Measuring distraction:
the Peripheral Detection Task

M.H. Martens & W. van Winsum
TNO Human Factors, Soesterberg, The Netherlands

Abstract

The possibilities for measuring workload or driver distraction by means of the Peripheral Detection Task during driving with in-vehicle equipment were investigated in a driving simulator experiment. The results show that the Peripheral Detection Task is a very sensitive method of measuring peaks in workload, induced by either a critical scenario or messages provided by a driver support system. The more demanding the task, the more cues will be missed and the longer the response times to the Peripheral Detection Task. Also, the experiment showed that the hypothesis that PDT measures the width of the functional field of view (perceptual tunnelling) is not supported. The results favour the 'cognitive tunnelling' hypothesis. This is consistent with the hypothesis that the PDT measures the (cognitive) selectivity of attention.

Introduction

In-vehicle systems may have a negative effect on safety if they increase workload or distract the driver (Verwey, Brookhuis & Janssen, 1996). Sudden increases in workload can occur during the interaction of the driver with the in-vehicle system, since the driver has to divide his/her attention between the outer world and the system inside the vehicle. Even if the system does not require the driver to look inside the vehicle on a display, the system may distract by providing information to the driver (e.g. speech messages) or performing actions that the driver did not expect or initiate. Since distraction is basically the inability to pay sufficient attention to all present tasks, or one task requires attention to a degree that other things are missed, the present paper will discuss workload and distraction as similar concepts. Although the two phenomena are not equal, the principles of measuring workload could also be useful for measuring distraction, caused by in-vehicle systems (with either visual or auditive messages). Therefore, the paper discusses the possibilities for using sensitive measures of workload, which may also be applicable for measuring distraction of in-vehicle equipment.

Most of this workload or distraction concerns short-lasting peaks that are often difficult to detect with the traditional methods for measuring workload. Especially the sudden increases in workload or even short but high peaks are potentially dangerous because they often cannot be predicted and anticipated. If workload is predictable, the driver will generally try to control workload by making the primary driving task easier if possible. This can be done by lowering the current driving speed (e.g. Harms, 1991). While driving, workload or distraction caused by a driver support system is added to the workload induced by the primary driving task. Although there are several methods for measuring workload, good methods for measuring variations in workload are lacking. Methods of workload are usually aggregated over time. This makes traditional subjective measures of workload sometimes difficult to interpret, because it is unclear whether the driver refers to overall workload or peaks in workload (De Waard, 1996). Especially with subjective measures of workload this results in problems of interpretation.

Especially self-report and physiological measures are mainly suitable for measuring workload over longer periods of time while they are unable to detect short-lasting variations in workload or short distraction. A possible exception to this is the use of event-related electro-cortical indices such as

P300 amplitude or Event-Related Desynchronization of alpha rhythm (e.g. O'Donnell & Eggemeier, 1986). An alternative measure is calculating the time that subjects look at the in-vehicle display. This can be seen as a measure of distraction, since the visual attention of the driver is distracted from outside the vehicle to inside the vehicle. When an incident occurs while the driver is looking at the display this may result in an accident (Van Winsum & Claessens, 1998). The problem with this method is that this can only measure distraction to a visual display, and it cannot measure distraction in case of speech messages or an increase in workload induced by the in-vehicle system performing some action. Therefore, just measuring the number and duration of fixations to the display will not be sufficient.

A possibility for measuring workload or attentional distraction is measuring the detection of stimuli in the functional visual field. Studies trying to measure variations in workload already worked with the phenomenon that the functional visual field decreases with increasing workload. During a driving experiment on the road, Miura (1986) presented spots of light on the windscreen under different horizontal angles with respect to the position of the driver, and measured reaction times for detecting the stimuli. With increasing complexity of the driving task (higher traffic density) reaction time increased. Also, reaction time increased as the functional visual field decreased. The results were interpreted as indicative for a reduction of the visual field of view with higher complexity of the driving task. Similar results have been reported by Williams (1985, 1995). In a number of experiments it appeared that with increasing foveal load, visual tunnelling occurred, resulting in a higher reaction time to more peripheral stimuli. The ability to process peripheral information decreased as foveal load increases. It has been questioned by some whether this really is a visual tunnelling effect or whether it is a ‘cognitive tunnelling’ effect. Dirkin and Hancock (1985) state that the term ‘visual tunnelling’ should be replaced by ’cognitive tunnelling’, since the phenomenon is indicative of a shift towards increasingly selective patterns of attending. According to these authors it is a measure of cognitive selective attention, since experimental evidence has shown that if peripherally located stimuli were relevant to the performance of a primary centrally located task, decrements in performance did not occur. This increase in selectivity has already been discussed a long time ago by Easterbrook (1959) who hypothesised that increases in arousal restrict the utilisation of cues from the sensory environment. The phenomenon is however usually associated with stress instead of with workload. Illustrations of this are the clear occurrences of tunnel vision under severe fatigue or in reported cases of near-death experiences.

This discussion indicates that the mechanism behind the visual or cognitive tunnelling phenomenon is not entirely clear. Still, the approach may be useful for measuring variations in workload. An added advantage of this approach is that mere peripheral detection without the need for a complex decision is a low-level easy-to-automate process that requires little conscious attention. By this, the disadvantages of secondary tasks, that need to be loading to some extent in order to show effects, can be avoided. In the experiment the measure used was based on the idea that the functional visual field decreases with increasing workload.

In a driving simulator study (TNO Human Factors driving simulator, for details see Hogema & Hoekstra, 1998; Hoekstra, van der Horst & Kaptein, 1997) that was part of the European project IN-ARTE (Transport Telematics project TR4014 of the EU), the possibilities for measuring driver workload via the Peripheral Detection Task were investigated to see if it was sensitive to short lasting peaks in workload.

The Peripheral Detection Task (PDT)

The PDT was used to measure workload of driver support systems while driving in different traffic scenarios, with some critical scenarios and some normal scenarios. While driving on a 80 km/h road and a motorway, a small red square was presented on the simulator screen in front of the subject during one second. Subjects were required to respond as soon as a red square was detected by pressing a microswitch that was attached to the index finger of the dominant hand. Reaction time (RT) was measured in ms. If a reaction was not detected within 2 s from the onset of the stimulus this was coded as a missed signal (after 2s, the signal disappeared from the screen). On average each 4 s, with random variation between 3 and 5 s, a stimulus was presented at a horizontal angle of 11 to 23° to the left of the line between the eyes of the subject and the centre of the screen. Stimuli were presented at a vertical angle between 2 to 4° above the horizon. The task required little conscious attention and could be performed without turning the head to the direction of the stimulus. Average RT and fraction of missed signals (number of missed divided by total number of stimuli) were used as performance indices. A higher RT and a higher fraction of missed signals were interpreted as the result of higher workload. At unexpected moments in time, subjects were confronted with critical incidents, such as a braking lead vehicle, a sharp curve etc. A total of 54 subjects participated in the experiment, with 18 subjects driving without any warning system, 18 subjects driving with tactile warnings and another 18 subjects driving with auditive warnings for lateral and longitudinal control. Since the aim of this report is not to advise on which system to use, but rather to see if this method can be used for measuring workload, the results of the subjects driving without a system and the subjects driving with one of the systems are taken together if nothing else is indicated.

Results

The reliability of the PDT and its functional meaning was assessed to determine its usefulness for detecting peaks and variations in workload. The average RT and fraction of missed signals were computed for several driving situations. If more complex driving situations result in larger RTs or higher fractions of missed signals then PDT can be considered as sensitive to variations in workload. Responses to PDT stimuli were grouped and processed separately for a number of different situations, that were related to critical driving scenarios. Average RT and fractions of missed signals were compared with what was considered to be the easiest situation, straight road driving with a 80 km/h speed limit on the rural road, and normal driving with the speed limit of 120 km/h on the motorway. These situations were thus used as a reference in tests of differences in RT and misses with repeated measurements analysis of variance. The results of the RTs and the fraction of missed signals are shown in Figure 1 and Figure 2 respectively. The results showed that driving in narrow curves clearly results in deteriorated performance on both RT [$F(1,51)=34.75$, $p<0.001$] and misses [$F(1,51)=9.73$, $p<0.01$]. The approaching of an intersection, and especially if a full stop must be made, results in a large increase in workload as evidenced by increased RT [$F(1,51)=61.69$, $p<0.001$ and misses [$F(1,51)=73.37$, $p<0.001$]. This also occurs if the driver interacts with a lead vehicle, either when overtaking [$F(1,50)=39.13$, $p<0.001$ for RT and $F(1,51)=45.54$, $p<0.001$ for misses) or when the lead vehicle brakes unexpectedly [$F(1,42)=20.09$, $p<0.001$ for RT and $F(1,46)=27.87$, $p<0.001$ for misses). For example, if the lead vehicle brakes, the fraction of missed signals on the PDT is 5 times as high as the reference scenario (driving on a 80 km/h road). The results indicate that both RT and fraction of missed signals are sensitive to variations in workload.

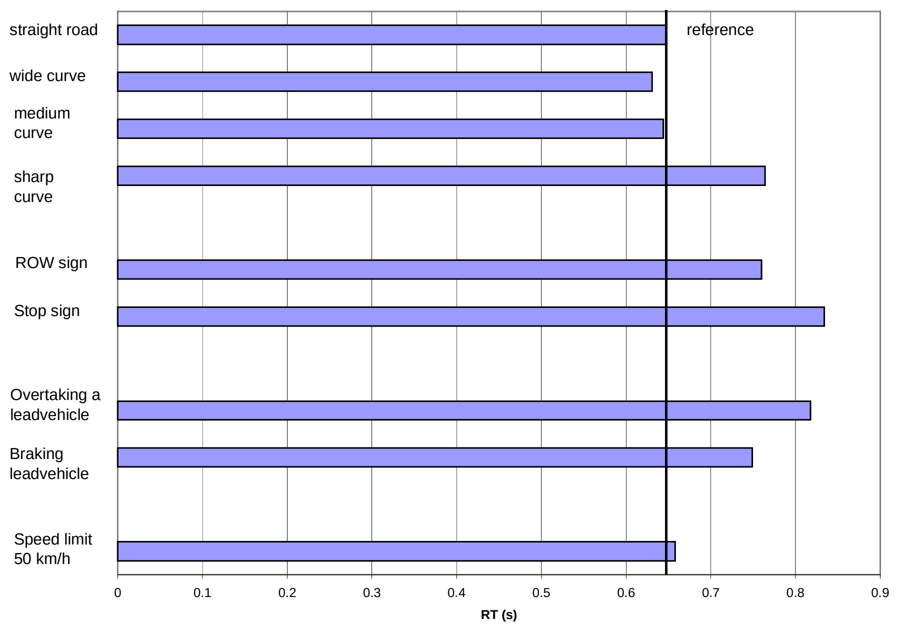

Figure 1. Average RT on PDT for selected situations on rural road.

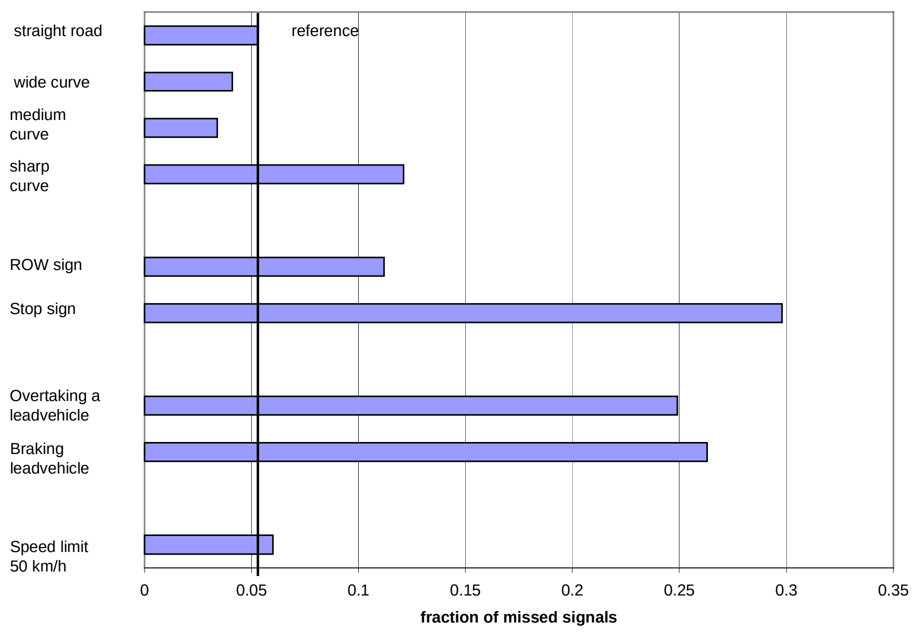

Figure 2. Fraction of missed signals on PDT for selected situations on rural road.

The critical incidents on a motorway, especially a lead vehicle that brakes unexpectedly [$F(1,41)=20.53$, $p<0.001$ for RTs and $F(1,45)=78.88$, $p<0.001$ for the misses] and a package that falls off a truck (unexpected obstacle) [$F(1,15)=23.65$, $p<0.001$ for RTs and $F(1,32)=41.59$, $p<0.001$ for misses] resulted in a larger increase in RT and in the fraction of missed signals on the

PDT, compared to the control condition of driving on a 120 km/h motorway. The results for the RTs and the fraction of missed signals are shown in Figure 3 and Figure 4 respectively.

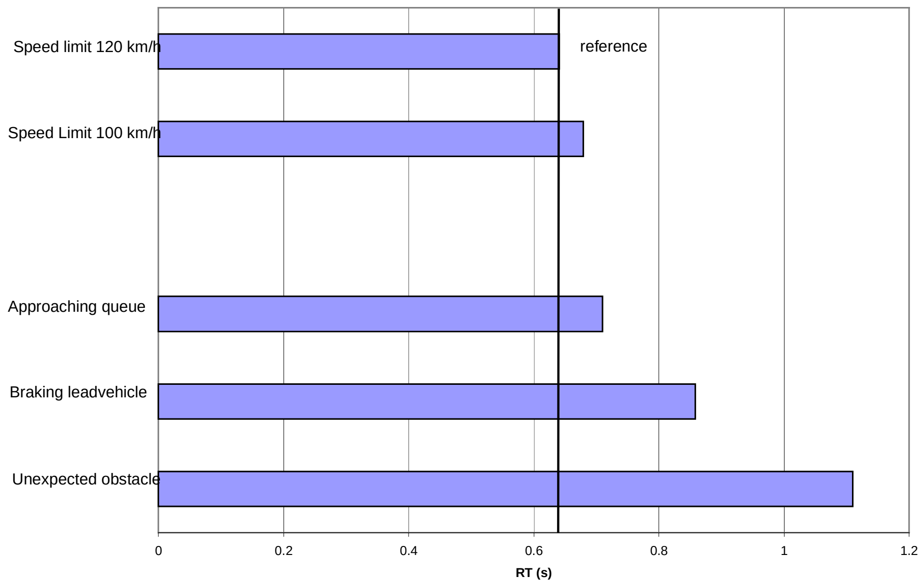

Figure 3. Average RT on PDT for selected situations on motorway.

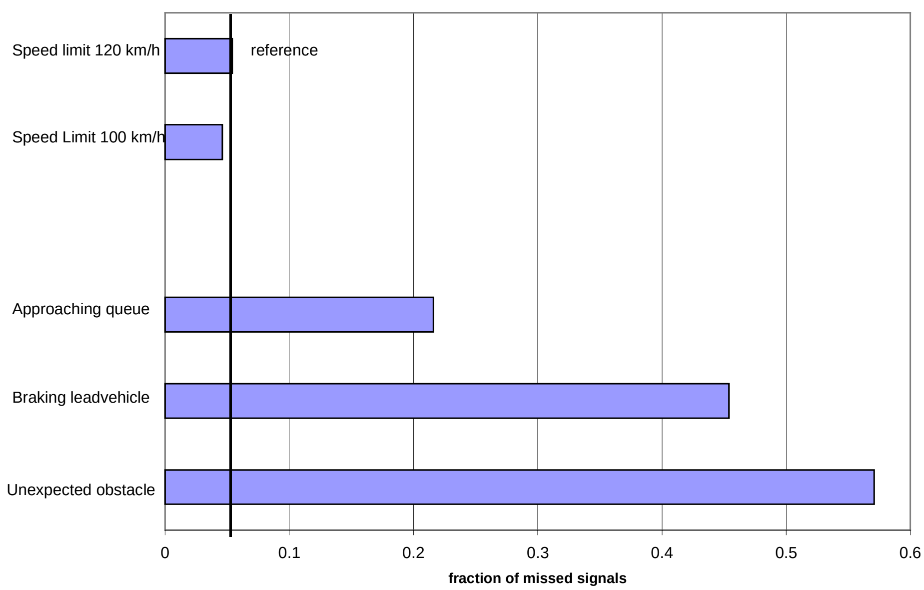

Figure 4. Fraction of missed signals on PDT for selected situations on motorway.

These results indicate that both RT and misses are sensitive to differences in driving situation. Situations that require immediate actions and that are characterised by a sudden and unexpected change in criticality result in deteriorated performance on the PDT. This suggests that the PDT is suitable for measuring variations in workload. Performance on the PDT also strongly deteriorated when a speech warning message was presented compared to group of subjects that did not receive any message for the critical scenario. This appeared from both RT and fraction of missed signals. The increases in workload caused by tactile messages did not statistically differ from the condition without any warnings. These results together indicate that the PDT is also sensitive for measuring differences in workload or distraction between non-visual modes of driver support systems.

Further statistical tests (for more information see van Winsum, Martens & Herland, 1999) investigated whether PDT measures variations in size of the functional field of view, (perceptual tunnelling), as a function of variations in workload, or a cognitive selectivity in attention (cognitive tunnelling). It was tested how RT and the fraction of missed signals are affected by both horizontal angle at which the stimulus was presented and workload. RT and fraction of missed signals were computed as a function of horizontal angle. It was assessed whether there is a statistical interaction between workload and horizontal angle. If the PDT is sensitive to perceptual narrowing or perceptual tunnelling, then such an interaction would be expected

The horizontal angle of stimulus presentation did not affect performance on the PDT, and the slope of performance as a function of horizontal angle was not steeper in the critical traffic conditions. These results indicate that the hypothesis that PDT measures the width of the functional field of view (perceptual tunnelling) is not supported. However, since the effect criticality of the traffic scenario on RTs, and especially on the fraction of missed signals, is statistically significant, the results favour the ‘cognitive tunnelling’ hypothesis. This is consistent with the hypothesis that the PDT measures the (cognitive) selectivity of attention.

Conclusions

Performance on the Peripheral Detection Task proved to be sensitive to variations in primary (driving) task demand and to variations between the demand or distraction of in-vehicle messages (non-visual). The evidence suggests that PDT measures the variations in selective attention, in which the selectivity of attention increases with workload (cognitive tunnelling).

References

De Waard, D. (1996). *The measurement of drivers’ mental workload*. PhD Thesis, University of Groningen.

Dirkin, G.R. and Hancock, P.A. (1985). An attentional view of narrowing: The effect of noise and signal bias on discrimination in the peripheral visual field. In: I.D. Brown, R. Goldsmith, K. Coombes & M.A. Sinclair (eds.) *Proceedings of the Ninth Congress of the International Ergonomics Association*, Bournemouth, 2-6 September 1985. London: Taylor and Francis.

Easterbrook, J.A. (1959). The effect of emotion on cue utilization and the organization of behaviour, *Psychological Review, 66*, 183-201.

Harms, L. (1991). Experimental studies of variations in cognitive load and drivinf speed in traffic and in driving simulation. In: A.G. Gale, I.D. Brown, C.M. Haslegrave, P. Smith & S.H. Taylor (eds.) *Vision in Vehicles-III* (p. 71-78). Amsterdam: Elsevier, North Holland.

Hoekstra, W., Van der Horst, A.R.A. and Kaptein, N.A. (1997). Visualisation of road design for assessing human factors aspects in a driving simulator. *Proceedings Driving Simulator Conference (DSC ’97)*, 8-9 September, Lyon, France.

Hogema, J.H. and Hoekstra, W. (1998). *Description of the TNO Driving Simulator* (Report TM-98-D007). Soesterberg, The Netherlands: TNO Human Factors Research Institute.

Miura, T. (1986). Coping with situational demands: A study of eye movements and peripheral vision performance. In A.G. Gale, I.D. Brown, C.M. Haslegrave, P. Smith & S. Taylor (eds.), *Proceedings of Vision in Vehicles*, (p. 205-216). Amsterdam: Elsevier, North Holland.

O'Donnell, R.D. and Eggemeier, H. Th. (1986) Workload Assessment Methodology. In: K.R. Boff, L. Kaufman and J.P. Thomas (Eds); *Handbook of Perception and Human Performance*, Volume II, (42.1-42.49). New York, Wiley.

Verwey, W.B., Brookhuis, K.A. & Janssen, W.H. (1996). Safety effects of in-vehicle information systems (Report TM-96-C002). Soesterberg, The Netherlands: TNO Human Factors Research Institute.

Williams, L.J. (1985). Tunnel vision induced by a foveal load manipulation. *Human Factors*, *27*, 221-227.

Williams, L.J. (1995). Peripheral target recognition and visual field narrowing in aviators and nonaviators. *The International Journal of Aviation Psychology, 5*, 215-232.

Van Winsum, W. & Claessens, F.M.M. (1998). *Effecten van mogelijke vormen van informatiepresentatie van de OBU op rijgedrag en verkeersveiligheid* (Report TM-98-C052). Soesterberg, The Netherlands: TNO Human Factors Research Institute.

Van Winsum, W., Martens, M. & Herland, L. (1999*) The effects of speech versus tactile driver support messages on workload, driver behaviour and user acceptance.* Report TNO Human Factors Research Institute (in press), Soesterberg, the Netherlands.