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EVALUATION OF THE TACTILE DETECTION RESPONSE TASK (TDRT) IN A LABORATORY TEST USING A SURROGATE DRIVING SET-UP

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ABSTRACT:

This paper presents findings of a laboratory experiment which aimed at evaluating the sensitivity and intrusiveness of Tactile Detection Response Task (TDRT) methodology. Various single-task, dual-task and triple-task scenarios were compared. The task scenarios included a surrogate of driving (tracking task) and different secondary tasks (N-back, surrogate reference task (SuRT)). The results suggest that the TDRT is sensitive to load levels of secondary tasks which primarily demand for cognitive resources (N-back). Sensitivity to variations of visual-manual load could not be shown (SuRT). TDRT seems also to be able to differentiate between primary task modes which vary in terms of cognitive load (visual against auditory tracking task). Results indicated intrusiveness of TDRT on primary task performance and secondary task performance depending on the type of underlying task scenario. As a conclusion, TDRT can be recommended as a method to assess attentional effects of cognitive load of a secondary task, but should be used with caution for secondary tasks with strong motor demands.

1 INTRODUCTION

The Detection Response Task (DRT) is a novel method based on a simple stimuli-response task similar to the well-known Peripheral Detection Task (PDT) [1]. Both methods measure effects of secondary task load on driver attention and are intended for evaluation of in-vehicle information and control system interfaces. The participant presses a button in response to frequent stimuli presented at a randomly varied interval of 3 to 5 seconds. PDT uses LEDs for presenting visual stimuli. However, visibility of the stimuli can vary with lighting conditions. To avoid this limitation, the TDRT has been developed which presents a vibrating (tactile) stimulus to the participant's shoulder [2]. The TDRT is one of three alternative DRT methods which differ in mode of stimulus presentation. The other two DRT methods use visual stimuli.

There is strong support for the PDT, among other methods, as a measure of visual distraction, but it is not well established as a measure to assess cognitive demand [16]. Furthermore, a standardized measurement method that specifically addresses cognitive demands of tasks during handling an in-vehicle interface is lacking up to now. The DRT was recognized by the International Standards Organization (ISO) as a promising method for assessing attentional effects related to cognitive demands of an in-vehicle interface. The experiment presented in this paper was part of a set of coordinated international studies which supported the ongoing development of an ISO standard on the DRT [3]. The studies mainly worked on open issues with regard to sensitivity of the new method.

Although the main focus of the TDRT is to measure effects of cognitive load, other types of secondary task load such as sensory-actuator demands and/or perceptual-motor demands may also affect TDRT results. The driver-task model used in this standard conceptualises driver attention as the allocation of resources to a set of activities [14]. Driving activities are related to Michon’s driver-task model [15]. Non-driving activities include the operation of secondary tasks or performance of the DRT.

Other open questions referred to intrusiveness, as the effects of TDRT on primary task and secondary tasks have not been systematically investigated so far. The current study was designed to examine these issues by focusing on the following research questions:

- To what extent is the TDRT sensitive to different load types and load levels of both primary task and secondary task?

- How does the TDRT affect the primary task performance, secondary task performance, or subjective workload?

A set of hypotheses was defined which was based on these research questions. It was expected that TDRT would be able to differentiate between different levels of cognitive load, if task primarily demands for cognitive resources. In case of perceptual-motor tasks, it was hypothesised that TDRT would be sensitive to perceptual (visual) demands. Additionally, it had to be taken into account that some of the existing DRT studies reported manual response conflicts in case of strong motor demands of tasks.

2 METHOD

The experiment was performed in the HMI laboratory of BASt in 2013.

2.1 Participants

A total of 22 licensed drivers (10 female, 12 male) volunteered in participating in the study. Age of the participants ranged from 19 to 64 years (mean 41.7, standard deviation 13.9).

2.2 Surrogate driving task

A surrogate of driving was used as primary task in the experimental set-up. Participants had to perform a continuous sensomotor tracking task using a steering wheel as input device for manually controlling the tracking deviation. The task was to minimize tracking deviation over a given winding track.

Two types of tracking task with different modalities of feedback to the participant were used: a) visual tracking, and b) auditory tracking. Each tracking type was conducted at two difficulty levels depending on the bendiness of the track: easy = low bendiness, hard = high bendiness (Figure 1). The tracks of both difficulty levels were of the same function, but speed of the cursor on the track was higher for the hard condition than for the easy condition. The track of the hard condition thus featured more bends per time unit than the track of the easy condition.

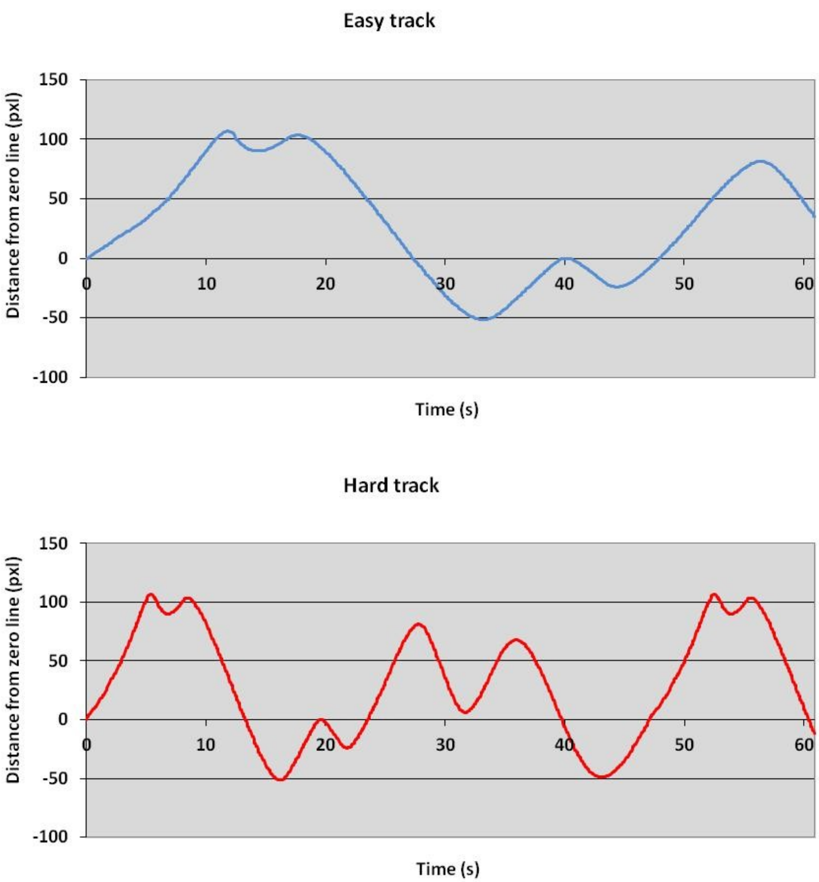

Figure 1: Tracking paths used for the easy (above) and hard tracking task

Track and tracking deviation were visually presented to the participant when performing the visual tracking task. No visual feedback was presented to the participant during execution of the auditory tracking task. In this case, the participant only received acoustic feedback indicating the extent of deviation (via tone frequency) and the direction of deviation, i.e. the side of the track where the deviation drifted to (via left/right speaker). No acoustic output was generated, if tracking deviation did not exceed the tolerable range of the given track. As long as tracking deviation exceeded the tolerable range of the track, a tone was given to the driver. The frequency of the tone corresponded to the extent of tracking deviation and reached from 890 Hz up to 3540 Hz.

The cognitive load imposed to the participant, i.e. mental effort to control tracking deviation, was higher for the auditory tracking task than for the visual tracking task [4]. Thus the manipulation of feedback modality (visual; auditory) allowed for variation of primary task in terms of perceptual-cognitive demands, whereas the manipulation of tracking difficulty (easy; hard) primarily varied the perceptual-motor demands of primary task.

2.3 Secondary tasks

Two secondary tasks were included in the study, the Surrogate Reference Task (SuRT) and the N-back Task. SuRT is a visual-manual search task, whereas the N-back Task imposes mainly cognitive load on the participant. Each secondary task was conducted at two load levels.

The SuRT required the participant to visually search a display for a target circle which was surrounded by a set of distractor circles [5]. After detection of the target circle the participant responded by pressing the right or left key of a numeric keypad thus inducing a visual cursor moving to the target circle. Visual perceptual load was varied in terms of size of the distractor circles in comparison to the target circle (easy = large difference in size; hard = small difference in size) [6]. The two SuRT levels additionally differed in terms of manual load. Only few keystrokes to reach the target were needed on the easy level, whereas the hard level required a higher amount of inputs. A new sub-task appeared on the screen as soon as the participant confirmed completion of the preceding sub-task.

During N-back Task a series of spoken digits were presented to the participant by a computer [7]. In the 0-back condition (easy) the participant was required to orally repeat the last number heard. In the 1-back condition (hard) the participant had to repeat the second last digit.

2.4 TDRT

The tactile stimuli of the TDRT were presented by a small electrical vibrator which was fixed to the participant’s shoulder or upper arm. According to the present version of the standard, the vibrator should be placed on the shoulder and easily detectable while not inducing discomfort to the participant. In case participants found it uncomfortable to have the vibrator applied on the shoulder, the vibrator was placed on the upper arm. An analysis of TDRT response times did not reveal any significant differences between the two positions. Therefore, this factor is not being reported separatedly in the result section. A push button was attached to the participant's left index finger or thumb. The participant responded by pressing the push button against the steering wheel. TDRT stimulus was on for max. 1 second and switched off when a response was given. Time between stimuli was randomly varied between 3 and 5 seconds.

2.5 Experimental set-up

The participant's seat was centrally positioned behind the steering wheel and a LCD display (Figure 2).

Figure 2: Experimental set-up for a triple-task scenario which combines visual tracking task, SuRT and TDRT

Track and tracking deviation were visually presented on the LCD display during visual tracking task. The acoustic feedback of tracking deviation during auditory tracking task was presented by two speakers, one on the left and the other on the right hand side of the LCD display. A small LCD display and a keypad were located on the right hand side of the participant. These elements were used for the operation of the SuRT task.

2.6 Experimental design

A within-subject design was employed with primary task, secondary task and use of TDRT (with; without) as independent factors. Primary task included four levels which varied by modality (visual tracking; auditory tracking) and difficulty (easy track; hard track). Secondary task was varied by task type (SuRT; N-back; no secondary task) and difficulty (easy; hard). An incomplete factorial design was implemented which covered the research questions to be examined and resulted in various task scenarios (triple-task; dual-task; single-task settings). Triple-task settings were used in task scenarios where the TDRT was performed concurrently with primary task and secondary task [8].

Dependent variables derived from TDRT measures were reaction time and hit rate. Root mean square deviation of tracking task was used as a primary task performance indicator. Secondary task performance indicators were derived from SURT (mean response time) and N-back (percentage of correct answers). Rating Scale Mental Effort (RSME) was used as a subjective measure of mental workload [9]. Following each trial, participants were asked to estimate their personal effort for completing the task and tick the RSME score on a hard copy of the rating scale.

2.7 Procedure

Following a brief introduction, participants performed several trials for training of single-task and dual-task scenarios (tracking tasks and TDRT, but without secondary tasks). They then performed the main trials of the same task scenarios. In the second part of the experimental session dual-task and triple-task scenarios (visual tracking task, secondary tasks and TDRT) were applied. The participants again received some training on the scenarios in the beginning and then performed the main trials. The order of trials was randomized between participants.

2.8 Statistical methods

Two-way repeated measures ANOVAs were used to identify effects of task type and task difficulty on the dependend variables TDRT response time and RSME: Secondary task type (N-back; SuRT) x secondary task difficulty (easy; hard); primary task type (visual tracking; auditory tracking) x primary task difficulty (easy; hard). The effects of TDRT on RSME were analyzed by using a two-way and a three-way repeated measures ANOVA: Secondary task type (N-back; SuRT) x TDRT (without; with); primary task type (visual tracking; auditory tracking) x primary task difficulty (easy; hard) x TDRT (without; with). The level of α for all ANOVAs was set to .05. Partial η^2 is reported as a measure of relative effect size. Multiple pairwise comparisons which included Bonferroni correction were applied as post-hoc tests.

Owing to violation of normal distribution, non-parametric tests (Friedman's rank test, Wilcoxon signed ranks test) were applied to the remaining analysis of effects, i.e. effects on TDRT hit rate and on primary and secondary task performance. Significance levels are reported in the figures below.

3 RESULTS

TDRT response time

Figure 3 includes two triple-task scenarios which were combinations of primary task, secondary task, and TDRT: a) N-back + visual tracking + TDRT, b) SuRT + visual tracking + TDRT.

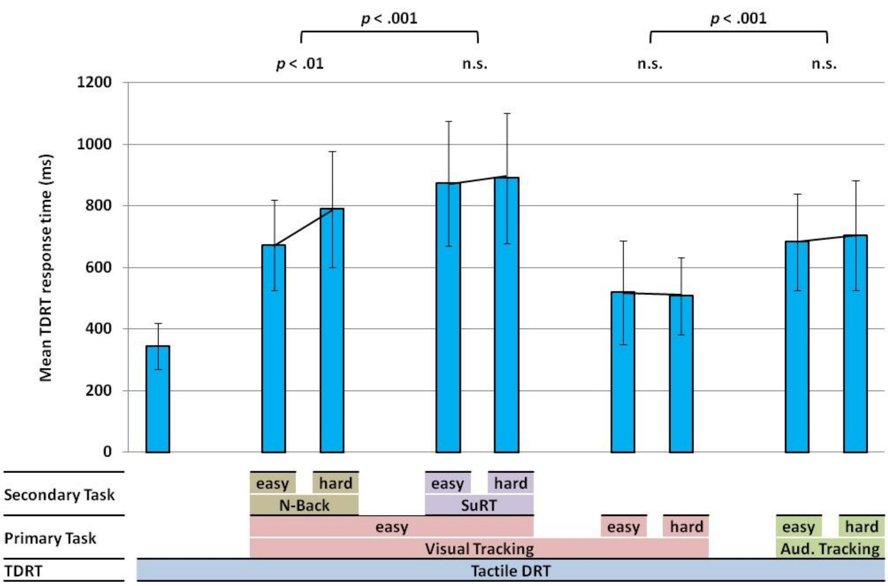

Figure 3: TDRT response time for different task scenarios. Error bars: standard error of the mean

The main effect of secondary task type was significant ($F(1, 21) = 31.1$, $p < 0.001$, $\eta^2 = 0.60$), as was the main effect of secondary task difficulty,

($F(1, 21) = 6.9$, $p < 0.05$, $\eta^2 = 0.25$). The interaction between the two factors was also significant, ($F(1, 21) = 10.1$, $p < 0.01$, $\eta^2 = 0.32$). The hard N-back task resulted in significantly increased TDRT response time compared to easy N-back task. There was no significant difference between TDRT response times for the hard and the easy SuRT. The dual-task scenarios (visual tracking + TDRT, auditory tracking + TDRT) did not display any significant differences between TDRT response times of easy and hard tracking task. However, tracking mode (visual, auditory) revealed a significant effect on TDRT response times ($F(1, 21) = 79.4$, $p < 0.001$, $\eta^2 = 0.79$).

TDRT hit rate

Mean hit rate was above 0.8 for all applied task scenarios and conformed to ISO-draft (Figure 4).

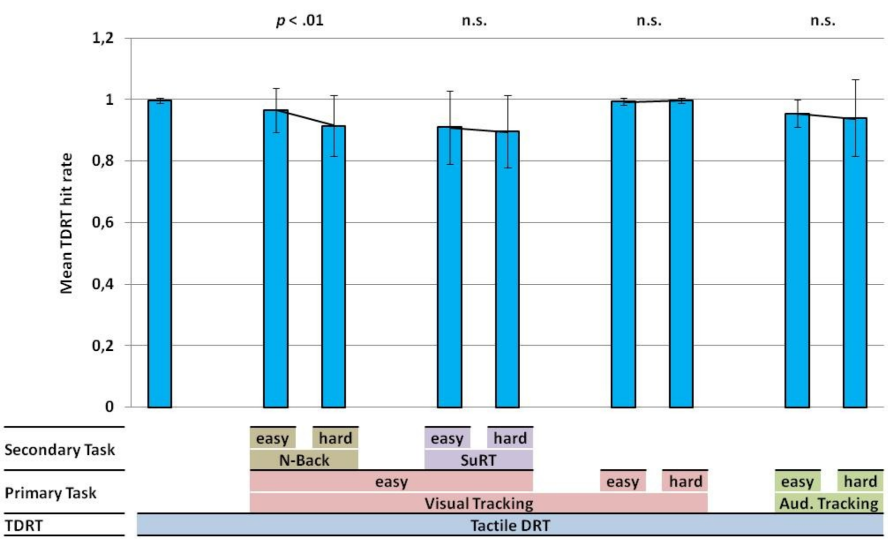

Figure 4: TDRT hit rate for different task scenarios. Error bars: standard error of the mean

For the triple task conditions, the factor secondary task difficulty only showed an effect on TDRT hit rate during execution of N-back task ($p < 0.01$). Hard and easy SuRT were not significantly different in terms of TDRT hit rate. None of the dual-task scenarios (visual tracking + TDRT, auditory tracking + TDRT) showed a significant difference between TDRT hit rates for easy and hard tracking tasks.

Root mean square deviation of tracking task

Figure 5 shows the effects of TDRT (with/without TDRT) on tracking performance.

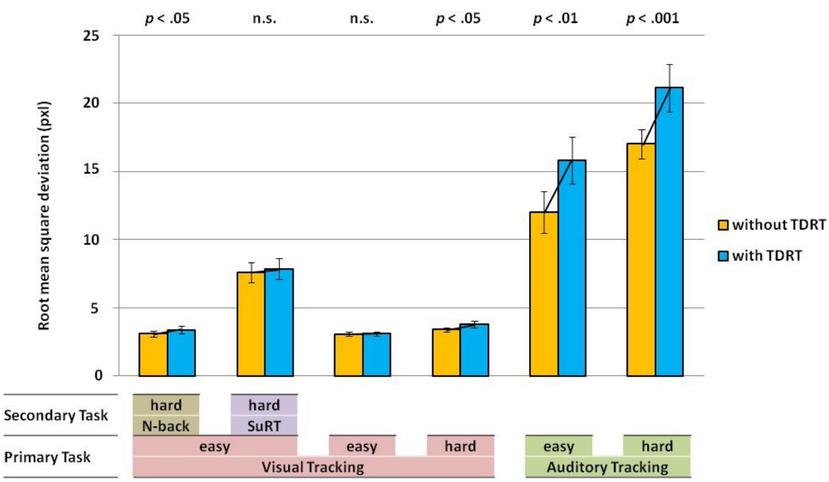

Figure 5: Root mean square deviation for task scenarios without/with TDRT. Error bars: standard error of the mean

The task scenario consisting of N-back + visual tracking with TDRT resulted in a significantly higher tracking deviation compared to the task scenario without TDRT. The task scenario which included SuRT instead of N-back did not show a significant increase of tracking deviation between without and with TDRT execution. There was a clear effect of secondary task type (N-back; SuRT) which led to higher tracking deviation for task scenarios which included SuRT. In case of task scenarios without secondary task, tracking deviation significantly increased when TDRT was performed concurrently with primary task, except for the scenario which included easy visual tracking.

N-back performance

N-back performance (percentage of correct answers) was used as an indicator in the task scenario consisting of N-back task, visual tracking and TDRT (with/without). There was no statistically significant difference between conditions with and without TDRT.

SuRT response times

SuRT response time was used as an indicator in the task scenarios which consisted of visual tracking, SuRT and TDRT (with/without). SuRT response time significantly increased when TDRT was applied (Figure 6).

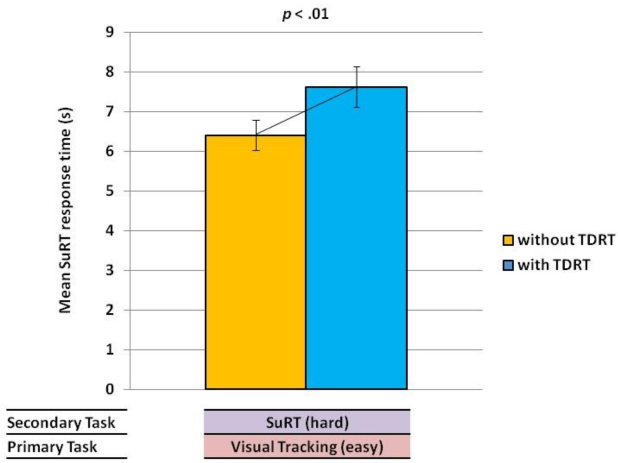

Figure 6: SuRT response time for task scenarios without/with TDRT. Error bars: standard error of the mean

RSME

RSME score increased when the task scenarios included TDRT execution (Figure 7). For task scenarios consisting of primary and secondary task, the main effect of TDRT on RSME was significant ($F(1, 21) = 23.6$, $p < 0.01$, $\eta^2 = 0.53$), as were the main effect of secondary task type ($F(1, 21) = 26.1$, $p < 0.001$, $\eta^2 = 0.55$) and the interaction effect ($F(1, 21) = 4.5$, $p < 0.05$, $\eta^2 = 0.18$). Post-hoc tests revealed that RSME score only tendentially increased for the task scenario SuRT + visual tracking with TDRT compared to SuRT + visual tracking without TDRT.

For task scenarios which did not include secondary task, a three-way ANOVA was applied to analize the effects of the factors tracking task type, tracking task difficulty and TDRT on RSME scores. The main effects were significant (Tracking task type: $F(1, 21) = 138.1$, $p < 0.001$, $\eta^2 = 0.87$;

tracking task difficulty: $F(1, 21) = 6.1$, $p < 0.05$, $\eta^2 = 0.23$; TDRT: $F(1, 21) = 90.1$, $p < 0.001$, $\eta^2 = 0.81$). The interactions did not show significant effects.

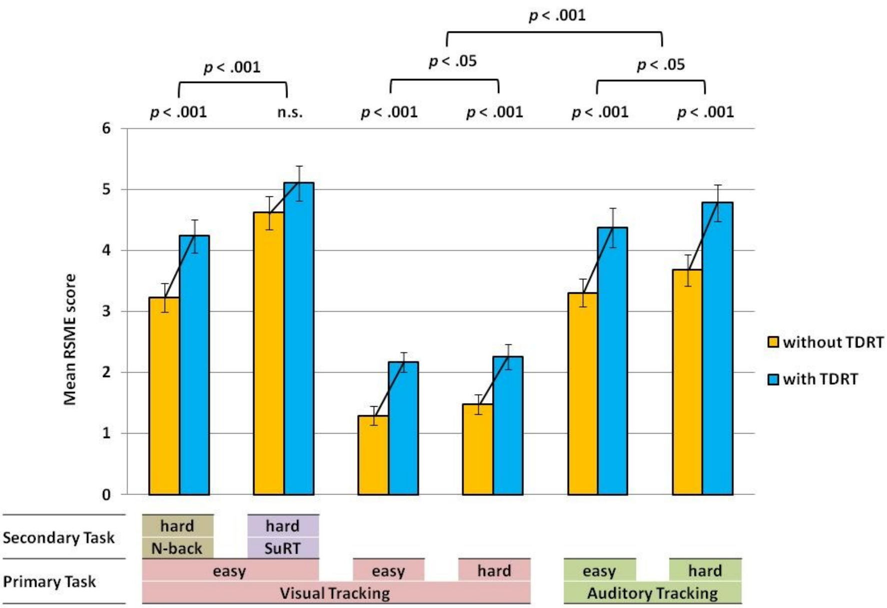

Figure 7: RSME results for task scenarios without/with TDRT. Error bars: standard error of the mean

4 CONCLUSIONS

Sensitivity of TDRT

Sensitivity of TDRT to different levels of cognitive load imposed to the participants was studied in task scenarios which contained N-back as a secondary task (N-back + visual tracking + TDRT). TDRT response times and TDRT hit rates received for the two difficulty levels of N-back were shown to be significantly different. The results suggest that TDRT is able to differentiate between different load levels of secondary tasks which primarily demand for cognitive resources.

No significant difference in terms of both TDRT response times and TDRT hit rates could be shown between easy SuRT and hard SuRT (task scenario: SuRT + visual tracking + TDRT). However, secondary task type (N-Back; SuRT) showed a significant main effect on TDRT response time. TDRT response times of task scenarios containing SuRT were significantly longer than those of task scenarios containing N-back task.

The results shown for N-back and SuRT are in line with findings from previous DRT studies [10] [11]. As both the SuRT and the TDRT demand for motor resources, a possible interference between SuRT and TDRT may be the reason why TDRT performance decreased in task scenarios which included SuRT compared to task scenarios which included N-back. Finger coordination effects may have overlapped with bimanual coordination effects [17] [18], as the two hands performed different actions at the same time. The left hand operated on the steering wheel and performed manual TDRT response by pushing the finger button while the index finger and/or middle finger of the right hand carried out keystrokes needed for the input to the SuRT. In contrast, during task scenarios with tracking task + N-back, both hands were coupled to the steering wheel and performed the same movement while only the TDRT response button had to be pushed.

Although interlimb coordination effects, besides visual perception effects, could be a possible explanation for the differences between the TDRT results of N-back and SuRT task scenarios, they do not fully explain why the TDRT was not able to differentiate between easy and hard SuRT. It seems that easy and hard condition did not differ much in total visual-manual workload, because manipulation of visual-manual workload might not have worked in the intended way because of the possibility to self-pace the SuRT response frequency. SuRT screens occurred more often for the easy SuRT condition than for the hard SuRT condition. Thus, the number of manual responses to the SuRT was higher for the easy SuRT than for the hard SuRT. As a consequence, the impairing effect of motor interferences was more pronounced during easy SuRT than during hard SuRT. Future studies should address this issue in order to avoid the above mentioned differences of easy and hard SuRT regarding motor demands, e.g. by considering tasks, where manual workload can not be self-regulated by the participant.

Furthermore, compensatory effects in the participants' behaviour and prioritization of task may also have played a role [19]. Drivers are able to adapt their attentional behaviour to the demands of the situation and the task [20]. In our study, participants' attention could have been attracted by the SuRT rather than by the TDRT, because self-paced SuRT allowed for higher frequency of inputs and held more visual appeal. In the highly demanding triple task scenario consisting of tracking task + SuRT + TDRT, participants could have been inclined to compensate the high overall workload through reducing workload induced by the TDRT which appeared to be the less prominent task. However, this relationship is far from being clear and has to be further investigated in future studies.

Another hypothesis of this study addressed sensitivity of TDRT to load levels of primary task in dual-task scenarios, i.e. tracking task + TDRT without secondary task. No significant difference between load levels of tracking tasks in dual task scenarios could be shown in terms of both TDRT response time and TDRT hit rate. However, RSME results showed a significant difference in mental workload between the two load levels of tracking task. This was true for the visual type of tracking task as well as for the auditory type. Similar results were shown in studies on Occlusion technique where RSME also had been used as an indicator [4]. The results of the current study suggest that the TDRT was not sensitive to this variation of tracking task load.

Mode of tracking task showed a strong effect on TDRT response time. TDRT response times of the auditory tracking task were significantly longer than those of the visual tracking task, thus reflecting the difference in task demands of visual and auditory tracking. Auditory tracking task demands for more resources of working memory and uses cognitive resources more intensively than the visual tracking task does. It can be concluded that the TDRT is sensitive to differences in cognitive demands of primary task, thus confirming findings of a former driving simulator study [12]. The fact, that the two load levels of tracking task did not differ significantly in terms of TDRT response time, provides an indication of the existence of a minimum difference in cognitive load beyond which the TDRT is not able to differentiate between load levels.

Intrusiveness of TDRT

The results show some indications for intrusiveness of TDRT on primary task performance. It can be seen from Figure 5 that the inclusion of TDRT in task scenarios resulted in a decrement of tracking task performance, i.e. root mean square deviation increased. As both tracking task and TDRT are manually operated, one may assume that the decrement of primary task performance was caused by interferences between tracking task and TDRT due to the demand for motor resources. However, it seems that also mental demands of TDRT intruded on primary task performance, especially in those cases where the cognitive demand of the underlying task scenario was high. This can be seen when the task scenario visual tracking + N-back with/without TDRT is compared with the task scenario visual tracking with/without TDRT. The former task scenario imposed higher cognitive load on the participant due to N-back execution. In this case, the cognitive load of N-back seemed to intensify the negative effect of TDRT on primary task performance, thus significantly increasing root mean square deviation. In the other case (N-back not included) the effect of TDRT on primary task performance was not significant. The results confirm assumptions, that intrusion of a workload method does not represent a static property of the method, but may vary depending on the type and level of the considered tasks [13].

The effect of TDRT on secondary task performance depended on the type of secondary task. TDRT did not intrude on N-back task performance. However, SuRT response time increased significantly with TDRT, thus indicating that TDRT intruded on SuRT performance.

Comparison of TDRT and RSME results

A comparison of TDRT and RSME results in differentiating between task scenarios which varied in secondary task type and tracking task difficulty is shown in Table 1. Task scenarios did not include TDRT execution, when mean RSME score was used as an indicator.

Table 1: Comparison of TDRT and RSME results in differentiating between different types and levels of task load

	Compared task scenarios	Mean TDRT response time	Mean RSME score
A B	Vis. Tracking (easy) + SuRT (hard) vs. Vis. Tracking (easy) + N-back (hard)	A > B, $p < 0.05$	A > B, $p < 0.001$
A B	Vis. Tracking (hard) vs. Vis. Tracking (easy)	A < B, n.s.	A > B, $p < 0.05$
A B	Aud. Tracking (hard) vs. Aud. Tracking (easy)	A > B, n.s.	A > B, $p < 0.05$

The comparison identified partial conformity of the two methods in their sensitivity to different types and levels of task load. Both methods were able to differentiate between dual-task scenarios which varied in cognitive load of secondary task. However, only RSME indicated significant differences between single-task scenarios which varied in visual-motor demands of tracking task.

The effect of TDRT execution on RSME scores were studied by applying TDRT method and RSME method concurrently. The result revealed an overall increase of self-reported workload for task scenarios which included TDRT execution compared to task scenarios which did not include TDRT execution (Figure 7). This confirms the above discussed assumption that the increase in overall workload of task scenarios was caused by mental and motor demands of the TDRT. It appears likely that the intrusiveness of the TDRT on primary task and secondary task performance is closely connected with the increase in workload. Participants might have adjusted their effort for primary task and secondary task operation in order to compensate for the increased workload resulting from TDRT execution.

Similar to other secondary task methods for workload assessment [13], the TDRT can not be expected to accurately reflect the workload that would be associated with task scenarios in which the TDRT is not included. If an additional workload measure (e.g. RSME) is used for comparison of task scenarios without TDRT vs. with TDRT, then an appropriate adjustment of the workload results seems to be advisable.

Summary

The results suggest that TDRT is sensitive to effects caused by differences in cognitive load. TDRT seems to be not sensitive to load levels of tasks which primarily demand for visual-manual resources. A recommendation of the

DRT Task Force to not use TDRT for task scenarios with strong motor demands can be confirmed. There are indications that TDRT is intrusive on primary task and secondary task performance. It is recommended to control whether intrusion remains on a tolerable level, especially if both TDRT and performance indicators are used in an experiment. Future experiments are recommended to confirm sensitivity to further secondary tasks and study intrusion on task performance more extensively.

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References

[1] Martens, M. H., van Winsum, W.: \`Measuring distraction: the Peripheral Detection Task´. Soesterberg: TNO Human Factors, 2000, http://www.rijschool-simulator.nl

[2] Engström, J., Aberg, N., Johansson, E., Hammarbäck, J.: \`Comparison between visual and tactile signal detection tasks applied to the safety assessment of in-vehicle information systems (IVIS)´. Proceedings of the 3rd International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, Rockport (Maine), 2005

[3] ISO/DIS 17488: `Road vehicles – Transport information and control systems – Detection-Response Task (DRT) for assessing attentional effects of cognitive load in driving´. ISO/ TC 22/SC 13/WG 8, 2014

[4] Gelau, C., Schindhelm, R.: `Enhancing the occlusion technique as an assessment tool for driver visual distraction´. IET Intelligent Transport Systems, 2010, Vol. 4, Iss. 4, pp. 346-355

[5] Mattes, S., Föhl, U., Schindhelm, R.: `Empirical comparison of methods for off-line workload measurement´. AIDE Deliverable 2.2.7, 2007, EU project IST-1-507674-IP

[6] Conti, A. S., Dlugosch, C., Bengler, K.: `The effect of task set instruction on Detection Response Task performance´. In de Waard, D., Brookhuis, K., Wiczorek, R., Di Nocera, F., Barham, P., Weikert, C., Kluge, A., Gerbino, W., and Toffetti, A. (Eds.), Proceedings of the Human Factors and Ergonomics Society Europe Chapter 2013 Annual Conference, 2014. http://www.hfes-europe.org/

[7] Mehler, B., Reimer, B., Dusek, J.A.: `MIT AgeLab delayed digit recall task (nback)´. MIT AgeLab white paper 2011-3B, 2011

[8] Engström, J., Larsson, P., Larsson, C.: `Comparison of static and driving simulator venues for the Tactile Detection Response Task´. Proceedings of the 7th International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, New York, 2013

[9] Zijlstra, F. R. H.: `Efficiency in work behaviour – a design approach for

modern tools´. Delft University Press, Delft, 1993.

[10] Bruyas, M.-P., Dumont, L.: `Sensitivity of Detection Response Task (DRT) to the driving demand and task difficulty´. Proceedings of the 7th International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, New York, 2013

[11] Young, R. A., Hsieh, L., Seaman, S.: `The Tactile Detection Response Task: preliminary validation for measuring the attentional effects of cognitive load´. Proceedings of the 7th International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, New York, 2013

[12] Diels, C.: `Tactile Detection Task as a real time cognitive workload measure´. In P. D. Bust (Ed.), Contemporary ergonomics, London: Taylor & Francis, 2011, pp. 183-290

[13] Eggemeier, F. T.: `Properties of workload assessment techniques´. In P. A. Hancock and N. Meshkati (Eds.), Human Mental Workload, Amsterdam: Elsevier, 1988

[14] Engström, J., Monk, C. A., Hanowski, R. J., Horrey, W. J., Lee, J. D., Daniel V. McGehee, D. V., Regan, M., Stevens, A., Traube, E., Tuukkanen, M., Victor, T., C. Y. David Yang, C. Y. D.: `A conceptual framework and taxonomy for understanding and categorizing driver inattention´. Project report, 2013, US-EU ITS Cooperation, Driver Distraction and HMI WG. http://ec.europa.eu/digital-agenda/en/news/us-eu-inattention-taxonomy-report

[15] Michon, J. A.: `A critical view of driver behavior models: what do we know, what should we do?´ In: Evans, L., Schwing, R.C. (Eds.), Human Behavior and Traffic Safety. New York: Plenum Press, 1985, pp. 485-520

[16] Pettitt, M. A.: `Visual demand evaluation methods for in-vehicle interfaces´. PhD thesis, University of Nottingham, 2008

[17] Whitall, J., Forrester, L., Song, S. `Dual-Finger Preferred-Speed Tapping: Effects of Coordination Mode and Anatomical Finger and Limb Pairings´. Journal of Motor Behavior, 1999 Dec, 31(4), pp. 325-339

[18] Walter, C. B., Swinnen, S. P. `Asymmetric interlimb interference during the performance of a dynamic bimanual task´. Brain and Cognition, 1990, 14, pp. 185-200

[19] Wege, C. A., Pereira, M., Victor, T. W., Krems, J. F.: `Behavioural adaptation in response to driving assistance technologies: A literature review´. In A. Stevens, C. Brusque & J. F. Krems (Eds): `Driver Adaptation to Information and Assistance Systems´. London: IET, 2014, pp. 13-34

[20] Metz B., Schömig N., Krüger H.-P.: `Attention during visual secondary tasks in driving: adaptation to the demands of the driving task´, Transportation Research Part F: Traffic Psychology and Behaviour 2011, 14(5), pp. 369-380