this experiment was to examine how gazing at
an in-vehicle navigation display affects acceptable driving,
particularly breaking. Seven in-vehicle information system
tasks were tested under two real driving conditions on a
test track. The two conditions were:
• the participant was asked to look at the in-vehicle
  information system only while driving;
• the driver was instructed to complete the in-vehicle
  information system tasks while looking at the road
  enough so as not to feel dangerous.

The results showed that the average foot transfer time
was 0.3 seconds. There was no difference in foot transfer
time between different display conditions. The display
position influenced ability to recognise stop lamps on the
preceding vehicle such that the further the display was
positioned from the front, the longer the response time and
the more cases where the driver did not recognise the stop
lamps. The results also showed that vehicle velocity had no
influence on the response time for each display position.
The average response time when looking straight forward
was 0.57 seconds (+/- 0.21), and all but 3 response times
were within 1 second. The number of cases where
participants did not recognise the stop lights increased as
the display position moved downwards. The results of the
condition where the drivers were asked to complete the
IVIS tasks while looking at the road enough to not feel
dangerous showed some interesting results. On average the
drivers took 0.17 seconds (+0.05) to move their eyes from
the front to the display device and 0.16 seconds (+0.04) to
move their eyes from display device back to the front. The
drivers spent an average of 1.05 seconds (+0.44) looking at
display device. These figures show that the average eye
diversion time (away from road) was 1.38 seconds
(+0.44s). The eye movement times in this report were
similar to a previous simulation experiment (0.15seconds-
previous Japanese paper). The results showed that the eye
diversion time was significantly slower at 80 km/h
compared to 20, but there was no difference between other
speeds. Quantitative analysis with assumption that the
driver cannot see the display when gazing showed that the
response time when drivers are looking directly forwards
is 0.63 seconds and the response time when choosing when
to look at display is 1.37 seconds. Therefore this study
suggests that when drivers are gazing at a display device it
is difficult to grasp traffic conditions. The response time is
longer when looking at an in-vehicle display even when
the driver doesn’t feel in danger whilst completing the
activity during driving. The results of this study are
interesting and suggest that even with ‘chunkable’ tasks
and the driver free to choose when to use a display, their
reaction time to unexpected events doubles on average
(from 0.63 seconds to 1.37 seconds). This suggests that the
time spent looking inside the vehicle is always a problem.

A.20 Niiya (2000)
The aim of this study was to evaluate a Toyota navigation
system using the occlusion technique. The navigation
system was tested under occlusion conditions with a
shutter open time of 1.5 seconds and a close time of 5
seconds. The navigation system tasks were also tested
under a no occlusion condition. The recognition time of
the elderly subjects was greater than the younger subjects,
even in the no occlusion condition. The results show that
some of the navigation system tasks would have failed the
JAMA guidelines as they clearly took over 6 seconds. The
TSOT was almost equal to the Total Glance Duration
(TGD) while the vehicle was in motion. Therefore the
authors suggested that the occlusion method could be an
evaluation method for Total Glance Duration (TGD), and
the technique can simulate the actual visual recognition
behaviour of drivers. The authors also suggested that a
shutter open time of 1.7 seconds (to include transition time
of 0.2 seconds) might be more appropriate than an open
time of 1.5 seconds.

A.21 Noy et al. (in press)
The aim of this study was to investigate occlusion as a tool
to assess visual distraction from IVIS. 24 subjects
completed two sessions. In the first session 3 in-vehicle
task were completed whilst occluded and non-occluded. In
the second session the same tasks were completed in a
driving simulator in 30 second intervals. Chunkability
indices (R) were calculated for each task using the
following equation:

\[ R = \frac{TSOT_{mean}}{TTT_{unocc \ mean}} \]

The results showed that scrolling tasks had a higher R
ratio than the static tasks, which in turn had a high ratio than
the radio-tuning task. The tasks did not differ tremendously
in terms of TTT therefore differences between tasks can
only be an attribute to inherit characteristics such
chunkability. The visual search tasks in this study produced
similar results to Krems et al. (2000). A significant decrease
in driving performance in terms of standard deviation lane
performance and number of lane exceedences was observed
in the dual-task conditions when compared with the baseline
but there was no difference in the duration of lane
exceedence. There was also no significant difference in lane
keeping measures under the different dual-task conditions.
The reason for this maybe because there was no way to
partition the data according to dual-task and single task
episodes. Perceived demand scores were consistently rated
more difficult for driving than during occlusion. The scoring
visual search tasks was rated significantly more demanding
on both static visual search and radio-tuning tasks. The
results of this study also support JAMA’s guidelines to
prevent scrolling text from appearing in-vehicle displays.
The authors concluded that the chunkability indices
generated using occlusion were positively correlated with
the majority of the subjective measures of workload. It was
not possible for the authors, they were chunk ability indices
to driving performance. This study highlights of promise of
the occlusion technique based on the finding that the inherit characteristics of task and not the TTT affect the chunkability indices.

A.22 Tijerina et al. (1998)

The aim of this study was to investigate the demand/workload of route guidance systems. Sixteen participants of different ages and gender completed destination tasks on four different navigation systems and two non-destination tasks (radio/phone). The results indicate that, on average, all three systems with visual-manual methods of destination entry were associated with lengthy completion times, longer eyes-of-road-ahead times, longer and more frequent glances to the device, and greater numbers of lane exceeding compared with the voice system. However, the voice system was associated with substantially longer and more frequent glances away from the road scene for each destination entry. The results also showed that performance differences between younger and older test participants tended to be reduced with voice systems. Regardless of the navigation system, the destination entry task took substantially longer to complete than the phone-radio comparison test. The test participants favoured the voice input over visual-manual methods. The authors suggested that destination entry while driving with visual-manual methods should be not be advised based on their data. The authors concluded that voice recognition technology is a viable alternative to visual-manual destination entry while driving.

A.23 Weir et al. (2003)

The aim of this study was to investigate the effect of the secondary tasks and occlusion parameters on driver performance in the primary and secondary tasks. The study also aimed to investigate the effect of relatively long task durations on driving performance and glance behaviour and to compare occlusion goggles and screen blanking methods of secondary task interruptions and evaluation. The final aim of the study was to help suggest possible performance or comfort related boundaries on secondary task variables. The primary task in this study was a simulator driving task which involved driving on a straight road with random occurring lateral disturbances. The secondary task involved alphabet entry on a HMI. The study comprised of 5 separate phases or experiments.

Experiment 1 involved the volunteers completing the baseline secondary task only, accomplished continuously with no occlusion. The results showed that the entry rate was approximately 1 per second and the error rate was approximately one every two minutes (<1% of entries). The subjective ratings did not differ between runs.

Experiment 2 involved completing a secondary task with (a) screen blanking and (b/c/d) occlusion. The screen blanking results showed that the 1-second ON time has higher rate of no entries and higher rate of errors compared to the 2 and 3 second ON times. The occlusion results showed that the 1-second goggles OPEN time has much higher rate of no entries. The error rate diminished to a negligible level for open times greater than 1.5 seconds. The entry rates across configurations (Entries/TSOT) were all similar at about 1 per second and similar to screen blanking results. There was no trend of keystroke error rate with different goggle OPEN time.

The 1 second goggle OPEN time was rated by the subjects to be significantly more difficult than the other OPEN times. The ratings were significantly more difficult than experiment 1, where no occlusion was used. The ratings for screen blanking compared to goggles showed small but not significant preference for screen blanking. The results showed that there was a relatively little effect of altering goggle CLOSE time. The subjective ratings showed that the task became slightly more difficult as the goggle CLOSE time increased. In general there was no increase in error or entry rate as the run length increased from 90 to 180 seconds. The simulator run length had no impact on subjective ratings.

Experiment 3 involved the subjects performing the baseline primary driving task only with no secondary task. The experiment provided results for comparison.

Experiment 4 involved completing the primary driving task with occlusion using goggles. The results showed that there was little variation in lane position as occlusion time is increased up to 2 seconds, then lane keeping performance degraded as occlusion time increases to 2.5 seconds and greater. The 4 second occlusion time produced the greater standard deviation of lane position. For the longer occlusion times there was a decrease in lane keeping performance as the run time progressed beyond 30 seconds. The goggle CLOSE times of 1 to 2.5 seconds had similar subjective ratings. As the CLOSE time increases over 2.5s the subjective ratings showed the task became significantly more difficult/uncomfortable.

Experiment 5 involved completing the primary and secondary tasks combined, with no occlusion or screen blanking (driver paced). This experiment was intended to be the ‘normal’ driving plus secondary task entries. The error rates on the secondary task were similar to those for the baseline secondary task with no occlusion.

There was a trend for a reduced error rate as the run length increased. The entry rate over total glance time was similar to the rate observed in experiment 1 and 2. Lane keeping performance showed little variation with increase in run duration. The lane keeping performance values were similar to the results of experiment 4 for primary task occlusion times of two seconds or less. There was little change in lane keeping performance and driver behaviour as the run duration increased. There was also little variation in percentage of device fixation between the 30 second, 60 second and two minute repeat runs (glance time = fixation time plus transition time). The glance behaviour to the road is seen to be relatively constant as the run duration increases, with perhaps a small increase in the mean glance time and the glance percentage for the longer runs. There was no significant difference in mean subjective ratings as the run duration increased. The subjective ratings were similar to those from experiment 4 for CLOSED times of 2 seconds or less and also similar to experiment 2 for OPEN times 1.5 seconds or greater.
Overall the results show no clear preference for the screen blanking or occlusion goggle method – both are satisfactory and acceptable to subjects. Occlusion CLOSED times of up to 2s (when used to interrupt driving task) do not degrade task performance. Occlusion OPEN times of 1.5 sec or greater provide satisfactory secondary task performance when used to simulate intermittent task activity. The results show that a broad range of CLOSED or OFF times are acceptable and values in the range of 1-3 seconds seemed to be preferred. The standard deviation of lane position was found to be a more sensitive and useful measure of lane keeping performance than counting lane exceedences. The results also showed that relatively long secondary task durations (up to 120-180 seconds) do not degrade primary and secondary task performance, behaviour or ratings.
### Appendix B: Table of research methods and conclusions

<table>
<thead>
<tr>
<th>Author papers</th>
<th>Aim</th>
<th>Set up</th>
<th>Means of occlusion</th>
<th>Pacing</th>
<th>Intervals variability</th>
<th>Vision interval</th>
<th>Occlusion interval</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiang, Brooks and Weir (2001)</td>
<td><em>To observe and measure the use of a contemporary navigation system by typical drivers in over-the-road conditions, with regard to destination entry.</em></td>
<td>Instrumented vehicle2000 Acura 3.2 RL.</td>
<td>No occlusion.</td>
<td>Driver determined intervals - no occlusion.</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>10 participants: 5 males, 5 females (5 engineers) average age 33 average mileage -13,400/ year only 1 participant had experience of navigation systems familiar with area.</td>
</tr>
<tr>
<td>Baumann, Keinath, Krems, Bengler (in press).</td>
<td><em>To report results from 2 studies where the validity and usability of the occlusion technique was investigated.</em></td>
<td><em>Field study to assess validity of occlusion method outside laboratory.</em></td>
<td>BMW navigation system: a) parked car no occ. b) parked car with occ. c) driving with occ.</td>
<td>a) No occlusion. b) PLATO goggles. c) No occlusion.</td>
<td>a) n/a b) System paced. c) Driver chooses without goggles/ blanking.</td>
<td>a) n/a b) 1.5 seconds. c) n/a</td>
<td>a) n/a b) 3 seconds. c) n/a</td>
<td>43 participants: 11 males, 32 females, average age 23(-4.1).</td>
</tr>
<tr>
<td>Baumann, Keinath, Krems, &amp; Krems (in press)</td>
<td><em>To compare the occlusion procedure with an alternative methods that uses global measures to evaluate IVIS (such as TTT&lt;15 Seconds).</em></td>
<td>Psion Series pro hand held computer.</td>
<td>a) No occlusion. b) PLATO goggles.</td>
<td>a) n/a b) System paced.</td>
<td>a) n/a b) Fixed.</td>
<td>a) n/a b) 1.5 seconds. c) n/a</td>
<td>a) n/a b) 3.5 seconds.</td>
<td>24 participants: 12 males, 12 females aged: 35-55 average age: 44.13 (+/- 7.12).</td>
</tr>
<tr>
<td>Bengler &amp; Rosler (in press)</td>
<td><em>Implementation of User Interface (UI, called ITSWAP) for service operation.</em></td>
<td>Vehicle mock-up.</td>
<td>PLATO goggles.</td>
<td>System paced (PC driven).</td>
<td>Variable (according to normal distribution).</td>
<td>1.3-1.7 seconds.</td>
<td>2.8-3.2 seconds.</td>
<td>11 participants.</td>
</tr>
<tr>
<td>Baumann, Rosler, Jahn &amp; Krems (in press)</td>
<td><em>To validate the occlusion procedure and the peripheral detection task (PDT) as techniques to assess IVIS.</em></td>
<td>Not detailed.</td>
<td>PLATO occlusion goggles.</td>
<td>Not detailed.</td>
<td>Not detailed.</td>
<td>1.3-1.7/seconds.</td>
<td>2.8-3.2/seconds.</td>
<td>20 participants.</td>
</tr>
<tr>
<td>Baumann, Gelau, Krems, Keinath. (2001)</td>
<td><em>Evaluation of handwriting input, blind operation ratio and chunkability of different task types.</em></td>
<td>BMW navigation system. a) parked car no occ. b) parked car with occ. c) driving with occ.</td>
<td>a) No occlusion. b) PLATO goggles. c) No occlusion.</td>
<td>a) n/a b) System paced. c) Driver chooses without goggles/ blanking.</td>
<td>a) n/a b) 1.5 seconds. c) n/a</td>
<td>a) n/a b) 3 seconds. c) n/a</td>
<td>a) n/a b) 1.3 seconds. c) n/a</td>
<td>26 participants (students): 25 females, 1 male average age 23 (+/-4.2). 13 participants randomly assigned to each group (occlusion/no-occlusion)</td>
</tr>
<tr>
<td>Bengler &amp; Rosler (in press)</td>
<td><em>To compare the occlusion procedure with an alternative methods that uses global measures to evaluate IVIS (such as TTT&lt;15 Seconds).</em></td>
<td>Psion Series pro hand held computer.</td>
<td>a) No occlusion. b) PLATO goggles.</td>
<td>a) n/a b) System paced.</td>
<td>a) n/a b) Fixed.</td>
<td>a) n/a b) 1.5 seconds. c) n/a</td>
<td>a) n/a b) 3.5 seconds.</td>
<td>24 participants: 12 males, 12 females aged: 35-55 average age: 44.13 (+/- 7.12).</td>
</tr>
<tr>
<td>Training</td>
<td>Study design</td>
<td>Dependent variable</td>
<td>Additional information</td>
<td>Conclusion drawn</td>
<td>Lessons learned</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>--------------</td>
<td>--------------------</td>
<td>------------------------</td>
<td>------------------</td>
<td>----------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before trials</td>
<td>Not detailed</td>
<td>Important information</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Not detailed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Trained on handling navigation system entered 2 destinations for practice for the driving condition, participants are allowed to practice driving and familiarise with car.**

- **2 factor mixed design: input factor (no-occlusion: 16) occlusion (14) & driving (13) varied as independent samples - randomly assigned length of input factor (short, medium, long) - repeated measures 15 address charts indicating destination to be entered by participant reactions video taped.**

<table>
<thead>
<tr>
<th>No Errors</th>
<th>Time to complete</th>
<th>Conclusion drawn</th>
<th>Lessons learned</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) TTTnon-occl</td>
<td>b) TTToccl</td>
<td>c) TTTdriving</td>
<td><em>TTTdriving was greater than TTToccl and TTTnon-occl.</em></td>
</tr>
<tr>
<td>TSOT</td>
<td>TSOT:TTT</td>
<td><em>Strong correlations between TTTnon-occl, TTToccl and TTTdriving (particularly between TTTnon-occl and TTTdriving).</em></td>
<td></td>
</tr>
<tr>
<td>ratio (a,b,c)</td>
<td></td>
<td></td>
<td><em>Average TSOT = 31.9 seconds.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Average TSOT:TTTnon-occ = 0.63.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Non-occlusion conditions have a higher number of errors &amp; driving condition have a larger number of errors.</em></td>
</tr>
</tbody>
</table>

**5 trials for practice.**

- **Independent samples design (occlusion / no occlusion groups)/participants were asked to read & understand text and memorise the two motorway abbreviations - answered 2 questions 25 trials per participant.**

<table>
<thead>
<tr>
<th>No of correct answers</th>
<th>Total task time</th>
<th>Results were compared to eye movement data from a simulator study.</th>
<th><em>The frequency of correct answers was significantly lower under the occlusion condition compared to the non-occlusion condition for both motorway questions and general content questions.</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>the questions.</td>
<td>Total shutter open time.</td>
<td></td>
<td><em>The occlusion technique seems a reliable and valid method for evaluating visual and dialog aspects of in-vehicle Information Systems.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>TTT alone cannot be used as the only criterion to evaluate the visual distraction of IVIS.</em></td>
</tr>
</tbody>
</table>

**Not detailed.**

- **Repeated measures design (occlusion / no occlusion) 2 hours per session questionnaire.**

<table>
<thead>
<tr>
<th>Error type (relative frequency).</th>
<th>Total task time</th>
<th><em>ITSWAP is effective handwriting input.</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Task solution time.</td>
<td>Total shutter open time.</td>
<td><em>Several inputs done without visual contact.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Inputs are interruptible.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Selection of functions on UI needs improvement.</em></td>
</tr>
</tbody>
</table>

**Not detailed.**

- **Repeated measures design (2 groups AB - entered destination in reverse order city streets & urban freeway, navigation mainly touch screen 3 city trials.**

<table>
<thead>
<tr>
<th>Eyestroke, keystroke, keystroke timing, eye fixations, entry errors.</th>
<th>Used touch screen displays to enter destinations: instrumentation: cameras, recording, driving control &amp; vehicle response sensors Primary task - maintain vehicle speed, following distance, lane position/destination entry less important/to hurry 2 city routes - 1.1 mile long (33 mph)/urban freeway - 6 miles - 65kmp/h weekdays (9.30-11/30) (1:30-3.30).</th>
<th><em>A contemporary navigation system can be used with acceptable safety while driving in actual traffic conditions.</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><em>Glance duration &amp; eyes off road behaviour can be within previous suggested rules of thumb.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Entry time of 30-40 seconds were acceptable to the drivers when there was no need to enter the destination quickly.</em></td>
</tr>
</tbody>
</table>

**Researchers believe in vehicle information systems can be used safely by drivers.**

---

*Continued ....*
<table>
<thead>
<tr>
<th>Author paper</th>
<th>Aim</th>
<th>Set up</th>
<th>Means of occlusion</th>
<th>Pacing</th>
<th>Interval variability</th>
<th>Vision interval</th>
<th>Occlusion interval</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiang, Brooks &amp; Weir (in press)</td>
<td><em>Same as Chiang, Brooks &amp; Weir 2001 to be published in Applied Ergonomics special edition.</em></td>
<td>In-vehicle with occlusion technique, navigation goggles with (by PC).</td>
<td>Display on/off, shutter; goggles</td>
<td>System/ variables</td>
<td>Fixed/ variable</td>
<td>Time/no open</td>
<td>Time/no shutters down</td>
<td>32 participants: 12 young (22.8, +/-1.86) and 20 elderly (65.8, +/-4.15) males Vs females</td>
</tr>
<tr>
<td>Curry, Greenberg &amp; Blanco employees (2002)</td>
<td><em>To assess eye glance behaviour measures and their relationship to surrogate candidates such as driving performance (lane keeping) and task completion times (static and dynamic).</em></td>
<td>In-vehicle (Volvo).</td>
<td>Dynamic, static-vehicle &amp; static mock-up.</td>
<td>No occlusion</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>29 participants from Ford or Visteon Automotive Systems age 45-55 (7 males, 8 females) and 56-65 (7 males, 7 females).</td>
</tr>
<tr>
<td>Fichtenberg (2001)</td>
<td><em>To determine how different occlusion interval times affect the total shutter open time (TSOT) and accuracy of the participant, with less chunkable tasks than Karlsson &amp; Finchburg (2001).</em></td>
<td>In-vehicle (Volvo).</td>
<td>a) No occlusion b-d) PLATO occlusion goggles</td>
<td>a) n/a b-d) System paced</td>
<td>Fixed per test - did several variations.</td>
<td>a) All. b) 1.5 seconds. c) 3.5 seconds. d) 6 seconds.</td>
<td>15 participants: 12 males, 3 females aged 24-59 13 volunteers participated in previous experiment.</td>
<td></td>
</tr>
<tr>
<td>Gehu and Krems (in press)</td>
<td><em>To review other recent occlusion research literature.</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green (1999)</td>
<td>To propose SAE standard for 15 s rule for IVIS to promote safety in design of systems.</td>
<td>In-vehicle with navigation systems (Peugeot 607 Renault Leguna II).</td>
<td>Occlusion goggles with 4 liquid-crystal display screens shutter driven by PC through software.</td>
<td>System paced (by PC).</td>
<td>Fixed.</td>
<td>1.7 seconds.</td>
<td>5 seconds.</td>
<td>32 participants: 12 young (22.8, +/-1.86) 16-elderly (65.8, +/-4.15) males Vs females young participant had perfect vision no experience of navigation systems.</td>
</tr>
</tbody>
</table>
Training | Study design | Dependent variable | Additional information | Conclusion drawn | Lessons learned
--- | --- | --- | --- | --- | ---
Before trials | Important information

Not detailed. | 2x2x6x3 mixed factor design age group x2 (middle-aged, older) gender x2 environment x 3 (dynamic, static-vehicle, static mock-up) task category x 6 secondary IVIS tasks (inc. phone, radio, navigation system), 3 repetitions per task in each environment.

Total task Times)

Dynamic driving performance parameters:

lateral lane position (LATDEV), yaw rate (YWRDEV), No. lane violation (LNVOL), SD of headway (HPDEV), Avg & SD vehicle speed, YMPH/YMPHDEV eye glance measure Total glance time (TGT), mean single glance time (MSGT), longest eye glance to display (LEGDSP), Number of eye glances to display (NEGDSP).

*Task completion time; measured in the simulator (TTT), is highly correlated with total glance time (TGT), therefore TTT dynamic is an appropriate surrogate for visual demand.

*TGT is highly correlated with the number of lane violations committed during a task.

Opportunity to practice both tasks immediately before start.

Repeated measures design 6 tasks (1 type1/3 type2) all tasks without goggles, 2 with goggles, total = 8 tasks/participant each task repeated 5 times under every condition random order.

TSOT Static Task completion time accuracy of sub (error rate).

Task type 1 - matrix task Task type 2 - string task - much less chunkable.

*For less chunkable tasks: Longer occlusion interval times decrease overall performance and ability to perform the task in terms of accuracy and time.

*Not all tasks are chunkable.

Experimenter demo each task. Participant repeat 2 consecutive successfully trials/immediately priorit then repeated twice: once with goggles open, once with no goggles.

Repeated measures design of each participant group completed tasks on each car with & without goggles 1/2 participants started with specs, half without10 tasks with occluded goggles 5 navigation; 3 phone; 1 air con; 1 cluster 1/2 did task in reverse order. Each task repeated twice, i.e. with & without goggles.

Task completion time TTT (without shutter)/TTTocc (with shutter)/TSOT/TTT TTTocc/(TTT+TTTclose) accuracy(error rate) No. open/close cycles/total of car/each time of.

1.7s vision interval = 200ms focus adjust time and 1.5s dwelling time Shutter CLOSE time was the same as Niya (2000).

*No noticeable difference in task completion time with goggles off and goggles open.

*There is a correlation between TSOT and TTT.

*The TTTocc < 1.25.

*(TTT+TTTclose) criterion appears to be very sensitive to the absolute value of TTT rather than task complexity.

*The ‘TSOT/TTT ratio’ is also sensitive to TTT not complexity.

A single criterion is not appropriate to determine visual distraction induced by the use of a system by the driver.

Continued ....
<table>
<thead>
<tr>
<th>Author papers</th>
<th>Aim</th>
<th>Set up</th>
<th>Means of occlusion</th>
<th>Pacing</th>
<th>Interval variability</th>
<th>Vision interval</th>
<th>Occlusion interval</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Karlsson &amp; Fichtenberg (2001)</td>
<td><em>To determine how different occlusion intervals affect the TSOT.</em>&lt;br&gt; <em>To compare the results with the ISO proposed criteria (TToocc/Static+ Tclogged).</em>&lt;br&gt; <em>To investigate subjects feeling towards occlusion spectacles.</em></td>
<td>In-vehicle with navigation system.</td>
<td>Goggles with liquid-crystal shutter response time of shutter &lt;10msec; transparency - 73% open/ 12% closed.</td>
<td>System paced.</td>
<td>Fixed per test - several combinations.</td>
<td>a) 1.0 seconds. b) 1.0 seconds. c) 1.5 seconds. d) 1.5 seconds. e) 1.5 seconds.</td>
<td>10 participants: all male aged 25-51.</td>
<td></td>
</tr>
<tr>
<td>Karlsson, Baumann, Gelau, Bengler and Krems (2001)</td>
<td><em>To present the occlusion technique for visual-system evaluation as a simple and valid method for assessing different aspects of the in-vehicle HMI.</em></td>
<td>In-vehicle (Volvo).</td>
<td>PLATO occlusion goggles.</td>
<td>a) No occlusion b-e) System paced.</td>
<td>Fixed per test - did several variations.</td>
<td>a) n/a b) 1.5 seconds. c) 1.5 seconds. d) 1.5 seconds. e) 1.5 seconds.</td>
<td>20 participants.</td>
<td></td>
</tr>
<tr>
<td>Bengler and Gelau (2000)</td>
<td><em>To describe the occlusion technique as an evaluation instrument during the design process.</em>&lt;br&gt; <em>To produce the summary of experimental results from four experiments.</em></td>
<td>PC/AT 486 with 17&quot; monitor. Special keyboard with time markers.</td>
<td>Display on/off. System paced.</td>
<td>Fixed at different intervals.</td>
<td>0.2-1.2 seconds 8 stages.</td>
<td>Not detailed.</td>
<td>25 participants.</td>
<td></td>
</tr>
<tr>
<td>Hashimoto &amp; Atsumi (2001)</td>
<td><em>To obtain an upper limit TGT that does not interfere with unsteadiness and lateral deviation.</em>&lt;br&gt; <em>To obtain best test bench based evaluation method that correlates with TGT.</em></td>
<td>In-vehicle with Goggles with navigation system.</td>
<td>System paced.</td>
<td>Fixed per test - several combinations.</td>
<td>a) 0.5 seconds. b) 1.0 second. c) 0.5 seconds. d) 1.0 second. e) 3.0 seconds.</td>
<td>10 participants: all male aged 25-51.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
This paper discusses Krems. Keinath, Baumann, Bengler
and Gelau (experiments 1-3) 1) Discriminate between simple and
presented in this table complex versions of visual display.

2) Investigate the impact of dialogue
interruption on task performance.

Thorough training immediately
before test controls and tasks
of RTI:

- Repeated measures design each
text - 5 destination entry, volume, brightness adjustment and
choosing establishment from list 5 conditions 8 tasks
order tasks/conditions varied.

- Dynamic Task Completion Time
(TTT static) Total Task Time
concluded TTT occl/TTT
closedTTT TTT occl/TTT
closed ratio.

- In occluded conditions each
participant did only 2 tasks
Time for task completion
measured subjective rating for
to say how occlusion felt TGT
Static = 0.680:660:740:67
(1,3,4,6s).

- *TTT should be < 8s
- *Single Glance Time is not
a good measure of visual
distraction because participants feel more
uneasy as Total Glance
Time (TGT) increases.

- *TTT had fairly high
correlation with TGT.

- *TSOT had very high
correlation with TGT.

- *TTT is a good measure of
visual distraction.

- Occlusion pattern of open-
1 sec/closed-1.0s has the
closest correlation with TGT.

- *There is a necessity upper
limit in the number of
interactions with IVIS.

- *TSOT and TTT static have
a very high correlation.

- Older people find occlusion
spectacles less frustrating
than younger people.

Not detailed

- Repeated measures design independent variable: task
complexity (simple/complex) 160 tasks/person (80 simple/80
complex). Task = 10x10 stylised card/map route A-B

- Number of correct tasks

- Simple Vs complex sampled
for pre-determined timepape
discussed in Keinath et al.

- When occlusion is system
paced

- *The probability of errors
for complex tasks is greater
than the probability for
simple tasks for all
occlusion periods.

- *The probability of
mistakes in both complex
and simple tasks decreased
as the visual occlusion
interval is increased.

- *The occlusion technique is a valid
procedure (when system and user paced) for
evaluating displays as it can make a
distinction between display designs of
varying complexity.

- *A 1 second visual interval may be optimal
for distinguishing between simple and
complex tasks.

Not detailed

- Independent sample design
independent variable: task
complexity (simple/complex) 160 tasks/person (80 simple/80
complex). Task = 10x10 stylised card/map route A-B

- Presentation period

- Simple verses complex
samples for presentation
periods determined by the
participants.

- When occlusion is
computer-based:

- *Fewer tasks are solved
correctly during complex
tasks compared to
simple tasks

- *Complex tasks take
significantly longer to
solve than the simple tasks.
## Appendix B (Continued): Table of research methods and conclusions

<table>
<thead>
<tr>
<th>Author papers</th>
<th>Aim</th>
<th>Set up</th>
<th>Means of occlusion</th>
<th>Pacing</th>
<th>Interval variability</th>
<th>Vision interval</th>
<th>Occlusion interval</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Research papers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Krems, Keinath, Baumann, Bengler and Gelau (2000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Experiment 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Krems, Keinath, Baumann, Bengler and Gelau (2000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Experiment 4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lansdown, Burns &amp; Parkes (in press)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monk, Boehm-Davis &amp; Trafton (2002)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morita, Mashiko &amp; Okada (1998)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Experiment 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morita, Mashiko and Okada (1998)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Experiment 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table

<table>
<thead>
<tr>
<th>Author papers</th>
<th>Aim</th>
<th>Set up</th>
<th>Means of occlusion</th>
<th>Pacing</th>
<th>Interval variability</th>
<th>Vision interval</th>
<th>Occlusion interval</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krems, Keinath, Baumann, Bengler and Gelau (2000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Experiment 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Krems, Keinath, Baumann, Bengler and Gelau (2000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Experiment 4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lansdown, Burns &amp; Parkes (in press)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monk, Boehm-Davis &amp; Trafton (2002)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morita, Mashiko &amp; Okada (1998)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Experiment 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morita, Mashiko and Okada (1998)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Experiment 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Training Study design Dependent variable Additional information Conclusion drawn Lessons learned

**Before trials**

Not detailed. Independent samples design (2x3 design) 6 groups, each with 15 participants 40 tests/participant Task = stylised telephone list - look for numbers corresponding to names Task complexity x 2 Independent variable x 2 (presentation time/complexity). No. of mistakes. Dialog interruption with secondary task (graphic coding) simple task - number returns in same position after interruption complex task - number came back in random position. When a primary task interrupted an interruptible secondary task: *The probability of errors in the simple condition is always lower than in the complex conditions. *As the length of the occlusion period increases, fewer errors are made in the primary task. Designers should develop interfaces with discrete sub-tasks.

Not detailed. 3 goes at primary task - verbal answers single factor between participants design 40 tests/participant Task = stylised telephone list - look for numbers corresponding to names Task complexity x 2 (simple/complex) Individual variable (complexity). No. of errors in primary and secondary task. Dialog interruption with secondary task (semantic coding) secondary task was during the interruption = visual task requiring eye movement. When a primary task is interrupted by a less interruptible secondary task: *In complex tasks the probability of error in the secondary task is much higher than in the simple task. *The occlusion technique has some promise although the empirical basis is lacking.

**Instruction on VCR task 2 x 2 practice VCR only2x 60 s tracking practice only 2x switching practices - 5s VCR - 5s tracking until program complete.**

Repeated measures design (4x2 design/VCR task = primary task task time not including volunteers did a tracking task significant ly increases when with discrete sub-tasks. 2x 60 s tracking design) VCR task = primary task task time not including volunteers did a tracking task significant ly increases when with discrete sub-tasks. Resumption lag total VCR task time not including interruption. In the ‘occluded period’ the volunteers did a tracking task which requires full attention. There was an easy and hard version of tracking task. *TTT of the primary task significantly increases when a difficult secondary task interrupts. *The average resumption lag is 1.6 seconds. *The point in which a task is interrupted has an influence on resumption lag. *Resumption lag provides information on one source of TTT variability. Designers should develop interfaces with discrete sub-tasks.

Not detailed. Participants instructed to continuously look at IVIS, 7 IVIS positions plus not looking at IVIS (8 conditions) 3 speeds - 40/60/80 km/h each condition measured twice total 576 trials (12x2x3x8) participant asked to read out numbers on display every 1 s so as to have to gaze continuously participants rated feeling of uneasiness. 'Response time' - Time from car brake illuminating to participant pressing brake pedal/foot transfer time - time from releasing accelerator to pressing brake. *The average response time when looking straight forwards is 0.57 seconds. *The number of cases of not recognising brake lights increases as the display position moves down. *Average eye diversion time was 1.38 seconds. (0.17 s front to display, 1.05 s display, 0.16 s display to front). *Eye diversion time was slower at 80 km/h compared to 20 km/h. *Response time looking forwards was 0.63 s. *Response time when looking at display 1.37s.

Not detailed. Participants instructed to look at road enough so it doesn’t feel dangerous, not required to read numbers from display 4 speeds - 20/40/60/80 km/h display position: 40 deg left/27 deg down each task repeated twice total trials 120 (15x2x4). *Average eye diversion time was 1.38 seconds. (0.17 s front to display, 1.05 s display, 0.16 s display to front). *Eye diversion time was slower at 80 km/h compared to 20 km/h. *Response time looking forwards was 0.63 s. *Response time when looking at display 1.37s.

**Continued ....**
Appendix B (Continued): Table of research methods and conclusions

<table>
<thead>
<tr>
<th>Author paper</th>
<th>Aim</th>
<th>Set up</th>
<th>Means of occlusion</th>
<th>Pacing</th>
<th>Interval variability</th>
<th>Vision interval</th>
<th>Occlusion interval</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Niiya (2000)</td>
<td>To evaluate a navigation system using the occlusion technique.</td>
<td>Vehicle mock-up Touch screen Toyota navigation system.</td>
<td>Goggles with shutter.</td>
<td>System paced.</td>
<td>Fixed.</td>
<td>1.5 seconds.</td>
<td>5 seconds.</td>
<td>10 participants aged 19-61</td>
</tr>
<tr>
<td>Noy, Lemoine and Klachan (in press)</td>
<td>To investigate occlusion as a tool to assess visual distraction from IVIS.</td>
<td>Not detailed.</td>
<td>PLATO goggles.</td>
<td>System paced.</td>
<td>Fixed.</td>
<td>1.5 seconds.</td>
<td>3 seconds.</td>
<td>24 participants: 15 males, 19 females aged 21-34, average age: 23.8 years, valid licence for 3 years, drove &gt;1500 km/year, participants paid plus bonus for obeying driving rules and fines for speeding/accidents, all participants had 20/20 vision.</td>
</tr>
<tr>
<td>Noy, Lemoine and Klachan (in press)</td>
<td>To derive lane keeping measures under dual-task conditions.</td>
<td>Driving simulator STISIM at 80km/h.</td>
<td>No occlusion.</td>
<td>Driver determined.</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>As above.</td>
</tr>
<tr>
<td>Tijerina, Palmer &amp; Goodman (1998)</td>
<td>To investigate the demand/workload of route guidance.</td>
<td>In-vehicle (Toyota): Driven on systems test track-4 route guidance systems (3-visual- manual, 1-voice).</td>
<td>7.5 mile oval</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>As above.</td>
<td>16 participants (males and females): 2 age categories younger - &lt;35 years older - &gt;55 years valid driving licence, participants had no significant prior experience with navigation systems.</td>
</tr>
<tr>
<td>Training</td>
<td>Study design</td>
<td>Dependent variable</td>
<td>Additional Information</td>
<td>Conclusion drawn</td>
<td>Lessons learned</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>--------------</td>
<td>---------------------</td>
<td>------------------------</td>
<td>------------------</td>
<td>-----------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before trials</td>
<td>Repeated measures design</td>
<td>Total Shutter Open Time (TSOT) Total Glance Duration (TGD) Total number of visual recognition.</td>
<td>Extra focus adjust time was 0.2-0.3 s.</td>
<td>*TSOT is almost equal to Total Glance Duration (TGD) while the vehicle is in motion.</td>
<td>*The occlusion method could be a suitable evaluation method for Total Glance Duration (TGD).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Experiment repeated with and without shutter - influence of shutter on recognition time 4 navigation tasks plus 10 data entry tasks performed.</td>
<td></td>
<td></td>
<td>*Elderly participants have longer recognition times, even in 'no occlusion' conditions.</td>
<td>*A shutter open time of 1.7 seconds may be more appropriate.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Repeated measures design 3 secondary in vehicle tasks (2xtelematic visual searches, 1xradio tuning) repeated each task 10 times.</td>
<td>TSOT:TTTunocc mean ratio (R) perceived demand scores. R (chunkability) = TSOTmean/TTTunocc mean the greater the chunkability the smaller the R value (mean - across 10 trials for practice task)</td>
<td>*Scrolling tasks have a higher R ratio than the static tasks. This supports JAMA's guidelines to prevent scrolling text from appearing in vehicle displays.</td>
<td>*This study highlights promise of the occlusion technique based on the finding that the inherent characteristics of task and not the TTT affect the chunkability indices.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performed tasks in occluded and non-occluded conditions until performed at a consistent rate.</td>
<td>Repeated measures design 3 secondary in vehicle tasks (2xtelematic visual searches, 1xradio tuning) repeated each task 10 times.</td>
<td>Standard deviation lane position (SDLP) No. and duration of lane exceedence (NLE, DLE)15% time to line crossing (15% TLC)</td>
<td>*Driving performance decreases in terms of SDLP and NLE under dual-task conditions compared to baseline.</td>
<td>*Perceived demand scores were consistently rated more difficult for driving than during occlusion.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Practiced in simulator.</td>
<td></td>
<td>*Chunckability indices generated using occlusion were positively correlated with the majority of the participant measures of workload.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Repeated measures design Driving = primary task IVIS task = secondary task4 scenarios differing only in direction of road curvature 3 driving with secondary task 1 driving with no task (baseline) 1 task/scenario repeated at 30s intervals.</td>
<td>Mean glance duration Mean glance frequency Total glance time (TGT) to road ahead TGT to in-vehicle device TGT to note card No. lane exceedence lane exceedence duration total task time Driver preference/impression.</td>
<td>Light traffic present on test track participants asked to drive 45mph on straight &amp; 60mph on curve (if task complete) if not complete maintain 45 and attempt to complete.</td>
<td>*Visual-manual navigation tasks are associated with increased completion times, longer eyes-of-road ahead times, longer and more frequent glances to the device, and greater numbers of lane exceedence compared to the voice system.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Familiarised with each navigation system (4x/category) while parked in 2 phases (morn/afternoon).</td>
<td>Two-between (age/gender), 3-within (guidance system/destination category/destination target) participant design plus 2 non-destination tasks for comparison (radio/phone) Order of trials balanced non-destination tasks interspersed.</td>
<td></td>
<td>*Performance differences between younger and older participants tends to be reduced with voice systems.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*The destination entry task took substantially longer to complete than the phone-radio comparison test.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Voice recognition technology is a viable alternative to visual-manual destination entry while driving.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Continued ....
<table>
<thead>
<tr>
<th>Author paper</th>
<th>Aim</th>
<th>Set up</th>
<th>Means of occlusion</th>
<th>Pacing</th>
<th>Interval variability</th>
<th>Vision interval</th>
<th>Occlusion interval</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weir, Chiang, Brooks (2003)</td>
<td>* To study the effect of the secondary task and occlusion parameters on driver performance in primary and secondary tasks.</td>
<td>Driving simulator. 6 DF motion base 180 degree field of view.</td>
<td>1) No occlusion. 2a) Blanking. 2b) PLATO goggles. 2c) PLATO goggles. 2d) PLATO goggles. 3) No occlusion. 4) PLATO goggles. 5) No occlusion - no-screen banking.</td>
<td>1) n/a 2) System paced. 3) n/a 4) System paced. 5) Driver determined.</td>
<td>2a) 1, 2, 3 seconds. 2b) Varies systematically. 2c) ON/OFF cycles. 2d) PLATO systematically. 3) n/a</td>
<td>1) n/a 2a) 1, 2, 3 seconds. 2b) 1, 1.5, 2, 2.5, 3 seconds. 2c) 2 seconds. 2d) 1, 1.5, 2, 2.5, 3 seconds.</td>
<td>Weir, Chiang, Brooks (2003)</td>
<td>* To compare occlusion goggles and screen blanking methods of secondary task interruptions and evaluation. *To help suggest possible performance or comfort related boundaries on secondary task variables.</td>
</tr>
</tbody>
</table>
1) 3 minutes practice followed by 3x60s runs. 
2) 3 min practice, then 1 x 90s run with each ON/OFF combo. 4 participants did 180sec combo. 
3) 3x30s runs. 
4) 180sec entry-touch screen-entered words at own pace. 
5) two minutes practice run, then three sets of entry runs while driving.

**Training** | **Study design** | **Dependent variable** | **Additional information** | **Conclusion drawn** | **Lessons learned**
---|---|---|---|---|---
Before trials | Repeated measures design each participant accomplished all five experiments. 2x1/2 participants did goggles first, 1/2 blanking first. Order of ON/OFF combo randomised. 5/3x30s entries, with 30 between 2x60s entries with 30s between 1x120s entry. Primary driving task-straight road with random lateral disturbance-2 lanes, daytime conditions, 50 MPH. Drive safely in lane. Secondary task-HMI generic alphabet entry-touch screen-entered words at own pace. Participants told secondary task less important than primary (secondary at own pace). | Driver control inputs Driver/vehicle system response Performance lateral lane position blanking/occlusion parameters/timing subjective ratings Driver glance behaviour Task timing Total task time (TTT) Secondary task entry/errors Participant rating ease/comfort of performing driving task. | 1) Baseline secondary task only, accomplished continuously with no occlusion. 2) Secondary task with occlusion or screen blanking. 3) Baseline primary driving task only, no secondary task. 4) Primary driving task with occlusion using goggles. 5) Primary and secondary tasks combined, driver placed with no occlusion of screen blanking. | *No clear preference for the screen blanking or occlusion goggles method.*  
*Occlusion CLOSED times of up to 2s (when used to interrupt driving task) do not degrade task performance.*  
*Occlusion OPEN times of 1.5 sec or greater provide satisfactorily secondary task performance when used to simulate intermittent task activity.*  
*A broad range of CLOSED or OFF times are acceptable, and values in the range of 1-3 seconds seemed to be preferred.*  
*Standard deviation of lane position is a more sensitive and useful measure of lane keeping performance than lane exceedences.*  
*Relatively long secondary task durations (up to 120-100 made seconds) do not degrade primary and secondary task performance, behaviour or ratings.*  
*A suitable occlusion technique could be to use CLOSED times of up to 2s and OPEN times of 1.5 sec or greater, using either goggles or screen blanking.*
Abstract

In-vehicle information systems (IVIS) can provide useful information to support the driving task, reduce stress and make a journey more comfortable. A few brief glances to an IVIS are not likely to have a significant effect on safety. However the visual distraction caused by some in vehicle systems that require longer and more frequent glances is of concern.

Occlusion is a technique that can be used to assess the visual distraction associated with operating an in-vehicle information system (IVIS). The technique is used for simulating the shift in visual attention between the driving scene and the IVIS. This is done using a shutter to hide and expose the IVIS from view, or goggles that also block or reveal the visual scene (the IVIS). The amount of time (duration and frequency) that the IVIS is visible or occluded (blocked from view) is controlled during occlusion. The basic idea is to investigate whether in-vehicle tasks can be carried out in short bursts of visual attention towards a display screen (typically 1 to 2 seconds).

This literature review was carried out to identify previous research on the occlusion technique as a measure of the distraction imposed by IVIS. A number of issues need to be considered when developing a standard protocol with which IVIS might be assessed. The review considers the technique in terms of issues such as shutter open/closed times, and the variables against which the system should be assessed. In addition, issues such as training, sample demographics, test environment, number of trial repetitions, impact of primary distracter tasks and how to deal with system response delays are considered.

Related publications

TRL540 EU Statement of Principles for HMI: Final report by A C Board and A Stevens. 2002 (price £40, code HX)
TRL359 A preliminary study of in-vehicle interfaces for electronic toll collection by D Watts, J Rattle and A Stevens. 1998 (price £35, code H)
TRL348 User requirements of on-board units for electronic toll collection by P T McCabe. 1998 (price £35, code H)
TRL345 Measures for assessing on-board units for electronic toll collection - Parts 1 and 2 by J Holder and J Sutherland. 1998 (price £35, code H)
TRL318 The use of mobile phones while driving by A Stevens and D A O Paulo. (price £20, code C)
CR181 Autoguide system proving and usability trials by R West, R Kemp and S Hack. 1989 (price £20, code C)
PPR009 In-Vehicle Information System (IVIS) user manual usability and safety checklist by N Brook-Carter. 2004 (price £10, code 1)
PPR011 Occlusion: practical aspects of the occlusion method to measure visual loading and task interruptability by N Brook-Carter, A Stevens, N Reed and S Thompson. 2004 (price £15, code 1X)
PA3536/99 A safety checklist for the assessment of in-vehicle information systems. A user's manual. (price £25)

Prices current at August 2004

For further details of these and all other TRL publications, telephone Publication Sales on 01344 770783, or visit TRL on the Internet at www.trl.co.uk.