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Assessing position of in-car display with Detection Response Task

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Introduction

Information systems, which are widely integrated in vehicle, usually involve visuo-manual non-driving tasks, increasing visual demand and decreasing driving performances [1,2]. In this context, the display position is important as it may strongly influence the visual demand. Existing Guidelines assume that installation lower than 35° of vertical eccentricity have a detrimental effect on driving performance [3,4]. This effect results from time transition between eyes fixation towards road and information display and increase in cognitive load [5]. For example, when using GPS system, drivers need to move their eyes from the electronic map toward the real road environment to make two distinct cognitive processing: physical control of the vehicle and mental strategic decisions. As the effort required for these processing increases, the overall visual demand also increased [6]. Thus, assessing visual demand due to specific display installation with accurate tools is a fact of matter for traffic safety.

However, very few studies have assessed the visual demand involved by display installation. In a related experiment [5], the authors deducted effect of display position from breaking-reaction time to a visual stimulus, driving performance, and subjective rating while performing a non-driving task. Detection Response Task (DRT) should be an efficient and reliable tool for that purpose. The DRT is a standardized method, which consists in recording stimulus-response time during a secondary task: longer reaction times and reduced hit rate are indicative of higher cognitive load. Many researches showed that DRT is sensitive to the level of visual demand and cognitive load implied by non-driving task [ie. 7,8,9,10,11]. Different versions of the DRT, which use visual displays, are especially appropriate to capture the visual demand of a non-driving task. The stimulus can be a red light located on the dashboard (Remote DRT: R-DRT), or mounted on a head display (Head-mounted DRT: H-DRT) (Fig. 1), or a tactile stimulation (Tactile DRT: T-DRT).



Fig. 1. Left: head-mounted display; right: remote display

Sensory interference should mainly occur for the R-DRT because the stimuli appears in the visual periphery, or entirely outside the field of view, as gaze is directed away from the location of the DRT stimulus [12]. The H-DRT should be less sensitive to sensory interference since the stimulus remains in the same position within the field of view [12]. However, if the eyes move relative to the head, the H-DRT is potentially sensitive to visual eccentricity, due to the reduced sensitivity in the visual periphery [12]. Thus, R- and H-DRT may potentially be used to capture specific related-effect of the visual display eccentricity.

The present study aimed at investigating how visual demand is increased by the display position, using two visual versions of the DRT. Three visuo-manual tasks involving different levels of visual demand were compared. These tasks were performed with a display installed in two different positions. The hypothesis was that DRT would demonstrate a higher visual demand for the lower position than for the higher position.

Method

Sixteen drivers (25 to 45 years old) drove on a 2x2 highway in a driving simulator (CARDS3, Technocentre Renault). They were asked to perform three non-driving tasks: two modalities of a standardized task, and one navigation entry. Tasks were performed with an interface located in either a low or high position.

The DRT consisted in pushing a button when a red light appeared. The button was attached to the participant's index finger. For R-DRT, the red light was set on the dashboard. For the H-DRT, it was set on a head-mounted display (see Fig. 1). Reaction time and hit rate were recorded. Visual demand was assessed by performing the two DRT versions concurrently with the three non-driving visuo-manual tasks.

The standardized task was the Surrogate Reference task (SuRT: [13]). It is a self-paced search task with visual and manual components. It consists in locate a target (a big circle) among distractors (smaller circles). To indicate target location, the participants pressed the left-right keypad buttons to move a gray outline bar to the region that contained the target circle and pressed the "enter" key to confirm their selection. Two levels of complexity (easy and hard) were set in order to vary the level of cognitive load: difference in size and number of distractors made target easier to discriminate for Easy SuRT than for Hard SuRT condition. Task lasted 60 sec. Number of targets correctly detected, errors, and hit rate were recorded.

Navigation entry consisted in texting a destination with a navigation system. Drivers activated the system by touching icon of the application., a text zone and a keyboard were Then displayed. The city name was 7 letters long. After validation, the street name was 9 letters long. After validation, navigation started. Time from activation to starting navigation was recorded.

All tasks were performed with an interface located in high or low position (respectively 15° or 30° of visual angle below the view axis (see Fig. 2). Navigation entry and SuRT were expected to be more demanding in low than in high position.



Fig. 2: experimental setting; display in high (left) and low position (right); arrow indicates localization of the remote stimulus for R-DRT

Results

H- and R-DRT indicated that visual demand was higher when participants operated with the display in the low position rather than in the high position (see Fig. 3): reaction times were slower ($F(1,15)=9.84$; $p<.007$), and hit rate was lower ($Z=2.85$; $p<.004$).

This result was supported by tasks performance: in low position, hit rate for SuRT was lower ($Z=2.94$; $p<.003$) and navigation entry was slower ($F(1,15)=7.74$; $p<.02$).

There were some differences between H- and R-DRT. First, reaction time for H-DRT tended to be faster than for R-DRT ($F(1,15)=3.96$; $p=.065$), but there was no significant difference according to the display position. Then, hit rate was lower for R- than for H-DRT in low position ($Z=3.39$; $p<.001$). In-depth analysis showed that this effect was significant when performing navigation entry ($Z=2.03$; $p<.05$) and Hard SuRT ($Z=2.41$; $p<.02$). Finally, no difference was found for Easy SuRT, nor for H-DRT, according to display position.

Additional results suggested that H- and R-DRT discriminated visual demand involved by the different tasks. Thus, hit rate was significantly lower for Hard SuRT than for Easy SuRT ($Z=3.53$, $p<.001$), and lower for navigation entry than for Hard SuRT ($Z=3.28$; $p<.001$). There was no difference between H- and R-DRT. Reaction time was also slower when performing Hard SuRT than Easy SuRT ($p<.01$), but not influenced by display position. No more difference or interaction has been founded.

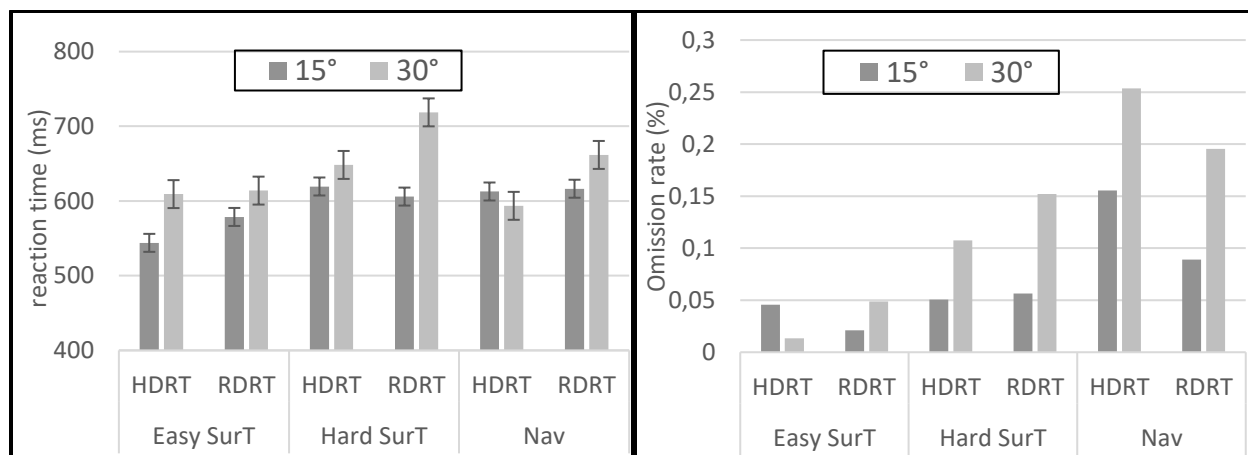


Fig. 3: left: reaction time for Task x DRT x display position; right: omission rate for Task x DRT x display position; Nav = navigation task

Discussion

Results show some effects of the display position. Reaction time and hit rate were both affected by a change of 15° of visual angle to perform a non-driving task. This effect confirmed results showed by [5] and indicates that DRT is an effective and reliable tool to assess visual demand involved by display position.

H- and R-DRT seemed to lead to some particularities in the task processing. While using R-DRT in a low position, lower hit rate and slower reaction time indicated that distance between DRT stimulus and display had an influence on the processing. It is consistent with the founding of Conti et al., and Vilimeck et al. [8,11]. However, the lack of interaction suggests that H-DRT was also, in some respect, subject to visual eccentricity effects.

Hit rate also indicated some difference in visual demand of the task. Navigation entry and Hard SuRT appeared more complex than Easy SuRT. However, this difference was observed in lower position only. Moreover, difference in DRT reaction time was found for Easy SuRT, but did not depend on display position. Taken together, results suggested that task performance involved specific aspects that were difficult to discriminate in the present study.

Conclusion

As expected, DRT appeared to be a relevant tool to assess visual demand involved by display position. This is an important result since installation of information system may impact traffic safety. The method provides benefits as it is inexpensive, easy and quick to implement. Moreover, these results have implication on the use of DRT itself. Installation of the tested-task interface should be carefully determined because it modulates visual demand assessment. Specific aspect of the tested task should also be taken into consideration.

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