DRIVER STRATEGIES WHEN INTERACTING WITH INFORMATION AND COMFORT SYSTEMS

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ABSTRACT

The safety implication of new in-vehicle technologies is a leading concern for car manufacturers. Several methods aim to measure the driver distraction induced by driver information and assistance systems. One of these methods, denoted the Lane Change Test (LCT), aims to measure quantitatively the degradation of the driving performance induced by secondary tasks. An experiment involving 17 participants was conducted from September to November 2006 to investigate the robustness of the method. A calibration task was used to compare performances in PC and in simulator environments. Radio and navigation tasks were performed in four different vehicles to assess the relevance of the method to discriminate among different types and location of in-vehicles devices and displays. In addition to the main indicator suggested in the LCT procedure (mean lateral deviation), features of the secondary tasks (latency, duration) were considered. The results confirm the transferability of the method from PC to vehicle-based environment, but question the sensitivity of its main indicator to discriminate between vehicles and functions.

INTRODUCTION

With the continuous development of in-vehicles comfort, information and assistance systems, the impact on driving safety and more specifically on driver loss of attention is a leading concern. Driver distraction encompasses the withdrawal of attention which might impair both the vehicle control and object or event detection [1] . Depending on sources and on definitions (e.g. distraction, inactivation, inattention, drowsiness), driver inattention represents up to 50% of accidents [2] . When split between the various causes of inattention, the figures for secondary-task distraction are closer to over 22 percent of all crashes and near-crashes [3] , which is in-line with recent French results [4] .

As clearly stated in [5] , risk increases with exposure to a hazard. Risks induced by driver distraction vary with the type, timing, intensity, frequency and duration of this distraction. It is crucial to understand the relative importance and weighting of these different components of exposure and how they contribute to distraction risk. Whereas research studies are essential to provide a better understanding and knowledge of the driver (e.g. strategies, capabilities and limitations), car manufacturers face a pressing need for simple, cost-effective, objective and reliable method to measure the potential impact of new in-vehicle systems on driver distraction and safety. Methods currently discussed at an international level (ISO TC22 / SC13 / WG8) are intended as "tools to help system designers ensure that the intended benefits outweigh the risks of devices and features that are meant to be used while driving" [6] . One of these methods, denoted the Lane Change Test (LCT) aims to measure quantitatively the degradation of the driving performance induced by secondary tasks. Previous experiments conducted in the LAB proposed improvements in terms of experimental protocol (e.g. vehicle-based protocol) and analysis (e.g. individual reference trajectory, eye-tracker data, position on lane). To build on efforts to assess the LCT method ([7] , [8]) a new experiment was conducted on a simulator in autumn 2006. The main objectives were to assess the relevance and robustness of the LCT method, to identify its main limitations and if necessary refine it. The present paper reports results on the robustness of LCT at two levels: the impact of the experimental set-up and the relevance of the method to discriminate among different types and location of in-vehicles devices and displays.

METHOD

To achieve these objectives, an experiment involving 18 subjects is conducted in a PC environment and in a vehicle-based simulator, from September to November 2006. A calibration task, derived from the ADAM project is used to compare performance in PC and in simulator environments. In vehicle-based simulator, three similar secondary tasks are performed in four different vehicles: the change of radio frequency, the selection of a radio station in a list and the entry of data in a navigation system. In addition to the main indicator suggested in the LCT procedure (mean lateral deviation), three categories of indicators were considered: driving (trajectory, distance covered, speed, position on lane), lane change (latency, duration, quality) and secondary tasks (latency, duration, quality).

Participants

Seventeen participants of two age groups ([25-54] and [60-70]) were recruited through public notice. All had valid driver's licences, a minimum of 4 years of driving (mean=28 and max=48) and drive on average 16000 kilometers per year (min=5000 and max=25000). The same participants were involved in the four successive sessions.

Apparatus

Vehicle-based set-up - Four different production vehicles were tested. Attention was paid to ensure that the systems tested were comparable in terms of functions provided and modalities of interaction. The vehicles were positioned in front of a 2x3 meters video screen where the driving scene was projected. Front wheels of the test vehicle were placed on swivelling plates to reduce friction to ground and keep the steering wheel forces at a realistic level. The steering wheel movement was tuned to replicate that of a computer game steering wheel in terms of ratio between steering wheel movement and resulting computed turning circle. The movement of the left front wheel was transformed into an electrical signal compatible with the LCT software from the movement of one of the swivelling plates (Figure 1).

Figure 1. Technical set-up of vehicle-based experiment, with swivelling plates.

PC-based set-up - The visual LCT scene was displayed on a 17" monitor with a net refresh rate of 50 Hz, a resolution of 1024x768 pixels with a colour depth of 24 bit. For the lateral control of the simulated vehicle, a computer game steering wheel was used (Figure 2).

Figure 2. Technical set-up of PC-based experiment, with calibration task display on right hand side.

Secondary tasks displays – In both settings, for a calibration task, a dedicated 15" monitor was positioned on the right side of the route scene and a simplified keyboard (limited to arrow keys) was used to perform the designation and selection task. In the vehicles, when not necessary the display was removed from the scene. For the other secondary tasks (radio manipulation, interaction with the navigation system), displays available in the tested vehicles were used.

Data collection equipment – In both settings, video camera were placed to collect three complementary views: driver's face (to identify changes in gaze direction), over the shoulder view (to record overall situation) and HMI view (to focus on driver's interactions with in-vehicles systems measuring secondary tasks performance). Additional markers were provided to enable the experimenter to highlight events of interest (e.g. beginning / end of secondary tasks). Scenario and recording (system and video) were automatically launched from the experimenter workplace.

LCT Software and task - The tool developed in the context of the ADAM project [9] was used to perform the Lane Change Test. The Lane Change Test (LCT) is a simple laboratory dynamic dual-task method that aims to quantitatively measure performance degradation on a primary driving-like task while a secondary task is being performed. The LCT comprises a simple driving simulation that requires a test participant to drive along a straight 3-lane road at a constant, system controlled, speed of 60km/h. Participants are instructed in which of the lanes to drive by signs that appear at regular intervals on both sides of the road (Figure 3). Participants use the vehicle steering wheel to maintain the position of the simulator vehicle in the centre of the indicated lane and are prompted to change lanes according to the instructions on the signs. The only visual feedback the participants get is the front view (i.e. no rear nor side view provided in mirrors). Engine sound was simulated to increase situation realism. The scene consisted of a series of 3 km test tracks, with lane change signs displayed every 150m. Participants had to perform manoeuvres as quickly and efficiently as possible. Actions on the steering wheels were instrumented and transmitted to the simulation tool in order to reproduce on screen lateral changes.

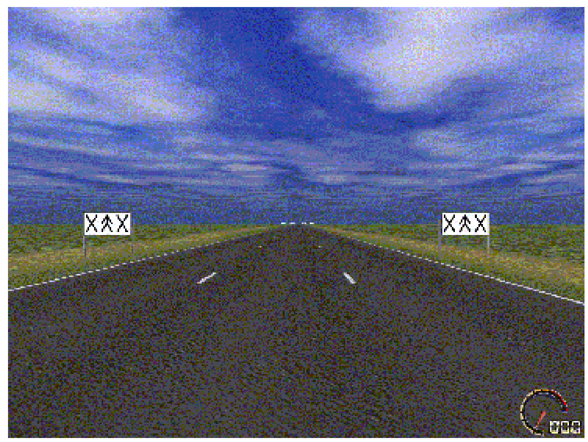

Figure 3. The LCT scene, with an example of lane change sign display.

Experimental design

Run plan - For each vehicle tested, the experiment used a 2 (age group: medium, senior) x 5 (secondary task: none, calibration, radio scrolling, radio list and navigation) x 3 (occurrence: at the sign, 50m before, 50m after) repeated measures design. For the PC session, the design was simplified with only two values for the secondary tasks (none and calibration) and no variation of the instruction occurrence.

Secondary tasks - To enable comparison between LCT studies, the Surrogate Reference Task (SuRT) was used as a calibration task (standardized reference). It required the participants to locate a target among visually similar distractors (visual demand) and then select the portion of screen containing the target (manual demand). Difficulty in this calibration task could range from very easy to very complex, in varying the size of the target and the number of portions of screen. In the present study, an easy level was chosen, with a target much larger than the distracters and only 2 portions of screen (Figure 4).

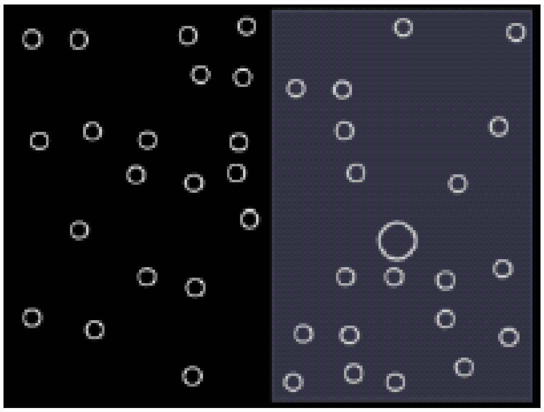

Figure 4. Screen corresponding to the Surrogate Reference Task, in the "easy" condition.

In addition, three other tasks were tested in each of the four vehicles: radio frequency scrolling, radio station selection and destination entry in the navigation system. The radio scroll task was very similar in all vehicles, the main difference being the position of arrows (up/down versus left/right) used to scroll the frequencies. However, whereas for vehicles 1,2 and 4, a continuous press resulted in a continuous scrolling, the 3rd device paused every time a station was found. This resulted in multiple actions on the same key to reach the goal and led us to expect larger lateral deviation with this latter device. The radio list task was also very similar and comparable, the only difference being the existence of a “List” button on vehicles 1 and 2, and of a change mode button on vehicles 3 and 4. The navigation tasks differed both in terms of navigation in menus and accessibility of interaction devices: input devices were located on the front panel for vehicles 1, 2 and 4 and on the right side of the driver for vehicle 3. This latter convenient position was expected to reduce the lateral deviation.

To avoid boredom, radio and navigation tasks were mixed and occurred between 1 and 2 times each within each track. To ensure comparable conditions between subjects and between successive vehicles, secondary tasks instructions were pre-recorded and automatically issued at a same moment defined in distance to lane change sign.

Programme - Prior to the experimentation, all participants tested the experimental set-up, essentially to ensure that none of them suffered from the simulator sickness. Four different sessions of two weeks each were organized between September and November 2006. For each vehicle, every participant went through sessions of two hours, including training, measures and debriefing. Each of the four sessions began with a training period, whose objective was for the participants to become familiar with both the primary (drive and change lanes) and the secondary tasks. For the measured runs, the participants drove along 10 successive tracks: without secondary task (tracks 1 and 10), with calibration task (tracks 2 and 9) and with mixed secondary tasks (tracks 3 to 8). The PC session took place at the end of vehicle sessions. To counterbalance LCT learning effect, 1/3 of the participants performed the PC session after vehicle 2, 1/3 after vehicle 3 and the last this after vehicle 4.

RESULTS

The objective and subjective data collected consisted of vehicles parameters, LCT simulator logs, experimenter’s markings, audio and video recording of participants’ actions and comments, experimenter’s observations, interviews and questionnaire items.

Effect of the experimental environment

Whereas the method currently discussed at ISO level was initially defined as a stand alone PC-based method, it is also envisaged for in-vehicle experimental settings. The relevance of the method needs to be assessed in both settings, and the possible differences between the settings clarified.

Lane change performance - The lane change performance was assessed in measuring the mean deviation from an optimal trajectory. Each actual trajectory was compared to a normative one, defined in [6] . The mean deviation in lane change per task was analysed in a repeated measures analysis. To exclude outliers, comparisons between means were made using 95% confidence intervals. Performances in baseline condition (drive) are similar for all participants (senior and medium) in both experimental conditions (PC and vehicle). The lateral deviation is slightly larger with PC than with vehicles for the senior participants. Compared to baseline situation, the calibration task induced a larger lateral deviation for all participants in both experimental settings (Figure 5). The lane change performance with the calibration task was slightly worst with the PC than with vehicles. With vehicles, the performance is comparable in both age groups, whereas it is slightly worst for the senior group in PC setting.

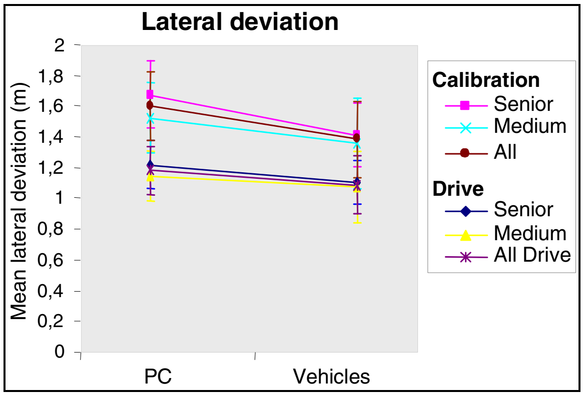

Figure 5. Mean lateral deviation in both experimental settings for both age groups.

Calibration task performance - In terms of secondary task performance, we considered two points: the percentage of successful trials and the number of trials per track. Because of the experimental conditions (constant speed), the mean time interval between trials was actually redundant with the number of trials per track. The percentage of successful trials is comparable for both age groups in both settings (Figure 6). In PC settings, the number of trials per track is similar, whereas it is larger for the medium age group in vehicle settings. This could be due to the increased realism in the vehicle settings, which leads the senior participants to focus on the driving task to the detriment of the calibration task.

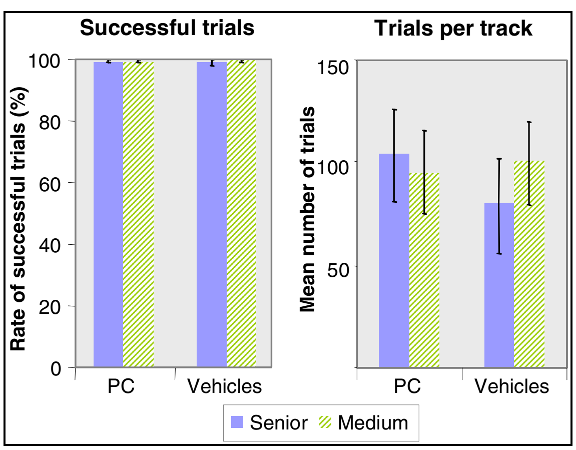

Figure 6. Rate of successful trials and mean number of successful trials per track.

Effect of the vehicle

One of the main objectives of the LCT method is to enable the degradation of the driving task to be measured. Rather than comparing in a given vehicle the respective impact of different tasks, one of the major objective of the LCT method is to assess the degradation induced by various design options. Therefore, in the present study, the aim was to evaluate the relevance of the LCT to discriminate between vehicles, whose differences were in terms of locations of devices and displays.

Lane change performance - To compare the performance with the four vehicles, it was decided to try and improve the calculation of lateral deviation. Indeed, the normative lateral seemed too theoretical and not reflecting differences in individual strategies. To reflect individual practices in terms of lane change initiation and performance, it was decided to calculate a more accurate deviation on the basis of participants average lane changes (initiation of the change, rate of change) in the baseline condition. For both age groups, similar trends were observed with normative and adapted deviations, but deviation values were smaller for both age groups with the adapted model and no more differences appear between secondary tasks for the medium age group (Figure 7).

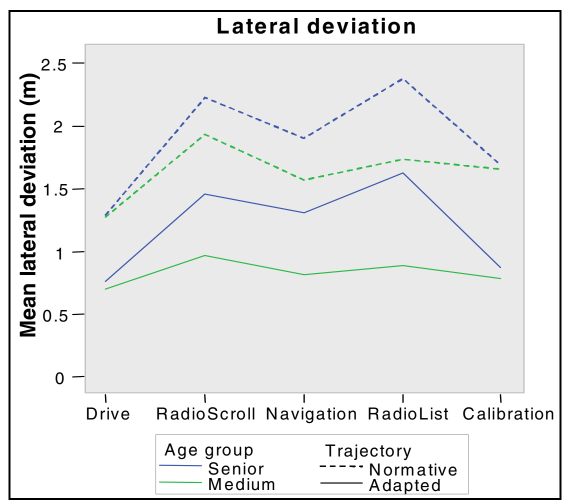

Figure 7. Comparison between normative and adapted lateral deviations for both age groups.

Values of adapted lateral deviations were then compared according to age and vehicle factors (Figure 8). For the medium age group, performances were similar whatever the secondary task and the vehicle. Two explanations are put forward: either the lateral deviation is not an appropriate discriminating indicator, or all tasks were too close in terms of impact on lateral control of the vehicles.

For the senior participants, deviation values were larger with the first vehicle. This could be due either to the vehicle itself, or to a lack of experience with the LCT method. The classification of vehicles as a function of induced deviation is not straightforward: vehicles 2 and 3 seem the most acceptable when considering the radio scroll and the navigation tasks, whereas vehicle 4 seems acceptable for the radio list task. Surprisingly, for the senior group, the task estimated as the most difficult (navigation) induced much less deviation than the two other tasks (radio list and radio scroll). In all vehicles, senior participants showed smaller adapted deviations when entering an address in the navigation system than when interacting with the radio device (selecting in a list or scrolling frequencies. However, the large standard deviations in lateral deviations show that differences between vehicles are not significant: participants individual differences have more impact than differences between systems and between vehicles. An analysis of the impact of secondary task occurrence on lane change performance was also conducted. It aimed at assessing if the position on the trajectory, corresponding to different dimensions of the primary task (e.g. sign detection, change initiation, change manoeuvre, position adjustment) had an impact on the quality of the lane change. The diversity in individual strategies resulted in no significant impact of the occurrence, and suggested that deeper investigation was required to analyse results as a function of driver strategies [10] .

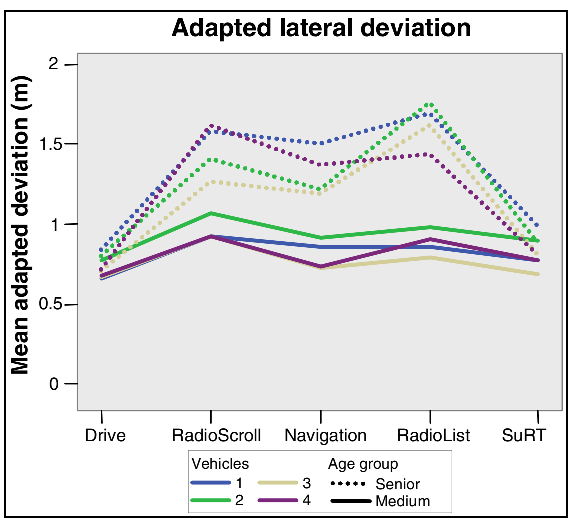

Figure 8. Lateral deviation for both age groups and all four vehicles.

<u>Calibration task performance</u> - The continuous increase in the number of trials (Figure 9), combined with a regular success rate (Figure 10), suggest a learning effect: with practice participants are gradually able to perform more and more trials, without degrading the quality of the secondary task, nor the quality of the lane change task.

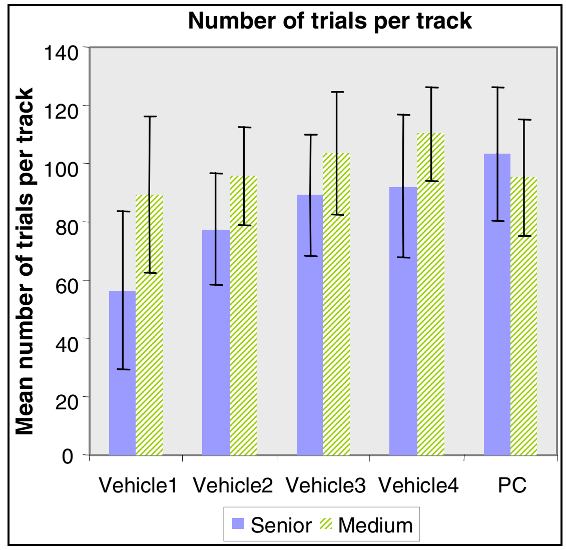

Figure 9. Number of trials per track in the SuRT.

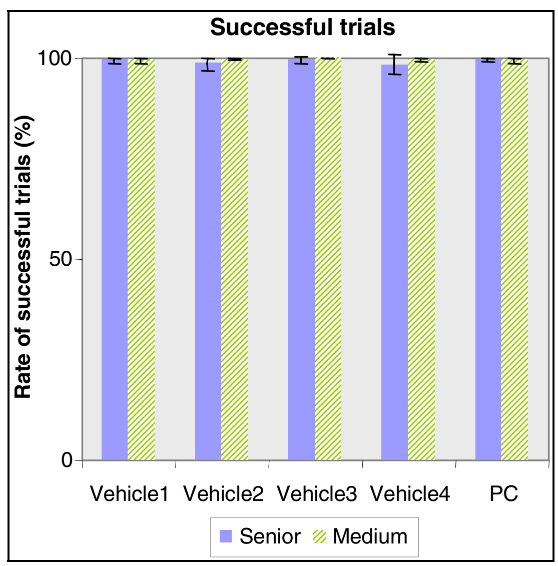

Figure 10. Percentage of successful trials in the SuRT.

<u>Radio and navigation tasks performance</u> - Even though the standardized LCT is limited to the analysis of the deviation metric, it was decided to consider additional indicators and assess their potential added value. The secondary tasks were characterized in terms of duration and latency and compared according to the age and vehicle factors. To calculate duration and latency, the start of action was defined as the first action on the device.

For both age groups and all vehicles, the navigation task is the longest (between 50 and 60 seconds), while radio tasks are much shorter (20-30 seconds for the radio scroll and 15-20 seconds for the radio list). The longer duration of all tasks with the first vehicle, especially for the senior participants raises the question of a learning effect (Figure 11 and Figure 12). Even though the usability of the device could be questioned, the similarity between vehicles 1 and 2 gives credit to a learning effect. The differences in duration of radio tasks for both age groups and in all vehicles are not significant.

It must be noted that unexpectedly, the longest tasks (navigation) induce the smallest lateral deviation. A closer analysis of subjective data (observer notes) and video recordings show that participants were more careful with the navigation tasks which they considered as more complex. With radio tasks, which they considered as simple and short, they tended to pay less attention to the driving tasks and focused completely on the secondary tasks.

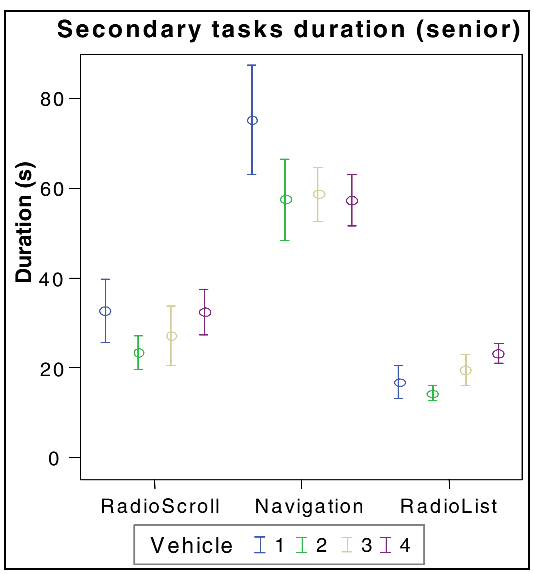

Figure 11. Secondary tasks duration, senior participants.

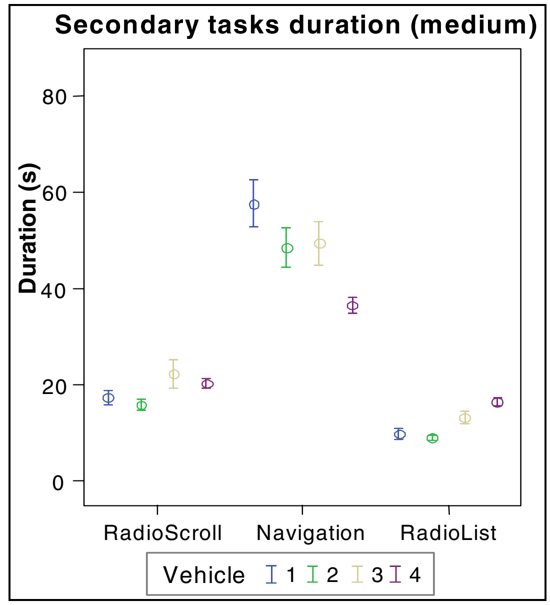

Figure 12. Secondary tasks duration, medium participants.

For both age groups, a learning effect is also observed with the first vehicle when considering the tasks latency (Figure 13 and Figure 14). The gradual reduction of latency suggests that with practice participants get familiar with what is expected and confident with their ability to initiate tasks. Typically, they learnt with practice that for navigation and radio list tasks they can initiate actions even before the end of the verbal instructions. The participants showed the largest latency for the radio scroll task, possibly due to the structure of the instruction: indeed, in the radio instruction, the relevant information, i.e. the frequency wave length is at the end of the message (e.g. “now, with the arrows, select the frequency 102.3”). No difference between vehicles is noticed for the medium group.

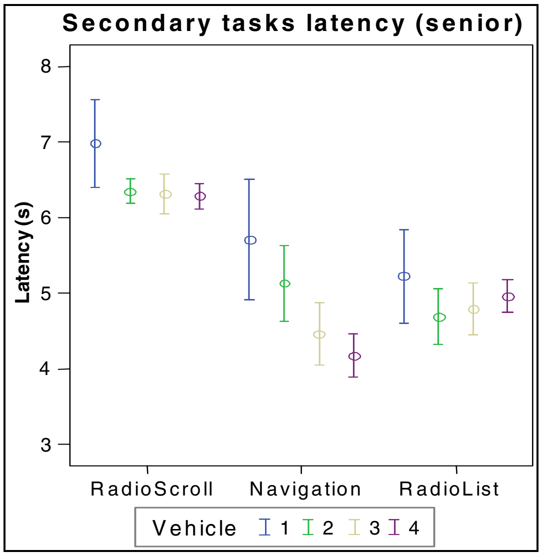

Figure 13. Secondary tasks latency, senior participants.

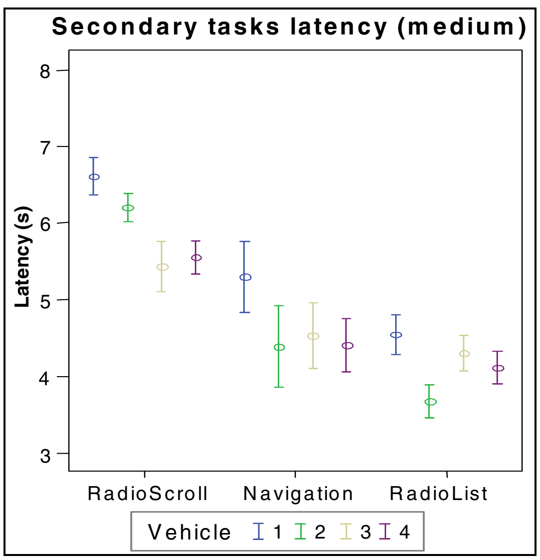

Figure 14. Secondary tasks latency, medium participants.

Compared to medium age participants, senior participants showed larger secondary tasks duration for all tasks and all vehicles but smaller latency. In other words, it took senior participants more time to initiate and to complete the tasks. For both age groups, both duration and latency values are larger with the first vehicle. This suggests a learning effect: the participants gradually learnt to anticipate the tasks, initiating actions even before the end of the instructions. Moreover, with practice they also improved their performance and gradually perform tasks faster.

The standard deviations observed for the navigation task confirms differences in practices observed during the experiments, and described in other studies on cognitive heuristics [11] . Indeed, two strategies were identified: "in a hurry" corresponding to people initiating tasks as soon as the instruction issuing and trying to get rid of it, and "careful" corresponding to driver giving priority to the lane change task and performing the secondary task only when not conflicting with the driving, occasionally interrupting it to focus on the driving.

DISCUSSION

PC versus vehicle setting

The LCT method enables the degradation induced by a secondary task to be measured in both settings. Although slightly degraded, the lane change performances in vehicles and in PC settings seem comparable, as the same trends are observed. For the senior participants, two points were observed. First, the steering wheel used in PC setting was more sensitive and initially induced larger deviations. As a consequence, it look participants longer to manage correctly the lane change tasks. Second, the reduced realism in the PC setting induced a difference in senior participants involvement and performance. Typically, in the vehicle settings they usually gave priority to the driving task and focused more frequently their attention on the road than on the calibration display. To get a better knowledge of the participants monitoring activity in both settings and confirm the previous observation, a detailed analysis of people eye movements could be envisaged.

Whereas the mean deviation is slightly larger in PC settings, the indicator is not sufficient to identify if the measured degradation is due to a less accurate lateral control or to an increased number of missed lane changes. To investigate this issue, the quality of the lane change performance will be analysed in counting the number of missed lane changes and in distinguishing erroneous changes (change towards the wrong lane) from missed changes (change not performed).

Comparison of vehicles

Beyond an increased realism, one of the objectives of transferring the LCT method in vehicle settings is to test the impact of current systems and technologies already in operation, or at least integrated in the car cockpit. This gives car manufacturers the opportunity to compare various models, or design options in realistic environment. To control biases such as order and learning effects, one would aim for a mixed run plan, where the different options are randomly compared by same participants. Ideally, in our experiment for example, the four vehicles should have been simultaneously available for testing. However, for logistic reasons, this was not possible for at least two reasons: a lack of space to position the vehicles, and a lack of material to equip and instrument four vehicles in parallel. Such an ideal experimental plan is hardly conceivable. As a consequence, two options are envisaged to control the risk of learning effect: either test again the first vehicle at the end of the experiment if the same participants are involved, or consider new participants for each vehicle. This last point is not the most appropriate, as not only it raises the question of inter-individual differences but also the issue of lack of experience with the method (and the associated poor results). The question of involving the same participants in series of studies investigating successively different systems is another difficult one. Combined with the observation of different driver strategic profiles (quick versus careful), it raises the issue of participant selection and experiments reproducibility.

Individual strategies

The differences in performances between senior and medium age participants is mainbly related to the difficulties encountered by senior people to handle simultaneously the primary driving tasks and the secondary tasks. Two assumptions are put forward to explain the variations between performances within a same age group. Within the senior group, the standard deviation reflects not only age differences, but also lack of practice with dual task. Typically, the ratings to a questionnaire on familiarity with the dual task are consistent with the observed performance. Within the medium age group, the differences are directly related to the two main strategies observed and described as “in a hurry” and “careful” profiles. To go a step further in the description of these strategies, the individual performances will be described according to the moment of occurrence of the secondary task instruction. The underlying assumption being that a same individual might adapt his/her strategy to the context, delaying for example actions if those are conflicting with demanding primary tasks (e.g. detect the lane change sign, initiate the lane change).

LCT method versus heuristic evaluation

Human factors approaches and methods enable the usability of interfaces and devices to be assessed. Heuristic evaluation, for example, consists in reviewing functions and/or features of an interface and comparing them with series of criteria (e.g. readability, consistency, accessibility). Sufficient experience in usability issues should enable experts to anticipate the impact of limited usability on driver distraction, and might consequently be redundant with method such as LCT. However, such approaches require experience and detailed investigation of strategies implemented in realistic situations. In the present study, the identification of driver strategies and their impact on the primary task (i.e. interruption of the secondary tasks to perform efficiently and safely the lane change) would not have been straightforward. In other words, whereas the quality and limits of interfaces could easily be assessed by usability experts, one can not avoid analysing driver behaviour in ecological context. And typically, whereas it does not seem sufficient per se to measure driver distraction, the LCT method provides a cost effective and simple means to put drivers in simplified realistic settings. Last of all, LCT experiments could benefit from studies conducted in similar conditions and focusing on control and monitoring strategies during lane changes [12] .

Protocol

The observations during the experiments, coupled with the analysis of actual trajectories showed compensation actions at the end of secondary tasks. Generally, after the last action (i.e. after the “end” marker), the driver adjusts his/her course to replace the vehicle in the middle of the lane. In the current analysis, deviation is calculated per task, which means that only periods between the start and the end of a task are considered. Adjustments actions, which are consequences of the secondary tasks performance are excluded from the analysis. Additional thoughts are needed to define clearly those periods of analysis.

CONCLUSION

Various methods are currently envisaged to measure the impact of distraction on driving efficiency and safety. A series of simulator experiments was conducted with 17 participants of two age groups (senior and medium) to assess the relevance and reliability of one of these methods, denoted Lane Change Test (LCT). In addition to a “drive only” condition, four secondary tasks were proposed: target selection, radio frequency scroll, radio selection in a list and address input in a navigation system. To ensure that the method could be applied in both PC-based and vehicle-based settings, performances in both environments were compared. The consistent results obtained in both settings suggest the suitability of the method to both laboratory and more ecological settings. To assess if the method was sensitive enough to discriminate between devices and displays, four different vehicles were compared. The main indicator proposed by the method, the lateral deviation, showed no difference between vehicles, nor between the radio and navigation tasks. The robustness of the method needs to be questioned when different individual strategies have more impact than differences between the functions tested. Additional indicators, such as the latency and the duration of secondary tasks seems promising, but need to be completed with a better assessment of the lane change task itself, mainly to discriminate low quality of lateral control from errors in lane changes (omission or incorrect change).

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