Age and gender difference in driving style and fuel efficiency on highway driving

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Abstract

This study aims to comparatively analyze the effects of drivers' characteristics such as age, gender, and driving style on fuel efficiency. In order to compare age and gender differences in driving style, fuel efficiency and effectiveness of eco-driving education, 52 drivers were participated in field operational experiments. The driver's age and gender were counterbalanced. The participants were asked to drive approximately 10km on the highway according to their daily driving style, and the fuel efficiency and driving behaviour were collected . As a result, it was found that there was a significant difference in the driving fuel efficiency on the highway depending on the age and gender. The difference in driving styles that reflected the age and gender affected the fuel efficiency on the expressway. The result suggested that the age and gender should be taken into consideration in eco-driving education or assistant system development to maximize the effects by providing customized coaching strategy.

Keywords: Fuel Efficiency, Driving Style, Driving Pattern, Eco-Driving, Age Difference, Gender Difference

Introduction

Improving fuel economy is an essential requirement to meet consumers' demand in age of high oil prices and the strengthened exhaust gas regulation around the world. Thus, attention has been paid to improving energy efficiency in such ways as eco-driving. Large amount of studies on fuel efficiency improvement have been conducted with regard to such facts as vehicle, road environment, driver, and driving behavior [1]. As for vehicles, there have been intensive researches on reducing the car body weight, improving the engine efficiency, etc., and as for road environment, on road design, traffic flow, speed limit control, etc. [2]. Improvement of vehicles and road environment for achieving higher fuel economy, however, involves a tremendous amount of expense and time [3].

In contrast, changes in driving style for improving fuel efficiency can be achieved in a relatively short period of time through appropriate education and promotion programs, and thus this should be addressed prior to other considerations [4]. Berry [5] and Van Mierlo et al. [6] investigated the effect of driving styles and traffic systems on fuel efficiency. There has been no systematic analysis, however, on the effect of drivers' characteristics such as age and gender on fuel efficiency. According to some researches on the area of driving safety, the differences in age and gender significantly impact on driving performance [7, 8], which is expected to lead to different fuel efficiency. Thus, this study conducted field operation tests on the actual highway and analyzed the effect of age and gender on fuel efficiency.

Method

Participants

In order to analyze the effect of driving styles on fuel economy, 52 drivers were recruited as shown in Table 1. The younger drivers' ages were ranged from 25 to 35, and older ones from 55 to 65. The participants have been driving at least twice a week for three years or longer. Their health condition was good enough to participate in the three-hour driving experiment. Those with chronic diseases such as high blood pressure or those who needed mental health treatment were excluded.

Experimental setup

As shown in Fig. 1, an instrumented passenger car (engine displacement: 3,300cc) was used to monitor the fuel efficiency and driving behaviors. The monitoring system was designed to collect driving information (vehicle speed, engine speed, engine load, steering wheel angle, real-time fuel consumption, etc.), GPS, driver's eye movement (gaze position, blinking, etc), physiological data (electrocardiogram, skin conductance

Table 1. Participants overview

	Younger		Late middle age	
Gender	Male	Female	Male	Female
# Subject	13	13	13	13
Age*	27.54 (2.90)	30.46 (3.10)	60.69 (1.89)	57.08 (2.06)

* Note. Means with standard deviations

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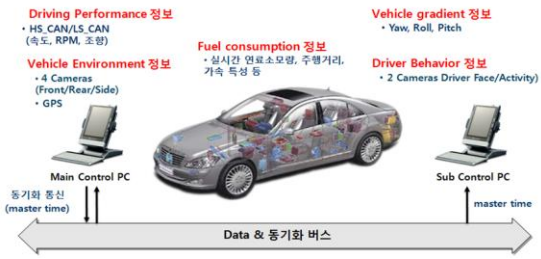

Figure 1. Instrumented vehicle for on-road experiments

level, etc), and videos for driver views (driver's face and pedal manipulation) and surroundings views (front, back, left and right sides) [9]. All data was synchronized at the master time of 100Hz. The vehicle running information including fuel consumption was collected from CAN communication data.

Procedure and road condition

An experimental procedure was designed and conducted as in Fig. 2, to analyze the effect of driving styles and drivers' characteristics on the fuel efficiency. The overall experiment procedures consist of three sessions: pre-driving, main driving experiment, and post-driving. In the pre-experiment step, following informed consent, a safety check, physiological sensor attachment and completion of a pre-experimental questionnaire, participants were asked to get in the vehicle for the gaze tracker setup. After completing the experimental setup, the main driving session was started with 20 minutes adaptation time in the instrumented car. The adaptation driving was conducted on a rural road and an urban road in low traffic density areas. Following the adaptation period, the main experiment was conducted on the highway. For safety reasons, the

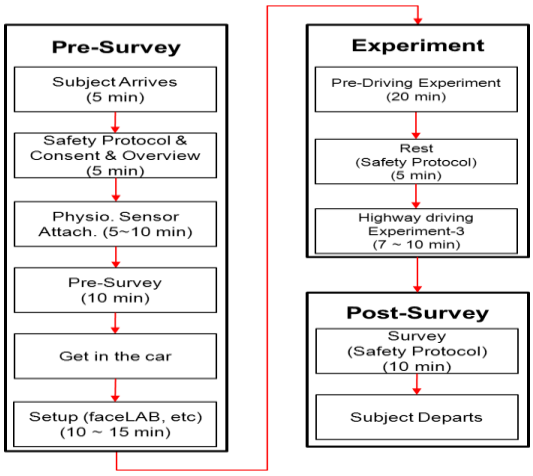

Figure 2. Experimental protocol overview

experiment was conducted only on a dried road surface.

The driving road was a section of 36km highway which consisted of two lanes in each direction and divided by median barriers. The speed limit of the road was 100kph. There are about 8km of up and down hills at around 3% to 5% slope in the experimental section. For participants to drive as if they would do their own styles, the experiments should be conducted under relatively low traffic condition. Thus, the driving experiment was conducted at 11:00 to 11:30 in the morning and 3:30 to 4:00 in the afternoon to avoid the rush hours.

Driver behavior measures

To analyze the effect of driving behaviors on the fuel efficiency, the following driving behavior measures in Table 2 were considered. The driving behavior

Table 2. Driver behavior measures for analyzing fuel efficiency

Categories	Variables	Definitions	Units
Fuel Efficiency	Millage	The ratio of the traveled distance to the amount of fuel burned	km/l
Vehicle Control	AvgVel	Average velocity	kph
	AvgRPM	Average engine speed (RPM)	rev/min
Accelerator Pedal	PsAcCount	The number of pressing an accelerator pedal	count
	PsAcAvgTime	Average time for pressing an accelerator pedal	sec
	PsAcStdTime	Standard deviation of time for pressing an accelerator pedal	sec
	PsAcAvgDep	Average depth of pressing an accelerator pedal	%
	PsAcStdDep	Standard deviation of depth of pressing an accelerator pedal	%
	RlA2AAvgTime	Average time for releasing an accelerator pedal	sec
	RlA2AStdTime	Standard deviation of time for releasing an accelerator pedal	sec
Brake Pedal	PsBrCount	The number of pressing a brake pedal	count
	PsBrAvgTime	Average time for pressing a brake pedal	sec
	PsBrStdTime	Standard deviation of time for pressing a brake pedal	sec
	RlB2BAvgTime	Average time for releasing a brake pedal	sec
Gear Shift	Gear_SelAvg	Average level of gear selection	level
	Gear_SelStd	Standard deviation of level of gear selection	level
Steering Wheel	SWL_VelAvg	Average angular velocity of steering wheel	degree/sec
	SWL_VelStd	Standard deviation of angular velocity of steering wheel	degree/sec
	SWL_AngStd	Standard deviation of steering wheel angle	degree

measures in relation to accelerator, brake, and gear were more specified than the previous studies [2]. In particular, the ways of pressing on the accelerator and brake pedal were specified with such factors as depth, frequency, and time, to analyze the effect of a certain behavior on eco-driving more accurately.

Analysis

Since the optimal fuel efficiency may be varied depending on the speed of the vehicle, the experiment data was divided based on the speed ranges by 10kph. For instance, the data of the 80~90kph range during the experiment was collected and classified as a section of 80kph, and other sections in the same manner.

Based on the data sets classified as above, the variables of high influence on fuel efficiency among driving behavior measures were selected by means of the stepwise regression analysis of SPSS, and the explanatory power of the regression model was analyzed. As for the differences in fuel efficiency depending on age and gender were analyzed by means of ANCOVA (Analysis of Covariance). Intake air temperature and speed sections were considered as the external factor covariates that might affect the fuel efficiency.

Results

Regression model for estimating fuel efficiency

The estimation model on the fuel efficiency and driving behavior measures was constructed by means of the stepwise regression analysis, and the contribution of specific driving behavior variables for improving or reducing the fuel efficiency was analyzed. The results may support to develop a guideline for appropriate driving behaviors that would enhance eco-driving.

This study included the variables in Table 2 to build the fuel efficiency model based on the driver behavioral measures. To select variables of the regression model, the stepwise regression method was adopted, and the explanatory power of the regression model was 85.2% (Adjusted R Square = 0.852), which suggested that a reasonable regression model can be created only based on the driver behavioral measures.

According to the contribution of the selected variables in the regression model (see Table 3), 78.8% of the model explanatory power was occupied with depth of the accelerator, average speed, and average RPM. The result indicates that when the accelerator was stepped on slightly to a limited extent with RPM remaining low and speed remaining high, the fuel efficiency can be maximized.

In addition, rather than keeping the step on the accelerator, often releasing the accelerator for increasing coast-down time would be advantageous, which was supported by the fact that the contribution of three variables, i.e., the number of pressing accelerator, the standard deviation of time for pressing accelerator and the standard deviation of depth of pressing the accelerator, was about 12.1%.

Table 3. Variable contribution in regression model

No	Variables	Contribution	Std.C. (Beta)	Sig.
1	PsAcAvgDep	-26.1%	-0.678	0.000
2	AvgVel	30.7%	0.796	0.000
3	RPMAvg	-22.0%	-0.570	0.000
4	PsAcCount	5.7%	0.147	0.000
5	StdVel	3.6%	0.094	0.000
6	Gear_SelAvg	-5.6%	-0.144	0.000
7	PsAcStdTime	3.4%	0.087	0.001
8	PsAcStdDep	3.0%	0.077	0.006

Age and gender differences in fuel efficiency

In order to analyze the effect of age and gender on the fuel economy, analysis of covariance (ANCOVA) was conducted with a covariate of the in-take air temperature that might affect fuel efficiency regardless of driving behaviors. Because a road condition highly affected on the fuel efficiency, the highway was divided into two sections, i.e., flat and uphill. As shown in Table 4, age and gender significantly impacted on the fuel efficiency in the flat section where the effect of road conditions would be minimized. That is, both the main effect of the age (p=0.001) and the main effect of gender (p=0.014) on the fuel efficiency were significant in the flat section while no difference was found in the uphill section where the road condition was influential regarding both age (p=0.100) and sex (p=0.249).

Discussion

In this study, driving experiments were conducted on an actual expressway to comparatively analyze the contribution of driving behavior measures to fuel efficiency and the differences in fuel efficiency depending on age and gender. As a result, a regression model with the explanatory power of 85% was created based on the driver behavioral measures, and it was found that the three driving behavior variables – depth of pressing the accelerator, average velocity, and average RPM had the contribution of around 80% among the all variables used in the regression model.

Table 4. Age and gender differences in fuel efficiency

Road Type	Gender	Age			
		Younger		Late Mid Age	
Flat	Male	10.4	(1.5)	11.1	(1.8)
	Female	10.8	(1.4)	11.8	(1.7)
Uphill	Male	7.1	(1.2)	6.6	(1.1)
	Female	7.2	(0.8)	7.0	(1.5)

The other contribution of additional variables related to specific driving styles except the depth of pressing the accelerator was about 12%.

The findings of this study, therefore, suggest that it would be desirable to design an eco-driving education program with two steps: step 1 focuses on the three variables which would be readily understood and bring in outstanding effects (speed, RPM, and depth of pressing the accelerator); step 2 includes elaborate manipulation of the accelerator to improve the other 12%.

In addition, this study demonstrated that age and gender have significant effect in this regard. According to the findings, drivers of late middle age recorded higher fuel efficiency than young drivers, and female drivers higher than male drivers. If such differences were taken into consideration in designing eco-driving education programs and supporting systems, the provided supports would be better optimized to the drivers' characteristics. Specifically, for young male drivers whose fuel efficiency on a flat road was the lowest, the driving style variables with high contribution such as the accelerator depth, speed, and RPM should be focused on, but for late middle age female drivers whose fuel efficiency was the highest, elaborate manipulation of the accelerator need to be addressed to improve their fuel efficiency further.

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