The Relative Effects of Visual and Visual-auditory Feedback on Eco-driving and Driving Workload

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1. Introduction

Most prior studies on eco-IVISs (in-vehicle information system) provided drivers with visual feedback on their driving performance (Birrell and Young, 2011). One advantage of visual feedback is that it can provide the same amount of information much faster than auditory feedback. For example, whereas auditory information must be provided in a particular sequence, visual feedback can provide several pieces of information on a screen at one time. However, considering that drivers largely rely on vision for driving-related information, more visual information from an eco-IVIS can lead to attentional overload (Liu, 2001).

According to multiple resource theory (Wicken, 2002), to the extent that two or more tasks involve the same modality, a person's workload will increase resulting from demand for common perceptual resources. However, if information is given across multiple modalities, the demand for perceptual resources will be distributed in a way that minimizes the increasing workload. The meta-analysis by Burke et al. (2006) supported this assertion by showing that multimodal feedback (e.g., visual-auditory feedback) was more effective than single-modal feedback (e.g., visual feedback only) in terms of both performance and workload.

However, most prior studies on eco-driving have merely focused on improving the participants' driving performance, paying little attention to the different types of feedback that can enhance performance without significantly increasing workload. Therefore, the present study examines the relative effects of two in-vehicle feedback types, visual and visual-auditory, on eco-driving and workload. Furthermore, considering the recent increase in use of HMI (e.g., navigation, entertainment system, safety guidance) systems in vehicles (Rouzikhah et al., 2013), the study also attempted to investigate the effects of using an in-vehicle HMI system in addition to the eco-IVIS. Thus, the effects of the eco-IVIS only (secondary task condition) and both the eco-IVIS and a navigation system (tertiary task condition) on eco-driving performance and mental workload were compared.

2. Method

Participants and settings

Thirty-eight adults participated in the study. Their mean age was 27, and the average number of months of driving experience was 69. During the study, the participants drove on the roads and highways of the capital city of South Korea, for a total of 20.7km and an average driving time of 32 minutes.

Dependent variables and measurement

The dependent variables included objective eco-driving behaviors and subjective ratings of workload. Following table showed the definition of dependent variables and their measurement method.

[Table 1] Definition of dependent variables.

Variable	Definition	Measurementtool
# of excessive RPM	The event which the engine exceeded 3000 RPM	EW200BT
Fuel efficiency	The average kilometers driven per one liter of gas	EW200BT
% of speeding time	% of exceeding the posted speed limit of any road	Observation
Driving workload	Driver's subjective workload	Driving Load Index (DALI)

Independent variables and Procedures.

There were two independent variables in the current study: the type of in-vehicle feedback and the task condition. For the type of feedback, visual feedback and visual-auditory feedback were compared specifically; the sole difference was whether feedback information on driving performance was given only visually, or both visually and aurally. In addition, the study attempted to compare the relative effects of the two driving task conditions, secondary task and tertiary task conditions, on the driving workload. In the secondary task condition, the car was equipped with the eco-IVIS only, whereas in the tertiary task condition, it was equipped with both the navigation system and an eco-

IVIS. Thus, the study adopted an ABC mixed design with a within-group factor (feedback type) and a between-groups factor (task condition).

3. Results

Following table indicated means and standard deviations for each measured variable.As indicated in the table 1, Visual-auditory feedback was more effective in improving the fuel efficiency and decreasing the decreasing the number of excessive RPM episodes. However, for the percentage of speeding time, the effects of two feedback types were comparable. Despite the inconsistent results across the behaviors, however, considering the fuel efficiency is influenced by all driving related behaviors, and there were no significant differences between two feedback types on driving workload, we still suggest visual-auditory feedback is more effective way to improve eco-driving. Thus the results of this study strongly suggest that providing visual-auditory feedback compared to visual only feedback utilizing eco-IVIS is more effective way in terms of both promoting eco-friendly driving behaviors and maintaining driving workload.

[Table 2] Means and standard deviations on each observed variable.

	Variable	Baseline	Visual	Visual-Auditory
Secondary Task	Fuel efficiency (km/l)	6.88 (0.54)	7.84 (0.40)	8.16 (0.38)
	% of speeding time	5.49 (3.88)	1.44 (1.27)	1.77 (1.64)
	# of excessive RPM episodes	23.05 (15.19)	4.74 (2.84)	2.74 (3.40)
	Driving workload	45.02 (18.64)	63.48 (11.20)	65.52 (14.63)
Tertiary Task	Fuel efficiency (km/l)	6.70 (0.46)	7.96 (0.5)	8.32 (0.4)
	% of speeding time	6.87 (4.33)	1.17 (1.15)	3.68 (7.54)
	# of excessive RPM episodes	22.37 (12.23)	4.11 (3.5)	2.21 (1.62)
	Driving workload	55.86 (13.36)	63.97 (11.34)	65.98 (13.80)

4. References

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