HMI ASPECTS OF THE USABILITY OF INTERNET SERVICES WITH AN IN-CAR TERMINAL ON A DRIVING SIMULATOR

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(Received June 1, 2001)

An experiment on the usability assessment of various control interfaces of an in-vehicle Internet browser, was carried out on the Renault driving simulator with a fictional web site that offers services such as: district map, route planning, electronic messaging, leisure programs, and phone directory.

Twenty seven subjects aged from 26 to 69 years carried out this experiment; while performing a car-following task they manipulated an in-car web site by using three control devices: a keyboard, a touchpad, and a voice command. In the quantitative part of the experiment, subjects performed tasks such as writing names, selecting items and moving a cursor on a map, using the keyboard or the touchpad. In the qualitative part, subjects used the in-vehicle web service in a realistic scenario and were allowed to choose the control devices they wanted (voice, touchpad or keyboard). Assessment criteria were speed, distance to the target vehicle, lane position, visual activity, action on the system, operating time, error rate and post trial questionnaire.

Based on these criteria, the results showed that browsing while driving seems to remain both complicated and dangerous even when using a simplified browser. However, the results also indicated that, depending on the type of tasks, the different control modes did not have the same efficiency.

Key Words: In-vehicle man-machine interaction, Internet browser, Driving simulator, Interaction modalities, Multimodal interface

1. INTRODUCTION - PROBLEM

Over the past few years, a lot of ITS (Intelligent Transport Systems) have been developed in the automotive industry, like guidance systems or Adaptative Cruise Control. Within a few years, travellers will be likely to have access to new services, ranging from traditional traffic information to all-encompassing travel information, with the possibility to have all information related to transport (private as well as public) but also for leisure and shopping[1]. New trends in mobile communication technology will allow users to communicate with anybody at any time and anywhere, even while driving, using Internet facilities. However, in comparison to a “traditional” in-vehicle system, using an Internet environment involves certain specific characteristics which, with the additional factor of use inside a vehicle, may require new control command devices. Thus, technical devices like touchpad or voice command[2], which have been unfrequently used up to now in an in-vehicle ITS context, appear of prime importance for the usability of the future mobile Advanced Transport Information Services (ATIS).

In this framework, Renault, INRETS and UBS carried out an experiment on a driving simulator about the usability assessment of various control interfaces of an in-vehicle Internet browser. This prospective study was part of a collaboration between the PROMISE (Personal Mobile Traveller and Traffic Information) and TELSCAN (TELematic Standards and Co-ordination of ATT system in relatioN to elderly and disabled travellers) projects, both funded by the European Commission as part of the Telematic Application Program. The PROMISE project dealt with the development of in-vehicle telematic applications or those accessible on mobile systems. The basic concept of PROMISE was that every traveller can be assisted by a PROMISE terminal (and its associated services) permitting access in real time to traffic and transport information. The overall objective of the TELSCAN project was to emphasise and ensure that the needs of elderly and disabled travellers are taken into account appropriately and efficiently in the development and in the methods of operating telematics systems. Thus, the experiment described in this paper includes in its sample people who are elderly.

2. EXPERIMENTAL DESIGN

2.1 Participants

This experiment was completed by 27 subjects:

- 20 active subjects (including 4 women) aged from 26 to 52 years, all employed by Renault (average age: 31.6 years); and
- 7 voluntary retired subjects (including one woman) aged from 60 to 69 years (average age: 62.9 years).

None of the subjects had used a driving simulator before and all of them (except 2 retired subjects) were familiar with computers.

2.2 Driving simulator

The experiment was carried out on a static driving simulator developed at the Renault Research Department. This simulator was composed of a real car and the road scene was displayed on a three-screen-system. Full rear vision was also provided to the driver as well as the noise from the engine[3]. The route followed was a motorway section on which the participant had to follow a specific car with a safety distance as constant as possible.

2.3 Internet browser

A prototype of a telematic application was designed in HTML format and loaded onto a local PC to simulate the access of various services. Pages of this application were designed on the basis of the PROMISE Internet browser studied in the PROMISE European Project. The Figure 1 shows the main page access to the experimental application.

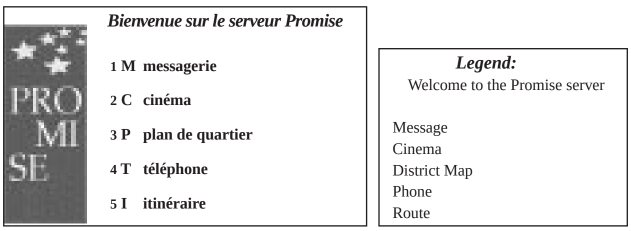

Fig. 1 Main menu of the experimental application

This rapid prototype was developed to test different devices (keyboard, touchpad and voice) to access some services which were chosen only for the needs of this experiment. The screen was located above the gear lever at eye-level and at the centre of the dashboard.

2.4 Interaction modalities: the input and output devices

The Internet navigator was controlled by three different input devices:

- a keyboard;
- a touchpad; and
- a voice command using a microphone.

2.4.1 Keyboard description

The keyboard was located on the dashboard, just above the gear lever. As depicted in Figure 2, the keyboard was composed of four specific buttons:

- a dual-function turning knob dedicated to the movement of a cursor in a list or to the scrolling of the alphabet. When pushing the turning knob, the “validation” operation is activated. This turning knob was the only possibility offered to the user to enter text.
- two simple pushbuttons, one (yellow) activated the action “back to home page”, and the other (red) the action “cancellation” or “back to previous page”,
- a four-way toggle switch was dedicated to moving a cursor in four directions (up, down, right, left). This particular button was mainly used to move the cursor on a map.

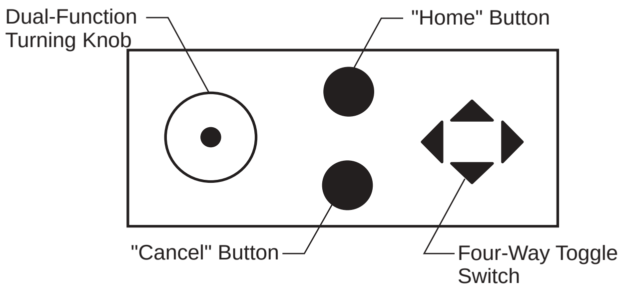

Fig. 2 Keyboard functionality

2.4.2 Touchpad description

A touchpad consists of a non-transparent surface which is sensitive to skin conductance and is similar to that provided on certain notebook computers (Figure 3). The surface catches the finger position and is highly sensitive because it does not require any contact pressure.

In this experiment, a touchpad, 9cm wide and 7cm high, was located on the steering wheel close to driver’s hands. As illustrated in Figure 4, the touchpad surface presented four different zones devoted to the actions “validation” (green zone), “cancellation” (two red zones) and “back to home page” (yellow zone). In addition to the simulating buttons, the purpose of the touchpad was to record any pattern (letter, digit, character) drawn with the finger by the user. The idea was to recognise the symbol drawn and to match it with predefined patterns triggering specific actions for the Internet navigator system.

For example, if the pattern was a letter or a digit, the action consisted in writing an alphanumeric item in a field of the web page. The actions understood by the recognition system were the following:

- uppercase letters and digits to enter characters in a field or to choose an item in a list (this was called "direct selection");
- downward and upward strokes to move a cursor in a list; and
- absolute position of the finger on the surface to move the absolute position of the cursor on a map. To activate this particular context, the user had to briefly press the touchpad.

Fig. 3 Example of touchpad

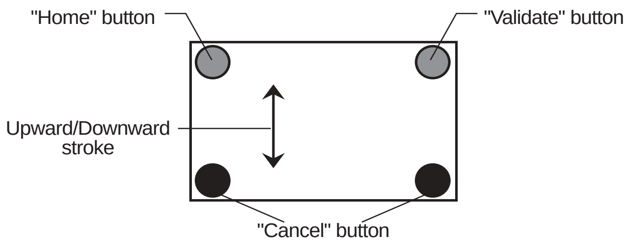

Fig. 4 Touchpad functionality

The recognition system was based on a neural network approach[4] with the distinctive feature that it did not require adaptation to the specific writing of the user.

2.4.3 Description of the voice command

Concerning the voice mode, a series of keywords were defined and were pronounced by the driver. Each keyword corresponded to a specific action, i.e.:

- "Validate" or "Validation", to confirm a selection or an action;
- "Cancel" or "Cancellation", to cancel an action or to correct a piece of text;
- "Home page", to return to the home page of the Internet navigator;
- "A", ..., "Z", "0", ..., "9", to enter a name or any other number or alphanumeric item in a field of a web page. Each letter or digit making up the alphanumeric item, name or number, was spelled one by one;
- "Up", "Down", "Left", "Right", to move a cursor on a map.

In addition, to select an item in a menu, the user had the possibility of pronouncing the corresponding word. For instance, to select the item "District Map" in the menu presented at the home page, the user simply uttered the words "District" and "Map": this operation mode was called "direct selection".

The microphone was located near the steering wheel so that the driver can keep his/her eyes on the road. It must be stressed that no real speech recognition was implemented: the experiment was carried out according to the experimental paradigm of the Wizard of Oz where the experimenter executes the voice commands pronounced by the subject. To avoid untimely recognition, the user had to press a "beep" button to activate the fictitious speech recognition.

2.4.4 Speech synthesis

Real speech synthesis, was used in two different ways:

- to explain to the driver the action he had to accomplish during the quantitative experiment; and
- to confirm the command (keyboard, touchpad or voice) the driver had executed and to notify the user which web page was activated. The goal was to permit the subject to keep eyes on the road without looking at the result of the command on the screen.

2.5 Instruction to drivers

Two types of experiments, the quantitative and qualitative one, were conducted on the driving simulator to evaluate the usability of the in-car Internet browser.

2.5.1 The quantitative experiment

The objective of this experiment was to measure precisely the effectiveness of the input devices when the subject was driving and, at the same time, executed three different actions:

1. "menu" action: in a list of 5 items from the homepage (Figure 1), the driver had to select the "District Map" item. Next, he had to cancel the action (which was equivalent to going back to previous page) and had to select the "Cinema" item;
2. "name" action: the driver was asked to write the name "MARTIN" in a field, and to validate it (Figure 5);
3. "map" action: on a map of Paris, the subject had to place a cursor on a precise location (UGC cinema) and then had to confirm (Figure 6).

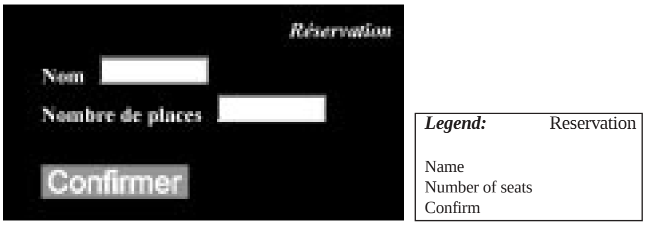

Fig. 5 HTML page corresponding to the Name action

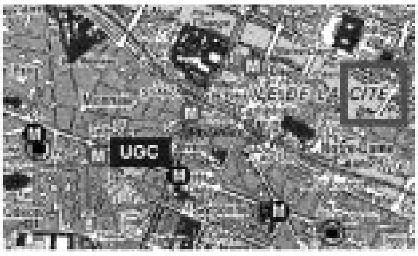

Fig. 6 HTML page corresponding to the Map action

Because measurements took into account real mistakes made by the recognition system (touchpad), the voice input device with fictitious speech recognition (Wizard of Oz) was not evaluated for the quantitative experiment.

Prior to the execution of the three different tasks (menu, name, map), the subjects, first, have become acquainted with the touchpad and keyboard, in a stationary car. Then, they trained on the driving simulator during 20km on the A86 motorway without handling any of the control devices. During this training, a reference situation of the driving state (speed, lane position, etc.) was recorded for each driver.

The three different actions (menu, name, map) were carried out on the same sections of the A86 and the drivers had to follow, from a reasonably safe distance, a leading vehicle moving at the speed of 110km/h, without any traffic. After explanation, by speech synthesis, of the action to be accomplished, a "beep" audio signal notified the subject that he had to execute the required task. Another "beep" indicated that the action had been correctly executed.

2.5.2 The qualitative experiment

Instead of executing specific actions as described in the previous paragraph, the driver had to follow a scenario that started with the reading of an electronic mail. On the basis of the mail content, the subject deduced the different tasks to be executed. The scenario proceeded in 4 steps:

1. reading the electronic mail sent by "François Dupont";
2. choosing a film and booking two seats (for the user and F. Dupont) at the UGC Odéon cinema;
3. selecting on the map the subway station to meet F. Dupont near the UGC Odéon cinema; and
4. phoning F. Dupont to tell him the appointment near the cinema.

To carry out the different actions (select an item, validate, cancel, enter a letter, moving a cursor, etc.), the driver could use any of the three control devices: simulated speech recognition, keyboard or touchpad. Hence, the goal of the qualitative experiment was to answer the question: what is, according to the user and the action to be accomplished, the most appropriate device?

As in the quantitative experiment, the drivers had to follow, from a reasonably safe distance, a leading vehicle moving at 110km/h. On the other hand, fluid road traffic was added and the users had to give priority to the driving task. The drivers were free to execute the scenario at the moment they considered most appropriate.

2.6 Hypothesis

First Hypothesis: new Internet services will require more complex interactions between the driver and the onboard system. Those secondary tasks may significantly interfere with the first one (i.e., the driving task itself). Nevertheless the new MMI technologies (e.g., touchpad) could be ideal solutions for the use of those telematic services while driving, for main applications related to the driving task such as traffic information, weather forecast, etc.

Second Hypothesis: according to the characteristics of the elementary actions, one or the other of the interaction modalities (i.e., "voice", "touchpad" or "keyboard") will be more or less appropriate for the interaction.

2.7 The collected data

2.7.1 Video data

The experiments were recorded on videotape. The use of a four-into-one video splitter device allowed the use of a single image comprising:

- a view of the subject filmed head on (face, regard);
- a view of the inside of the car (operation on the touchpad, keyboard and road scene);
- simulator parameters: speed, time-between vehicles, distance in relation to the leading car and lane position; and
- state of the screen (normal HTML page), actions carried out.

Examination was carried out afterwards and consisted in retranscribing the drivers' activity during the different test stages.

2.7.2 Data concerning the driving task

Three different types of data were recorded in this driving simulator experiment:

- the time between the target vehicle and the subject's vehicle;
- the speed of the subject's vehicle;
- the lane position.

All these data were recorded at a frequency range of 20Hz in order to have a good ratio between accuracy and data volume.

2.7.3 Data concerning web browsing activity

In the quantitative experiment, all the actions performed by the subjects on the web browser by the different control commands were recorded on computer at the same frequency range as driving data.

For the qualitative experiment, these data were obtained from the video recording.

2.7.4 Questionnaires

After each experimental situation, the subjects had to fill a questionnaire; for the whole study (quantitative and qualitative) 6 questionnaires were filled regarding the use of the driving simulator, the legibility of the screen, the usability of the touchpad, the usability of the keyboard, the differences between the interface control commands used and their impact on driving.

All the questionnaires were filled by the subjects in the presence of an observer who recorded at the same time spontaneous comments.

2.8 Measured parameters

Based on the data provided by the driving simulator, two clusters of parameters were computed. The parameters are listed below and have a suffix "das" to denote that they are measured during execution of task "a" by subject "s" using the interface "d" (touchpad, keyboard or reference situation).

The first cluster, called "parameters of the driving task", evaluated the impact of the use of the different control commands (touchpad or keyboard) on the driving performances:

- TIV_{das} : represented the mean of the time-between vehicles values (in seconds) during the execution of action "a".
- $TIV1525_{das}$: was the percentage (during the execution of action "a") of TIV values lying between 1.5 and 2.5 seconds (considered as a safe gap).
- VS_{das} : the mean speed (in km/h) of the subject's "s" vehicle.
- $VS80_{das}$: the percentage of VS values smaller than 80km/h (considered as an unsafe speed on a motorway).
- EL_{das} : the mean of the absolute lane position values (in meters, zero if no deviations) of the subject's "s" vehicle.
- $EL1_{das}$: the percentage of EL values higher than 1 meter (considered as an unsafe driving behaviour, see Figure 7).

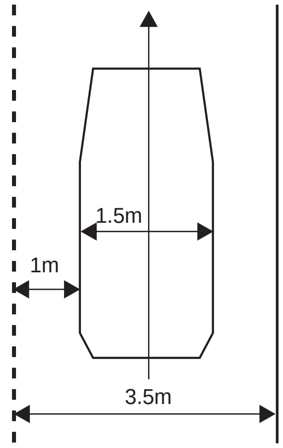

Fig. 7 The dimensions of the vehicle and the road

The second cluster called "parameters of the secondary task", evaluates the driver's ease to accomplish the task:

- $Time_{das}$: represented the time needed to accomplish the action "a".
- $Error_{das}$: was the rate of mistakes made during the execution. The error rate was defined as the ratio of the "number of elementary actions needed to execute the task" over the "minimum of elementary actions needed to execute the same task", i.e., #actions/#min. An elementary action was, for instance, one pressure of a keyboard button or one letter drawn on the touchpad. If no errors occurred during the task execution, "Error" = 1 (because #actions = #min).

3. RESULTS AND DISCUSSION

The TIV parameter (the time-between vehicles) had sometimes abnormal values, especially during the qualitative experiment. Indeed, when the speed of the driver's vehicle dropped, TIV also dropped whereas TIV should increase. This was due to the fact that the leading vehicle had sometimes to wait for the driver's vehicle because the subject drove too slowly and hence, lost contact with the leading vehicle. Because the measurements of TIV values were disturbed by the stops of the leading vehicle, it was decided not to take this parameter into account in the analysis of the data. The difficulty for the driver to follow the leading vehicle during manipulations of the control devices, was confirmed by the values of TIV and TIV1525 in the quantitative experiment: whatever the task and also whatever the input device, TIV was always higher than 4 seconds and TIV1525 less than 23%.

3.1 Global results of the quantitative experiment

In this section, the results are those obtained for the whole population, i.e., the young and the elderly drivers. A discriminant analysis was performed on each of the parameter clusters (the driving task and the secondary task).

"Fisher's discriminant analysis" [5,6] is a general statistical technique used in pattern classification to select, in a large parameter set, a small subset of parameters which are most significant for the discrimination between classes. In the present context, it consists of the following steps:

- assume (P_{iD1}, ..., P_{iDL}), are the L parameters measured for subject S_i (1 <= i <= N) manipulating the D control command (D = keyboard, touchpad or reference);
- to discriminate between the D devices, a discriminant variable, DV, is calculated as a linear combination of the parameters (P_1 ... P_L). The discrimination quality is given by a factor "k" where k = 0 (= 1) means respectively no discrimination and perfect discrimination;
- the discriminant parameters P_d are those with the strongest correlation with DV. Coefficient "C(P_d, DV)" with (0 <= C <= 1) evaluates the correlation between P_d and DV.

3.1.1 Driving task analysis

The goal of the analysis was to determine which parameters among VS, EL, EL1 and VS80 (TIV was eliminated) will significantly distinguish between a keyboard manipulation, touchpad manipulation and the reference situation (recorded without handling any control, see the above paragraph, "The Quantitative Experiment"). In other words, given a secondary task (menu, name, map) the purpose was to identify the input device (touchpad or keyboard) which most/less disturbed the driving task.

After elimination of incomplete data (several subjects had no lane position's measurement), 17 (task "name") or 18 (tasks "menu" and "map") drivers participated in the discriminant analysis. Interesting parameters are VS and EL: Figure 8 shows the mean values and standard deviations for each task (menu, name, map) and the reference. For a given task, the mean value of parameter VS or EL, obtained when using the keyboard, is directly compared to the one obtained when using the touchpad. Parameters VS80 and EL1 are not illustrated here because they generally confirmed the information given by VS and EL respectively.

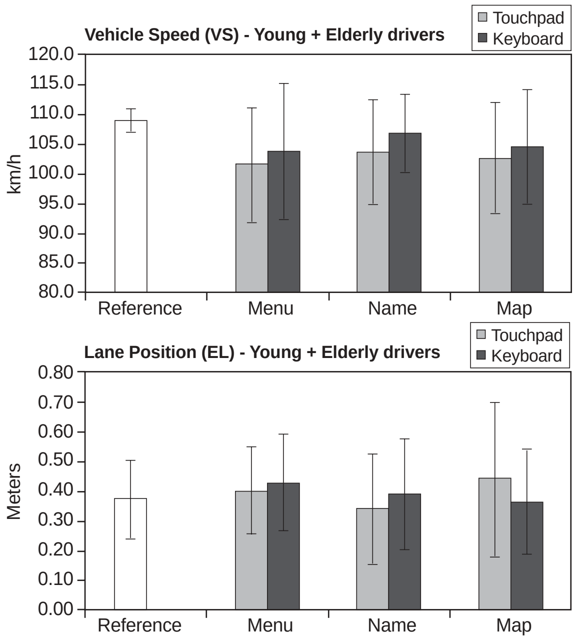

Fig. 8 Means and standard deviations of VS and EL parameters

Discriminant analysis shows that, whatever the task (see Table 1):

- no discrimination was possible between keyboard/touchpad and keyboard/reference (k factor was too low or no parameters were correlated with DV);
- as shown in Table 1, the only significant discrimination, with VS parameter, is the one between touchpad and reference. Here, VS drops 7km/h on average, compared to the reference, when the subject manipulates the touchpad.

Concerning "menu" and "name" instructions, Table 1 shows that lane position was always lower for the touchpad compared to the keyboard, but the result was not significant. This is probably due to the fact that the touchpad was located on the steering wheel, contrary to the keyboard. On the other hand, drivers had a lot of difficulties to accomplish the "map" instruction with the touchpad: EL parameter is high and EL1 was 9.7% com-

Table 1 Driving task parameters: discriminant analysis between touchpad, keyboard and reference

Task		VS (km/h)			EL (m)			Discriminant Analysis			
		TP	Key	Ref	TP	Key	Ref	DV k factor	C (VS, DV)	C (EL, DV)	Comment
Menu	M	**101.7**	103.9	**109.0**	0.40	0.43	0.37	0.68 discrim TP/Ref	0.80	–0.21	Parameter VS discriminates touchpad and reference
	SD	9.7	11.4	1.9	0.15	0.16	0.13				
Name	M	**103.7**	107.0	**109.0**	0.34	0.39	0.37	0.74 discrim TP/Ref	0.68	0.27	Parameter VS discriminates touchpad and reference
	SD	8.7	6.6	1.9	0.18	0.19	0.13				
Map	M	**102.7**	104.6	**109.0**	0.44	0.36	0.37	0.67 discrim TP/Ref	0.81	–0.37	Parameter VS discriminates touchpad and reference
	SD	9.3	9.8	1.9	0.26	0.18	0.13				

Caption: M = mean value, SD = standard deviation, TP = touchpad, Key = keyboard, Ref = reference, DV = discriminant variable, C (VS, DV) = correlation between VS and DV, C (EL, DV) = correlation between EL and DV.

pared to 5.6% (keyboard) and 4.7% (reference). The reason is that in order to move the cursor on the map with the touchpad, subjects had to keep their eyes continuously on the screen.

3.1.2 Secondary task analysis

The goal of this analysis was to evaluate the performances of the subject to execute a task by manipulating the touchpad or the keyboard while driving. The question is: will "Time" and/or "Error" parameter(s) significantly distinguish a manipulation of the keyboard from a manipulation of the touchpad?

Exactly the same subjects as those of the "Driving Task Analysis" were selected. Figure 9 shows the mean values and standard deviations for each task (menu, name, map). Given a task, the mean value of parameter Time or Error, obtained when using the keyboard, is directly compared to the one obtained when using the touchpad. It should be mentioned that, because of a technical constraint, no error rate was available in the case of execution of the "map" instruction with the touchpad.

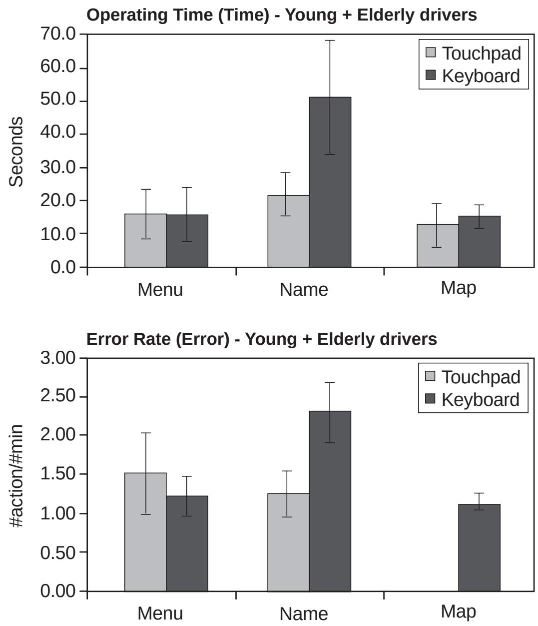

Fig. 9 Means and standard deviations of Time and Error parameters

Table 2 Secondary task parameters: discriminant analysis between touchpad and keyboard

		Time (seconds)		Error		Discriminant Analysis			
		TP	Key	TP	Key	DV k factor	C (Time, DV)	C (Error, DV)	Comment
Menu	M	15.9	15.6	1.54	1.24	0.37	–0.05	–0.91	No discrimination
	SD	7.5	8.2	0.53	0.26				
Name	M	**21.7**	**50.7**	**1.28**	**2.32**	0.87	–0.88	–0.98	Both parameters Time and Error discriminate touchpad and keyboard
	SD	6.4	16.9	0.29	0.38				
Map	M	12.5	15.2	/	1.16	0.06	1	/	No discrimination
	SD	6.7	3.6	/	0.10				

Caption: M = mean value, SD = standard deviation, TP = touchpad, Key = keyboard, DV = discriminant variable, C (Time, DV) = correlation between Time and DV, C (Error, DV) = correlation between Error and DV.

Discriminant analysis shows that (see Table 2):

- concerning tasks "menu" and "map", the keyboard and touchpad gave nearly the same results in terms of operating time and error rate (no discrimination). Of course, error rate was not available for the "map" action executed with the touchpad but, despite the difficulty of achieving the "map" task with the touchpad (see previous paragraph), the operating time was sometimes very small; and
- for the "name" instruction, there was an important difference in operating time and error rate values between the touchpad and keyboard. The touchpad is clearly much more advantageous: half the error rate and operating time of the keyboard.

3.2 Summary of the global results and comparison young/elderly drivers

On the whole, young and elderly drivers gave the following results:

- Time-between vehicles was systematically high regardless of the task and the input device. Each of the tasks should need an additional cognitive resource which prevents the user from following the leading vehicle.
- Whatever the task, the speed of the driver's vehicle significantly drops when the subjects manipulate the touchpad. The touchpad would impose a stronger cognitive load, but without affecting lane position (except "map" action) because the touchpad is located on the steering wheel.
- Lane positions increase when the subjects performed "map" instruction with the touchpad. In that case, the visual load was high because, in order to move the cursor on the map, subjects had to keep their eyes on the screen continuously.
- Lane positions are especially low (lower than reference, see Table 1) when users perform "name" action with the touchpad. Two factors would account for this result:
  - the position of the touchpad on the steering wheel; and
  - the ease to enter letters with the touchpad because it implies fewer manipulations and less visual activity.
- Concerning the "name" instruction, operating time and error were clearly much more interesting for the touchpad compared to the performances of the keyboard.

The same discriminant studies as above (driving task analysis and secondary task analysis) were performed on the young driver population only. Young subjects were exactly the same as those of the previous section. In that case, statistical studies were conducted on the 14 young drivers.

For the secondary task analysis (parameters Time and Error), the results showed that, whatever the task, young and elderly people had the same performance.

Concerning the driving task analysis (parameters VS and EL), there was an important difference: except for "menu" task, the discriminant analysis carried out on young people's data demonstrates that keyboard manipulations disturb the driving task much less compared to the set "young + elderly people". More precisely, data obtained during keyboard manipulations show that:

- for the "name" instruction, average value of VS (108.6km/h) was nearly the same as the reference (109.2km/h) and, average value of EL (0.35m) was less than the reference (0.39m); and
- for the "map" instruction, average value of VS (105km/h) was not significantly less than the reference (109.2km/h) and average value of EL (0.29m) was very small compared to the reference (0.39m).

3.3 Results of the qualitative experiment

3.3.1 Use of the different control devices

Analysis of the video images allowed observation of what type of control device was used for a given action. Seven different actions required for carrying out the scenario were defined:

- direct selection (of an element in a menu, tactile or voice mode only);
- confirm;
- cancel;
- root: allowed to return to the home page;
- data entry: this action comprised entering a letter to form a name (in the reservation stage) or a number (number of seats);
- moving up and down in a menu: this only concerned the action of moving the cursor in a menu to select an item; and
- moving on a map: moving the cursor in any direction on a plan or a map.

The results obtained (see Figure 10) showed that the touchpad was the most used by the subjects followed by the keyboard and finally the voice command.

When breaking down these results according to age, it appears that the younger subjects used the touchpad and the keyboard at the same rate while the subjects who were elderly mainly used the touchpad.

It should be stated that, as the voice command was simulated, its use was very efficient and then minimised the number of actions.

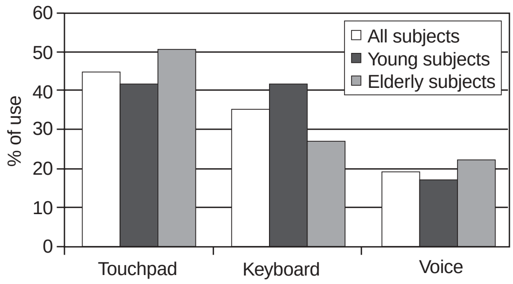

Fig. 10 Use of the different control commands according to age

The video analysis allowed differentiation of the actions performed by the subjects on the browser (see Table 3). The results obtained show that the touchpad was the most polyvalent control mode; it can be said that thanks to its position in the steering wheel area, the touchpad was easily adapted to simple and quick action (as root, cancel, confirm), however, its use for actions such as moving on a map was not intuitive. The voice device was favoured for the direct selection (the great majority of cases) and data entry actions.

Table 3 Use of the different control devices according to the action performed for all the subjects

%	Touchpad	Voice	Keyboard
direct selection	20.5	79.5	not possible
confirm	55	3	42
cancel	90	5	5
root	66.5	3	30.5
data entry	38	40	22
moving in a menu	45.5	0	54.5
moving on a map	43	0	57

The keyboard mode was also slightly favoured to the touchpad for moves in the menu and the map. Furthermore, it should be noted that the voice mode was never used for these actions.

Subjects' comments show that the tonal feedback of actions performed by voice synthesis was a valuable aid, as this reduced the need to check on the screen that their action had been taken into account. This sound feedback appeared of prime importance for the subjects.

The possible effect of age was not apparent for the Select, Confirm, Cancel and Root functions. On the other hand, the distribution of actions carried out per mode was different for the other functions between the two age groups. Thus, whereas the young subjects mostly used the touchpad to enter a name or a number, with very little use of the voice mode, most of the elderly subjects chose the voice device.

3.3.2 Visual activity

Visual activity was obtained by the processing of video recordings; the analysis concerned the frequency of glances on four elements which were the screen located on the dashboard, the rear view mirrors (right, left, central), the touchpad and the keyboard (see Table 4). As expected, the screen was the element with the greater number of glances (67% of glance off road) concerning the control mode, the touchpad was glanced at more than the keyboard (15 versus 8%).

Drivers who were elderly tended to make more glances than the younger drivers and the main difference was that they looked twice less often at the rear view mirror than the younger drivers and made more glances on the screen and the keyboard.

Table 4 Percentage of glances according to age group

Frequency %	Age group		
	Young + Elderly	Young	Elderly
Screen	66.5	64.2	69.4
Touchpad	15.6	16.6	14.3
Rear view mirrors	9.7	12.4	6.4
Keyboard	8.1	6.8	9.9

3.3.3 Links between errors of interaction and change of control device

An attempt was made to find out to what extent, when an action was not completed, the failure was the result of wrong use of the control device by the subject and if this led to a repetition of the action using the same control device or a different one. The analysis of the video showed that in most of the cases, the repetition of the action is made with the same control device. The touchpad was the more concerned by the failure of action, this was not only due to the fact that it was the device most used, but also because its use required more practice than the subjects had in the experiment. It has also to be recalled that the voice command was simulated (operated by an observer) and this could explain why this control device was little affected by the failure of actions.

Furthermore, changes of control device were observed without them being preceded by a failure of the control device used previously. One interesting example concerned a subject who switched between the keyboard and the voice command as his vehicle started to take a bend.

3.4 Link between errors of interaction and effects on the driving task

In a qualitative way there was a link between errors of interaction and the increase of difficulties to control the driving task itself (lane position) even if it was not possible to confirm this trend due to the low number of cases. Nevertheless this phenomenon occurred when the system worked differently from what was expected by the subject (for example, when there is a "bad recognition" by the voice system or the tactile system, the result of the action differed completely from what is expected by the subject). In this case the driver focussed his attention much more on the secondary task than on the driving task itself.

Even if data failed in this experiment to confirm this trend in a quantitative way, it is an important point to take into account for the future design of such systems.

3.5 Data from questionnaires and interviews

3.5.1 Incidence of the use of the browser control devices on driving activity

In the quantitative experiment, most of the subjects indicated that operating the touchpad while driving was quite disturbing, especially for holding the trajectory. They also expressed the necessity to have a longer adaptation time to use the touchpad. The same results were obtained for the keyboard, and particular points were made for actions requiring prolonged use of the keyboard which forced the driver to operate the steering wheel with one hand only.

Whatever the browser control device used, some actions required a high level of visual attention and induced a disturbance from the driving task.

For the qualitative experiment, the subjects reported that the voice command was the best browser control device regarding safety, as it required little manipulation, did not prevent operation of the steering wheel and required little learning. The voice command also minimised the visual control of actions.

3.5.2 The subjects' interest in using such a system

A high proportion of the subjects (19 out of 27) said they were interested in using this kind of in-vehicle telematic system, provided that the services offered were related to the use of the vehicle, that is to say, traffic information, breakdown assistance, parking, etc.

It should be noted that the traffic information service generated more interest than the route or guidance services. Furthermore, of the services offered in this experiment, it was the District Map that most attracted the subjects. However, the subjects often wanted to consult it while the vehicle was not moving, as they thought it was too dangerous with respect to road safety.

3.6 Discussion

From the results of the quantitative experiment (comparison between touchpad and keyboard), it is not possible to confirm the first hypothesis: the touchpad device cannot be globally regarded as an easier and safer way to interact during driving with the Internet browser than the keyboard.

Particularly the results of the main driving task showed a significant drop of speed during touchpad interaction when this drop was less significant with the keyboard. This result is probably due to the fact that the touchpad device was a new one, unfamiliar for most of the subjects, and this drop could disappear with learning.

Concerning lane position, the results are more contrasted. They show clearly that the compatibility between driving and using a given control device depends directly on the task to be achieved. For example, the task of entering a name led to significantly less deviation if it was done with the touchpad device than if it was done with the keyboard. Whereas opposite results were obtained with the task of placing the cursor on a map location in which the four-way toggle switch led to less deviation by the driver. This trend, of a strong link between device and subtask, appeared even more strongly on the parameters (Time and Error) directly linked to the secondary task achievement.

The task of entering a name took half the time and half the number of errors when it was done with the touchpad device than with the ordinary rotary knob. Hence, there is a very strong "specialisation" of the device according to the task characteristics. The second hypothesis proposed is strongly validated.

Results from the qualitative experiment (comparison among touchpad, simulated voice recognition and keyboard), confirm a preference of the users for a given device according to the characteristics of the action to perform. It means that for a given task (for example, reading an electronic mail or choosing a film and booking two seats) people did not hesitate to change devices.

This result was not so obvious at the beginning of this study where one could have supposed that people would prefer to keep the same device throughout the achievement of the main goal (remember that obviously the experiment support permitted the achievement of all actions with all devices). Some sequences, on which those changes depended of the driving situation itself were observed.

All of those results lead to recommend combining, for complex interaction, different types of devices and giving the user the opportunity to choose the most appropriate according to:

- his/her own preference;
- the characteristic of the action and even more precisely, the characteristic of the variables manipulated during the action (symbolic variables as characters or numbers, continue variables, discrete variables, etc.);
- the level of familiarity with the device; and
- the characteristics of the driving situation.

4. CONCLUSION

This experiment concerned the evaluation of different control devices for an in-vehicle Internet navigator intended for different types of tasks on a driving simulator.

The main objective of this study was to measure the impact of different control devices on two types of users (under 60 years old and over 60 years old) and to determine, per type of task, the most appropriate control device.

Generally, reading the screen in the car was difficult for the elderly subjects because of their visual capacities but also of the too small character size and the fact that the screen was located too far from their eyes. Consequently, elderly subjects found it more difficult to use the keyboard for complex tasks (name or map actions) which required a high level of visual control. The actions of the Internet service which required important visual control introduced great perturbations in the driving activity. This was particularly the case for the touchpad in the map action whereas the use of the keyboard for this action had little impact.

For simple actions (confirm, cancel, moving in a menu), the touchpad and the keyboard had similar performances. The voice command was mainly used for direct selection in a menu and data entry; similarly to the touchpad, this control device seems to induce limited perturbation on driving activity and permits to complete the actions quickly. Voice interface (recognition as well as speech synthesis) was considered by the users as the best control device adapted to a driving context. From this experiment, one can say that potential interaction with an in-vehicle Internet service has to be strictly limited to simple actions (direct selection, cancel, confirm) performed with a touchpad or a voice command. For more complex interactions (data entry, moving on a map) it is strongly suggested to perform these activities while the car is stationary.

Finally, letting the user choose the device among several would probably be the best way to increase the compatibility with the driving task for complex interaction; even if, obviously, this improvement has limits beyond which those complex interactions become unsafe.

It was not really the main goal of this exploratory experiment to identify those limits. Nevertheless one important thing appeared in the qualitative experiment: the danger of the situation seems to depend on the capability of the driver to control the results of his action (thanks to the speech synthesis, for example) than the ease to achieve those actions themselves. It is certainly a major point to take into account in the design of future mobile Advanced Transport Information Services.

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