In-Vehicle Interface Assessment Framwork for Emerging Technologies

A case study for evaluating new driver-vehicle interaction design

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***Abstract*—This paper proposes an in-vehicle interface assessment framework for emerging technologies. The framework was validated through a driving simulator based case study with an emerging user interface design. The result suggested that it was useful to evaluate the effectiveness of the emerging technology based user interface designs.**

Keywords-Usability Assessment; Driver-Vehicle Interaction (DVI); User Interface; Emerging Technology.

I. INTRODUCTION

With advancing technology, drivers are more likely to engage in non-driving related tasks. Auto industries are attempting to develop new user interaction designs, such as voice and gesture command to reduce drivers' distraction [1]. However, it is important to determine if new concept of driver-vehicle interaction design is indeed effective.

Recent research suggested a usability evaluation toolkit for In-Vehicle Information Systems (IVISs) [2]. The toolkit comprises definition of usability criteria, selection of evaluation methods, desktop methods, and experimental methods. However, detailed information of the experimental methods was limited.

This paper aims to suggest and validate an in-vehicle interface assessment framework based on experimental methods.

II. IN-VEHICLE INTERFACE ASSESSMENT FRAMEWORK

A proposed assessment framework is illustrated in Figure 1. The framework begins with definition of usability criteria, which definition had to be context specific. Then usability criteria are used to guide the selection of methods which are most appropriate for evaluating usability. In the experimental methods phase, objective and subjective evaluations should be repeated until the usability criteria are met.

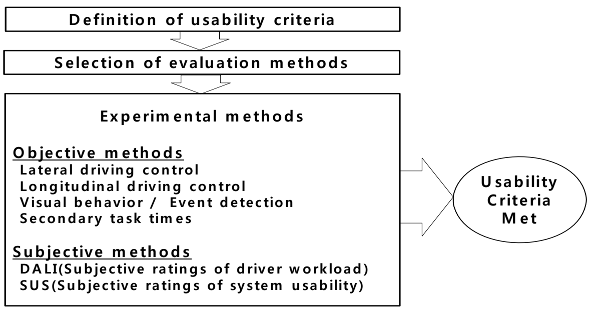

Figure 1. In-vehicle interface assessment framework.

III. CASE STUDY

A. Study Overview

A quantitative assessment framework was developed to understand the effectiveness of an emerging user interaction device on distraction. A comparative analysis between new user interface (NUI) and touch screen (TS) was conducted.

B. Definition of Usability Criteria

The usability criteria of new in-vehicle interface was defined by identifying input/output modalities and the context of use as shown in Table I and Table II.

C. Selection of Evaluation Methods

Objective and subjective methods were selected to evaluate actual performance levels and users' opinions as shown in Table III. Two subjective methods, i.e., the System Usability Scale (SUS) [3] and the Driving Activity Load Index (DALI) [4], were selected. The driving performance (primary task), secondary task and eye behavior were selected as the objective measures.

D. Experimental Setup

The simulator experiment was conducted in a fixed-based driving simulator. A gaze tracker was mounted on a dash board to collect eye behavior data. A touch pad for new input method were placed beside a gear lever.

TABLE I. INPUT AND OUTPUT DEFINITION

System	Input	Output
New User Interface	Touch Pad	Visual & Auditory
Conventional Interface	Touch Screen	Visual & Auditory

TABLE II. CONTEXT OF USE AND USABILITY CRITERIA

Factors	Criteria	Experiment Design
Dual Task Environment	Effectiveness, Efficiency, Interference	Secondary Tasks: AUI & Touch Screen
Environmental Condition	Effectiveness under varying driving conditions	Simulated Road Env.: Highway & Rural
Training Provision	Learnability	Training & Practice

TABLE III. SUBJECTIVE AND OBJECTIVE MEASURES

Domains	Measures	Method	Tool
Subjective Evaluation	Usability	Survey	SUS
	Workload	Survey	DALI
Driving Performance	Velocity	Simulated driving	Driving Simulator
	Steering Reversal Rate		
	Standard deviation of Lane Position		
	Lateral Acceleration		
	Lane crossing		
Eye Behavior	Single Glance Time	Eye tracker	FaceLAB 4.6
	Total Glance Time		
	Percent glance durations≥ 1.6s		
	Number of Glance		

TABLE IV. SUBJECTIVE AND OBJECTIVE MEASURES

Questions	Driving & Survey		Only Survey	
	NUI	*Touch Screen*	*NUI*	*Touch Screen*
Global attention demand*	2.62	3.69	2.58	3.25
Visual demand**	2.46	3.85	2.42	3.25
Auditory demand	2.54	2.69	1.58	1.83
Stress**	2.23	3.15	2.17	3.25
Temporal demand**	2.15	3.54	1.75	2.92
interference**	2.31	3.69	2.08	3.25

Note: Device type (* $p < .05$ ** $p < .01$)

E. *Experimental Procedure*

Twenty four participants, consisted of 12 driving group (Driving & Survey) and 12 non-driving group (Survey only), were recruited. Following informed consent and completion of a questionnaire, participants received 10 minutes of adaptation time in the simulator. Then, participants were trained in the NUI and TS operation. When the simulation was resumed, participants drove on a highway for about 20 minutes twice to perform either the NUI or the TS task. The tasks consisted of destination entry, MP3 play, emergency mode, and mute function.

F. *Results*

As shown in Figure 2, overall SUS results showed that the NUI score (65.7) was 6.7 percent higher than the TS score (61.1). Especially, the driving and survey group have rated significantly higher than the survey only group ($p=0.023$). Among the six items in DALI, five items of the NUI, including global attention demand, visual demand, stress, temporal demand, and interference, showed significantly lower workload than the touch screen (see Table IV).

For the objective methods, eye movement and driving performance changes are summarized in Table V. In general, the NUI showed higher performance and safer behavior than the touch screen.

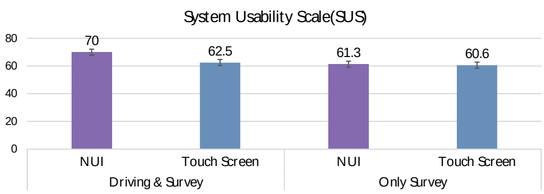

Figure 2. Result of System Usability Scale (SUS)

IV. CONCLUSION

This study proposed an in-vehicle interface assessment framework for emerging technologies which have not been used in automotive user interaction design. The results of the case study have shown that the proposed framework have suitable levels of validity. It was also demonstrated that the experimental methods using a driving simulator were useful to evaluate the effectiveness of the emerging technology based user interface designs which are hard to imagine their use cases in a driving context.

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TABLE V. DRIVING PERFORMANCE AND EYE BEHAVIOR MEASURES

		New UI				Touch Screen			
		Destination entry	*MP3 play*	*Emergency mode*	*Mute function*	*Destination entry*	*MP3 play*	*Emergency mode*	*Mute function*
Driving Performance	Velocity	90.85	91.75	90.25	95.78	93.94	88.77	90.98	89.96
	SRR	7.30	6.32	6.02	3.36	8.36	10.44	6.17	7.63
	SDLP	0.29	0.29	0.27	0.18	0.37	0.39	0.19	0.39
	Lateral Acceleration	2.36	2.43	2.56	2.46	2.54	2.69	2.52	2.41
	Lane crossing	0.31	0.00	0.00	0.28	0.65	0.70	0.00	0.56
Eye Behavior	Single Glance Time	1.24	0.91	0.58	0.35	1.29	1.13	0.69	1.16
	Total Glance Time	10.02	7.83	1.22	0.56	9.79	10.2	1.56	1.84
	Percent glance durations ≥1.6s	1.69	0.85	0.15	0.00	1.46	1.92	0.15	0.39
	Number of Glance	8.23	8.54	1.00	0.85	8.15	9.39	2.15	1.62