Proceedings of the 1st Human-Centered Transportation Simulation Conference, The University of Iowa, Iowa City, Iowa, November 4-7, 2001 (ISSN 1538-3288).

USING A DRIVING SIMULATOR TO PERFORM A WIZARD-OF-OZ EXPERIMENT ON SPEECH-CONTROLLED DRIVER INFORMATION SYSTEMS

Dietrich Manstetten – Wolfgang Krautter – Bernd Grothkopp – Frank Steffens – Petra Geutner
Robert Bosch GmbH, Corporate Research and Development, Dept. FV/FLI
P.O.Box 10 60 50, 70049 Stuttgart, Germany
Telephone (+49) 711 811-6670
Fax (+49) 711 811-7136
E-mail Dietrich.Manstetten@de.bosch.com

Submitted October 19, 2001

ABSTRACT

The paper describes a driving simulator application in the context of speech-controlled driver information systems. The objective is to study how drivers interact with such a system if it allows for natural-language communication. A prototype of such a system is under development but does not yet exist. Knowledge about typical dialogs appearing in this context as well as the effects of distraction on driving behavior is of great benefit for the development of such a system. That is why a Wizard-of-Oz experiment was conducted where the functionality of the information system was partly taken over by a human-controlled software environment. Trials with ten subjects in a driving simulator offered detailed insights into natural language dialogs on tasks dealing with navigation, car status, tourist information, and hotel reservations. The subjects' ratings of the system were very high and the speech-controlled approach was considered as extremely easy-to-use. In the simulator experiment the lane-keeping performance was not significantly affected by the verbal dialogs. But some subjects did react to the additional mental workload by reducing their speed even in the absence of traffic-related reasons. Finally, the experiment demonstrates how to apply the Wizard-of-Oz methodology in a driving simulator environment in an effective way.

1. INTRODUCTION

Speech recognition technology in the context of car applications has been increasingly studied in recent years. It provides an alternative and extension to traditional manual interfaces, and allows the driver to keep his or her hands on the steering wheel and eyes on the road. A detailed overview of the theme with a specific focus on human factors is given in (1). However, existing driver information systems (DIS) controlled by speech input have been restricted to devices that can be accomplished by low to medium vocabulary recognition systems with more or less rigid dialog structures. This results mainly from current limitations of speech recognition and language interpretation systems. From the usability point of view, for a DIS to be effective, its speech interface must approach natural language communication, (2) – (4).

1.1 The VICO Project

New information intensive applications and services in the automotive environment require complex human-machine interaction which depends on a negotiable dialog between the driver and the service application. This task is addressed by the project Virtual Intelligent Co-Driver (VICO). The project is funded in part by the European Commission and brings together an international consortium consisting of the Robert Bosch GmbH, the DaimlerChrysler AG, the Istituto Trentino di Cultura, the University of Southern Denmark, and the Phonetic Topographics N.V. The overall objective of VICO is the creation of a conversational speech interface allowing natural, user-friendly, safe and comfortable communication with a virtual co-driver under adverse conditions in an automotive environment. See the project's web page (5) for additional information.

1.2 The Wizard-of-Oz Method

Information about the structure of natural language dialogs as well as subjective ratings by the user are extremely helpful to building the VICO project prototype. But this prototype does not yet exist. A well-known method to make experimental studies in such a situation is called the Wizard-of-Oz (WOZ) methodology, whereby a human operator, the wizard, performs some of the tasks of the system in a fashion transparent and so invisible to the subjects. The method was mainly applied in designing computer interfaces and speech recognition environments; see (6) for a general description. Applications of this method in the automotive environment were conducted, for example, at the University of Michigan for on-road experiments; see (7). The use of the WOZ method in driving simulator experiments is unknown to the authors.

1.3 Objectives

The main objectives of this study are to acquire information on typical dialogs end-users engage in when dealing with a natural language-controlled DIS, and to get additional subjective ratings from these users. Secondary objectives consist in studying the effects of distraction caused by the verbal dialogs on driving behavior and in learning about the planning and realization of a WOZ experiment in a driving simulator.

2. EXPERIMENT EQUIPMENT

2.1 Driving Simulator

To run the experiments a fixed-based driving simulator has been used. The hardware and software are based on the commercial simulator STISIM 500W, provided by Systems Technology Inc., (8). It consists of a local network of 4 PCs. Pedals and steering wheel are integrated in a mock-up of a vehicle's front half. The instrumentation, originating from a Fiat Coupe, is attached to the simulator as well. The driving scenery is projected onto three front screens of 180x135 cm each, providing a total field of view of 135°. Rearview mirrors are integrated in the front image scenery. Figure 1 gives an impression of the complete set-up. The simulator equipment has already been used successfully at Bosch for research studies on driver monitoring, (9), and for new DIS usability tests.

FIGURE 1 View of the Bosch driving simulator.

2.2 Working Environment for the Wizard

The VICO projects aims at the realization of a voice-controlled DIS prototype. This prototype not yet being available, the main challenge of the experimental set-up consisted in the development of the environment to be used by the wizard. On the one hand this environment had to resemble a true technical system to the subjects, while on the other hand it had to allow the wizard to perform all aspects which could not yet be achieved by actual technical components. The following parts were provided:

- The video image of the driver and the scenery were transmitted to a neighboring room including an acoustic channel to grasp the driver's utterances.
- A software interface was realized using e-SIM's development tool RAPID, (10), and ran on a laptop on the wizard's desk, also in a neighboring room. The interface used task-specific predefined answers which could be chosen by the wizard depending on the situation by a simple click on the text. This click executed an automatic speech synthesis of the text using Elan's TTS (text-to-speech) software Speak&Win, (11). Some of the answers contained variables, so that the wizard only had to type in the variables (Ex.: "I will reserve a room for %x nights", where the wizard only had to key in a number for %x). In cases where no predefined answer was appropriate the wizard would type in the complete answer himself. This being the most time-consuming option, to avoid undesirable waiting times for the user, the wizard could preempt his actual response with the utterance of "one moment, please." The speech synthesis itself could be varied in speed or stopped immediately allowing barge-in by the driver. Figure 2 gives an impression of the display on the wizard's laptop. (In the following the term VICO system denotes this experimental set-up if not stated otherwise.)
- The synthesized speech is transmitted to the simulator room and brought to the driver by means of cockpit-mounted speakers.

In the terminology of the VICO project the components of speech recognition, natural language understanding and dialog modeling are all done by the wizard. Only the final component of speech synthesis is of a true synthetic nature.

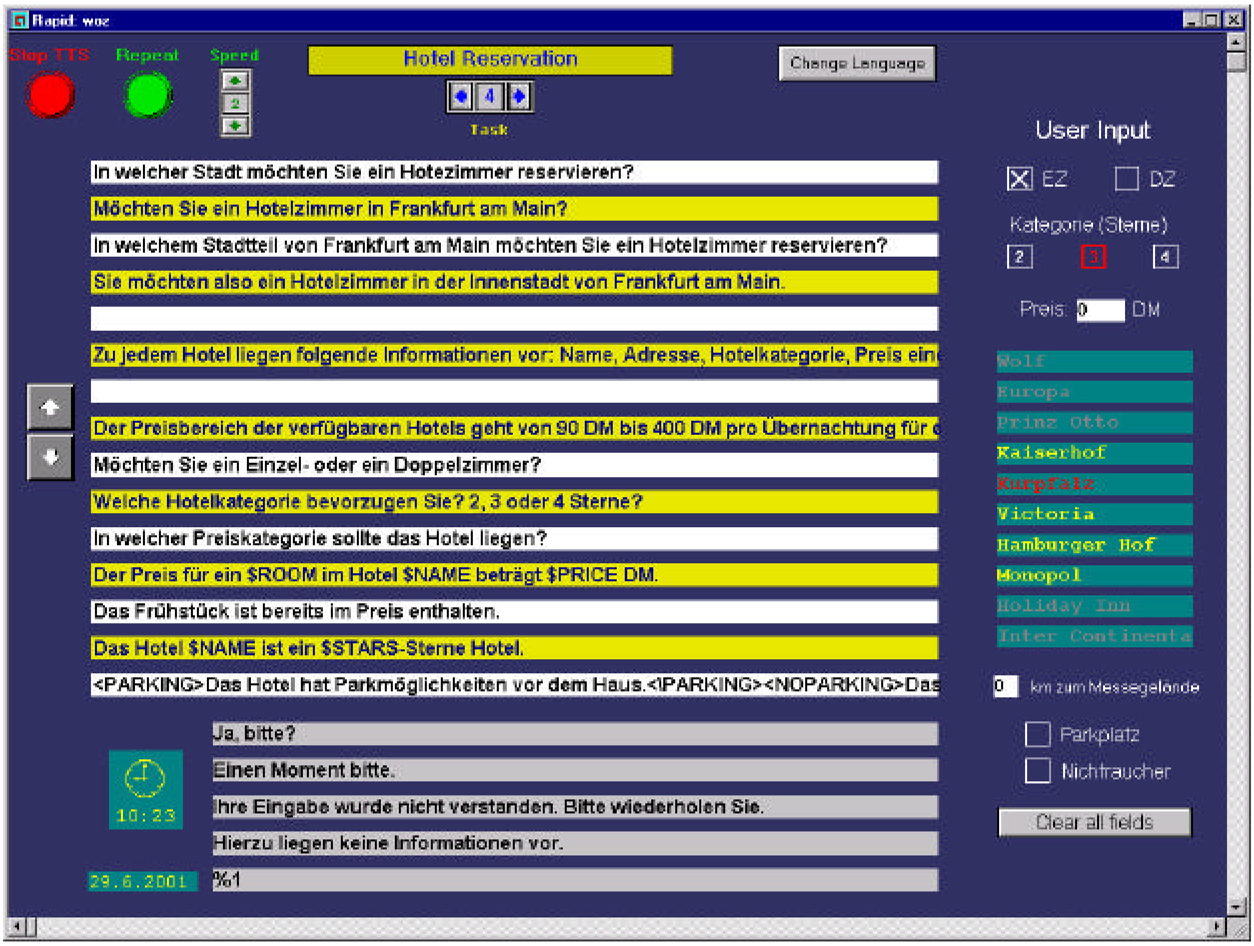

FIGURE 2 Software interface on the wizard's laptop to choose the appropriate answer.

Proceedings of the 1st Human-Centered Transportation Simulation Conference, The University of Iowa, Iowa City, Iowa, November 4-7, 2001 (ISSN 1538-3288).

2.3 The Driver's Side of the VICO System (Keyword vs. Push-to-talk)

For the subjects driving in the simulator the VICO prototype appears as a technical system where input and output is voice-only. This was decided after some pre-tests comparing the activation of the system by means of the spoken keyword "VICO" or by pressing a specific button on the steering wheel, the so-called Push-to-talk button. Users had no problems using the keyword whereas the simple button-press caused more difficulty by its addition of visual and manual cues.

2.4 Measurements

The main recordings of the experiments were performed using a 4-channel video splitter. Two camera views of the driver were combined with the center 45° image of the scenery and a screen showing the current driving data. One example image of such a video is given in Figure 3. (The driving data screen in the lower right denotes t for the total driving time [min:sec], D for the distance driven [km], V for the driver's speed [km/h], L for the lateral distance of the vehicle's center of gravity with respect to the center line of the road [m, positive to the right], T for the throttle position [%], B for the brake pedal force [N], S for the steering wheel angle [°], and G for the gear number.) The video records the sound in the simulator room as well, including the utterances of the driver and the replies coming from the speakers activated by the wizard.

In addition to the video recordings, all relevant driving data are sampled every 100 ms to a text file by the simulator software.

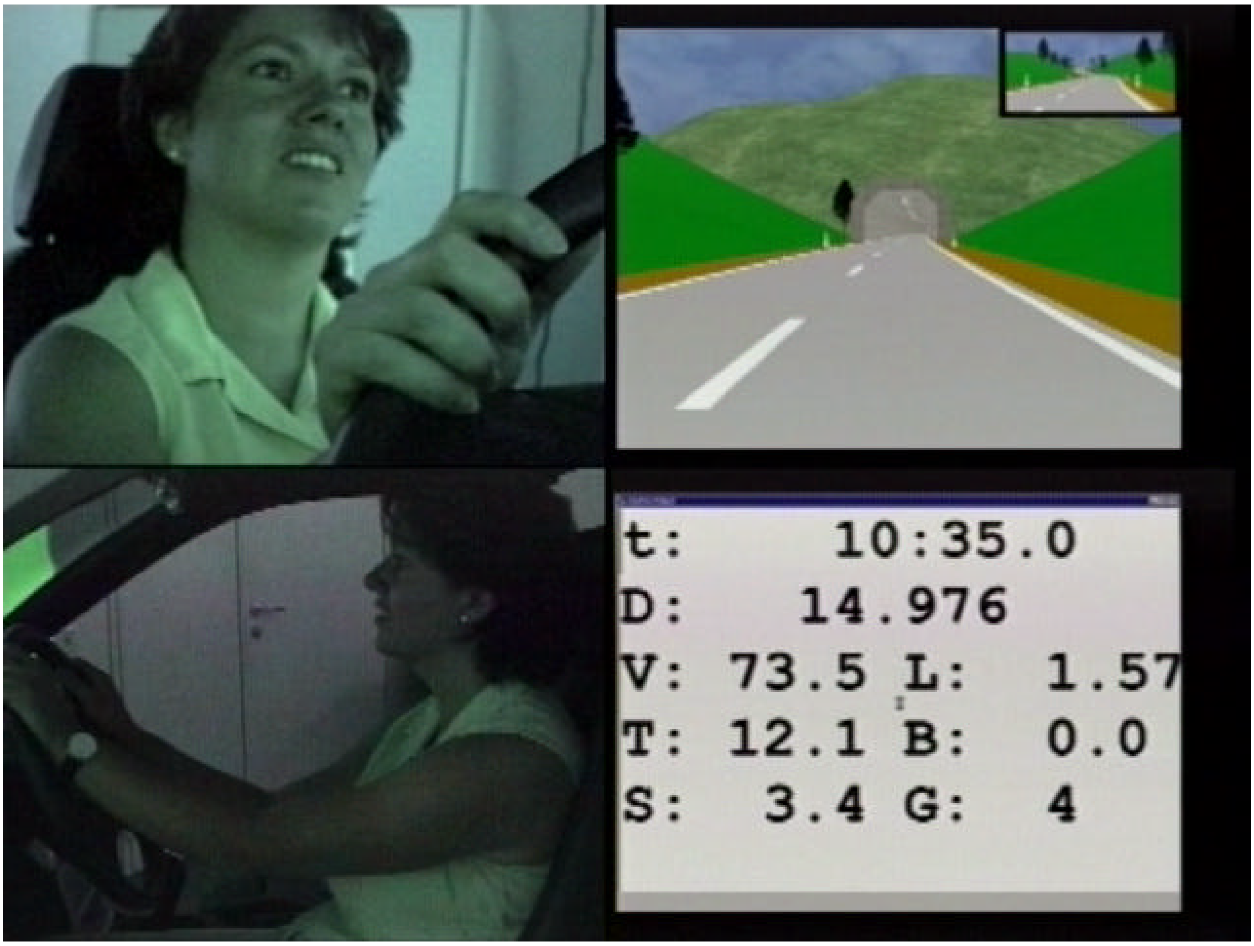

FIGURE 3 Typical video image recorded during experiment.

Proceedings of the 1st Human-Centered Transportation Simulation Conference, The University of Iowa, Iowa City, Iowa, November 4-7, 2001 (ISSN 1538-3288).

3. EXPERIMENTS

3.1 Cohort Selection

A cohort of 10 subjects was selected to participate at the experiment. These subjects were recruited internally from different research and adminstrative departments at Bosch. Special care was taken to achieve a certain mixture over age and gender being aware of the fact that 10 subjects cannot be representative of a proper population distribution. Actually, 5 female and 5 male subjects participated at the experiment. The age varied in a range from 24 to 60 years.

3.2 Task Description

Seven tasks have been defined to be performed by the subjects during the experiment. Their focus concentrates around the application areas intended by the VICO project, i.e. navigation, car status and manual information, tourist information, hotel reservations. Most of the tasks were presented to the driver by a verbal instruction coming from speakers behind the car while driving and the speakers used for the VICO output. We call this “started by operator”. Two specific tasks were initialized by the VICO prototype itself as they give information to the driver which can be present in a true DIS. See Table 1 for a complete list of the defined tasks.

TABLE 1 Tasks Defined in the VICO Experiment

Task Name [Abbreviation]	Task Introduction (translated from German)	started by	Comment
Current Time [Time]	“Ask the VICO system about the current time.”	operator	simple warm-up task for the subjects
Navigation [Nav]	“You are in the Gerlingen area. Use the navigation component of the VICO system to be directed to the trade fair in Frankfurt.”	operator	with the specific problem of two towns named Frankfurt in Germany
Tourism [Tour]	“On your way there is some time left. Ask VICO about tourist attractions in Heidelberg.”	operator	
Fuel [Fuel]	“Given the current driving conditions you will run out of fuel in 50 km.”	VICO	information from VICO; one repeat if no reaction
Car Manual [Man]	“Ask the VICO system about the current range without re-fueling and the consumption.”	operator	
Hotel Reservation [Hotel]	“You are approaching Frankfurt and decide to stay over night. Use VICO to make a hotel reservation in the center of Frankfurt according to your preferences.”	operator	
Traffic Information [Traf]	“The traffic flow on your route is distorted due to an accident. Should an alternative route be considered?”	VICO	direct question from VICO to the driver

3.3 Scenario Generation

The driving scenario was defined using the simulator’s scenario description language SDL, (12). The total length of the scenario was 53.4 km. It consisted of a mixture of rural highways, passing through two towns and a freeway section. This mixture was created mainly to give the subjects different impressions while driving and to keep the surrounding attractive by some variation. Otherwise, the subject may start “playing” with the VICO system, thereby making the wizard’s task very different.

All seven tasks described above were inserted into the scenario in a way that they always appear exactly at the same location. This was achieved by playing a pre-recorded wav file for the operator-initiated tasks which can simply be integrated into the scenario description. The two VICO-initiated tasks were started manually by the wizard when the specific location was reached.

Proceedings of the 1st Human-Centered Transportation Simulation Conference, The University of Iowa, Iowa City, Iowa, November 4-7, 2001 (ISSN 1538-3288).

FIGURE 4 Scenario segments of rural highway, town passing and freeway section.

3.4 Experiment Protocol

The trials were conducted during a one-week period in May 2001. The complete procedure lasted about one hour per subject. The starting point was a 10 minute test drive to get familiar with the operation of the simulator. During the trial run, the capabilities of the "VICO prototype" were briefly described and demonstrated by way of an example by the supervisor (a predefined dialog on cinema information and seat reservations). The third part of the procedure was the main scenario itself including the seven tasks which lasted about 30-35 minutes, depending on the driver's actual speed. After the trial a short interview was performed by the supervisor to ask for specific impressions, which was in turn followed by a questionnaire. Finally, the true nature of the prototype was explained to the subjects. This was done for three reasons: first, to ask the subject about his thoughts during the drive; second, to convey the importance that he or she not tell his or her coworkers about the nature of the experiment — to avoid giving prior knowledge to other subjects; last, so that subjects are not left with unrealistic conceptions of current speech-controlled applications.

It should be noted that the supervisor left the room during the driving sessions to avoid any distraction effects his presence could cause.

4. RESULTS

4.1 Dialog Evaluation

To evaluate the dialogs all utterances from the user and the subject were transcribed using the video recordings of the experiment. Of mention is that even though the given tasks were highly complex, particularly as regards their completion while driving, only a single task failed to be executed, and that by a single subject. Moreover, the reason for the failure was that the subject did not initiate the Current Time dialog with the key word "Vico". Consequently, he received no response from the system. All other tasks came to a successful end point.

The length of the dialogs showed relatively low variance. When variance does appear in the duration of tasks, it stemmed mainly from a few subjects having clearly longer durations than the majority of the subjects. One example is the Tourism dialog where the duration of the task for subjects No. 2 and 5 was more than 60 seconds longer than for the other eight. Table 2 gives an overview of all the durations for the 10 subjects.

TABLE 2 Dialog Durations

Duration [s]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Mean**	**StdDev**
Current Time	18	16	15	17	16	15	12	12	13	13	14,7	1,6
Navigation	75	80	63	71	68	74	61	98	78	64	73,2	7,8
Tourism	147	210	131	105	214	103	111	144	128	128	145,6	30,8
Fuel	115	99	142	64	64	54	71	59	67	59	78,3	22,0
Car Manual	50	69	58	55	64	67	57	57	58	50	57,2	5,5
Hotel Reservation	197	187	242	130	174	160	154	158	239	179	180,2	26,2
Traffic Information	62	51	66	46	51	47	37	47	68	55	53,2	7,3
Sum	**664**	**712**	**717**	**488**	**651**	**520**	**503**	**575**	**651**	**548**	**602,9**	**76,1**

Proceedings of the 1st Human-Centered Transportation Simulation Conference, The University of Iowa, Iowa City, Iowa, November 4-7, 2001 (ISSN 1538-3288).

The dialog structure of an individual task showed much less variation than expected, too. In most applications the subjects accepted some kind of guidance by the system. Consequently, variance appeared mainly at specific decision points. As one example, Table 3 shows all the answers given by the VICO prototype for the Navigation dialog. This dialog turned out to be very straightforward. Once the destination is cleared, the route guidance can be initiated. Nonetheless, some variance did appear as two subjects (No. 4 and 8) chose an unforeseen destination. Note that only 9 of the predefined 17 answers were actually used by the wizard. For example, no subject ever asked for the length of the route or the typical driving time. Interestingly, not a single user employed the word "navigation" to initiate the dialog, even though that word was explicitly given in the task description. Rather, a phrase like "I want to go to Frankfurt" was most popular.

TABLE 3 Answers from the VICO System for the Navigation Dialog (translated from German)

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Sum**
Predefined Answers for the Navigation Task											
What is your driving destination?								✓			1
There are two towns named Frankfurt in Germany: Frankfurt / Main and Frankfurt / Oder. Which Frankfurt do you mean?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
Do you want to drive to Frankfurt / Main or to Frankfurt / Oder?								✓			1
Frankfurt / Main, right?	✓										1
You want to drive to Frankfurt / Main. Which location?	✓	✓	✓	✓	✓	✓	✓		✓	✓	9
You want to the trade fair area in Frankfurt / Main?	✓	✓	✓		✓	✓	✓		✓	✓	8
So you want to drive to %1 [variable for destination].				✓				✓			2
One moment, the route will be computed.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
Please follow the main road.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
Standard Answers for all Dialogs											
Yes, please?	✓	✓	✓		✓	✓	✓	✓	✓	✓	9
One moment please.											0
Your input was not understood. Please repeat.											0
There is no information available.											0
%1 [variable for free text]											0

The exact evaluation of the other dialogs is beyond the scope of this paper. But some general remarks on the dialogs should be given:

- Subjects dealt with the system in a very polite way. Moreover, subjects did not really try to stop overly lengthy explanations from the system.
- In all tasks a simple limited set of predefined answers was sufficient to manage the situation. Throughout the whole experiment — that is, considering all trials — the "free text" option was used only six times.
- The subjects behaved in a disciplined fashion. They did not try to test the VICO system by asking about the existence of God, say. But some of them initiated additional tasks by themselves. In general, these tasks were relatively simple, e.g. "What's my current speed?", and the wizard's environment was comfortable enough to manage these situations.
- Some dialogs were resumed by the user after an already successful end. One example was to check whether there were other gas stations than the one already chosen.

- As part of the experiment, at a specific point during the drive the system responded to a user inquiry by saying that it failed to understand the input. The users were not in the least confused by this and simply repeated their command using a slightly changed wording.

4.2 Driving Behavior

It was not the main objective of the experiment to study the effects of distraction on driving behavior that complex verbal tasks may have. Notwithstanding, some evaluation of driving performance was done by analyzing the files recorded from the simulator.

For that purpose two kinds of driving errors were defined:

- a lane-keeping error is defined as the vehicle's center of gravity coming within less than 50 cm of the edge of the lane. Lane-keeping errors are denoted either by L or R for errors to the left or to the right, respectively.

- a speed error is considered when the difference of the vehicle's speed to the actual speed limit is more than 25% of the speed limit. Speed errors are denoted by S+ if the speed limit is exceeded and S- if the vehicle's speed is too low. (Of mention is that a speed error is not considered immediately following a change in the prescribed speed limit.)

Figure 5 gives an example of the driving data for one subject. The duration of the tasks is indicated by bars in the center and an abbreviation of the task name. The letter "U" stands for an additional user-defined task. The speed curve is shown in the upper area together with a thin line representing the speed limit. Two circles indicate speed errors S- as defined above. (Note that the two stops in the urban area around km 10 are traffic related. Hence, they are not counted as speed errors.) The current lane position is given in the lower area and the outer lines represent the edge of the lanes in driving direction whereas the inner lines are placed 50 cm inside and represent the marks for lane keeping errors. The subject did not make any lane errors. (The four peaks in the freeway section between km 33 and km 53 were the result of passing maneuvers on slow-moving vehicles.)

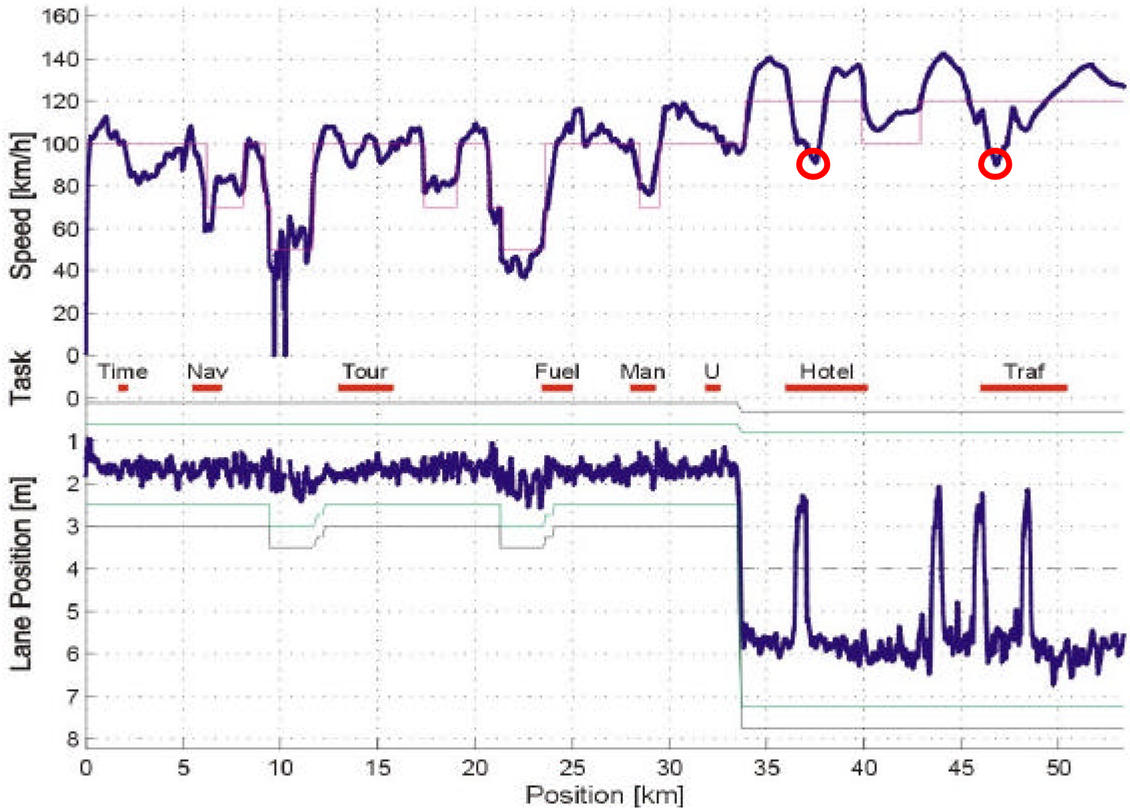

FIGURE 5 Driving data for subject No. 4.

Overall, not one accident occurred during the trials. Table 4 shows the number of driving errors performed by each individual subject. Considering that the typical interaction time with the VICO system represented about one third of the total driving time (10 minutes out of a 30-minute drive) the lane-keeping error rate shows no change, whether the subjects were interacting with VICO or not — from which we can infer that the lane-keeping task is not affected by talking and listening to the VICO prototype. On the other hand, there is a significant trend that low speed errors S- appear much more frequently while interacting whereas high speed errors appear much more frequently while not interacting with the system. This reflects the different nature of low and high speed errors. Speeding S+ is a normal fact during driving and sometimes drivers do it intentionally. Low speed errors S- are a typical countermeasure when the mental workload gets too high and may occur in the simulator environment mainly because drivers are less attentive to their speedometers while interacting.

TABLE 4 Driving Errors per Subject

Type of Driving Error	1	2	3	4	5	6	7	8	9	10	Sum
Driving with Interaction with VICO											
L Lane-keeping error to the left	-	-	-	-	1	-	2	5	-	4	12
R Lane-keeping error to the right	3	-	-	-	-	-	-	5	-	1	9
S- Speed error with speed more than 25% below limit	3	1	-	2	5	-	1	1	4	4	21
S+ Speed error with speed more than 25% above limit	-	-	2	-	-	-	1	-	-	-	3
Driving without Interaction with VICO											
L Lane-keeping error to the left	-	1	-	-	-	-	1	12	1	8	23
R Lane-keeping error to the right	5	-	-	-	-	-	-	11	-	1	17
S- Speed error with speed more than 25% below limit	1	-	-	-	1	-	-	1	1	-	4
S+ Speed error with speed more than 25% above limit	-	-	-	-	5	-	3	4	-	9	21

A task-related dependence of the driving errors is indicated in Table 5. Due to the different length of the dialogs and, especially, due to the different traffic situations a direct interpretation seems to be difficult. The dialogs with hotel reservation and traffic information tasks appeared in the freeway section where the wider lanes make lane-keeping easier. Furthermore, the different speed limits throughout the experiment change the basis for the calculation of speed errors.

TABLE 4 Driving Errors per Task

Type of Driving Error	Time	Nav	Tour	Fuel	Man	Hotel	Traf	Sum
L Lane-keeping error to the left	-	3	4	2	3	-	-	12
R Lane-keeping error to the right	-	3	2	1	1	2	-	9
S- Speed error with speed more than 25% below limit	-	-	9	-	-	7	5	21
S+ Speed error with speed more than 25% above limit	-	-	-	1	-	2	-	3

4.3 Subjective ratings about the VICO System

Subjects' initial statements after the trial were that they were generally very happy about the VICO system's easy-to-use interface. The main problems they reported dealt with some limited capabilities of the simulator itself, e.g. while turning. From the final questionnaire the following main results could be extracted:

Communication with VICO

On a scale from "1 = simple" to "5 = difficult", the general communication with VICO was rated with a mean value of 1.1, which can hardly be improved upon.

Specific Problems with the Interaction

The main problem identified was the difficulty some users had understanding statements made by VICO. Two of the subjects explained that their problems had to do with the quality of the speech synthesis, two others with some verbose informations, which made understanding so much more difficult. One subject mentioned that the system spoke too quickly, (even though he had already asked for a slower repeat during the trial — the only incidence of such a request throughout the whole experiment.).

Distraction Effects

On a scale from “1 = strongly distracted” to “5 = not distracted”, subjects judged their own distraction levels from driving while interacting with VICO with a mean value of 3.8. Specific distraction effects were mentioned while overtaking on the freeway and one subject realized he had been driving too slowly while listening to VICO’s directives, in the absence of a traffic related reason.

Final Rating of a Virtual Co-Driver

On a scale from “1 = pleasant” to “5 = unpleasant” the presence of a virtual co-driver was rated with a mean value of 1.3. The system’s good voice recognition, the large amount of available information it offered, and its very user-friendly, buttonless interface were all cited.

4.4 Unmasking the Wizard

At the end of the questionnaire subjects were informed of the true nature of the prototype they used. The final question was “What was your impression during the experiment?” On a scale from “1 = I believed VICO to be a technical system” to “5 = I was convinced that VICO was simulated by a human,” subjects answered with a mean value of 1.5. This value results from eight ratings with 1, one rating with 2, and one rating with 5. Most of the subjects explicitly stated their complete surprise in finding out about the Wizard’s role in the experiment.

5. CONCLUSIONS

The variety of the answers needed to manage the situation throughout the experiment was very low. During the dialog users can be guided to react in a specific way. The main challenge for managing the dialog in the real VICO prototype is not so much the internal structure of a specific dialog but the system’s capability to discern the context in which the user is making his or her statements, as well as the system’s being able to react to spontaneous changes the user might make during the dialog. Knowledge about the current context is very important for the interpretation of these changes.

The subjects’ ratings were extremely positive. The main benefits of the VICO system were considered to be its high level of functionality, its ease of use, and that it was seen to distract very little while driving. This demonstrates a high demand for a VICO-like system once it is technically feasible.

The high level of surprise test subjects showed when they were informed about the real nature of the prototype indicates that the WOZ methodology was effective in the driving simulator environment. This is no doubt due to the sufficiency and ease-of-use of the wizard’s prepared software interface. (In light of this statement, we are completely aware of the theoretical possibility that our subjects only expressed their surprise in order to satisfy their experimenters’ expectations, however we trust the sincerity of our subjects’ comments.)

Subsequent research will be defined according to the needs of the VICO project and may cover a basic evaluation of a more detailed dialog concept before programming of the real prototype begins. This comprises studying the user’s reaction on misunderstandings and completely false answers given by the system. Another important question is on additional performance measures beside the driving behavior utilized in the present experiment. Secondary tasks on object or event detection would allow studying effects on the driver’s attention. The final VICO prototype may be used to perform a detailed comparison between voice-only concepts and traditional systems using buttons and displays.

ACKNOWLEDGMENT

This work has been supported in part by the European Commission in the framework of the VICO project, which is part of the Human Language Technologies action in the Information Society Technologies programme. The authors gratefully acknowledge contributions of Peter Bock, Professor of Machine Intelligence and Cognition (Department of Computer Science at the George Washington University, Wash. DC) to the experiment design. We also thank Jacomo Corbo, student of Electrical Engineering at McGill University, Montreal, for carefully correcting an earlier version of the manuscript. Additional thanks to the anonymous reviewer for several helpful comments.

REFERENCES

1. A.W. Gellatly, "The Use of Speech Recognition Technology in Automotive Applications". Dissertation, Virginia Polytechnic Institute and State University, 1997.

2. J.L. Campbell, C. Carney, and B.H. Kantowitz, "Human Factors Design Guidelines for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO)". Federal Highway Administration Report No. FHWA-RD-98-057, 1998.

3. C. Little, "The Intelligent Vehicle Initiative: Advancing Human-Centered Smart Vehicles". Turner-Fairbank Highway Research Center, 1997. http://www.tfhrc.gov/pubrds/pr97-10/p18.htm. Accessed July 19, 2001.

4. D. Benson, and P. Gomes, "Speech Recognition is Key to Market Success for In-vehicle Information Systems". SRI Consulting, 1998. http://future.sr.com/ITS/ITS-SpeechPR0499.sthml. Accessed July 19, 2001.

5. P. Geutner, "VICO (Virtual Intelligent Co-Driver)". http://www.vico-project.org/. Accessed July 19, 2001.

6. N. Dahlbäck, A. Jönsson, and L. Ahrenberg, "Wizard of Oz Studies – Why and How". Knowledge-Based Systems, Vol. 6, No. 4, pp. 258-266, December 1993.

7. A. Smiley, "Overview and Methodologies of the ITS Safety Evaluation Process". ITS America and NHTSA, Proc. Workshop on Safety Evaluation of Intelligent Transport Systems, pp. 5-20, Reston, Virginia, May 1995.

8. R.W. Allen, T.J. Rosenthal, B.L. Aponso, D.H. Klyde, F.G. Anderson, and J.P. Chrstos, "A Low Cost PC Based Driving Simulator for Prototyping and Hardware-in-the-Loop Applications". SAE Paper No. 98-0222, 1998.

9. M. Rimini-Döring, D. Manstetten, T. Altmüller, U. Ladstätter, and M. Mahler, "Monitoring Driver Drowsiness and Stress in a Driving Simulator". Proc. Intern. Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, Aspen (Col.), August 14-17, 2001.

10. e-SIM Ltd., "E-SIM – The Virtual Product Company". http://www.e-sim.com/non_flash/navigator/index.html. Accessed July 19, 2001.

11. Elan Informatique, "Elan text to speech technology". http://www.elantts.com/speech/index.htm Accessed July 19, 2001.

12. R.W. Allen, T.J. Rosenthal, B.L. Aponso, Z. Parseghian, M. Cook, and S. Markham, "A scenario definition language for developing driving simulator courses". Proc. Driving Simulation Conference 2001, pp. 369-378, Sophia Antipolis (Nice), France, September 2001.