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Comparing aging and automaticity: A study on the effects of secondary tasks on driving ability.

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Abstract

The purpose of this study was to determine which factor-age or automaticity of driving skill has a larger effect on the change of driving ability caused by secondary tasks. The experiment was conducted with a group of young drivers in their 20s (25.3 ± 0.9 y) and taxi drivers in their 50s (57.5 ± 5.8 y) with driving experience 2 y (2.2 ± 1.9 y) and more than 20 y (26.1 ± 5.7 y), respectively. The test was composed of a rest phase (3 min), a control phase (1 min), and a task phase (1 min). The tasks of sending text messages or searching navigation aids were selected as the secondary tasks. During the control and task phases, subjects were asked to drive at a speed of 90 km/h and a following-distance of 30 m from the automobile in front. The increase in workload was not significantly different between the two age groups. However, the decrease in driving ability was steeper for taxi drivers than for the young drivers. This show that aging has a greater effect on driving ability than automaticity in driving skill does when this ability is loaded with a simultaneous secondary task.

Keywords: Aging, Automaticity, Secondary task, Driving ability.

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Introduction

Recently, drivers have begun using navigation aids, cell phones, and other electronic devices while driving, to get the information necessary for driving or to conduct the work necessary for daily life. These electronic devices may be viewed positively because they contribute to the convenience of drivers and to handling the work of driving in some respects. However, driving demands concentrated attention. Therefore, if electronic devices are used during driving, drivers face more information processing, thus an increased workload [1]. The decreased driving ability caused by the use of electronic devices during driving can cause traffic accidents [2-5].

Numerous studies have attempted to elucidate the effect of secondary tasks, such as driver's use of electronic devices in the vehicle, on driving ability. The use of cell phones or navigation aids during driving has increased the following-distance and the variability of speed and decreased the average speed of automobiles on the road [6-8]. In addition, the use of these devices increases the workload of drivers and therefore their tension or stress levels. As a result, the sympathetic nervous system is activated, thus increasing the heart rate and Skin Conductance Level (SCL) [9,10]. Most of these prior studies were conducted with young people who had only short driving experience. Recently, a few studies have been done on middle-aged drivers who had considerable driving skills and experience [11]. It was found that even commercial motor drivers with more than 20 y of experience suffered a decrease in driving ability when they used cell phones or navigation aids when driving [11].

In general, the older a person becomes, the more reduced his physical and cognitive ability becomes [12-15]. If a person has been in a specialized profession long, he acquires automaticity in the skills of the work [16]. Studies have been conducted on the effect of the implementation of secondary tasks on driving ability separately for a group of young people and a group of middle-aged people. However, there have been no studies conducted with these two groups at the same time and considering both aging effects and levels of automaticity in driving skill.

This study was conducted with a group of experienced drivers in their 50s (commercial motor drivers with experience of 20 y or more) who were expected to have automaticity in driving skills, and a group of young drivers in their 20s who had a relatively short period of driving experience (about 2 y) but were expected to have good physical and cognitive capabilities, to determine which factor, aging effects or automaticity in driving skill, has a larger effect on the change of driving ability caused by secondary task performance.

We measured driving ability by using average following-distance and velocity deviation, which have been widely adopted in prior studies. In addition, we monitored the subjects' workload by measuring SCL. The secondary tasks of Sending a Text Message (STM) using a cell phone and searching for a destination using a Navigation System (SN) were selected because they had been used in many prior studies.

Methods

Subjects

10 male college students with an average age of 25.3 ± 0.9 y and driving experience of 2.2 ± 1.9 y, and 12 male taxi drivers with an average age of 57.5 ± 5.8 y and driving experience of 26.1 ± 5.7 y were selected for the study. The group of young driver and taxi driver recruited students who were attending the university and regional taxi company respectively. At this time, items such as age, sex, visual acuity, driving experience, driving time per week, vehicle type, central nervous system related surgery or disability were included in the applicant's supporting documents and the subject were selected based on the documents. Also, they were asked to abstain from smoking, alcohol, coffee, or other external factors, which can affect subjects' physiological status and driving ability. The contents of the test were explained to the subjects prior to the start of the test so that they could fully understand them. The test started only when the subjects were accustomed to driving in the simulator as indicated by an absence of accidents or wandering from the correct lane. In order to define the level of automaticity between the two groups, three stages of cognitive, associative, and autonomous phases were set [17], and subjects in the cognitive phase during preliminary experiments were excluded from main experiment. The experiments were carried out after informed written consent was obtained. The protocol for the research project has been approved by Institutional Review Committee of Konkuk University within which the work was undertaken and that it conforms to the provisions of the Declaration of Helsinki.

Driving simulator

The automobile simulator (GDS-300S, Gridspace Co.) used for this test was a driving simulator installed in the laboratory. The subject obtains the visual information required for driving through three monitors (32" LCD monitors) showing the front and both sides of the vehicle (Figure 1). The automobile model was a 'Click' manufactured by HYUNDAI motor company in South Korea and its driving devices (such as steering wheel, accelerator pedal, brake pedal, parking brake, turn signal lever, emergency light, wiper lever, head light lever, gear lever, safety belt, etc.) and display indicators (such as turn signal light, speedometer, RPM meter, temperature gauge, fuel gauge, and warning lamps) were the same as in the real automobile. Motor-driven power steering was imitated for the steering wheel input.

Experimental design

As shown in Figure 1, the test was composed of a rest phase (3 min) in which no driving was performed, a control phase (1 min) in which only driving was performed, and a task phase (1 min) in which either driving only was performed or a secondary task was performed during driving (driving+STM or driving+SN). During the control and task phases, subjects were asked to drive in simulation on the second lane of a three-lane road at a speed of 90 km/h and a following-distance of 30 m from the automobile in front. During this time, data on the speed and the following-distance were displayed on the bottom of the simulator screen as feedback to the subject.

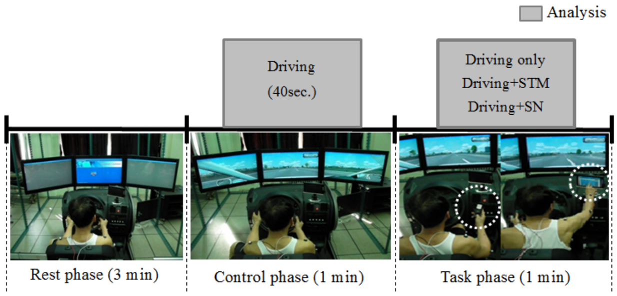

***Figure** 1. Experimental design and analysis blocks. STM: Sending Text Message; SN: Searching Navigation.*

The tasks of Sending Text Messages (STM) or Searching Navigation aids (SN) were selected as the secondary tasks. The STM task involved the subjects sending a message dictated by the experimenter. Since young driver can be more familiar with electronic devices than older driver, this may cause difference in behavioral performance. In order to control these factors, preliminary experiments for selecting sentences to be used in the secondary task were conducted for 5 people in their 20s and 5 people in their 50s. We selected sentences that showed exact words of Sending Text Message (STM) and Searching Navigation (SN) with no typo error within 1 minute and used for this in experiment. The message was composed of simple sentences that could be transmitted during driving (e.g., "I will call you back later."). The task of SN was to search for the name of a building dictated by the experimenter (e.g., "Seoul Campus, Konkuk University") using the navigation system (STN-7600D, NOVA electronic Co.) provided by the research team. These sentences were simple and composed up with Korean words that are familiar to most participants. Searching for the building using an acronym was not allowed, and all subjects were instructed to use the same method for their search. The subjects were given sufficient practice time (30 min) to become accustomed to the navigation system. As shown in Figure 1, the cell phone was located in a place where the driver could easily access it and the navigation aid was affixed to the top right of the dashboard.

All subjects were asked to perform all three tasks-driving only, driving+STM, and driving+SN. The testing order was counterbalanced, and a rest time of 30 min between tasks was allowed to prevent simulator sickness.

Skin conductance level

Using the MP100 and Acknowledge version 3.8.1 (Biopac Systems, Inc., Goleta, CA, USA), we measured the skin conductance level (SCL) at a 50 Hz sampling rate in all phases of the test. The electrodes were attached to the second joint of the middle and index fingers of the left hand. We ignored SCL data from the first and last 10 s of the control and task phases to define a zone of 40 s in the middle of the phase, and the average value of SCL in this zone was calculated for each phase individually (Fig. 1). We used Equation 1 to calculate the relative change in SCL in the task phase compared to the control phase.

Relative change in SCL (%)=(SCL_{Task}-$SCL_{Control}$)/$SCL_{Control}$ × *100* → (1)

$SCL_{Control}$=Average SCL for 40 s in control phase

SCL_{Task}=Average SCL for 40 s in task phase

Average following-distance and velocity deviation

The data on following-distance between the subject's automobile and the automobile in front, and the data on the speed of the subject's automobile, were acquired from the driving simulator. To determine how well the subject maintained a distance of 30 m and a speed of 90 km/h while driving, we designated the 40 s of the task phase remaining after removing the starting and ending ten-second periods as the data collection period for calculating the average following-distance and velocity deviation. Velocity deviation was calculated using Equation 2.

Velocity deviation (%)=(Designated speed-Actual running speed)/(Designated speed) × 100 → (2)

Statistical treatment

A repeated-measures ANOVA, calculated by PASW ver. 18.0, was used to detect significant effects of task (driving only, driving+STM, and driving+SN) and group (age=20s and age=50s) on the relative change in SCL, the average following-distance, and the velocity deviation. Significance was set at $p<0.05$.

Results

The relative change in SCL across tasks and groups is shown in Figure 2a. The relative change in SCL is significantly impacted by task ($p<0.001$) but not by group (Table 1). Bonferroni a posteriori tests show significant differences between driving only and driving+STM ($p=0.001$) and between driving only and driving+SN ($p=0.002$). This means that the presence of a secondary task causes activation of the sympathetic nerves. There was no significant difference between driving+STM and driving+SN.

The average following-distance across tasks and groups is shown in Figure 2b. The average following-distance was significant for task (p 0<0.001) and group ($p=0.036$) (Table 1). Bonferroni a posteriori tests showed significant differences between driving only and driving+STM ($p<0.001$) and between driving only and driving+SN ($p=0.002$). This means that the average following-distance increased when a secondary task was present, and that a greater increase is shown in the group of people in their 50s than by the group of people in their 20s. However, no significant difference was found between driving+STM and driving+SN.

The average velocity deviation across tasks and groups is shown in Figure 2c. There was a significant difference in velocity deviation by task ($p<0.001$) and group ($p=0.025$) (Table 1). Bonferroni a posteriori tests showed that there were significant differences between driving only and driving+STM ($p=0.002$) and between driving only and driving+SN ($p=0.001$). This means that the velocity deviation increases when the secondary task is present, and that a greater increase is shown in the group of people in their 50s than by the group of people in their 20s. However, no significant difference was found between driving+STM and driving+SN.

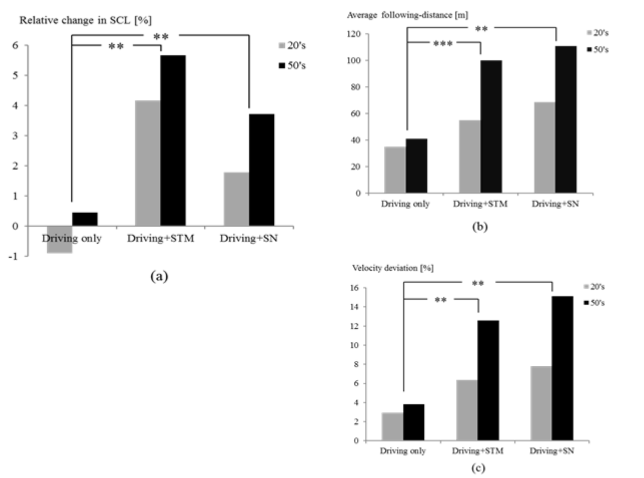

Figure 2. *(a) The relative change in SCL, (b) average following-distance, and (c) velocity deviation across tasks (driving only, driving +STM, and driving+SN) and age groups (age=20s and age=50s). STM: Sending a Text Message; SN: Searching a Navigation Aid;* $^{**}p<0.01$; $^{***}p<0.001$.

Table 1. *The relative changes in SCL, average following-distance, and velocity deviation across tasks (driving only, driving+sending a text message, and driving+searching a navigation aid) and groups (age=20s and age=50s).*

	Source	Type III sum of squares	df	Mean square	F	Sig.
Relative change in SCL	Task	344.696	2	172.348	10.256	0
	group	49.319	1	49.319	1.987	0.171
	Task × group	1.112	2	0.556	0.033	0.967

Average following- distance	Task	32039.39	2	16019.7	13.964	0
	Group	15816.7	1	15816.7	5.037	0.036
	Task × Group	5251.042	2	2625.521	2.289	0.115
Velocity deviation	Task	768.856	2	384.428	10.819	0
	Group	379.236	1	379.236	5.868	0.025
	Task × Group	129.949	2	64.974	1.829	0.174

Discussion

The objective of this study was to determine which factor-aging effects or level of automaticity in driving skill-has the greater effect on the changes in driving ability caused by secondary tasks. This study was conducted with a group of young drivers in their 20s with driving experience of about 2 y and a group of taxi drivers in their 50s with driving experience of more than 20 y.

For both groups, the implementation of a secondary task during driving caused additional driver workload, causing a positive relative change in SCL compared to the driving only case. However, there was no difference between the two groups in terms of the size of this change. This means that simultaneous driving and implementation of secondary work increased the workload by the same amount in the two groups. The increases in the workload led to impaired driving ability, as inferred from the fact that for both groups, the implementation of the secondary task increased the average following-distance and velocity deviation. These results are consistent with those of prior studies. [6,7,9-11,18]. However, the decrease in driving ability was steeper for drivers in their 50s than for those in their 20s. Almost the same results were obtained for two different tasks (sending a text message versus searching a navigation aid), meaning that there was no difference in the amount of driver impairment due to the type of secondary task.

It is known that when there are dual tasks to be implemented and one of the tasks is overlearned to the stage of automaticity, the person can perform the dual task reasonably well [16]. Therefore, our research team anticipated that even when there is an aging effect, the taxi drivers in their 50s would show less decrease in driving ability than those in their 20s, or the same decrease, because they have achieved sufficient automaticity in their driving skill to cancel the effect of the secondary task. Thus, we recruited an experienced taxi drivers with the expectation who showed better automaticity of driving skills and less distributed when gave the secondary task during the experiments. It is predicted that experienced drivers will have a high level of automaticity in driving. Therefore we hypothesis that experienced taxi drivers did not changed driving skill and performances while driving under divided attention. However, it was not enough to overcome the secondary task. The results of our study showed that the simultaneous performance of driving and the secondary task increased the workload to the same level in both groups, and also the level of automaticity was the same after preliminary experiment and after the main experiment. These results can be confirmed from the data of the SCL parameter. From the results, automaticity did not have a significant effect on driving performance. Instead, the aging effect was dominant, making the taxi drivers in their 50s more adversely affected in measures of driving ability, although workload was not significantly different between two age groups, the driving ability such as average following-distance and velocity deviation were decreased more steeper for the 50s than for the 20s. It is generally known that, as a person gets older, their physical and cognitive capabilities fade along with distance detection ability and response speed [12-15]. Notably, it was reported that there is a significant decrease in abilities such as speed prediction, attention shift, attention distribution, and distance awareness-which are highly related to driving performance-when people reach their 50s [19]. Therefore, the results of this study show that aging has a greater effect on driving ability than automaticity in driving skill does when this ability is loaded with a simultaneous secondary task.

In conclusion, the comparison between young drivers in their 20s having short driving experience and taxi drivers in their 50s with long driving experience showed that the reduction in driving ability caused by the performance of a secondary task was more affected by the aging effect than by the level of automaticity in driving skill. Additional in-depth studies on the relation between aging and automaticity are therefore recommended, but based on groups among which age and driving experience vary independently.

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Declaration of Conflicting Interests

The authors declare that there is no conflict of interest.

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