Analysis of Driver Behavior based on Experiences of Road Traffic Incidents investigated by means of Questionnaires for the Reduction of Road Traffic Accidents

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The number of persons injured due to Traffic Accidents in Japan has exceeded 1 million during each of the past eight years (as of 2006), and reducing the number of traffic accidents has become an urgent issue. We believe that reducing the opportunities for encountering traffic incidents, which may lead to traffic accidents, is an effective means of reducing the number of traffic accidents. Previous analysis of traffic incidents using drive recorders was conducted primarily to analyze the factors which cause traffic accidents and to analyze driver behavior. This study utilized a questionnaire investigation to collect examples of traffic incidents which occur during ordinary driving, analyzed the driver behavior and driver mental and physical states immediately before encountering the traffic incident, and identified driver characteristics which make traffic incidents more likely. We also conducted a comparison with the regression analysis results from previous research concerning daytime subjective sleepiness – a factor that is likely to lead to serious accidents. Based on these results, we propose a direction for further research concerning physiological signal-driven driving support systems that detect driver physiological signals in order to prevent traffic accidents.

Keywords: *Driver Monitoring, Mental and Physical States, Physiological Signals, Regression Analysis*

1. Introduction

The number of traffic accident fatalities in Japan has declined in each of the last six years, reaching the low 6,000s for the first time in 51 years, and the number of traffic accidents and number of persons injured have declined in each of the last two years. These declines are thought to be the result of the comprehensive multilateral efforts shown in Table 1 (stronger enforcement of drinking-and-driving laws, mandatory seatbelt use, and other revisions to the Road Traffic Law, as well as expanded installation of safety systems in vehicles, reinforcement and expansion of traffic safety education, and other factors) [1]. However the number of injuries in traffic accidents exceeded 1 million for the eighth consecutive year (Figure 1), and reducing the number of traffic accidents themselves has become an urgent issue for the creation of a sustainable transportation society. There are three factors operating immediately before a traffic accident: the driving environment, the vehicle, and the driver (Figure 2). Of these factors, the largest proportion of accidents is thought to result from the driver. Among the examples shown in Table 2, Indiana University in the United States (1977) concluded that

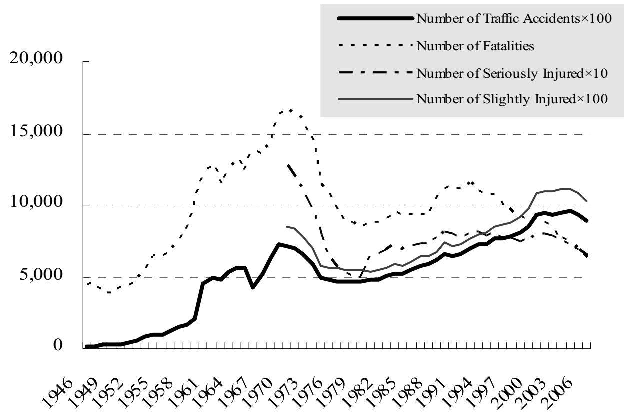

Figure 1. Changes in road traffic accidents, fatalities, and injuries in Japan [1]

90% of accidents were the result of human factors [2], while the Japan Ministry of Land, Infrastructure and Transport homepage (2000) concluded that human factors [3] cause 75% of accidents. In one study concerning unsafe driver behavior, Virginia Tech. (2006) reported that inattention was responsible in 65% of cases, while drowsiness was responsible in 12% [4]-[7]. In addition, the EU 6th Framework Programme SENSATION reported that 25% of traffic accidents in the UK were caused by fatigue [8]. Detailed research concerning unsafe driver behavior remains an issue of the greatest importance.

Table 1. Countermeasures for reducing traffic fatalities in Japan

Category	Measures
Legislation	A. Introduction of Occupant Protection Criteria (1994) B. Prohibition of Drunken driving C. Improvement of usage rate of seatbelt (from below 50% to 90% or higher)
Infrastructure	D. Maintenance and expansion of traffic environment
Vehicle	E. Expansion of Installation of safety systems in vehicles (Airbag, ABS, ESC, etc.,) F. Improvement of crashworthiness of vehicle
Education	G. Improvement of Safety Driving Education for Drivers

Table 2. Examples of human factors just before traffic accident

Research institution (researcher)	Factor	Rate
Indiana Univ., USA (Treat 1977)	A. General human error	90%
NHTSA, US DOT Virginia Tech. (Klauer 2006)	B. Inattention (including distraction) C. Drowsiness	65% 12%
MLIT, Japan: HP (Traffic accident statistics in Japan, 2000)	C. Human error (late to notice danger, incorrect judgment, inappropriate operation)	75%
EU: 6th Framework programme / AIDE: HP (Wang, et al.1996)	D. Inattention (including distraction, drowsiness, not looking ahead)	25%
EU: 5th Framework programme / AWAKE: HP	E. Hypo-vigilance	10 -20%

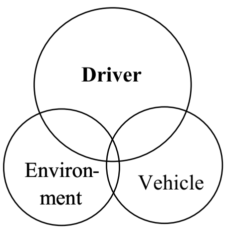

Figure 2. Three factors in traffic accidents

Investigating and analyzing traffic accidents is one effective step that can help to reduce them. In *Recommendations Related to the Conduct of Traffic Accident Investigations* published by the Safety Engineering Committee of the Science Council of Japan, it is stated that in addition to investigation and analysis of traffic accidents, other important issues include understanding the human factors involved in traffic accidents, as well as investigation and analysis of traffic incidents in order to detect the signs of an imminent accident [9].

Previous analysis of driving incidents using drive recorders was conducted primarily to analyze the factors that cause traffic accidents and to analyze driver behavior, however it has not clearly identified any relationship with the driver's mental and physical state [10][11][12].

Concerning driver mental and physical states, previous research has involved issues such as analysis of the relationship between traffic accidents and drowsiness [13][14][15], analysis related to irritation and hostility among young drivers, analysis of traffic incidents involving taxi drivers, and analysis of driver aggressiveness. However, the focus has been on understanding the overall conditions of the driver mental and physical states [16]. In addition, while there have been many studies concerning driver haste while driving [17][18], lowered concentration [19], and similar factors, the relationships between these factors and the driver's mental and physical states immediately before the accident have never been made clear.

For the purpose of reducing traffic accidents, this study used a questionnaire investigation to collect examples of traffic incidents which occurred during ordinary driving, analyzed the driver behavior and driver mental and physical state immediately before encountering the traffic incident, and identified driver characteristics which make traffic incidents more likely.

This study defines "driver characteristics" as an overall concept that includes the driver behavior and the mental and physical state of the driver. We also conducted a comparison with the regression analysis results from previous research concerning daytime subjective sleepiness – a factor that is likely to lead to serious accidents.

2. Questionnaire Investigation Method

2-1. Determining the range of traffic incidents to be investigated

The methods used for previous analysis of traffic incidents involved drive recorders. These recorders are triggered by sudden braking and therefore operate in areas of apparent risk when an accident is relatively close at hand. As a result, previous analysis did not include analysis of the driver mental and physical state [10][11][12].

This study expanded the investigation area (Figure 3) to include the driving area of potential accident risk. By means of a questionnaire investigation, we collected information concerning traffic incidents which occurred during ordinary driving, regardless of whether or not the brakes were operated.

This study defines traffic incidents as circumstances in which the driver's vehicle seemed likely to strike another vehicle or a pedestrian.

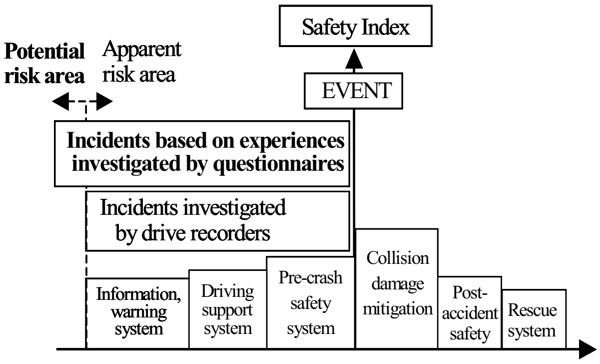

Figure 3. Investigation area

2-2. Defining the Incident Situations

Seven traffic incident situations (Figure 4) were defined as potential accident risks. These were based on the seven accident types that were set as traffic accident models in the Phase 3 ASV Promotion Project of Japan [20].
The accident types were illustrated on the questionnaire page, and the contents of the questionnaire were explained to the respondent in advance. The respondent then completed the questionnaire concerning the incident which he or she encountered. Respondents were also permitted to describe freely any incidents which were different from those shown in the illustration.

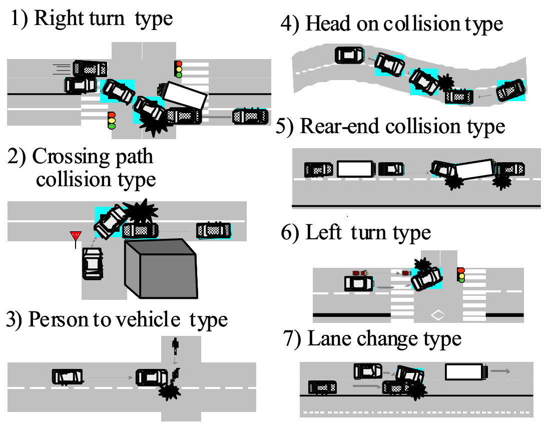

Figure 4. Incidents categorization based on traffic accidents

2-3. Determining the Questionnaire Items

The questionnaire respondents were drivers who possessed driver's licenses and who drive on a daily basis and we obtained responses concerning traffic incidents experienced by these respondents within the past two or three years. Investigation 1 involved 2,000 persons (1,117 male and 883 female) who responded to the web survey. Investigation 2 involved 35 persons (30 male and 5 female) affiliated with Aichi Prefectural University in Japan who agreed to participate in the investigation. The investigations were carried out from April 13 to April 28, 2007. The web survey was contracted to an external survey company.
For the questionnaire items, in order to create a comparison with the traffic accident types, 19 items *(no safety confirmation, inappropriate assumption, desultory driving, not looking ahead, failure for hazard prediction,* etc.) were set concerning driver behavior immediately before the incident. These were based on driver behavior classified as Traffic Law violations (as defined by the National Police Agency in Japan). 10 items were set concerning mental and physical states (*haste, lowered concentration, drowsiness*, etc.). In total, 29 selections were created for each of the seven accident types shown in Figure 4.
As factors which affect the number of traffic incidents experienced, we focused on a subjective daytime sleepiness index (hereafter "subjective sleepiness") and comprehensive driving aggression (hereafter "aggression"). For subjective sleepiness, all eight items were used from the Epworth Sleepiness Scale method of evaluation, which is used as an evaluation method for subjective sleepiness [21].
For aggression, six items were selected from among the 16 question items related to irritation and hostility that were developed by Kasuga *et al* [16] based on a Japanese version of the Buss-Perry method of evaluating aggression [22]. The score (Yes = 1, No = 0) total was set as a simplified aggression index.
Here, the aggression index indicates irritation and hostility during driving, and is hypothesized to manifest itself in the mental and physical state of haste. "Haste" is defined as the feeling and act of hurrying forward.

3. Investigation Results and Analysis

3-1. Basic Statistics of the Questionnaire Results

The questionnaire investigation results shown in Table 3 show for other items than No. of respondents, the average values per person in the top level and the minimum (left) and maximum (right) values in the second level. In Investigation 1, the average age was 41.1 years, the average driving experience was 19.9 years, the average number of traffic incidents was 2.39, the average subjective sleepiness score was 6.02, and the average aggression score was 1.68. In Investigation 2, the average age was 28.1 years, the average driving experience was 9.1 years, the average number of traffic incidents was 2.34, the average subjective sleepiness score was 6.50, and the average aggressiveness score was 1.54. Previous research reported that the ratio of traffic incidents to traffic accidents that cause minor injuries is 300:1 [12]. Multiplying the number of traffic accidents that resulted in minor injuries in 2006 (819,600) by 300 and dividing by the number of driver's license holders (78.25 million) gives 3.1 traffic incidents per person per year. The order matches the investigation results from this study, which obtained a similar value. This can be said to validate the correctness of the questionnaire investigation results.

In contrast, as shown in Figure 7, the most frequent accidents which actually occur are, in order, rear-end collision (31%), crossing path (26%), pedestrian (9%) and right turn (9%).

Table 3. Basic statistics from questionnaire investigation results

	No. of respondents		Age		Driving experience (years)		Occurrences of traffic incidents (No. of incidents)		Epworth Sleepiness Score (points)		Aggression score (points)	
	Male	Female										
Investigation 1 (Web)	2,000		41.1		19.9		2.39		6.02		1.68	
	1,117	883	19	69	1	50	0	8	0	21	0	6
Investigation 2 (Interview)	35		28.1		9.1		2.34		6.50		1.54	
	30	5	19	57	1	35	0	5	0	13	0	5

In addition, the sampling error for the questionnaire items in Investigation 1 was calculated using statistical Formula (1).

$$b = \sqrt{(K(\alpha) \times P \times (1-P)) \div n} \qquad (1)$$

Here, K(α) is derived from a normal distribution table, where α is the significance level. As we used 95% as the significance level, we obtained K(α) = 1.96. Sample size N was 2,000. P indicates the percentage for each of the questionnaire items. It is known from the statistics that the maximum value of the statistical sampling error is obtained when P is 0.5. The result of this calculation gave us 2.2% as the sampling error in Investigation 1.

This is within the sampling error range of 1 – 3% that is used in investigations by Japanese government agencies, and is considered to be a reasonable investigation result.

3-2. Traffic Incident Situations

In Investigation 1, the most common traffic incidents based on the accident types (Figure 5) were, in order, crossing path (17.6%), lane change (15.9%), left turn (12.8%), right turn (12.1%), and rear-end collision (10.7%). The results of previous research using drive recorders that are shown in Figure 6 [10][11], the most common incidents are, in order, rear-end collision (26.3%), right and left turn (17.7%), pedestrian (16.2%), and crossing path (9.7%).

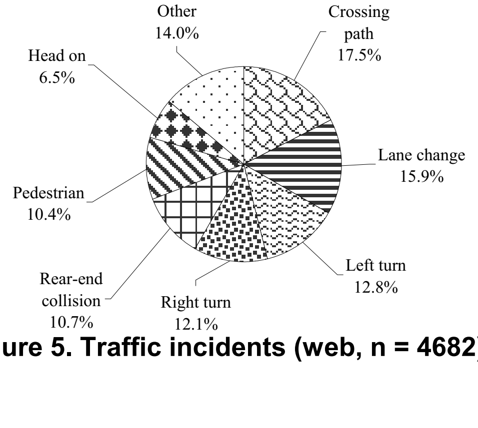

Figure 5. Traffic incidents (web, n = 4682)

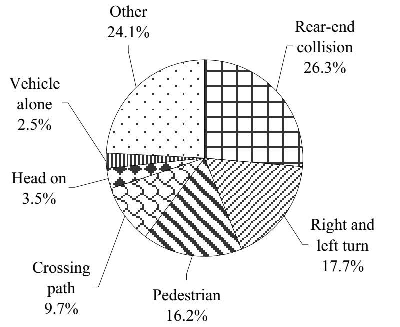

Figure 6. Traffic Incidents by the drive recorder investigation

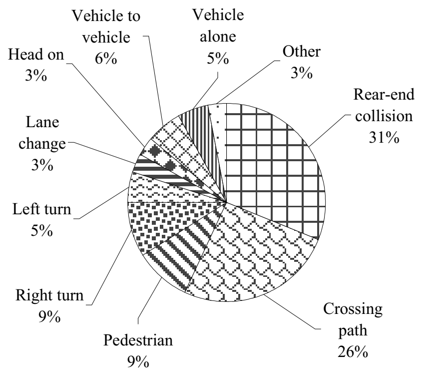

Figure 7. Traffic accidents ratio based on the accidents category [1]

When we compare these three sets of results, we see that in actual accidents and the drive recorder investigations, the most frequent accident was rear-end collisions, which accounted for a similar percentage of the totals in each set of results. Investigations using drive recorders are a method which primarily identifies near-miss accidents that are closer to actual accidents.

On the other hand in Investigation 1, rear-end collisions accounted for less than 1/3 of the results in either of the other investigations. The No. 1 most common incident was crossing path, while the No. 2 incident was lane change, showing a different results structure than the other investigations. Questionnaire investigations are an investigation method which can identify a broad range of potentially dangerous driver states. In the results of Investigation 1, 86% of the traffic incident situations can be explained by the accident models in the Phase 3 ASV Promotion Project of Japan [20].

he investigation method used for this study can therefore be described as reasonable. As was proposed in 2000 by the Expert Committee for Safety Engineering in the Science Council of Japan [9], for future traffic accident investigations, it will be necessary to add driver questionnaire investigations to the existing statistical analysis of accidents, detailed on-site accident investigations, and investigations of near-miss accidents using drive recorders, and to analyze factors by means of comprehensive investigations which include steps for preventing accidents immediately before they occur.

3-3. Driver Behavior

The driver behaviors immediately before the incidents, as identified by Investigation 1, are shown in Figure 8. In order, the most common results were *no safety confirmation* (30.9%), *inappropriate assumption* (23.2%), and *desultory driving* (12.5%).

Here, *desultory driving* refers to a state of diminished attention due to conversation, distracting thoughts, or drowsiness. *Normal* is defined as the driver concentrating on driving. In contrast, among Traffic Law violations resulting in accidents that cause fatalities or injuries, as released by the National Police Agency (Figure 9[1]), the most common behaviors are *no safety confirmation* (40%), *glance at the road* (22%), and *failure for hazard prediction* (15%). While the top position is the same in both sets of results, the percentages of the second and lower positions in the results are different, and a future detailed investigation will be necessary. The human error factor in Investigation 1, excluding *traffic environment* and *other*, accounted for 74%, a value which is close to those from previous research [3] [4].

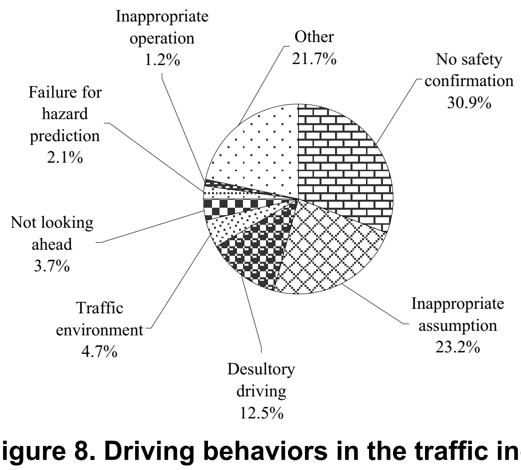

Figure 8. Driving behaviors in the traffic incidents

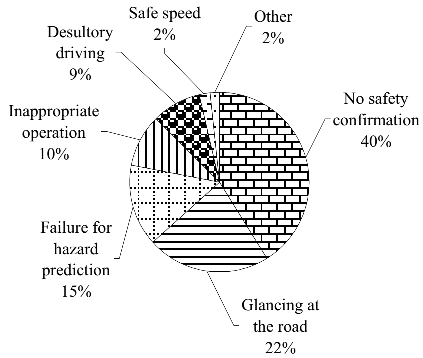

Figure 9. Traffic law violations resulting in fatalities and injuries [1]

3-4. Driver's Mental and Physical States

As determined by Investigation 1, the most frequent mental and physical states of the drivers immediately before the incidents (Figure 10) were, in order beginning with the most frequent, *haste* (22%), *lowered concentration* (21.9%), and *normal* (15%). In the results of this study, *haste* occupied the top position, while *lowered concentration* occupied the second. This matches the positions of *haste* in the top position and *lowered concentration* in the second position from previous studies which investigated driver mental and physical states immediately before an accident occurs [23].

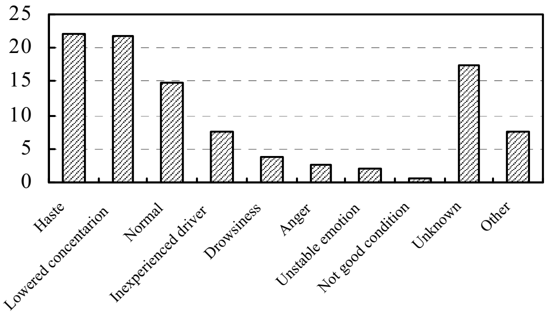

Figure 10. Driver's mental and physical states (units: %)

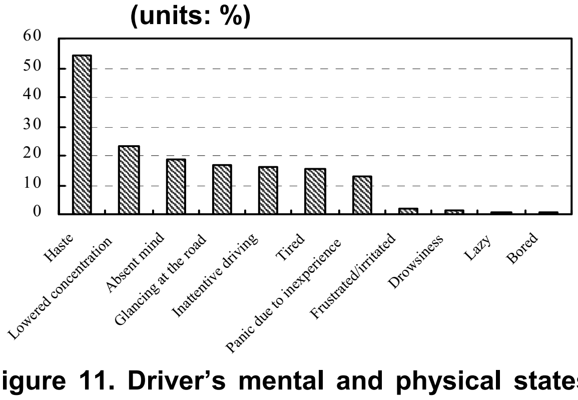

Figure 11. Driver's mental and physical states (from research [23]) (units: %)

Based on this, we can conclude that *haste* and *lowered concentration* are important factors in the mental and

physical states of drivers immediately before an accident, with consideration for areas of potential danger.
It will be necessary to focus on these factors in order to consider ways to reduce traffic accidents.

3-5. High-occurrence Combination of Driver's Mental and Physical State or Driver's Behavior with Traffic Incident Situations

Table 4 shows the top 10 combinations of the driver mental and physical state and driver behavior which resulted in the most traffic incidents with the traffic incident situations, as determined by Investigation 1. The No. 1 and No. 2 combinations are *haste* plus *no safety confirmation* resulting in *crossing path* and *lane change* incidents. The No. 6 combination is *lowered concentration* plus *desultory driving* resulting in *rear-end collision* incidents. The No. 1 combination in Investigation 2 was *lowered concentration* plus *desultory driving* resulting in *rear-end collisions*.

Table 4. Occurrence rate of traffic incidents

Rank	Mental and physical states	Driver behaviors	Incidents type	Number of response	Ratio (%)
1	Haste	No safety confirmation	Crossing path	140	2.93
2	Haste	No safety confirmation	Lane change	114	2.38
3	Lowered concen-tration	No safety confirmation	Left turn	103	2.15
4	Lowered concen-tration	No safety confirmation	Crossing path	90	1.88
5	Normal	Normal	Pedestrian	88	1.84
6	Lowered concen-tration	Desultory driving	Rear-end collision	79	1.65
7	Haste	No safety confirmation	Right turn	77	1.61
8	Un-known	No safety confirmation	Left turn	76	1.59
9	Haste	Inappropriate assumption	Right turn	74	1.55
10	Un-known	No safety confirmation	Lane change	67	1.40

From the combinations of mental and physical states for each driving behavior in both Investigation 1 and 2, it can be noted that the mental and physical states related to *no safety confirmation* are *haste* and *lowered concentration.* For *inappropriate assumption,* they are *normal, haste,* and *lowered concentration.* For *desultory driving,* they are *lowered concentration* and *drowsiness.* For *not looking ahead carefully,* the related mental and physical states are *lowered concentration* and *glancing at the road*. Kasuga *et al* found a significant correlation between traffic incident experiences and irritation and hostility during driving, and stated that a lack of attention (lowered concentration) during driving was related to many traffic incidents [16]. This statement matches the result of this study.
The above analysis results show that when considering ways to reduce traffic accidents, *no safety confirmation, desultory driving (drowsiness, conversation, distracted by thoughts),* and *inappropriate assumption* are driving behaviors which require attention, while driver mental and physical states which require attention are *haste* and *lowered concentration*.

3-6. The Effects of Sleepiness and Aggression on Traffic Incident Situations, Driver Behavior, and the Driver's Mental and Physical States

In Investigation 1, we examined the effects of subjective sleepiness and aggression on traffic incident situations, driver behavior, and the driver's mental and physical states basis using the trend analysis procedure described below.
First of all, we divided respondents into two groups – a high score group and a low score group. To do so, we used the average values of both the subjective sleepiness score (6.02 points in the Epworth Sleepiness Score) and the aggression score (1.68 points) that were derived from the basic statistics of the questionnaire investigation results shown in Table 3. Here we set the boundary between the high score group and the low score group as the average values of all subjective sleepiness scores and all aggression scores.
We then performed trend analysis by comparing the differences among the same component items in the high score group (the group with both high subjective sleepiness scores and aggression scores), and the low score group (the group with both low subjective sleepiness scores and low aggression scores). Accordingly we compared the composition of the two groups in terms of traffic incident situations, driver behavior, and driver mental and physical states. When the absolute value of the difference (hereinafter referred to as the percentages for the component items) exceeds the sampling error of 2.2% for the questionnaire items, we judged that the component item has a significant effect on the traffic incident. For items *Unknown* and *Other*, we excluded them from the objects for comparison.
First, in order to examine the effects of sleepiness and aggression on the traffic incident situations, we compared the percentages for the component items of the high score group and low score group. The results are shown in Figure 12, where the sampling error of 2.2% was shown as horizontal dotted line. The traffic incident situation with a difference exceeding the sampling error of 2.2% (calculated by Formula (1) in

Section 3-1) was the *head on collision* type of incident (2.8%). This is thought to be the result of reduced attention in the forward direction occurring when both sleepiness and aggression are high.

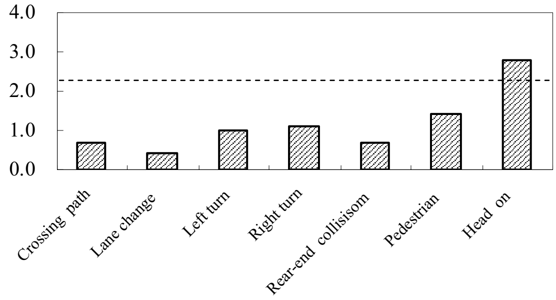

Figure 12. Effects of sleepiness and aggression on traffic incident situations (units: %)

Next, we compared the composition of the high score group and low score group in order to examine the effects of sleepiness and aggression on the driver behaviors immediately before a traffic incident that are shown in Figure 8. The results are shown in Figure 13.
The driver behavior with a difference exceeding the sampling error of 2.2% (calculated by Formula (1) in Section 3-1) was *desultory driving* (3.8%). This makes it clear that the focus for driving behavior will have to be on *desultory driving*.

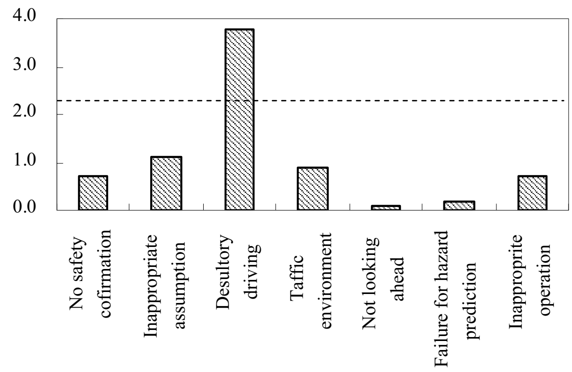

Figure 13. Effects of sleepiness and aggression on driver behavior (units: %)

In order to examine the effects of sleepiness and aggression on the driver mental and physical states that are shown in Figure 10, we compared the high score group and low score group as shown in Figure 14. The mental and physical states which have a difference exceeding the sampling error of 2.2% (calculated by Formula (1) in Section 3-1) are *haste* (9.1%), *normal* (6.4%), and *drowsiness* (2.5%).
Based on the above, it is clear that the traffic incident situation which is affected by sleepiness and aggression is *head on*, and that the driver behavior which is affected by sleepiness and aggression is *desultory driving*, while the mental and physical states that are affected by sleepiness and aggression are *haste, normal,* and *drowsiness*.

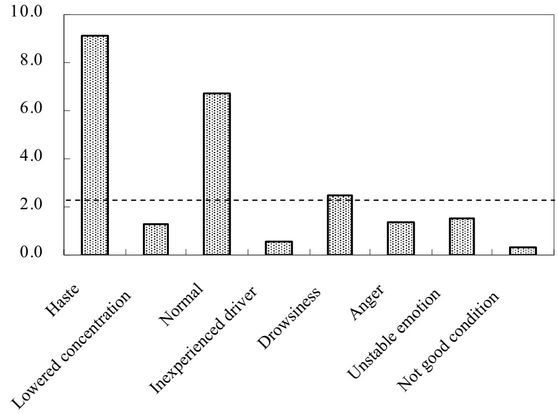

Figure14. Effects of Sleepiness and Aggression on the driver's mental and physical states (units: %)

These results also show that the driver behavior which requires attention is *desultory driving,* and the important mental and physical states are *haste* and *drowsiness.* It will be necessary to recognize these as important factors in order to work to reduce traffic accidents.
When we summarize the analysis results to this point, as shown in Table 5, we see that it is possible to identify the specific driver mental and physical states which correspond to driver behaviors.

Table 5. Relation between driver behavior, and mental and physical states

Driver behavior	Driver's mental and physical states		
No safety confirmation	Haste	Lowered concentration	-
Inappropriate assumption	Normal	Haste	Lowered concentration
Desultory driving	Lowered concentration	Drowsiness	-
Not looking ahead	Lowered concentration	Glance at the road	-

3-7. Effects of the Subjective Sleepiness Score and Aggression Score

Traffic accidents resulting from drowsiness can result in serious accidents. Research by Noda reported that a correlation was found between the number of traffic accidents experienced (including traffic incidents) and the subjective sleepiness score as determined by the Epworth Sleepiness Scale method of evaluation [15]. The sample size for this previous research was 87, which is on the same order as the sample size of 35 for Investigation 2 in this study. In addition, the study was conducted on an interview basis, and the ages and driving histories of the respondents were similar. As a result, we concluded that this study is a suitable object of comparison, and performed regression analysis.

Because the estimated average number of traffic incidents encountered per year is 3.1 (as described in Section 3-1), we have judged that the traffic incidents which were investigated in this study are ordinary phenomena, and set the number of traffic incidents as the response variable. In addition, because a scatter plot of the aggression scores and traffic incident occurrences shows correlation with an aggression score of 2 or higher, we added the aggression score to the explanatory variables. With the number of traffic incidents as the response variable Y, the subjective sleepiness score (X_1) and aggression score (X_2) as explanatory variables, and C_0 as a constant term, 1% was used for the data level of significance and regression analysis was performed using Formula (2).

$$Y = \sum_{i=1}^{k} a_i \cdot Xi + C_0 \qquad (2)$$

Here, k = 2.

Based on the results of previous research by Ueda [25], it is known that when r is the coefficient of correlation and n is the number of samples, then the following is true.

$$r^2 > 4 / (n+2) \qquad (3)$$

Therefore, our evaluation of the significance for the coefficient of correlation was performed in this way.

3-7-1. Number of Traffic Incidents and the Subjective Sleepiness Score

Regression model 1 in Table 6 (n = 35) shows that a coefficient of correlation of 0.60 was obtained with a level of significance of 1% for occurrences of traffic incidents and the subjective sleepiness score. This is larger than the Formula (3) judgment value of 0.33, indicating that correlation is present. Regression model 2 (n = 87), which was used previously by Noda [15], shows that a coefficient of correlation of 0.49 was obtained with a level of significance of 1% for the number of traffic accidents including traffic incidents and the subjective sleepiness score. We have compared the regression coefficient and intercept calculated by Regression model 2 with Regression model 1 with the results of this study, and found that the orders of both match. This demonstrates that there is correlation between the number of traffic incident occurrences and the subjective sleepiness score that was used in this questionnaire investigation. The contribution rate (R^2) for the prediction formula obtained from regression model 1 in this study is 0.34. While this value is rather good in terms of statistical forecast accuracy, it is not sufficient for use as a predictive formula.

These results also match a conclusion which can be drawn from previous research [24] concerning the relationship between drowsiness and traffic accidents among taxi drivers, namely that the occurrences of traffic incidents alone cannot explain the Epworth Sleepiness Score (ESS). In order to improve the accuracy of the prediction formula, it will be necessary to conduct detailed studies of the traffic environment, the effects of other vehicles, and similar factors in the future.

Table 6. Results of Regression analysis for occurrences of traffic incidents

Model	Statistic	Response variable Y	Explanatory Variable		C_0
			X1	X2	
		Occurrences of traffic incident	Epworth Sleepiness Score (point)	Comprehensive Aggression Score (point)	
1 N=35 Based on Interview Investigation	Regression coefficient	-	0.30	-	0.39
	R,t	R=0.60	t=4.34	-	t=0.81
	P value	-	0.0001	-	0.43
	Adjusted R-squared	R^2=0.34	-	-	-
2 N=87 Referred from the paper[15]	Regression coefficient	-	0.24	-	0.65
	R,t	R=0.49	-	-	-
	P value	-	p <0.001	-	-
3 N=16 Comprehensive Aggression score of 2 or higher	Regression coefficient	-	-	0.83	0.13
	R,t	R=0.74	-	t=4.08	t=0.23
	P value	-	-	0.001	0.82
	Adjusted R-squared	R^2=0.51	-	-	-

3-7-2 Number of Traffic Incidents and the Aggression Score

As described in Section 3-5, Kasuga *et al* found a significant correlation between several traffic incident experiences and irritation and hostility during driving. We therefore performed regression analysis and obtained a coefficient of correlation of 0.74 with a level of significance of 1%. This is shown in regression model 3 (n = 16) in Table 6. This is larger than the Formula (3) judgment value of 0.47, and we can say that correlation is present. Correlation was confirmed with a comprehensive aggression score of 2 or higher, and the contribution rate (R^2) was 0.51, which statistically is not a bad value in terms of predictive accuracy. However in the same way as with subjective sleepiness, it is necessary to consider irritation and hostility together with other factors in order to make a prediction of the number of traffic incidents experienced. From the above, we have found that there is correlation between the occurrences of traffic incidents and subjective sleepiness and comprehensive aggression, with a level of significance of 1%. It will be necessary to focus on these factors in order to consider ways to reduce traffic accidents.

4. Conclusions

In this study, the questionnaire investigation of traffic incidents and the results of analysis make clear the following points.

(1) 86% of traffic incidents can be explained by the seven accident types that are defined in the Phase 3 ASV Promotion Project. In addition, this questionnaire investigation collected traffic incidents which were more closely linked to potential dangers in ordinary driving, in comparison with actual accidents and incidents investigated in the past by means of drive recorders. This study was able to verify the suitability of this investigation method. For future investigations concerning traffic accidents, it will be necessary to add driver questionnaire investigations to the existing statistical analysis of accidents, detailed on-site accident investigations, and investigations of near-miss accidents using drive recorders, and to adopt a comprehensive approach to preventing accidents immediately before they occur.

(2) In Investigation 1, human error accounted for 74% of the driver behaviors, a figure which is close to the results of previous research. In order to consider ways to reduce traffic accidents, it will be necessary to focus on human errors in the time immediately before an accident occurs. Driving support systems which utilize physiological signals can be expected to be effective as a countermeasure to the driver factors which can result in accidents.

(3) A relationship between the occurrence of traffic incidents and specific driver characteristics was made clear. For example, the driver mental and physical state of *lowered concentration* affects the driving behavior *desultory driving,* and the mental and physical state of *haste* affects the driving behaviors *no safety confirmation* and *inappropriate assumption.*

(4) From the interview-based Investigation 2, correlation was found between the occurrences of traffic incidents and subjective sleepiness and aggression (score of 2 or higher).

5. Issues for Future Research

Future research will be oriented towards the creation of an advanced physiological signal-driven driving support system that can prevent the potential dangers that lead to traffic accidents. We intend to use a driving simulator to reproduce the driver behavior that corresponds to the types of traffic incidents found from analysis of the questionnaire investigation results [26][27], in order to identify significant physiological signals which are related to lowered concentration (distraction) [28][29], subjective daytime sleepiness [30], comprehensive aggression, and other factors which take affect before the start of driving and which have effects on a comparatively long time axis [31][32][33].

We also intend to expand questionnaire investigation data. In addition, we will search for methods (Figure 12) which can detect in real time the factors which affect the driver mental and physical state, based on changes in the driving environment and other conditions.

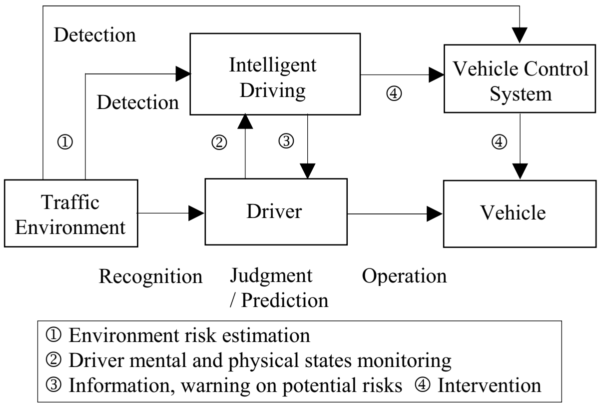

Figure 15. Intelligent driving support system using driver physiological signals

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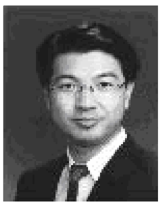

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