CIE5050-09 Additional Graduation Work

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Analysis of Effective Factors on Driving Behavior in Control Transitions Between Full-range Adaptive Cruise Control and Manual Driving

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1. Introduction

In recent decades, interest in automated vehicles and driving assistance systems has increased. Many vehicles in the market are already equipped with driving assistance systems such as Adaptive Cruise Control (ACC), which maintains a set speed and time headway. Several driving simulator and on-road experiments were carried out to understand the effects of ACC on driving behavior and the potential impacts on traffic flow efficiency and safety. Field Operational Tests (FOTs) have revealed that ACC potentially has positive effects on safety and throughput when it is activated ([1], [2]): exposure to the hazards associated with lane-changing was presumably reduced due to the fact that drivers followed the leaders for approximately twice as long as in manual driving when ACC was activated [1], indirect positive effects of ACC on throughput might occur by avoiding accidents and safety might increase by keeping longer headways [2]. However, microscopic simulation tests have shown that active ACC improved throughput only in light traffic [3] and the road capacity dropped in the case of high penetration rate of active ACC vehicles (50%) on the road with large preset headway setting (1.4 s) [4].

Some studies have revealed that control transitions [5] between ACC and manual driving have also substantial impacts on traffic flow ([6], [7]). A driving simulator experiment showed that these control transitions influence significantly on the longitudinal driving behavior. Drivers dropped their speeds after sensor failure condition and increased time headways after they reactivated ACC, which potentially reduce the positive impacts of ACC on traffic flow efficiency [7]. The circumstances in which these transitions are initiated could be affected by several factors such as characteristics of ACC, road and traffic conditions, and driver characteristics [8]. For example, ACC which is inactive at low speeds and have limited deceleration capability is frequently deactivated in dense traffic conditions or before changing lane[6]. Recently, full-range ACC which can be used in stop-and-go conditions has been introduced. A microscopic traffic simulation showed that full-range ACC could reduce travel time delay and increase traffic safety [9]. Notably, control transitions between full-range ACC and manual driving have a significant impact on driving behavior characteristics (speed, acceleration, distance headway and relative speed) [10]. However, these studies gained limited insights into the factors which affect these changes in driving behavior characteristics during control transitions. This study focuses on analyzing the factors (i.e., driver characteristics, ACC system settings and traffic conditions) which influence driving behavior characteristics in control transitions between full-range ACC and manual driving. Mixed linear model is estimated using data collected in an on-road experiment and questionnaires.

The paper is structured as follows. The next section discusses several factors related to driving behavior with ACC by reviewing previous studies. This section is followed by a description of data collection including system specification, participants and collected data, and loop detector data. Next, the results of preliminary analysis by using several statistical tests are presented. The specification of mixed linear model and the estimated results follow after the previous section. In the last section, the factors influencing driving behavior in control transitions between full-range ACC and manual driving and limitation of the estimated results are discussed.

2. Literature Review

In this section, previous studies analyzing the factors which influence driving behavior with ACC are reviewed. In last decade, many studies focused on observing the change of driving behavior with ACC and finding how it affects traffic flow efficiency and safety but these factors did not focus on the factors that change driving behavior with ACC. In addition, few studies associated with control transitions or full-range ACC were done since the interest of them started quite recently. As a result, five studies are referred to in this section and they are ordered by types of factors which were examined in their analyses: the first two studies are focused on driver characteristics, the third on traffic condition, and the fourth and fifth on road environment and headway settings. Notably, the last study is the only one that involved full-range ACC among the others. At the last part of this section, the research gap and research question are discussed.

Several studies explored the impact of driver characteristics such as driver demographic characteristics, driving experience over time and driving style by doing on-road experiments and using driving simulators. In a Field Operational Test (FOT), Ervin et al. [1] investigated the relationship between driver demographic characteristics (age and gender) and driving behavior with ACC in terms of frequency of system usage and headway adjustments on the freeway. Older drivers used ACC more frequently than middle-aged and younger drivers and males more frequently than females. Drivers reduced the headway setting less frequently as age increased for short headway settings (1.0s ~ 1.4s of headway time margin), while differences between groups were not significant for long headway settings (1.6s ~ 2.0s of headway time margin). In general, males made more adjustments to the headway setting than females. By using a motion-based driving simulator and a post-drive questionnaire, Xiong et al. [11] explored the relationship between drivers' adaptive behavior with ACC and driver characteristics such as age, gender, knowledge of-, trust in-, and experience with the system, and driving styles. Drivers were classified into three groups (conservative, moderately risky, risky) using cluster analysis with the hierarchical clustering method of Ward's minimum variance. Specific measures of drivers' adaptive behavior in the simulator experiment were used in the analysis such as total number of times that the ACC was disengaged, percentage of time each headway setting was selected, total number of warnings, and difference between average set speed and speed limit. The conservative group, driving at lower speeds and longer headway settings, and disengaging ACC less frequently, had the longest experience with ACC and the best knowledge of the system limitations. Comparing to the conservative group, drivers in the moderately risky group, who used higher set speeds, shorter headway settings, and disengaged ACC more frequently, reported the highest levels of confidence in their driving skills and the lowest levels of trust in ACC. It is interesting that the moderately risky group had the smallest number of warnings which appeared when the speed is lower than 40.3km/h or the leading vehicle brakes too hard. Drivers in the risky group, who had the most warnings, but used the longest headway setting and disengaged the ACC least frequently, reported the highest levels of trust in the system. It might imply that the drivers in the risky group relied on ACC too much which resulted to get the highest number of warnings.

In a FOT, Viti et al. [6] found that the traffic condition is one of the factors influencing driving behavior with ACC: in medium dense traffic conditions, drivers preferred to disengage ACC and resume manual control to have smaller distance headways and full control of the vehicle.

These studies, however, analyze driving behavior with ACC over the whole duration of experiment but not in specific situation such as control transitions. In a FOT, Xiong and Boyle [12] focused on understanding drivers' adaptive behavior in "closing" events, which are defined as the moments in which the automatic braking control of ACC is activated until any braking or deceleration ceases, regardless of whether a driver intervenes or not. Notably, not only the driver characteristics mentioned above but also other factors such as environment, vehicle speed and selected headway settings were used in this study. In a logistic regression model, it was shown that drivers are less likely to brake manually on the highway and when the vehicle speed is higher. Drivers intervene more often with short headway settings than with long or medium.

However, the studies reviewed above analyzed ACC which are inactive at low speeds and with limited deceleration capability. Since the functional limitations of ACC influence significantly the circumstances in which the control transitions are initiated [8], driving behavior with full-range ACC could be influenced by different factors. In an on-road experiment, Pereira et al. [13] found that the usage of full-range ACC was increased and the shortest time headway selected was decreased significantly when the drivers' experience with full-range ACC increased in urban environment. Yet, only a few factors such as drivers' experience over time and road environment (urban or motorway) were analyzed in this study and their effects on driving behavior in control transitions were not considered. As shown in previous studies, they were focused on analyzing factors affecting the driving behavior with ACC by doing on-road experiments and using driving simulator, but the effectiveness of these factors in control transitions were not observed. Since control transitions between ACC and manual driving have substantial impacts on traffic flow ([6], [7]), it is needed to observe how these factors might significantly impact on driving behavior in control transitions. In this study, the impact of driver characteristics, ACC system settings and traffic condition on driving behavior characteristics in control transitions between full-range ACC and manual driving are analyzed by using mixed linear model.

3. Data Collection

3.1. System specification

The system equipped in the vehicles for the on-road experiment is a full-range Adaptive Cruise Control (full-range ACC) that can control the speed in a range between 0 to 210 km/h and adapts the time headway at speed above 30 km/h. The desired time headway can be set as 1.0, 1.4, 1.8, and 2.2 s by the driver. The system can support the acceleration and deceleration in a range between 3 m/s^2 and – 3 m/s^2. The system can be in three states: inactive (state 1), active (state 2), and active and accelerate (state 3). When the system is inactive, the driver can activate it by pressing the on/off button, changing the desired speed setting, or by pressing the resume button. The driver can set a desired speed and time headway when the system is active. When the system is active, the driver can overrule the system temporally by pressing the gas pedal. The system gets back to the setting previously stored when the driver release the gas pedal. The system is automatically deactivated when the vehicle stands still for more than 3 seconds, but for less than 3 seconds the system automatically restarts the engine and moves the vehicle. The driver can also deactivate the system by pressing the on/off button or by braking. In addition, the system is also automatically deactivated in the case of system failures or safety critical situations when the system-support constraints are reached.

3.2. Participants and collected data

The on-road experiment was done on the A99 freeway by 23 employees of BMW in Munich. They were composed of 15 males and 8 females and the range of their ages was between 25 and 51 years old. All of them had valid driving licenses with more than a year of driving experience. 17 participants had experience of ACC and 8 of them were used to drive with ACC more than once a month. The experiment was done during the peak hours (7-9 am, 4-6 pm, 6-8 pm) from 29th of June to 9th of July in 2015. Written instructions on the experiment and questionnaires were given to the participants. The participants were asked to fill in these questionnaires which included questions related to their demographic characteristics, driving experience, experience with ACC, and driving styles [14] before the experiment. At the beginning of the experiment, participants tested the system and adjusted the gap setting based on their preference. During the experiment, they were free to specify whether to use the system and to change their speed at any time so they could drive as same as they did in a real life. Speed, acceleration, the system setting and state, GPS position of the vehicle, speed of the leader and distance headway between the vehicle and the leader were measured by sensors and radars. These measurements were then recorded in Controller Area Network (CAN) of the vehicle. Distance headway and speed of the leader were only measured when the distance between two consecutive vehicles was shorter than the maximum range of the radar (120 meters). After the experiment, the rest of the questionnaire related to the usage of the system during the experiment, workload of the experiment (NASA TLX), and usefulness and satisfaction of the system (Van der Laan scale) [15] was completed by the participants.

3.3. Loop detector data

On the test route of A99 freeway, 23 dual inductive loop detectors were equipped at a distance ranged between 320 meters and 3696 meters. In each lane, mean speeds and counts of vehicles at one minute intervals were collected at each position where detectors are located. The traffic conditions during the experiment were estimated by using loop detector data and reconstructed by using the Adaptive Smoothing Method (ASM), the method that takes into account the different velocities of propagation in free and congested traffic conditions [16]. The mean speed, flow and density at each 100 meters distance interval and 30 seconds time interval were finally calculated.

4. Preliminary Analysis and Results

The data collected in the on-road experiment and the questionnaires were analyzed to understand the influence of driver characteristics, ACC system settings, and traffic conditions (independent variables) on changes in driving behavior characteristics (dependent variables) registered in the intervals 10 s after and 10 s before the control transitions. In this paper, only the control transitions from inactive to active (12: State 1 to State 2) and from active to inactive (21: State 2 to State 1) are considered. The 4 dependent and the 22 independent variables analyzed are listed in Table 1. Driving behavior characteristics include mean distance headway (front bumper to rear bumper), mean relative speed (front vehicle speed – subject vehicle speed), mean speed, and mean acceleration. The driver characteristics comprise demographic characteristics, driving experience, information about driving style, self-reported workload, and information about the usefulness and satisfaction of ACC. Information on driving style was assessed by the multidimensional driving style inventory introduced by Taubman-Ben-Ari et al. [14] which are using 6-levels scale and scored in four different domains of driving style. Self-reported workload (NASA TLX) and usefulness and satisfaction of the system (Van der Laan scale) used same level of scales in questionnaires in the assessment which were suggested by Kyriakidis et al. [15].

ACC system settings consist of mean target speed and mean target time headway set by driver in the intervals 10s after and 10s before the control transition. Level of service (LOS) based on average traffic density is used for the traffic conditions.

Table 1 List of dependent and independent variables

Variable	Description	Type
1. Driving behavior characteristics (dependent variable)		
mDHWdif	Difference between the mean distance headways (front bumper to rear bumper) in the intervals 10s after and in the 10s before the transition (m)	Scale
mDVdif	Difference between the mean relative speeds (front vehicle speed - subject vehicle speed) in the intervals 10s after and in the 10s before the transition (m/s)	Scale
mSpeeddif	Difference between the mean speeds in the intervals 10s after and in the 10s before the transition (m/s)	Scale
mAccdif	Difference between the mean accelerations in the intervals 10s after and in the 10s before the transition (m/s^2)	Scale
2. Driver characteristics (independent variable)		
2.1. Demographic characteristics		
Age	Age of driver (years)	Scale
Gender	Gender of driver	Nominal (2 levels)
Edu	Level of education of driver	Nominal (2 levels)
Income	Personal gross annual income of driver (Euro)	Ordinal (5 levels)
Income_divided	Personal gross annual income of driver (Euro)	Ordinal (2 levels)
YLicense	Years of driving experience	Scale

Variable	Description	Type
2.2. Driving experience		
DriveLY	Mean frequency of driving days in the last year	Ordinal (5 levels)
DriveLY_divided	Mean frequency of driving days in the last year	Ordinal (2 levels)
DriveOR	Mean frequency of driving days on the experimental route in the last year	Ordinal (4 levels)
DriveOR_divided	Mean frequency of driving days on the experimental route in the last year	Ordinal (2 levels)
KmLY	Mean distance drove in the last year (km)	Ordinal (6 levels)
KmLY_divided	Mean distance drove in the last year (km)	Ordinal (3 levels)
ExpACC	Mean frequency of driving days using ACC in the last year	Ordinal (3 levels)
Accident	Number of car accidents driver involved in in the last 3 years	Ordinal (3 levels)
Accident_divided	Number of car accidents driver involved in in the last 3 years	Ordinal (2 levels)
2.3. Information on driving style		
Anxious	Anxiousness (6-levels scale)	Scale
Reckless	Reckless and careless (6-levels scale)	Scale
Angry	Angry (6-levels scale)	Scale
Patient	Patient and carefulness (6-levels scale)	Scale
2.4. Self-reported workload		
NASATLX	Workload of driver in the experiment (20-levels scale)	Scale
2.5. Information about the usefulness and satisfaction of ACC		
Useful_ACC	Degree of usefulness of ACC (5-levels scale)	Scale
Satisfy_ACC	Degree of satisfaction of ACC (5-levels scale)	Scale
3. ACC system settings		
mTargetSpeedb	mean Target speed in the interval 10s before transition (km/h)	Scale
mTargetSpeeda	mean Target speed in the interval 10s after transition (km/h)	Scale
mTargetTHWb	mean Target time headway in the interval 10s before transition (s)	Ordinal (3 levels)
mTargetTHWa	mean Target time headway in the interval 10s after transition (s)	Ordinal (3 levels)
4. Traffic condition (independent variable)		
DensityLevel	Average traffic density level (LOS)	Ordinal (3 levels)

The number of observations and drivers available for each variable are listed in Table 2. The number of drivers in each group of ordinal variables was relatively small since only 23 drivers participated in the experiment. 5 independent variables (Income_divided, DriveLY_divided, DriveOR_divided, KmLY_divided, Accident_divided) included one or more response with less than 3 drivers. Therefore, these variables were categorized into no more than three groups to balance the number of drivers in each group. Scores for driving styles, usefulness and satisfaction of ACC, and self-reported workload were calculated by averaging the scores of the corresponding items in the questionnaires.

Table 2 Number of observations, number of drivers, mean and standard deviation of dependent and independent variables in control transition from inactive to active (12) and from active to inactive (21)

		Control transition							
		12				21			
		N	#ID	Mean	Std.	N	#ID	Mean	Std.
1. Driving behavior characteristics (dependent variable)									
mDHWdif	Missing value	9				14			
	Valid	73	20	1.76	12.12	105	23	-10.19	20.08
mDVdif	Missing value	9				14			
	Valid	73	20	0.80	1.58	105	23	0.16	2.87
mSpeeddif	Valid	82	21	-1.43	2.86	119	23	-3.47	3.55
mAccdif	Valid	82	21	0.33	0.47	119	23	-0.58	0.49
2. Driver characteristics (independent variable)									
2.1. Demographic characteristics									
Age		82	21	31.95	7.17	119	23	30.81	6.23
Gender	Male	65	14			80	15		
	Female	17	7			39	8		
Edu	Msc	64	16			94	18		
	PhD	18	5			25	5		
Income	Missing value	21	3			21	3		
	20001-30000	35	9			57	10		
	50001-60000	2	1			6	1		
	60001-70000	4	2			6	2		
	70001-80000	18	4			25	6		
	90001-100000	2	1			4	1		
Income_divided	Missing value	21	3			21	3		
	20001-30000	35	9			57	10		
	> 30000	26	8			41	10		
YLicense		82	21	13.60	7.26	119	23	12.40	6.55
2.2. Driving experience									
DriveLY	Every day	22	5			24	6		
	4-6 days a week	7	3			14	3		
	1-3 days a week	43	9			64	11		
	Once a month to once a week	7	2			13	2		
	Less than once a month	3	1			4	1		
DriveLY_divided	> 3 days in a week	29	8			38	9		
	≤ 3 days in a week	53	12			81	14		
DriveOR	4-6 days a week	1	0			4	1		
	1-3 days a week	22	4			21	4		
	Once a month to once a week	11	4			26	6		
	Less than once a month	48	12			68	12		
DriveOR_divided	≥ once in a month	34	8			51	11		
	< once in a month	48	12			68	12		

		Control transition							
		12				21			
		N	#ID	Mean	Std.	N	#ID	Mean	Std.
KmLY	1-1000	9	3			19	3		
	1001-5000	17	3			18	3		
	5001-10000	16	5			35	6		
	10001-15000	16	3			18	4		
	20001-25000	10	3			11	3		
	25001-35000	14	3			18	4		
KmLY_divided	1-5000	26	6			37	6		
	5001-15000	32	8			53	10		
	20001-35000	24	6			29	7		
ExpACC	None	16	6			29	6		
	Medium	39	9			52	9		
	High	27	6			38	8		
Accident	0	74	17			98	18		
	1	4	2			11	3		
	2	4	1			10	2		
Accident_divided	0	74	17			98	18		
	≥ 1	8	3			21	5		
2.3. Information on driving style									
Anxious		82	21	2.43	0.40	119	23	2.42	0.36
Reckless		82	21	2.11	0.45	119	23	2.11	0.41
Angry		82	21	2.21	0.64	119	23	2.11	0.67
Patient		82	21	4.66	0.37	119	23	4.69	0.36
2.4. Self-reported workload									
NASATLX		82	21	28.44	11.91	119	23	31.12	12.25
2.5. Information about the usefulness and satisfaction of ACC									
Useful_ACC		82	21	0.90	0.41	119	23	0.96	0.43
Satisfy_ACC		82	21	1.07	0.47	119	23	1.07	0.49
3. ACC system settings									
mTargetSpeedb		82	21	98.16	36.68	119	23	110.55	32.28
mTargetSpeeda		82	21	86.60	34.56	119	23	108.12	33.41
mTargetTHWb	Missing value	40	18			0	0		
	1.0	14	5			49	9		
	1.4	7	3			32	7		
	1.8	21	4			38	8		
mTargetTHWa	Missing value	1	1			51	19		
	1.0	31	8			22	9		
	1.4	16	6			21	7		
	1.8	34	9			25	9		
4. Traffic condition (independent variable)									
DensityLevel	LOS AB	19	13			36	16		
	LOS CD	24	11			50	20		
	LOS EF	39	13			33	18		

The statistical tests are done for each pair of dependent and independent variables. Statistical tests were selected depending on the type of independent variable and the number of levels. Independent Sample t-Test (equal variance) or Welch's Test (unequal variance) were used when the independent variables were ordinal with 2 levels. These tests were used to know whether the mean values of driving behavior characteristics of two groups are significantly different. In case of ordinal variables with more than 2 levels, Analysis of Variance (ANOVA) (equal variance) or Welch's Test (unequal variance) was used with Post-Hoc Test by Scheffe's Method (equal variance) or Games-Howell Test (unequal variance). These tests were selected as Post-Hoc Tests since Scheffe's Method can apply to the set of estimates of all possible contrast among the factor level means and Games-Howell Test can give the best performance for pairwise comparisons when the sample sizes are greater than five [17]. These tests were used to know whether one group has significant different driving behavior characteristics than others. The homogeneity of variance was tested by Levene's Test in both cases. Scale variables were analyzed using Pearson Correlation and Simple Linear Regression Model to find linear relation with driving behavior characteristics. Pearson Correlation was also used to analyze the correlation between independent variables. For each type of control transition, results of tests which were statistically significant at the 0.05 level are reported in Table 3 and 4 and results of Pearson Correlation are shown in Table 5 and 6. Red boxes in Table 5 and 6 indicate that the correlation is higher than 0.40, which means the independent variables are highly correlated.

Table 3 shows that, when drivers transferred from Inactive to Active (12), the difference between mean distance headways after and before transition was significantly influenced by age of drivers, years of driving experience, education level, annual income, mean frequency of driving days and average driving distance. The difference of mean distance headways had a positive correlation with age of driver and years of driving experience, meaning that older and more experienced drivers are associated with longer distance headways after activation. Drivers with PhD degree had longer distance headways while drivers with Master degree had shorter distance headways after activation than before. However, the result for education level might be biased by the small sample size of drivers holding a PhD degree. Similarly, drivers with high income (more than 30000 euros per year) had longer distance headways while drivers with low income (20001 – 30000 euros per year) had shorter distance headways after activation than before. Since age of drivers is highly correlated to years of driving experience, education level and annual income according to Table 5, the results mentioned above are similar to the result related to age of driver. For driving experience, drivers who drove more than 3 days a week had longer distance headways while drivers who drove up to 3 days a week had shorter distance headways after activation than before. Similarly, drivers who drove at least once in a month on the experimental route had longer distance headways while drivers who drove less than once a month on the experimental route had shorter distance headways after activation than before. It can be concluded that drivers with more driving experience are related to longer distance headways after activation. Mean frequency of driving days and average driving distance have similar correlation with the difference of mean distance headways since high correlation between them can be found in Table 5. Table 3 also shows that a difference between mean speeds after and before transition was significantly influenced by average traffic density levels. It means that drivers decreased speeds more after activation at low densities (LOS AB) than at high densities (LOS EF).

Table 4 shows that drivers who experienced car accidents decreased the distance headways more than driver who never experienced car accident after deactivation when transferring from Active to Inactive (21). However, as in case of education level, this result might be biased by the small sample size of drivers who experienced a car accident. In addition, the difference between mean relative speeds after and before transition was significantly related to gender, experience of car accidents, degrees of usefulness and satisfaction of ACC. Female drivers had higher relative speeds while male drivers had lower relative speeds after deactivation than before. It means that female drivers increased their relative speed while male drivers decreased it after deactivation. To be specific, female drivers decreased their speed more than their leaders did while the male drivers decreased their speed less than their leaders did after deactivation. Experience with car accidents had a similar impact on relative speed: drivers who experienced car accidents increased their relative speed after deactivation, which means that their speeds decreased more than their leaders' speeds after deactivation. Degree of usefulness and satisfaction of ACC have positive correlation with the difference of mean relative speeds. It means that drivers who rated ACC as to be satisfactory and useful increased their relative speeds after deactivation. In other words, the drivers who had higher degree of usefulness and satisfaction of ACC decreased their speed more than their leaders did after deactivation. The difference between mean speeds after and before transition was significantly influenced by average traffic density levels. It replies that drivers decreased speeds more after inactivation at low densities (LOS AB) than at high densities (LOS EF).

Table 3 Results of statistical tests which were significant at the level 0.05 between dependent and independent variables in control transition Inactive to Active (12)

Control transition 12											
Dependent	Independent variable		N	#ID	Mean	Std.	Sig. (Levene's Test)	Sig. (Independent Samples t-Test / Welch's t-Test)			
mDHWdif	Edu	Msc	56	16	-0.760	9.771	0.035*	0.013*			
		PhD	17	5	10.065	15.420					
mDHWdif	Income_divided	20001-30000(€)	31	9	-2.223	11.943	0.674	0.048*			
		> 30000(€)	22	8	4.364	11.236					
mDHWdif	DriveLY_divided	> 3 days in a week	27	8	6.969	11.138	0.835	0.004**			
		≤ 3 days in a week	46	12	-1.296	11.734					
mDHWdif	DriveOR_divided	≥ once in a month	29	8	5.379	11.881	0.970	0.038*			
		< once in a month	44	12	-0.624	11.814					
Dependent	Independent variable		N	#ID	Mean	Std.	Sig. (Levene's Test)	Sig. (ANOVA / Welch's Test)	Post-Hoc Test (Scheffe / Games-Howell)		
									I	J	Sig.
mSpeeddif	DensityLevel	LOS AB	19	12	-2.445	2.718	0.829	0.017*	LOS AB	LOS CD	0.938
		LOS CD	24	11	-2.143	2.510			LOS CD	LOS EF	0.079
		LOS EF	39	13	-0.507	2.907			LOS EF	LOS AB	0.048*
Dependent	Independent variable		N	#ID	Mean	Std.	Correlation(Sig.) (Pearson Correlation)	Simple Linear Regression			
								R square	Sig.	Constant	b1
mDHWdif	Age		73	21	1.761	12.124	0.3920(0.001***)	0.154	0.001***	-18.988	0.641
mDHWdif	Ylicense		73	21	1.761	12.124	0.3900(0.001***)	0.152	0.001***	-6.967	0.626

Table 4 Results of statistical tests which were significant at the level 0.05 between dependent and independent variables in control transition Active to Inactive (21)

Control transition 21											
Dependent	Independent variable		N	#ID	Mean	Std.	Sig. (Levene's Test)	Sig. (Independent Samples t-Test / Welch's t-Test)			
mDHWdif	Accident_divided	0	87	18	-7.479	17.580	0.006**	0.023*			
		≥ 1	18	5	-23.289	26.158					
mDVdif	Gender	Male	69	15	-0.244	2.341	0.299	0.048*			
		Female	36	8	0.920	3.582					
mDVdif	Accident_divided	0	87	18	-0.217	2.759	0.805	0.003*			
		≥ 1	18	5	1.955	2.754					
Dependent	Independent variable		N	#ID	Mean	Std.	Sig. (Levene's Test)	Sig. (ANOVA / Welch's Test)	Post-Hoc Test (Scheffe / Games-Howell)		
									I	J	Sig.
mSpeeddif	DensityLevel	LOS AB	36	15	-4.437	3.779	0.406	0.020*	LOS AB	LOS CD	0.603
		LOS CD	50	19	-3.675	3.649			LOS CD	LOS EF	0.135
		LOS EF	33	17	-2.110	2.713			LOS EF	LOS AB	0.023*
Dependent	Independent variable		N	#ID	Mean	Std.	Correlation(Sig.) (Pearson Correlation)	Simple Linear Regression			
								R square	Sig.	Constant	b1
mDVdif	Useful_ACC		105	23	0.155	2.866	0.347(0.000***)	0.121	0.000***	-2.008	2.276
mDVdif	Satisfy_ACC		105	23	0.155	2.866	0.214(0.029*)	0.046	0.029*	-1.158	1.256

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Table 5 Results of Pearson Correlation for all pairs of independent variables in control transition inactive to active (12)

Correlations[a]

		Age of driver	Gender of driver (1=Male, 2=Female)	Level of education of driver (6=MSc, 7=PhD)	Personal gross annual income(EUR) (14=20001-30000(option 4), 15=rest of options(option 7,8,9,11))	Keeping years of driving license	Drive on avg last year (7=Every day to 4 days a week(option 1,2), 8=3 days a week to less than once a month(option 3,4,5))	Drive on avg on the experimental route(A9-A99) (7=Not every day but at least more than once a month(option 2,3,4), 8=Less than once a month(option 5))	Km on avg last year(12=1-5000km(option 2,3), 13=5001=15000km(option 4,5), 14=20000-35000km(option 7,8))	Experience ACC (1=none, 2=medium, 3=high)	Number of traffic accidents driver involved in when driving a car in the last 3 years(8=zero(option 1), 9= rest of options(option 2,3))	Anxious(6 Levels Scale: 1=Not at all, 2=Very little, 3=Little, 4=Moderate, 5=Much, 6=Very much)	Reckless(6 Levels Scale: 1=Not at all, 2=Very little, 3=Little, 4=Moderate, 5=Much, 6=Very much)	Angry(6 Levels Scale: 1=Not at all, 2=Very little, 3=Little, 4=Moderate, 5=Much, 6=Very much)	Patient(6 Levels Scale: 1=Not at all, 2=Very little, 3=Little, 4=Moderate, 5=Much, 6=Very much)	Nasa(TLX 20 levels, 6 categories : Mental demand, Physical demand, Temporal demand, Performance, Effort, Frustration)	Usefulness of Stop&Go ACC system(5 Levels Scale: negative -2 1 0 1 2 positive)	Satisfaction of Stop&Go ACC system(5 Levels Scale: negative -2 - 1 0 1 2 positive)	mean Target speed before transition(km/h)	mean Target speed after transition(km/h)	DensityLevel(1=LOS AB, 2=LOS CD, 3=LOS EF)
Age of driver	Pearson Correlation	1.000	-0.211955	.794**	.681**	.989**	-.396**	-.242*	.496**	.343**	-0.084	-.448**	.294**	0.011	-.314**	-0.019	-.349**	-.585**	-0.060949	0.042	-0.023
	Sig. (2-tailed)		0.056	0.000	0.000	0.000	0.000	0.028	0.000	0.002	0.451	0.000	0.007	0.922	0.004	0.868	0.001	0.000	0.586	0.706	0.834
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Gender of driver (1=Male, 2=Female)	Pearson Correlation	-0.211955	1.000	0.019	.278*	-0.213377	.252*	0.064	-.292**	-.435**	.237*	0.155323	-0.204302	-.228*	.339**	-0.144	.391**	0.048	.255*	0.2101446	-0.192
	Sig. (2-tailed)	0.056		0.862	0.030	0.054	0.022	0.568	0.008	0.000	0.032	0.164	0.066	0.039	0.002	0.196	0.000	0.665	0.021	0.058	0.083
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Level of education of driver (6=MSc, 7=PhD)	Pearson Correlation	.794**	0.019	1.000	.383**	.810**	-.224*	-0.032	0.205	.273*	-0.075	-.476**	0.047	-.365**	0.098	-0.042	-.376**	-.648**	0.045	0.153	-0.124
	Sig. (2-tailed)	0.000	0.862		0.002	0.000	0.043	0.775	0.064	0.013	0.503	0.000	0.674	0.001	0.381	0.709	0.001	0.000	0.689	0.171	0.267
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Personal gross annual income(EUR)	Pearson Correlation	.681**	.278*	.383**	1.000	.568**	0.044	0.049	.323*	-0.214	0.058	-0.013	.364**	0.214	-0.159	-.291*	0.181	-0.116	-0.241	-0.238	0.168
	Sig. (2-tailed)	0.000	0.030	0.002		0.000	0.738	0.708	0.011	0.097	0.657	0.920	0.004	0.098	0.220	0.023	0.162	0.373	0.061	0.064	0.197
	N	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
Keeping years of driving license	Pearson Correlation	.989**	-0.213377	.810**	.568**	1.000	-.420**	-.280*	.486**	.350**	-0.124	-.462**	0.2016703	-0.037	-.276*	-0.012	-.389**	-.594**	-0.036506	0.085	-0.042
	Sig. (2-tailed)	0.000	0.054	0.000	0.000		0.000	0.011	0.000	0.001	0.267	0.000	0.069	0.743	0.012	0.915	0.000	0.000	0.745	0.450	0.709
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Drive on avg last year (7=Every day to 4	Pearson Correlation	-.396**	.252*	-.224*	0.044	-.420**	1.000	.724**	-.677**	-.362**	0.071	.441**	0.138	-0.134	0.077	0.084	-0.019	-0.115659	0.085	-0.053	0.002
	Sig. (2-tailed)	0.000	0.022	0.043	0.738	0.000		0.000	0.000	0.001	0.524	0.000	0.216	0.232	0.493	0.455	0.867	0.301	0.448	0.638	0.984
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Drive on avg on the experimental route(A9-A99)	Pearson Correlation	-.242*	0.064	-0.032	0.049	-.280*	.724**	1.000	-.787**	-.502**	-.224*	.225*	-0.040	-.290**	.341**	0.084	-0.134	0.013	-0.103	-0.174	0.101
	Sig. (2-tailed)	0.028	0.568	0.775	0.708	0.011	0.000		0.000	0.000	0.043	0.042	0.720	0.008	0.002	0.454	0.231	0.911	0.357	0.118	0.365
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Km on avg last year(12=1-5000km(option 2,3),	Pearson Correlation	.496**	-.292**	0.205	.323*	.486**	-.677**	-.787**	1.000	.577**	.274*	-.305**	.319**	.352**	-.563**	-0.123	0.130	-0.087	-0.081	0.055	-0.010
	Sig. (2-tailed)	0.000	0.008	0.064	0.011	0.000	0.000	0.000		0.000	0.013	0.005	0.003	0.001	0.000	0.271	0.243	0.439	0.472	0.624	0.929
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Experience ACC (1=none, 2=medium, 3=high)	Pearson Correlation	.343**	-.435**	.273*	-0.214	.350**	-.362**	-.502**	.577**	1.000	-0.004	-.406**	0.118	0.150	-.225*	0.164	-.257*	-.431**	-0.039	-0.024	0.049
	Sig. (2-tailed)	0.002	0.000	0.013	0.097	0.001	0.001	0.000	0.000		0.970	0.000	0.293	0.178	0.042	0.142	0.020	0.000	0.727	0.832	0.660
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Number of traffic accidents driver involved in	Pearson Correlation	-0.084	.237*	-0.075	0.058	-0.124	0.071	-.224*	.274*	-0.004	1.000	0.174	.349**	-0.059	-.257*	0.133	.323**	-0.007	0.193	0.141	-0.100
	Sig. (2-tailed)	0.451	0.032	0.503	0.657	0.267	0.524	0.043	0.013	0.970		0.118	0.001	0.600	0.020	0.233	0.003	0.947	0.083	0.208	0.373
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Anxious(6 Levels Scale: 1=Not at all, 2=Very	Pearson Correlation	-.448**	0.155323	-.476**	-0.013	-.462**	.441**	.225*	-.305**	-.406**	0.174	1.000	.371**	0.1965133	-.351**	-0.035	.586**	.469**	-0.040	0.001	0.016
	Sig. (2-tailed)	0.000	0.164	0.000	0.920	0.000	0.000	0.042	0.005	0.000	0.118		0.001	0.077	0.001	0.752	0.000	0.000	0.724	0.994	0.889
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Reckless(6 Levels Scale: 1=Not at all, 2=Very	Pearson Correlation	.294**	-0.204302	0.047	.364**	0.2016703	0.138	-0.040	.319**	0.118	.349**	.371**	1.000	.511**	-.713**	-0.081	0.170	-0.162699	-0.031	0.004	-0.078
	Sig. (2-tailed)	0.007	0.066	0.674	0.004	0.069	0.216	0.720	0.003	0.293	0.001	0.001		0.000	0.000	0.467	0.128	0.144	0.785	0.970	0.485
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Angry(6 Levels Scale: 1=Not at all, 2=Very	Pearson Correlation	0.011	-.228*	-.365**	0.214	-0.037	-0.134	-.290**	.352**	0.150	-0.059	0.1965133	.511**	1.000	-.566**	-0.157	0.093	0.206	-0.117	-0.103	0.087
	Sig. (2-tailed)	0.922	0.039	0.001	0.098	0.743	0.232	0.008	0.001	0.178	0.600	0.077	0.000		0.000	0.159	0.406	0.064	0.297	0.355	0.437
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Patient(6 Levels Scale: 1=Not at all, 2=Very	Pearson Correlation	-.314**	.339**	0.098	-0.159	-.276*	0.077	.341**	-.563**	-.225*	-.257*	-.351**	-.713**	-.566**	1.000	0.1831445	-.255*	0.002	-0.004	-0.056	0.030
	Sig. (2-tailed)	0.004	0.002	0.381	0.220	0.012	0.493	0.002	0.000	0.042	0.020	0.001	0.000	0.000		0.100	0.021	0.985	0.974	0.617	0.791
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Nasa(TLX 20 levels, 6 categories : Mental demand,	Pearson Correlation	-0.019	-0.144	-0.042	-.291*	-0.012	0.084	0.084	-0.123	0.164	0.133	-0.035	-0.081	-0.157	0.1831445	1.000	-.281*	-.227*	0.093	-0.003	0.006
	Sig. (2-tailed)	0.868	0.196	0.709	0.023	0.915	0.455	0.454	0.271	0.142	0.233	0.752	0.467	0.159	0.100		0.011	0.040	0.408	0.981	0.958
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Usefulness of Stop&Go ACC system(5 Levels	Pearson Correlation	-.349**	.391**	-.376**	0.181	-.389**	-0.019	-0.134	0.130	-.257*	.323**	.586**	0.170	0.093	-.255*	-.281*	1.000	.673**	-0.040	0.009	-0.007
	Sig. (2-tailed)	0.001	0.000	0.001	0.162	0.000	0.867	0.231	0.243	0.020	0.003	0.000	0.128	0.406	0.021	0.011		0.000	0.719	0.933	0.947
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Satisfaction of Stop&Go ACC system(5	Pearson Correlation	-.585**	0.048	-.648**	-0.116	-.594**	-0.115659	0.013	-0.087	-.431**	-0.007	.469**	-0.162699	0.206	0.002	-.227*	.673**	1.000	-0.217	-0.146	0.187
	Sig. (2-tailed)	0.000	0.665	0.000	0.373	0.000	0.301	0.911	0.439	0.000	0.947	0.000	0.144	0.064	0.985	0.040	0.000		0.050	0.190	0.093
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
mean Target speed before transition(k	Pearson Correlation	-0.060949	.255*	0.045	-0.241	-0.036506	0.085	-0.103	-0.081	-0.039	0.193	-0.040	-0.031	-0.117	-0.004	0.093	-0.040	-0.217	1.000	.813**	-.512**
	Sig. (2-tailed)	0.586	0.021	0.689	0.061	0.745	0.448	0.357	0.472	0.727	0.083	0.724	0.785	0.297	0.974	0.408	0.719	0.050		0.000	0.000
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
mean Target speed after transition(km/h)	Pearson Correlation	0.042	0.2101446	0.153	-0.238	0.085	-0.053	-0.174	0.055	-0.024	0.141	0.001	0.004	-0.103	-0.056	-0.003	0.009	-0.146	.813**	1.000	-.505**
	Sig. (2-tailed)	0.706	0.058	0.171	0.064	0.450	0.638	0.118	0.624	0.832	0.208	0.994	0.970	0.355	0.617	0.981	0.933	0.190	0.000		0.000
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
DensityLevel(1=LOS AB, 2=LOS CD, 3=LOS EF)	Pearson Correlation	-0.023	-0.192	-0.124	0.168	-0.042	0.002	0.101	-0.010	0.049	-0.100	0.016	-0.078	0.087	0.030	0.006	-0.007	0.187	-.512**	-.505**	1.000
	Sig. (2-tailed)	0.834	0.083	0.267	0.197	0.709	0.984	0.365	0.929	0.660	0.373	0.889	0.485	0.437	0.791	0.958	0.947	0.093	0.000	0.000	
	N	82	82	82	61	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 6 Results of Pearson Correlation for all pairs of independent variables in control transition Active to Inactive (21)

Correlations[a]

		Age of driver	Gender of driver (1=Male, 2=Female)	Level of education of driver (6=MSc, 7=PhD)	Personal gross annual income(EUR) (14=20001-30000(option 4), 15=rest of options(option 7,8,9,11))	Keeping years of driving license	Drive on avg last year (7=Every day to 4 days a week(option 1,2), 8=3 days a week to less than once a month(option 3,4,5))	Drive on avg on the experimental route(A9-A99) (7=Not every day but at least more than once a month(option 2,3,4), 8=Less than once a month(option 5))	Km on avg last year(12=1-5000km(option 2,3), 13=5001=15000km(option 4,5), 14=20000-35000km(option 7,8))	Experience ACC (1=none, 2=medium, 3=high)	Number of traffic accidents driver involved in when driving a car in the last 3 years(8=zero(option 1), 9= rest of options(option 2,3))	Anxious(6 Levels Scale: 1=Not at all, 2=Very little, 3=Little, 4=Moderate, 5=Much, 6=Very much)	Reckless(6 Levels Scale: 1=Not at all, 2=Very little, 3=Little, 4=Moderate, 5=Much, 6=Very much)	Angry(6 Levels Scale: 1=Not at all, 2=Very little, 3=Little, 4=Moderate, 5=Much, 6=Very much)	Patient(6 Levels Scale: 1=Not at all, 2=Very little, 3=Little, 4=Moderate, 5=Much, 6=Very much)	Nasa(TLX 20 levels, 6 categories : Mental demand, Physical demand, Temporal demand, Performance, Effort, Frustration)	Usefulness of Stop&Go ACC system(5 Levels Scale: negative -2 1 0 1 2 positive)	Satisfaction of Stop&Go ACC system(5 Levels Scale: negative -2 1 0 1 2 positive)	mean Target speed before transition(km/h)	mean Target speed after transition(km/h)	DensityLevel(1=LOS AB, 2=LOS CD, 3=LOS EF)
Age of driver	Pearson Correlation	1.000	-.290**	.807**	.531**	.982**	-.335**	-0.114513	.412**	.299**	-0.163156	-.541**	0.134	-0.112	-0.141916	-0.071	-.473**	-.549**	-0.022	-0.034343	0.1146006
	Sig. (2-tailed)		0.001	0.000	0.000	0.000	0.000	0.215	0.000	0.001	0.076	0.000	0.146	0.225	0.124	0.441	0.000	0.000	0.811	0.711	0.215
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Gender of driver (1=Male, 2=Female)	Pearson Correlation	-.290**	1.000	-0.140	.409**	-.328**	.286**	0.026	-.226*	-.311**	.381**	0.157113	-.214*	-0.063	.309**	-0.065	.496**	0.069	0.159	0.177	-0.142
	Sig. (2-tailed)	0.001		0.128	0.000	0.000	0.002	0.780	0.013	0.001	0.000	0.088	0.020	0.495	0.001	0.480	0.000	0.457	0.084	0.054	0.125
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Level of education of driver (6=MSc, 7=PhD)	Pearson Correlation	.807**	-0.140	1.000	.375**	.801**	-0.133	0.155	0.130	.252**	-.185*	-.502**	-0.007	-.381**	.198*	-0.011	-.464**	-.598**	0.018	0.018	0.098
	Sig. (2-tailed)	0.000	0.128		0.000	0.000	0.148	0.093	0.158	0.006	0.044	0.000	0.936	0.000	0.031	0.908	0.000	0.000	0.843	0.845	0.287
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Personal gross annual income(EUR)	Pearson Correlation	.531**	.409**	.375**	1.000	.407**	-0.033	-0.095	.342**	-.214*	.313**	-.334**	0.086	0.135	0.076	-0.105	-0.023	-.374**	-0.075	-0.069	0.053
	Sig. (2-tailed)	0.000	0.000	0.000		0.000	0.750	0.350	0.001	0.034	0.002	0.001	0.398	0.185	0.458	0.303	0.820	0.000	0.466	0.500	0.607
	N	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98
Keeping years of driving license	Pearson Correlation	.982**	-.328**	.801**	.407**	1.000	-.346**	-0.163712	.398**	.317**	-.228*	-.479**	0.035	-0.132	-0.15256	-0.069	-.514**	-.554**	-0.042732	-0.056132	0.1544288
	Sig. (2-tailed)	0.000	0.000	0.000	0.000		0.000	0.075	0.000	0.000	0.013	0.000	0.703	0.151	0.098	0.458	0.000	0.000	0.644	0.544	0.094
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Drive on avg last year (7=Every day to 4	Pearson Correlation	-.335**	.286**	-0.133	-0.033	-.346**	1.000	.536**	-.524**	-0.148	0.081	0.152	0.020	-0.146635	0.062	0.129	-0.006	-0.163838	0.046	-0.005	0.001
	Sig. (2-tailed)	0.000	0.002	0.148	0.750	0.000		0.000	0.000	0.108	0.383	0.099	0.827	0.112	0.506	0.161	0.949	0.075	0.620	0.955	0.991
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Drive on avg on the experimental route(A9-A99)	Pearson Correlation	-0.114513	0.026	0.155	-0.095	-0.163712	.536**	1.000	-.742**	-.435**	-.267**	-0.132	-.203*	-.392**	.519**	0.175	-.181*	0.032	0.061	0.035	-0.096
	Sig. (2-tailed)	0.215	0.780	0.093	0.350	0.075	0.000		0.000	0.000	0.003	0.153	0.027	0.000	0.000	0.057	0.049	0.728	0.508	0.703	0.301
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Km on avg last year(12=1-5000km(option 2,3),	Pearson Correlation	.412**	-.226*	0.130	.342**	.398**	-.524**	-.742**	1.000	.495**	.369**	-.197*	.408**	.389**	-.600**	-.302**	0.077	-.190*	-0.081	-0.042	0.057
	Sig. (2-tailed)	0.000	0.013	0.158	0.001	0.000	0.000	0.000		0.000	0.000	0.032	0.000	0.000	0.000	0.001	0.408	0.038	0.381	0.651	0.541
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Experience ACC (1=none, 2=medium, 3=high)	Pearson Correlation	.299**	-.311**	.252**	-.214*	.317**	-0.148	-.435**	.495**	1.000	0.042	-.274**	.184*	0.073	-.261**	-0.007	-.190*	-.497**	-0.118	-0.126	.181*
	Sig. (2-tailed)	0.001	0.001	0.006	0.034	0.000	0.108	0.000	0.000		0.653	0.003	0.045	0.430	0.004	0.940	0.039	0.000	0.202	0.172	0.049
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Number of traffic accidents driver involved in	Pearson Correlation	-0.163156	.381**	-.185*	.313**	-.228*	0.081	-.267**	.369**	0.042	1.000	0.167	.348**	0.111	-.219*	0.158	.375**	-0.041	0.173	.193*	-0.101
	Sig. (2-tailed)	0.076	0.000	0.044	0.002	0.013	0.383	0.003	0.000	0.653		0.069	0.000	0.231	0.017	0.087	0.000	0.657	0.060	0.035	0.277
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Anxious(6 Levels Scale: 1=Not at all, 2=Very	Pearson Correlation	-.541**	0.157113	-.502**	-.334**	-.479**	0.152	-0.132	-.197*	-.274**	0.167	1.000	0.085	0.128	-.328**	0.109	.562**	.553**	-0.013	0.013	-0.019
	Sig. (2-tailed)	0.000	0.088	0.000	0.001	0.000	0.099	0.153	0.032	0.003	0.069		0.359	0.164	0.000	0.238	0.000	0.000	0.886	0.890	0.835
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Reckless(6 Levels Scale: 1=Not at all, 2=Very	Pearson Correlation	0.134	-.214*	-0.007	0.086	0.035	0.020	-.203*	.408**	.184*	.348**	0.085	1.000	.439**	-.577**	-0.083	0.084	-0.077762	0.041	0.044	-0.089
	Sig. (2-tailed)	0.146	0.020	0.936	0.398	0.703	0.827	0.027	0.000	0.045	0.000	0.359		0.000	0.000	0.371	0.361	0.401	0.657	0.633	0.337
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Angry(6 Levels Scale: 1=Not at all, 2=Very	Pearson Correlation	-0.112	-0.063	-.381**	0.135	-0.132	-0.146635	-.392**	.389**	0.073	0.111	0.128	.439**	1.000	-.520**	-0.099	0.096	0.164	-0.091	-0.088	-0.018
	Sig. (2-tailed)	0.225	0.495	0.000	0.185	0.151	0.112	0.000	0.000	0.430	0.231	0.164	0.000		0.000	0.285	0.298	0.075	0.326	0.339	0.847
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Patient(6 Levels Scale: 1=Not at all, 2=Very	Pearson Correlation	-0.141916	.309**	.198*	0.076	-0.15256	0.062	.519**	-.600**	-.261**	-.219*	-.328**	-.577**	-.520**	1.000	.222*	-.200*	-0.070	0.022	0.019	-0.002
	Sig. (2-tailed)	0.124	0.001	0.031	0.458	0.098	0.506	0.000	0.000	0.004	0.017	0.000	0.000	0.000		0.015	0.029	0.452	0.811	0.835	0.979
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Nasa(TLX 20 levels, 6 categories : Mental demand,	Pearson Correlation	-0.071	-0.065	-0.011	-0.105	-0.069	0.129	0.175	-.302**	-0.007	0.158	0.109	-0.083	-0.099	.222*	1.000	-.248**	-0.097	-0.020	-0.041	0.060
	Sig. (2-tailed)	0.441	0.480	0.908	0.303	0.458	0.161	0.057	0.001	0.940	0.087	0.238	0.371	0.285	0.015		0.007	0.296	0.833	0.657	0.520
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Usefulness of Stop&Go ACC system(5 Levels	Pearson Correlation	-.473**	.496**	-.464**	-0.023	-.514**	-0.006	-.181*	0.077	-.190*	.342**	.562**	0.084	0.096	-.200*	-.248**	1.000	.654**	0.037	0.098	-.187*
	Sig. (2-tailed)	0.000	0.000	0.000	0.820	0.000	0.949	0.049	0.408	0.039	0.000	0.000	0.361	0.298	0.029	0.007		0.000	0.690	0.291	0.042
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Satisfaction of Stop&Go ACC system(5	Pearson Correlation	-.549**	0.069	-.598**	-.374**	-.554**	-0.163838	0.032	-.190*	-.497**	-0.041	.553**	-0.077762	0.164	-0.070	-0.097	.654**	1.000	-0.056	-0.011	-0.103
	Sig. (2-tailed)	0.000	0.457	0.000	0.000	0.000	0.075	0.728	0.038	0.000	0.657	0.000	0.401	0.075	0.452	0.296	0.000		0.548	0.905	0.266
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
mean Target speed before transition(k	Pearson Correlation	-0.022	0.159	0.018	-0.075	-0.042732	0.046	0.061	-0.081	-0.118	0.173	-0.013	0.041	-0.091	0.022	-0.020	0.037	-0.056	1.000	.979**	-.189*
	Sig. (2-tailed)	0.811	0.084	0.843	0.466	0.644	0.620	0.508	0.381	0.202	0.060	0.886	0.657	0.326	0.811	0.833	0.690	0.548		0.000	0.040
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
mean Target speed after transition(km/h)	Pearson Correlation	-0.034343	0.177	0.018	-0.069	-0.056132	-0.005	0.035	-0.042	-0.126	.193*	0.013	0.044	-0.088	0.019	-0.041	0.098	-0.011	.979**	1.000	-.194*
	Sig. (2-tailed)	0.711	0.054	0.845	0.500	0.544	0.955	0.703	0.651	0.172	0.035	0.890	0.633	0.339	0.835	0.657	0.291	0.905	0.000		0.035
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
DensityLevel(1=LOS AB, 2=LOS CD, 3=LOS EF)	Pearson Correlation	0.1146006	-0.142	0.098	0.053	0.1544288	0.001	-0.096	0.057	.181*	-0.101	-0.019	-0.089	-0.018	-0.002	0.060	-.187*	-0.103	-.189*	-.194*	1.000
	Sig. (2-tailed)	0.215	0.125	0.287	0.607	0.094	0.991	0.301	0.541	0.049	0.277	0.835	0.337	0.847	0.979	0.520	0.042	0.266	0.040	0.035	
	N	119	119	119	98	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

5. Statistical Model and Results

Multiple control transitions are available for each driver (panel data). To capture this panel dimension and analyze the effect of within-subjects variables (e.g., ACC system settings and traffic condition) and between-subjects variables (e.g., driver characteristics) on driving behavior characteristics, a linear mixed-effect model containing fixed and random effects was estimated for each type of control transition. The general formula of the mixed linear model is specified as follows for observation *i*, driver *j* and transition type *t*:

$$Y_{ij}^{t} = \beta_0^t + \left(\sum_k \beta_k^t X_k^t\right) + \gamma_j^t Z_j^t + \epsilon_{ij}^t$$

Where

Y_{ij}^t is the dependent variable (i.e., difference between driving behavior characteristics in the interval 10 s after and in the 10s before the control transition);
β_0^t is the fixed intercept;
X_k^t is an independent variable k as fixed effect (i.e., driver characteristics, ACC system settings and traffic condition);
β_k^t is a parameter associated with X_k^t;
$Z_j^t \sim N(0,1)$ is an individual-specific error term as random effect
γ_j^t is a parameter associated $Z_j^t \sim N(0,1)$;
ϵ_{ij}^t is the observation-specific error term.

The impact of nominal, ordinal and scale independent variables (main effects and interactions between independent variables) on each dependent variable are estimated as fixed effects. Since repeated observations of multiple time intervals (panel data) are available for each driver, an individual-specific error term is estimated as random effect to capture this panel dimension. The individual-specific error term captures unobserved preferences which affect to each dependent variable made by individual over time.

The model was specified using forward stepwise model selection. At first step, the model was estimated including only the fixed intercept. Then an independent variable was entered as a fixed effect. Each one-variable model was tested. The first variable included in the model specification was the one which had the most significant impact on the dependent variable determined by p-value (significance level was 0.05). In the second step, each two-variable model including the first selected variable and the fixed intercept was tested. The model which included the most significant variable determined by p-value was selected and the second variable of it was included in the model specification. However, after the second variable was included in the model and the first variable became not significant, the variable which was expected to have less meaning on dependent variable was removed from the model. In this case, the second step was repeated to select the second variable. In addition, since ordinary maximum likelihood estimation (ML) was used in the model, the Bayesian Information criterion (BIC) was used as penalized likelihood method to check the balance between complexity and good fit of model in each step. Variables which resulted to have a non-significant impact on the dependent variable (improvement in BIC indicators smaller than 2 units) were removed from the specification. Moreover, to consider the multicollinearity between variables, the Variance Inflation Factor (VIF) of each variable was calculated to detect multicollinearity in each step. The independent variables which had VIF value exceeding 5 (high multicollinearity) were not considered in model selection [18]. The same steps are repeated until no adding variable was significant. Finally, the model with random effect on fixed intercept was tested and the random effect was included if it was statistically significant.

The mixed linear model of each dependent variable was estimated in each control transition. The dependent variables which were significantly related to the independent variables in Table 3 and 4 were used for estimating the models. The estimation results of mixed linear model for the control transition from Inactive to Active (12) are shown in Table 7 and 8 and those for the control transition from Active to Inactive (21) are shown in Table 9, 10 and 11. Each table includes descriptive statistics, estimates of fixed effects and BIC value. Figure 1, 2 and 3 illustrates impacts of the independent variable on the dependent variable in these two control transitions. In these figures, the value of the variable of interest was changed while other variables were fixed as mean value. The estimates of random effects were not included in any tables since the random effect in fixed intercept was excluded from all the models due to no significance.

The results shown in Table 7 indicate that age of drivers had significant impact on the difference between mean distance headways after and before activation. In other words, older drivers had larger difference of mean distance headways than younger drivers. Figure 1 illustrates that, drivers younger than 30 had shorter distance headways while drivers older than 30 had longer distance headways after activation. Table 8 shows that the impact of average traffic density levels on the difference between mean speeds after and before activation was significant. Drivers decreased their speed after activation in each traffic condition. The speed decreased significantly more in light and medium traffic conditions than in dense traffic conditions, whereas the degree of speed reduction after activation in light traffic condition had a relatively small difference to the one in medium traffic condition.

Table 9 indicates that the experience of one or more car accidents significantly affect the difference between mean distance headways after and before deactivation. Drivers who experienced car accidents decreased the distance headways after deactivation significantly more than drivers who have never experienced them. Table 10 shows significant impact of average traffic density levels on the difference between mean speeds after and before deactivation. The results in Table 10 are similar to the results in Table 8. Drivers decreased speed after deactivation in each density level and they decreased speeds more in lower density level. As shown in Table 11, the ratings of usefulness of ACC and the mean self-reported workload had a significant impact on the difference between mean relative speeds after and before deactivation. In Figure 2, drivers with degree of usefulness lower than 0.9 had lower relative speed after the transition while drivers with higher scores had higher relative speed after deactivation. It means that the drivers who rated ACC as to be useful (higher than 0.9) decreased their speed more than the decrease in speed of their leaders after deactivation. Figure 3 can be interpreted similarly: drivers with mean workload lower than 28.0 had lower relative speed while drivers with higher workload had higher relative speed after deactivation. It implies that the drivers who experienced higher workload (higher than 28.0) decreased their speed more than their leaders did after deactivation.

Table 7 Estimation results of the mixed linear model (Control transition Inactive to Active (12), dependvent variable: mDHWdif, independent variable: Age)

Descriptive Statistics[a]			
	Count	Mean	Std.
mDHWdif	73	1.761	12.124
Age	73	32.356	7.413
Estimates of Fixed Effects[a,b]			
	Estimate	Std. Error	Sig.
Intercept	-18.988	5.843	0.002
Age	0.641	0.176	0.001
a. 12 = Inactive to Active			
b. Dependent Variable: mDHWdif			
Information Criteria[a,b]			
BIC	571.142		

Figure 1 Impact of Age on mDHWdif

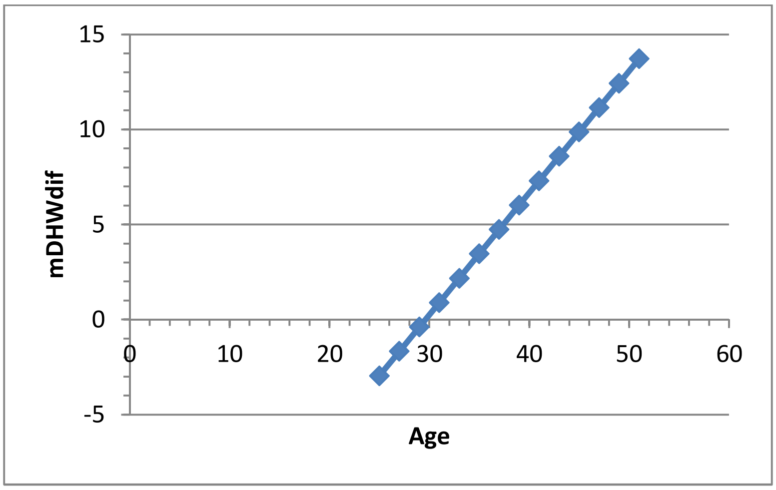


Table 8 Estimation results of the mixed linear model (Control transition Inactive to Active (12), dependent variable: mSpeeddif, independent variable: DensityLevel)

Descriptive Statistics[a]			
	Count	Mean	Std.
LOS AB	19	-2.445	2.718
LOS CD	24	-2.143	2.510
LOS EF	39	-0.507	2.907
Total	82	-1.435	2.863
Estimates of Fixed Effects[a,b]			
Parameter	Estimate	Std. Error	Sig.
Intercept	-0.507	0.433	0.245
LOS AB	-1.938	0.756	0.012
LOS CD	-1.637	0.701	0.022
LOS EF	0[c]	0.000	
a. 12 = Inactive to Active			
b. Dependent Variable: mSpeeddif			
c. This parameter is set to zero because it is redundant.			
DensityLevel (LOS AB, LOS CD, LOS EF)			
Information Criteria[a,b]			
BIC	413.397		

Table 9 Estimation results of the mixed linear model (Control transition Active to Inactive (21), dependent variable: mDHWdif, independent variable: Accident_divided)

Descriptive Statistics[a]			
	Count	Mean	Std.
No car accidents experienced	87	-7.479	17.580
One or two car accidents experienced	18	-23.289	26.158
Total	105	-10.189	20.081
Estimates of Fixed Effects[a,b]			
	Estimate	Std. Error	Sig.
Intercept	-23.289	4.496	0.000
No car accidents experienced	15.810	4.940	0.002
One or two car accidents experienced	0[c]	0.000	
a. 21 = Active to Inactive			
b. Dependent Variable: mDHWdif			
c. This parameter is set to zero because it is redundant.			
Accident_divided (zero accident experienced, one or two accidents experienced)			
Information Criteria[a,b]			
BIC	931.116		

Table 10 Estimation results of the mixed linear model (Control transition Active to Inactive (21), dependent variable: mSpeeddif, independent variable: DensityLevel)

Descriptive Statistics[a]			
	Count	Mean	Std.
LOS AB	36	-4.4367	3.77922
LOS CD	50	-3.6750	3.64900
LOS EF	33	-2.1103	2.71293
Total	119	-3.4715	3.54702
Estimates of Fixed Effects[a,b]			
Parameter	Estimate	Std. Error	Sig.
Intercept	-2.110303	0.594485	0.001
LOS AB	-2.326364	0.823027	0.006
LOS CD	-1.564697	0.765941	0.043
LOS EF	0[c]	0	
a. 21 = Active to Inactive			
b. Dependent Variable: mSpeeddif			
c. This parameter is set to zero because it is redundant.			
DensityLevel(1=LOS AB, 2=LOS CD, 3=LOS EF)			
Information Criteria[a,b]			
BIC	649.134		

Table 11 Estimation results of the mixed linear model (Control transition Active to Inactive (21), dependent variable: mDVdif, independent variable: Useful_ACC, NASATLX)

Descriptive Statistics[a]			
	Count	Mean	Std.
mDVdif	105	0.1550	2.86563
Useful_ACC	105	0.9505	0.43746
NASATLX	105	31.5238	12.26459
Estimates of Fixed Effects[a,b]			
Parameter	Estimate	Std. Error	Sig.
Intercept	-3.713389	1.045009	0.001
Useful_ACC	2.610824	0.611139	0.000
NASATLX	0.043995	0.021798	0.046
a. 21 = Active to Inactive			
b. Dependent Variable: mDVdif			
BIC	519.172		

Figure 2 Impact of Useful_ACC on mDVdif

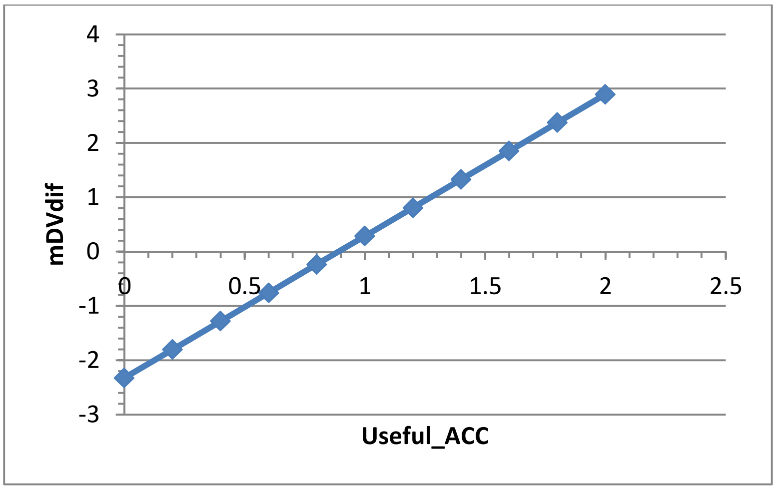
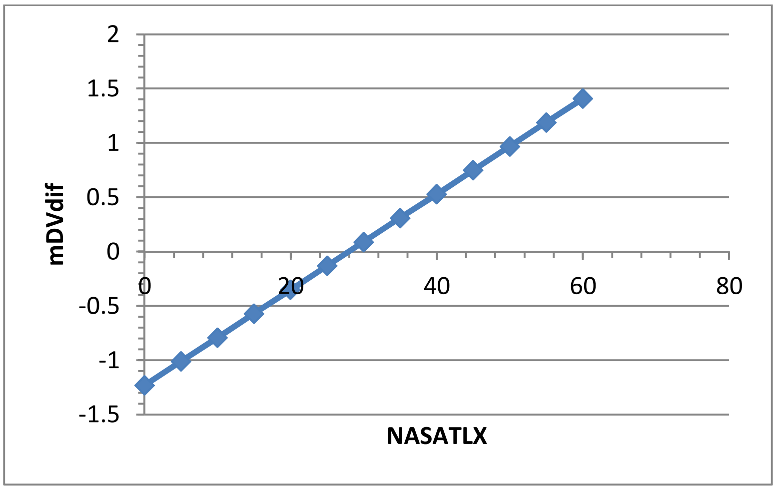


Figure 3 Impact of NASATLX on mDVdif



6. DISCUSSION AND CONCLUSION

This paper was aimed to identify the factors which significantly influence driving behavior characteristics in control transitions between full-range ACC and manual driving. Only the control transitions from inactive to active and from active to inactive were considered. Mixed linear models were estimated using the panel data collected in the on-road experiment, the questionnaires by 23 participants, and traffic data from the loop detectors.

During control transitions from inactive to active, the model results shows that age of drivers and traffic density levels had significant influence on driving behavior. Younger drivers had reduced their distance headways after activation, which could mean that younger drivers prefer to activate ACC with smaller headway settings compared to manual driving. In both control transitions (i.e. from active to inactive and from inactive to active), drivers decreased their speeds regardless of traffic density level and they decreased them less in denser traffic conditions. Possibly, drivers tend to drive more cautiously in control transitions that make their speeds lower and this tendency might lessen in denser traffic conditions in which the average speed of vehicles is already relatively low. In the control transition from active to inactive, experience of traffic accidents, degrees of usefulness of ACC and self-reported workload were also the factors which significantly affected driving behavior. Drivers who experienced car accidents reduced their distance headways after deactivation more than drivers with no experience of car accidents. This result could suggest several interpretations. Drivers who have never experienced traffic accidents might be more conservative and keep longer distance headways when resuming manual control. In a different point of view, drivers who experienced traffic accidents might drive more risky and keep shorter distance headways after deactivation and they could have shorter distance headways in potential safety-critical situations. Drivers who gave higher score to usefulness of ACC decreased their speed after deactivation more than their leaders did and same results were shown from drivers who experienced higher workload. These results also could be interpreted in several ways. Drivers who rated ACC as to be useful might keep higher speed before deactivation to maximize the system utilization and drivers with higher workload might keep lower speed after deactivation to minimize their workload during manual driving. These interpretations enhance the understanding of how driver characteristics or traffic conditions change the driving behavior in these control transitions which affect traffic efficiency and safety.

Although the estimated results of linear mixed model gave interesting conclusions, there are some limitations in this study. As the sample size of data for each independent variable was relatively small compared to the number of dependent variables, maximum three different dependent variables were considered in each model to get valid estimation. Because of this limitation, the model might not capture the effects of other factors which were not included as independent variables. Moreover, in case of independent variables with several categories, number of participants for certain category was too small compared to those for other categories, which might bias the estimated results of the model. For these reasons, it is recommended that future studies use the data collected by road-experiment with more participants in longer period to get abundant data for getting more validated results. In addition, future work is needed to analyze the significant factors on driving behavior in different types of control transitions which are not considered in this study (i.e. control transitions from state 2 to 3, 3 to 2, 1 to 3, and 3 to 1).

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