TRAFFIC SAFETY ANALYSIS IN UNDERGROUND URBAN EXPRESSWAYS USING DRIVING SIMULATION SYSTEM: MOVIC-T4

Student Number: 03M16208 Name: Takashi MAHARA Supervisor: Tetsuo YAI

MOVIC－T4 を活用した都市内地下道路の走行安全性分析

馬原 崇史

本研究では，新たに開発を行った小型可動式ドライビングシミュレーションシステム MOVIC-T4 を活用し，都市内地下道路の走行安全性分析を行った．まず，MOVIC-T4 による走行実験データの再現性検討を，実道走行データとの比較により行った．安全性分析では，周辺交通流条件が追従走行時の潜在的危険性に与える影響を把握した後，走行途中に事故車両が発生した状況での危険性を分析した．さらに前方停止車両の存在を伝える情報提供システムを模擬し，その安全性向上に対する効果を分析した．

1 Introduction

In recent years, underground construction is often considered during planning for new expressways in high-density urban areas. This is due to the lack of space for construction, the negative impacts on surrounding environment, and division of the community neighborhoods. However, in tunnels one often drives under high mental load due to low visibility and spatial pressure (1). As a result, the risk of an accident can be very high. In addition, due to the lack of variation in scenery or visual stimulus, fewer complex sensory perceptions are processed by the driver's brain in a tunnel. Consequently, the driver's attention level can deteriorate (2, 3). In urban expressways, there may be many conflicts with other vehicles as a result of high traffic volume and the existence of merging or diverging sections. Therefore, in an underground urban expressway, drivers are expected to face even higher risks under the combined pressure of driving inside a tunnel, and driving in an urban expressway. Due to these safety concerns, mitigation countermeasures need to be considered. Because there are no long urban expressway tunnels in existence yet, a driving simulation system that can reproduce any kind of virtual roadway is necessary.

The previous study (4) analyzed the deterioration of awareness level as the first approach to a traffic safety analysis in underground urban expressways using a fixed-base driving simulator which couldn't duplicate the acceleration cueing while driving. The results from the simulator experiments showed that driver's awareness level could deteriorate especially at basic segments between merging/diverging sections. This implies that drivers could enter the merging section at a low awareness level. However there are still problems. One is that the simulator used in the previous study didn't have a motion-base to duplicate the acceleration cueing which can affect the driver's awareness level significantly. The fixed-base simulator might induce the deterioration of awareness level more easily. Another one is regarding the index to evaluate the driver's awareness level. The previous study used the driver's blinking frequency to evaluate the awareness level which is said to correlate with the awareness level. But its time-resolution is low (e.g. numbers per one minute), and also the other undesirable factors might affect the blinking frequency. And the experimental traffic conditions were relatively monotonous due to low density of surrounding traffic and no merging/diverging traffic. Therefore the further study is needed using a more realistic simulator and more reliable index to evaluate the driver's awareness level, and experiments also need to be conducted under more complicated traffic conditions.

This study applied the motion-base driving simulation system: MOVIC-T4 (MOving VIrtual Cockpit by Tokyo Tech & Trion for Tokyo highways) to traffic safety analysis in underground urban expressways which was newly developed (5). First, the validation

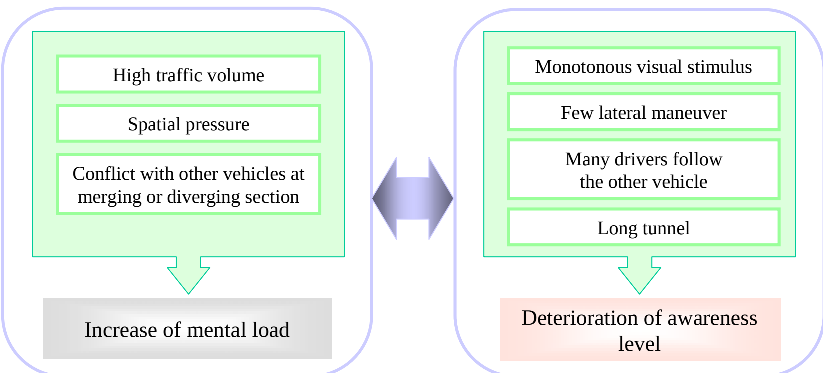


Fig. 1-1 Traffic accident risks in underground urban expressway

of MOVIC-T4 using field driving data was conducted for showing that MOVIC-T4 is eliciting similar responses as the normal real life situation. The field driving experiments were conducted at Aqualine tunnel and the same experiments were also conducted in MOVIC-T4. After validating the simulator driving data, the simulator experiments were conducted which aimed to analyze the potential risk in ordinary driving and to analyze the risk under more accidental situation such as the existence of accident vehicle ahead. Lastly the simple information system was demonstrated under the abovementioned risky traffic situation and analyzed its effectiveness.

2 OVERVIEW OF MOVIC-T4

Figure 1 shows the overall system configuration of the driving simulator named MOVIC-T4 (MOving VIrtual Cockpit by Tokyo Tech & Trion for Tokyo highways). The simulator has an average frame rate of 30Hz that varies depending on the traffic scenario, such as the number of surrounding vehicles. Hardware components include a HMD, a head-orientation tracking sensor, vehicle control devices, and a two-degree-of-freedom motion-base. The state of the control vehicle is calculated from the subject's driving control input and the roadway geometric structure database. The motion system is then based on the state of the control vehicle.

In this simulation system, around 60 surrounding vehicles can be generated. These vehicles are set to run automatically, with initial attributes such as starting position, desired running speed, desired distance headway, criterion of judgment in changing lanes, and vehicle type. Using these attributes, an algorithm for vehicles changing lanes was developed. Recorded data of subject's control vehicle included the driving path, speed, acceleration and braking, steering, and distance headway to the vehicle ahead. The driving path and speed for surrounding vehicles was also recorded.

HMD currently used in MOVIC-T4 has a 60 degree horizontal field-of-view, a resolution of 640*480 pixels and a weight of 1.0 kg. Coupled with the head tracking sensor, the effective field-of-view can reach 360 degrees. Compared with traditional projector-based driving simulators, the HMD-based system can attain a high level of realism due to the immersion into the virtual roadway. In addition, the scope and cost of HMD-based systems may be lower due to the reduction in the size of the physical display equipment and the required graphics requirements.

3 VALIDATION OF MOVIC-T4

3.1 Experimental procedures in the field

First, the subject wore the holter monitor for measuring

Fig. 2-1 Driving Simulator MOVIC-T4

Fig. 2-2 View of driving in Simulator

RRI and the SPL electrodes at the point A (see **Fig. 3-1**). At this point, the RRI and SPL under resting condition were measured. After that, subject drove the instrumented car as a practice driving from point A to point B where is close to the entrance of Aqualine. During this practice driving, the speed meter was hidden for the first experiment. After arriving the point B, subject took an enough rest.

1) Experiment 1: perceived speed test
Site: Aqualine (to Kisarazu)
Requirement:
Aqualine has two lanes, and the width of each lane is 3.6m. First, subject was required to drive at the speed which was felt to be 60 km/h for around 30 seconds in the left lane. Next, subject was required to drive at the speed which was felt to be 100 km/h for around 30 seconds in the right lane. And after that, the required speed was changed to "60 km/h ->100 km/h ->60 km/h ->100 km/h ->60 km/h". During each required speed, subject was asked to state the sign verbally when he felt the current driving speed as a required speed, and its time was recorded by the video recorder. The data of the first required speed of 60 km/h was excluded because it might be affected by initial disturbance.

2) Experiment 2: safety distance choice test
Site: Aqualine (to Kawasaki)
Requirement:
After an enough rest at the point C (Umihotaru Parking Area) for more than 10 minutes, subject started to drive for Kawasaki. First, subject was required to follow the other experimental car (called F-car) which was controlled by our staff at the distance which was felt to be his safety distance for around 30 seconds. First 30 seconds F-car drove at the speed of 60 km/h in the left lane. Next, F-car changed lane to the right and drive

at the speed of 100 km/h. Subject was also required to change lane and follow F-car at the distance which was felt to be his safety distance for around 30 seconds. And after that, the F-car's driving speed was changed to "60 km/h in the left lane ->100 km/h in the right lane ->60 km/h in the left lane ->100 km/h in the right lane ->60 km/h in the left lane". During each speed, subject was asked to state the sign when he felt the current distance as his safety distance. The data of the first safety distance under 60 km/h condition was excluded because it might be affected by initial disturbance similar to the experiment 1.

3) Experiment 3: perceived distance headway
Site: Aqualine (to Kisarazu)
Requirement:
After an enough rest at the point B for more than 10 minutes, subject started to drive for Kisarazu. During driving in Aqualine tunnel, subject was required to follow F-car whose speed is constant 70 km/h, and follow at the required distances which are 25m, 50m, 100m, and 150m. During each required distance, subject was asked to state the sign when he felt the current distance as the required distances. These four required distances ware randomly changed, and the sample of each distant data were more than 3 (sometimes 2 samples especially of 150m due to the surrounding vehicle's disturbance).

4) Experiment 4: Physiological data trend test
Site: Aqualine (to Kawasaki)
Requirement:
After an enough rest at the point C (Umihotaru Parking Area) for more than 10 minutes, subject started to drive for Kawasaki. First, subject was required to follow F-car at the distance which was felt to be his safety distance for around 210 seconds. F-car drove at the speed of 60 km/h in the left lane in this first 210 seconds. Next, F-car changed lane to the right and drove at the speed of 100 km/h. Subject was also asked to change lane and follow F-car. During this experiment, subject was asked not to speak anything and also experiment staff didn't also speak anything. The physiological data such as RRI (mental load index) and Skin Potential Level (SPL: awareness level index) in this experiment were analyzed whether the trend of the data were similar to that in the simulator experiment.

5) Experiments 5: Decelerating behavior
Site: Kanjo 4-gou in Seya-ku, Yokohama-city (long straight section)
Requirement:
Subject was asked to accelerate to the speed of 80 km/h by the sign "A" where subject was required to start to decelerate and stop as close to the stop position sign "B" (see. **Fig. 3-2** And also subject was required not to release the brake pedal after starting decelerating, that is, keeping decelerating. Adjusting the magnitude of deceleration was allowed. The same experiment was repeated 4 times after once practice experiment. In this experiment, the decelerating behavior including trend and maximum deceleration G-force and stopping position from the stop sign were analyzed.

3.2 Experimental procedures in the simulator

Experiment procedure in the simulator is basically same as that in the field. First, the subject wore the holter monitor for measuring RRI and the SPL electrodes in the experiment room. And the RRI and SPL under resting condition were measured. After that, subject drove the simulator MOVIC-T4 freely as a practice driving from point A to point B in MOVIC-T4. During this practice driving, the speed meter was hidden for the first experiment also in simulator experiment. After this practice driving, subject took an enough rest.

The other procedures of experiment 1 ~ experiment 4 were the same as that of the field driving experiments.

3.3 Results and discussions

1) Perceived driving speed
Figure 3-3 shows the mean of produced driving speed

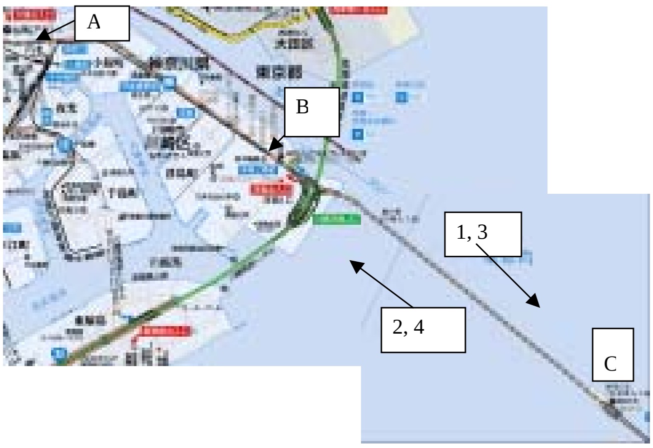


Fig. 3-1 Experiment site
(Aqualine: expressway under the sea)

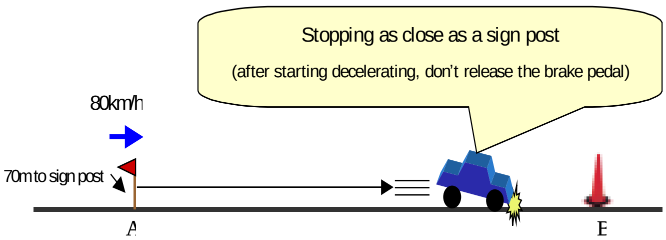


Fig. 3-2 Decelerating experiment

under the required speed for all subjects (N=10). As several previous research paper described, drivers tend to produce the larger speed than the required speed in real world. In other words, drivers tend to underestimate the driving speed. And the error from the required speed is larger in slower speed than in faster speed. The same trend can be observed also in simulator experiments. Regarding the difference between in real and in simulator, the mean values under both required speed are slightly higher in simulator than in real car. However the differences are not statistically significant. Therefore the produced driving speed under the required speed in simulator is almost same as that in real car when we see the data averagely for all subjects. That means the perceived speed in simulator is almost same as that in real car.

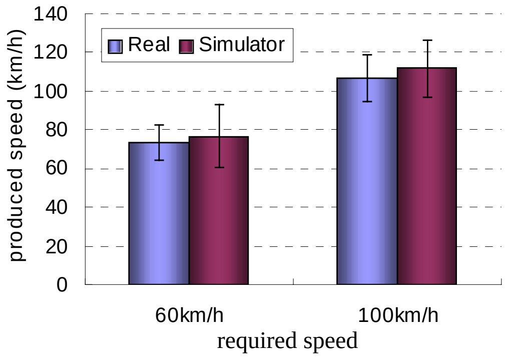
2) Perceived distant headway

Figure 3-4 shows the mean of produced distance under the required distance for all subjects (N=10). The produced distances in simulator are slightly lower than that in real world. But the difference is not statistically significant except the distance of 25m. The produced distance of 25 m is however still small. Usually the produced distance in simulator tends to be larger than that in real world due to the lack of full depth cues, that is, the image is 2D in simulator and 3D in real world. However the result in this analysis is opposite. Although the clear reason cannot be mentioned, one of the reasons might be the fact that the target roadway is inside tunnel. Inside tunnel the visual scene is very monotonous and dark, therefore the full depth cues in real world might also lack. The variance becomes to be larger in longer distance required. This is considered to be natural. The limitation of the resolution of visual display of simulator might well cause the higher variance at longer distance.

3) Safety distance choice

Figure 3-5 shows the mean of produced safety distance under two driving speeds. Both in the real and simulator experiments, the safety distance increased as driving speed became higher. This is because the higher driving speed might well give drivers higher perceived risk. As a result, the safety distance increases. This phenomenon is a well-known fact. Therefore, the safety distance change in simulator might be elicited as same response in real world.

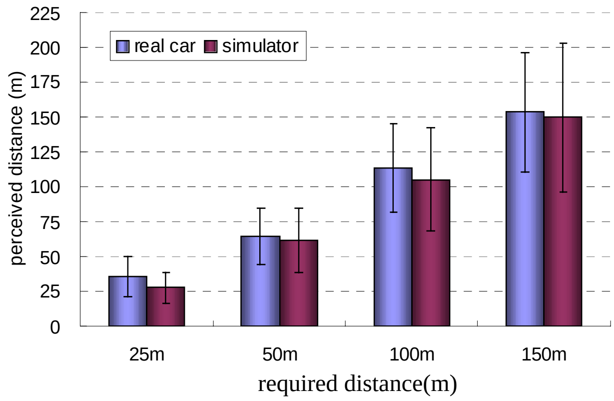
Regarding the difference between in real and simulator, the safety distance in simulator was shorter than in real world at the speed of 100 km/h while it was almost same at the speed of 60 km/h. This difference might be occurred the previous two validated data (perceived speed and distance). Although both of the two difference between in real and simulator is not highly statistically significant, the trend of the data helps explain this shorter safety distance in simulator. Of course this relationship cannot be verified completely



	60km/h	100km/h
Real	73.6 (10.6)	106.6 (12.5)
Simulator	77.4 (15.8)	111.7 (14.6)
t-test result	t=1.08, P=0.14	t=1.10, P=0.14

*Mean (SD)

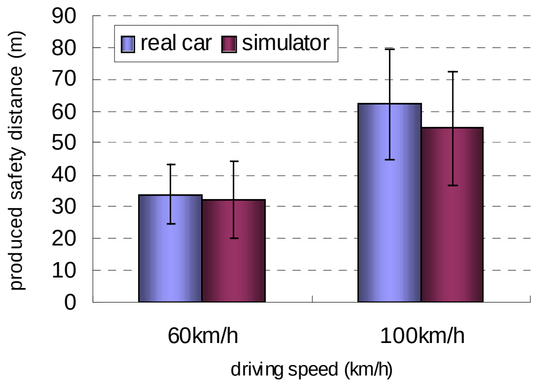
Fig. 3-3 Produced driving speed under the required speed (Mean of all subjects)



	25m	50m	100m	150m
real car	35.1 (14.4)	64.5 (20.6)	113.9 (31.6)	153.7 (42.8)
simulator	27.8 (11.2)	61.7 (23.6)	105.2 (36.6)	149.7 (53.3)
t-test result	t=2.63, P=0.051	t=0.62, P=0.26	t=1.24, P=0.11	t=0.34, P=0.37

*Mean (SD)

Fig. 3-4 Produced distance under the required distance (Mean of all subjects)



	60km/h	100km/h
real car	33.8 (9.4)	62.2 (17.2)
simulator	32.3 (11.9)	54.6 (17.8)
t-test result	t=0.53, P=0.30	t=1.66, P=0.052

* Mean (SD)

Fig. 3-5 Produced safety distance under two driving speeds (Mean of all subjects) because the other factors may affect the safety distance choice. But, this difference has to be taken into account when we conduct some safety analysis. For example, the shorter safety distance might induce the safety indices to become to be computed as slightly risky.

4) Decelerating behavior

Figure 3-6 shows the deceleration profile in real road. The deceleration transition in real road is moderate and maximum value is less than 0.4-0.6 G. In addition, the trends were almost consistent among the repetitions. Braking to a complete stop often involves high deceleration amplitudes of the order of 0.3-0.4 G, and 0.6 G or more when it is an emergency braking. And Figure 3-7 shows the deceleration profiles in simulator whose motion is ON. The deceleration transition in simulator is not moderate and maximum value is over 0.4-0.6 G. Simulated deceleration G-force must be scaled smaller than that in real world due to the limitation of motion-base movements. So the over-deceleration might be unavoidable in the simulator experiments. But the maximum deceleration can be a little bit reduced significantly by this motion-base (t=1.58, P=0.06, see Table 3-1). And the overestimation of distance might also cause this over-deceleration and immoderate transition of deceleration. The stop position from the sign post in simulator is also biased from that in real world (see Table 3-2). This might be induced by the visual problem that is the biased distance perception and the abovementioned deceleration cueing problem.

5) Physiological data

Figure 3-8 shows the time series of 1 minute average value of normalized SPL in real and simulator experiment. Normalizing the SPL data is conducted through subtracting the minimum value of SPL while bed resting and divided by the range between the maximum value while exercising and minimum value while bed resting for each subject. Accordingly, the normalized data takes the value from 0 to 1. The lower SPL means the lower awareness level of subject. As seen in the figure, the trends of two conditions are so similar. And the interaction effect of "time*condition" on SPL is not significant (F=0.75, P=0.61: test by Repeated measures ANOVA), that means both of the pattern of SPL change with time are same. SPL (awareness) in simulator seems to be generally lower than that in real, but the result shows the opposite trend in terms of normalized SPL. Though the clear reason for this trend cannot be said, one possible reason might be the difference of minimum and maximum value of SPL for normalizing. For example, the minimum value of SPL in simulator is lower than that in real, which induces the higher normalized SPL. And this lower minimum SPL in simulator might be attained because subjects could calm down easier in simulator experiment room due to little disturbance while there are more disturbance in real road experiment site such as surrounding vehicle's noise and existence of other people. Actually the SPL data in simulator is lower than that in real which is not normalized value.

Figure 6-9, Figure 6-10, Figure 6-11 and Figure 6-12 shows the comparison of time series of 1 minute average value respectively of RRI, HF, LF/HF ratio and CV-RR between in real and simulator. HF is the power for high frequency band (0.15-0.40 Hz) calculated by FFT (Fast Fourier Transform) result of RRI, and lower HF means higher mental load. LF/HF ratio is the ratio of the power for low frequency band (0.04-0.15 Hz) and high frequency band calculated by FFT (Fast Fourier Transform) result of RRI, and higher LF/HF ratio means higher mental load. CV-RR is coefficient of variance of RRI, and lower CV-RR means higher mental load. For all of them, the value were not change with time significantly both in real and simulator (no main effect of time on the value) and accordingly the interaction effect of "time*condition"

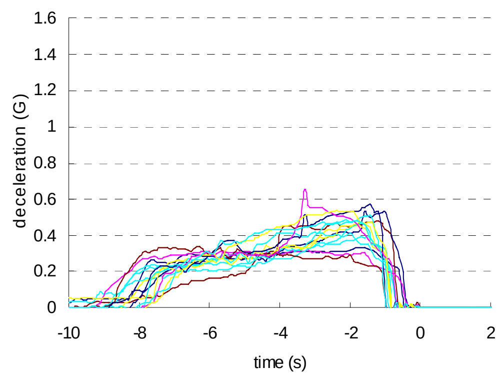


Fig. 3-6 Deceleration in real world

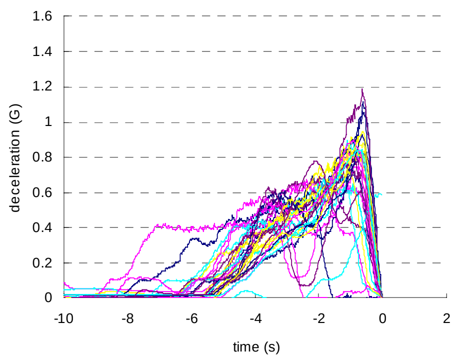


Fig. 3-7 Deceleration in simulator (Motion-ON)

Table 3-1 Comparison of maximum deceleration

	Real	Simlator (Motion-ON)	Simlator (Motion-OFF)
Mean of Max Deceleration (G)	0.46 (0.09)	0.83 (0.21)	0.90 (0.17)

* Mean (SD)

Table 3-2 Comparison of stop position from the sign post

	Real	Simlator (Motion-ON)	Simlator (Motion-OFF)
Stop position from the sign post (m)	1.4 (1.6)	5.6 (3.6)	5.0 (3.1)

* Mean (SD)

are also not significant. This means the time series trend of each index didn't differ significantly between in real and simulator. However these results cannot support the validity of mental load indices strongly because the value was not change with time due to the relatively monotonous traffic condition.

3.4 Summary of validation study

In this study, the basic driving data which are necessary to assess the traffic safety are validated using the field driving data. Results indicated that the perceived distance headway in simulator is slightly larger than that in real world (overestimation), but the difference is not so large comparing the other simulator presented in the other papers. This might be caused by that the roadway which is the target of MOVIC-T4 is inside tunnel. And the chosen safety distance in simulator is shorter than that in real world especially at the speed of higher speed. This phenomenon can be explained by the overestimation of distance in simulator. Of course there is possibility that the other factors also affect the safety distance. Regarding the physiological data such as RRI and SPL, these data averagely behaved similarly to that in real world. However the frequency-based indices such as HF and LF/HF ratio calculated by FFT don't necessarily have validity. Decelerating behavior in simulator was relatively highly different from that in real world, that is, larger deceleration was tend to produced in simulator. However the experiment with and without motion cueing indicated that the motion cueing can reduce the deceleration slightly.

These results of validation implies that when usual driving experiments, following distance can be produced slightly short, therefore the safety indices become slightly riskier. And when analyzing the response to the incident, behavioral data after starting deceleration must be modified (larger deceleration may induce the collision avoidance which is impossible in real world).

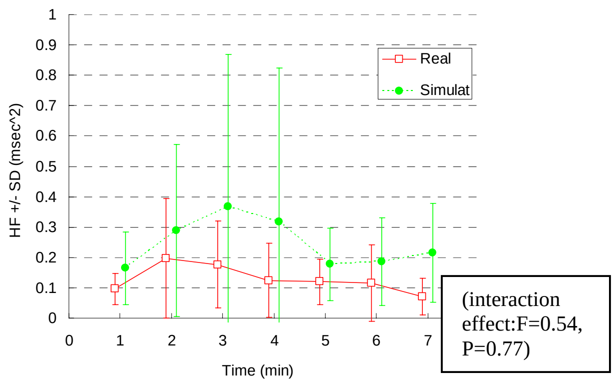


Fig. 3-10 Comparison of mean HF (the power for high frequency band) in real and simulator

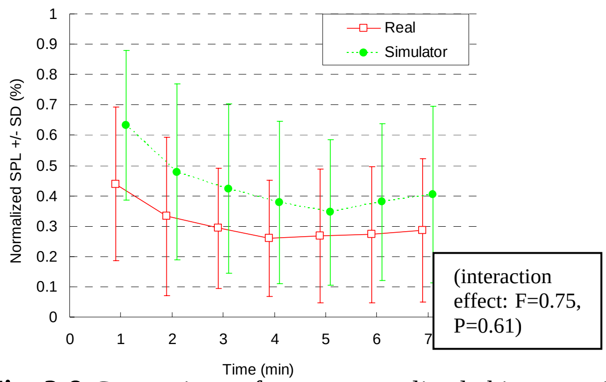


Fig. 3-8 Comparison of mean normalized skin potential level in real and simulator

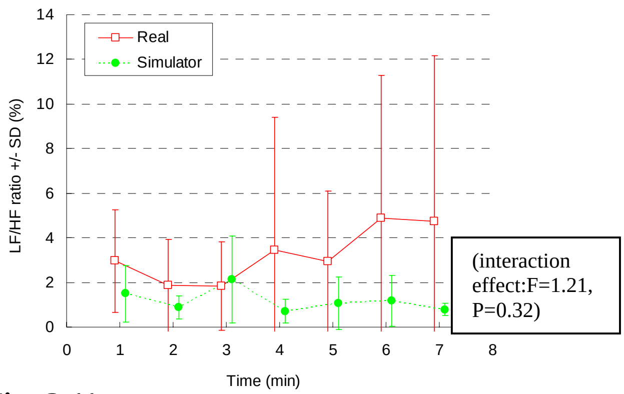


Fig. 3-11 Comparison of mean LF/HF ratio (the ratio of the power for low frequency band and the power for high frequency band) in real and simulator

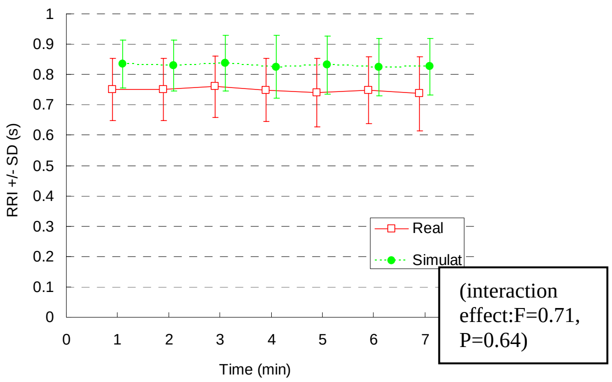


Fig. 3-9 Comparison of mean RR-interval in real and simulator

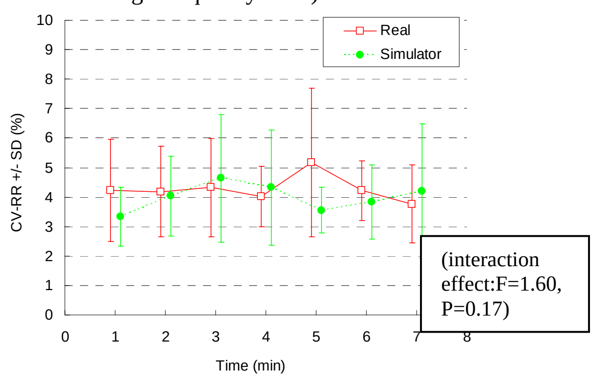


Fig. 3-12 Comparison of mean CV-RR (coefficient of variance of RRI) in real and simulator

4 Experiments for traffic safety analysis

4.1 Analysis of potential risks in ordinary drive.

4.1.1 Aim and outline of this experiment

This experiment's aim is checking the tendency of potential risks when we drive in underground urban expressways by various surrounding traffic conditions. We try to grasp the tendency by focusing on index of physiological data, like skin potential level, RRI and so on.

4.1.2 Experimental procedures

Subjects drive on the course (**Fig. 4-2)** in DS at 3types of surrounding traffic conditions. (see. **Fig. 4-1)**. They are directed to always follow the foregoing car. When the setting of surrounding traffic condition is large vehicle-many, foregoing car they must follow is large vehicle. On the contrary, when the setting of surrounding traffic condition is large vehicle-few, foregoing car they must follow is small vehicle.

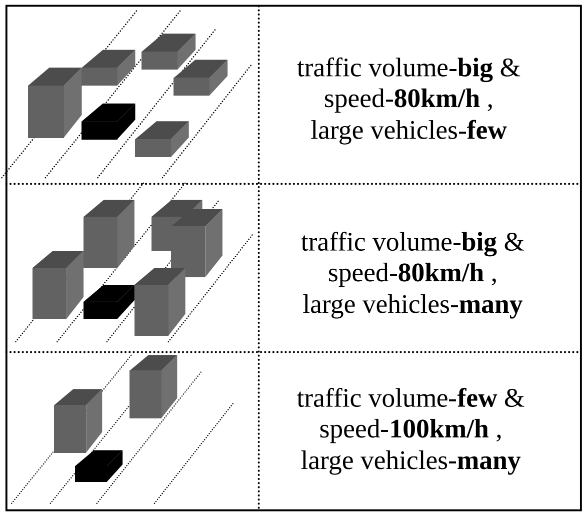


Fig. 4-1 surrounding traffic conditions

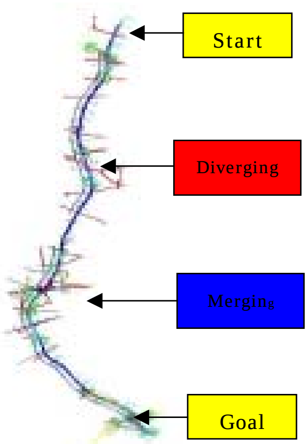


Fig. 4-2 underground urban expressway (in DS)

Table 4-1 subjects

	affiliation	age	number
Students &teacher	Tokyo tech	22～30	9people
Elderly people	Silver dispatch center	63～72	8people

4.1.3 Results and discussions

We evaluate the potential risks in ordinary drive by focusing on skin potential level and heart beat. **Fig. 4-3** is average SPL (normalized) of students**.** And **Fig. 4-4** is average SPL (normalized) of elderly people. They are slightly different by surrounding traffic conditions. First, at the case of left side condition, SPL simply and slightly descend by a gradual process. Next, at the case of middle condition, SPL descend fast under 0.2 within 5 minutes. And after that, slightly ascend with significant difference. At the case of right side condition, SPL descend little by little, and after 5 minutes, slowly ascend.

These results are bought under review like this. At middle condition, driving speed is low. Additionally drivers lose speed feeling due to surrounding large vehicles. As a result, their conscious level descend.

And last half, there are big and small curves in the course. So drivers with low conscious level get tensed up at the curves. Especially at the case of many large vehicles, this may be prominence because they can't see around enough.
About elderly people, changes of SPL are not big in their totally. But there is big difference by surrounding traffic conditions. First, at the left side, SPL is always high. And middle case, that isn't always high.

Next, **Fig. 4-5** is average RRI of students and elderly people. It can be said driver's stress is big when RRI becomes short. Wholly, students' RRI slightly descend by a gradual process. On the contrary, elderly people's RRI ascend a little. This is why we think elderly people come to be relaxed not stressed.

Fig. 4-6 is average HF($msec^2$) of students and elderly people. It can be said HF becomes small when driver have big stress. Except elderly people at left side case, this tendency is remarked.
Fig. 4-7 is average LF/HF of students and elderly people. It can be said LF/HF becomes big when driver have big stress.
And **Fig. 4-8** is average CV-RR of students and elderly people. It can be said CV-RR becomes small when driver have big stress or become nervous.

The result of LF/HF and CV-RR might indicate drivers' stress become bigger by a gradual process.

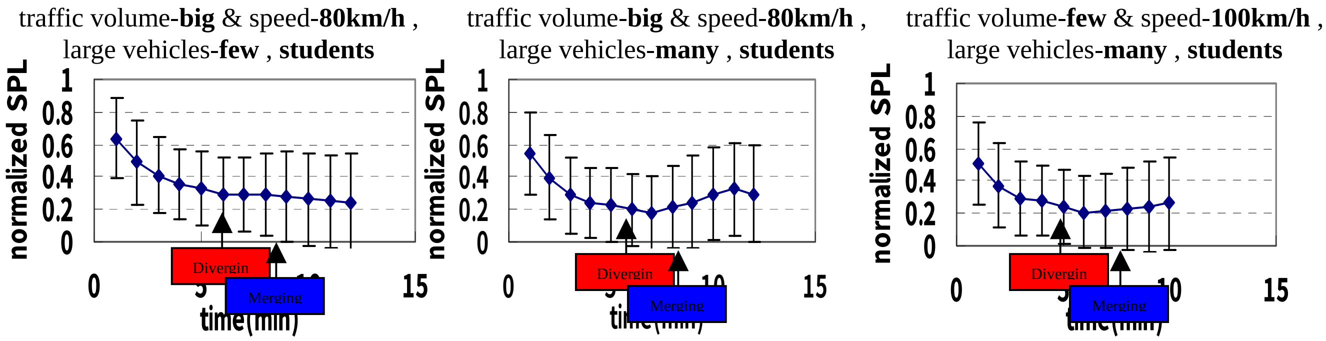


Fig. 4-3 Normalized SPL (average of students)

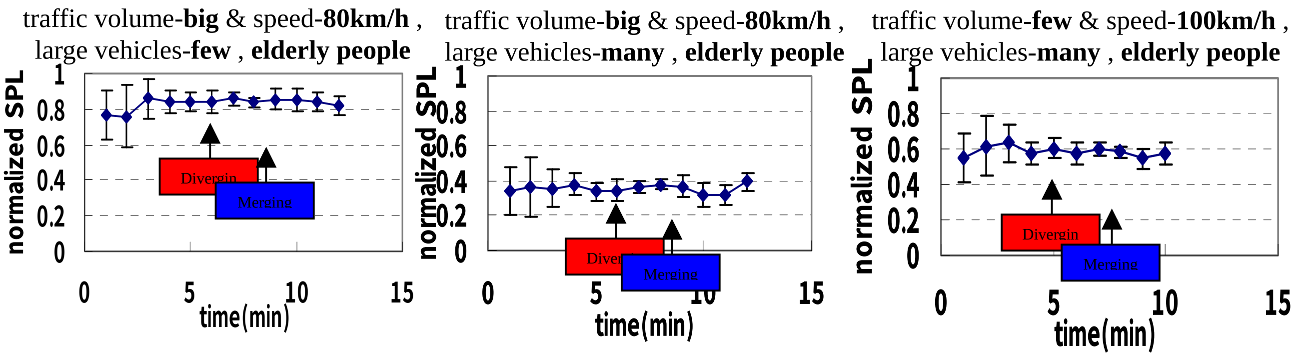


Fig. 4-4 Normalized SPL (average of elderly people)

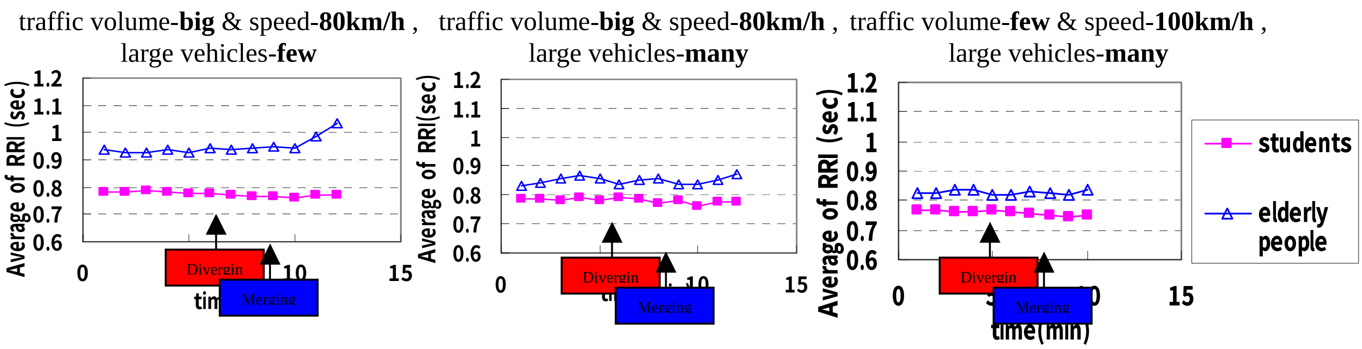


Fig. 4-5 Average of RRI (average of students and elderly people)

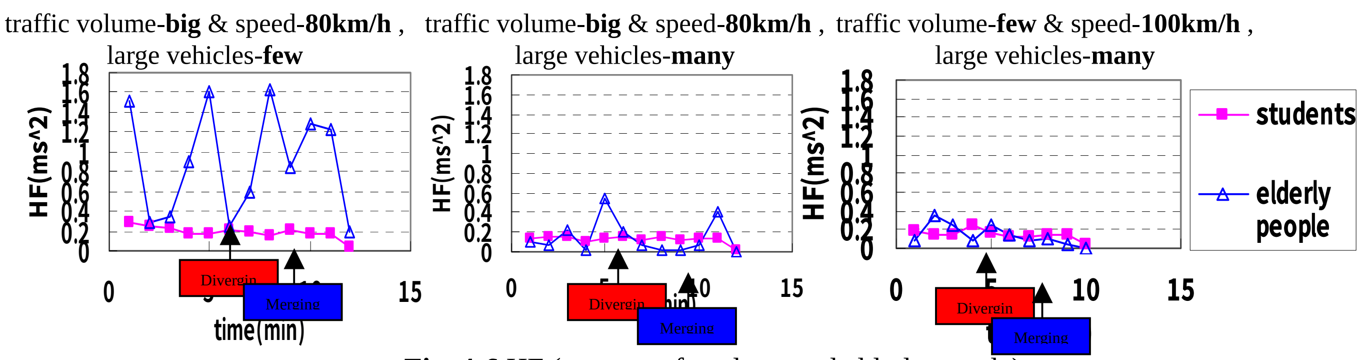


Fig. 4-6 HF (average of students and elderly people)

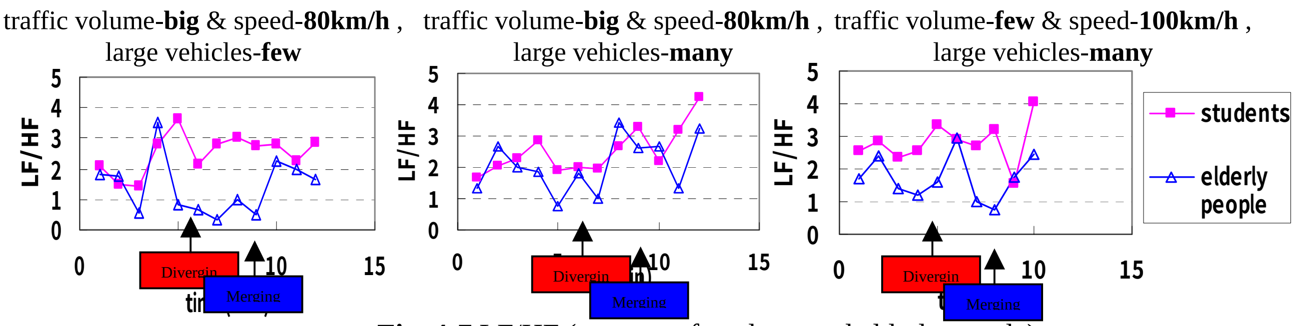


Fig. 4-7 LF/HF (average of students and elderly people)

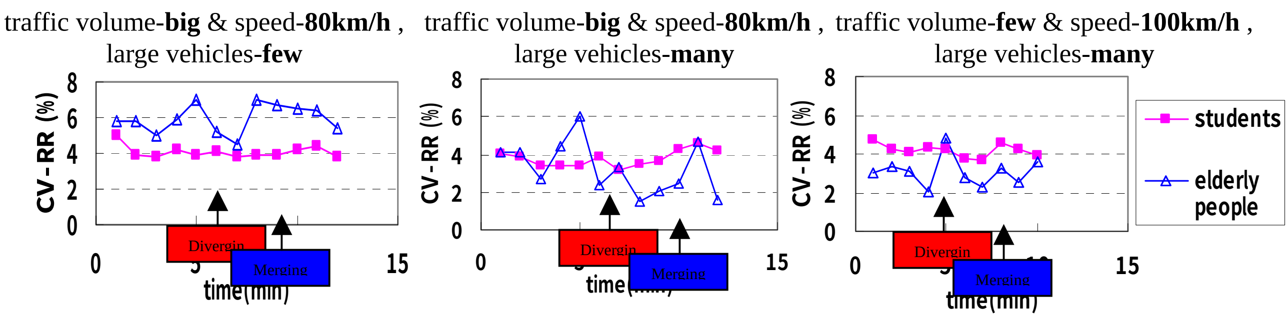


Fig. 4-8 CV-RR (average of students and elderly people)

4.2 Analysis of overt risks in traffic conflicts and information services' effectiveness.

4.2.1 Aim and outline of this experiment

This experiment's aim is checking the effectiveness of information service system when we drive in underground urban expressways and it happens traffic accident forward our car. As surrounding traffic condition, we use the conditions with high risks drivers become to be low conscious level. From the result of the previous experiment, we select the condition.

We try to analyze the effectiveness by focusing on index of Number of rear-end collision, Distance to collision, Reaction time from foregoing car's brake, and deceleration etc.

4.2.2 Experimental procedures

First, we divide subjects to 2groups. One group is 'with information', and the other is 'without information' group. Second, each subject drive 2 courses in DS. One course is 'accident at the diverging section' (**Fig.4-9**), and the other is 'accident at the merging section' (**Fig.4-10**).

They are directed to always follow the foregoing car like previous experiment.

Table 4-2 subjects

	affiliation	age	number
Students	Tokyo tech	22～25	9people
Elderly people	Silver dispatch center	63～72	9people

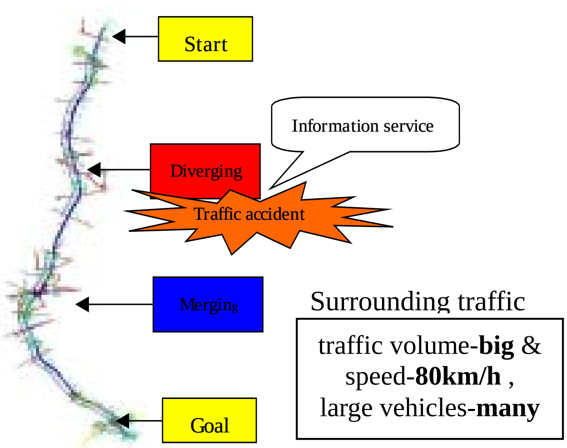


Fig. 4-9 experiment course (accident at diverging section)

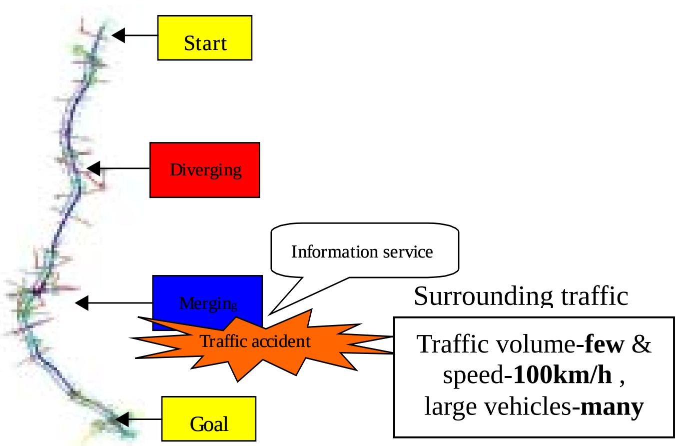


Fig. 4-10 experiment course (accident at merging section)

Table 4-3 Number of rear-end collision at diverging section

	with information	without infomatiion
students	0／3people	0／4people
elderly people	0／6people	4／5people
ALL	0／9people	4／9people

Table 4-4 Number of rear-end collision at merging section

	with information	without infomatiion
students	2／3people	2／4people
elderly people	1／6people	5／5people
ALL	3／9people	7／9people

Table 4-5 Distance to collision at diverging section

	with information	without infomatiion	t-value	P
students	29.5	21.8	1.08	0.34
elderly people	49.7	4.0	2.60	0.04
ALL	42.9	11.9	2.51	0.03

Table 4-6 Distance to collision at merging section

	with information	without infomatiion	t-value	P
students	9.4	15.9	-0.49	0.64
elderly people	28.1	0.0	3.20	0.02
ALL	21.9	7.9	1.76	0.10

Table 4-7 Reaction time from foregoing car's brake at diverging section

	with information	without infomatiion	t-value	P
students	-2.9	3.2	-3.90	0.00
elderly people	-1.1	2.3	-5.58	0.00
ALL	-1.7	2.7	-5.14	0.01

Table 4-8 Reaction time from foregoing car's brake at merging section

	with information	without infomatiion	t-value	P
students	1.9	2.1	-0.25	0.81
elderly people	2.6	4.4	-2.01	0.10
ALL	2.3	3.3	-1.44	0.17

Table 4-9 Average of deceleration at diverging section

	with information	without infomatiion	t-value	P
students	0.17(0.39)	0.40 (0.66)	-3.73 (-3.42)	0.02 (0.04)
elderly people	0.45 (0.71)	0.31 (0.62)	1.02 (0.56)	0.33 (0.60)
ALL	0.35 (0.60)	0.35 (0.64)	0.04 (-0.31)	0.97 (0.76)

(Inside of parentheses is max of deceleration)

Table 4-10 Average of deceleration at merging section

	with information	without infomation	t-value	P
students	0.48(0.73)	0.50 (0.77)	-0.18 (-0.49)	0.86 (0.65)
elderly people	0.59 (0.81)	0.11 (0.16)	3.63 (4.34)	0.01 (0.00)
ALL	0.56 (0.79)	0.34 (0.48)	2.23 (2.5)	0.04 (0.03)

(Inside of parentheses is max of deceleration)

Table4-3 & **Table4-4** are average of rear-end collisions' number at diverging or merging section. The tables compare group of 'with information' with group of 'without information'. Number of Rear-end collision at diverging section clearly decrease by information service.

On the other hand, Number of Rear-end collision at merging section also decrease, but Number of Rear-end collision is more than that of diverging section. We can 2 reasons for this. One reason is that surrounding traffic condition is different. Second reason is difference of information service's timing.

Drivers at the course of accident at diverging are have the information about 8 seconds before foregoing car' braking ramp. But drivers at the course of accident at merging are have the information about 1 second before foregoing car' braking ramp.

Table4-5 & **Table4-6** are average of distances to collision at diverging or merging section. Wholly, the distances become long by information.

Table4-7 & **Table4-8** are average of reaction time from foregoing car's brake. The timings clearly become fast by information, especially elderly people.

Table4-9 & **Table4-10** are averages of deceleration and max of deceleration. When we look students' average, deceleration of 'with information' group is smaller than that of 'without information' group. This indicates suddenly stops which are dangerous decrease. On the contrary, when we look elderly people's average, deceleration of 'with information' group is stronger than that of 'without information' group. This fact might indicate that information service contributes safety, but increases suddenly stops for elderly people.

5 Conclusions

This study conducted the validation study of driving simulation system: MOVIC-T4 and analyzed the traffic safety in underground urban expressways. In traffic safety analysis, the potential risk in underground urban expressway was clarified using driver's physiological data. And the result from the experiment of information service indicated that the service can enhance the safety in rear-end collision avoidance situations. For the futher studies, it's necessary to analyze the traffic safety in more complicated traffic conditions.

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