Submitted by the experts of Japan

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Results of a Study on Reduced Awakeness in Drivers Using ACSF

National Traffic Safety and Environment Laboratory, Japan

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Objectives and Methodology of the Study

Objectives:

1. To study the conditions under which awakeness is reduced in drivers while using ACSF on motorways;
2. To discuss the inhibitory effect that button-pushing at given intervals has on the awakeness reduction;
3. To propose, based on the results of the study, the time until the onset of warning should occur in the event where the driver availability recognition system is unable to confirm the driver activity.

Methodology:

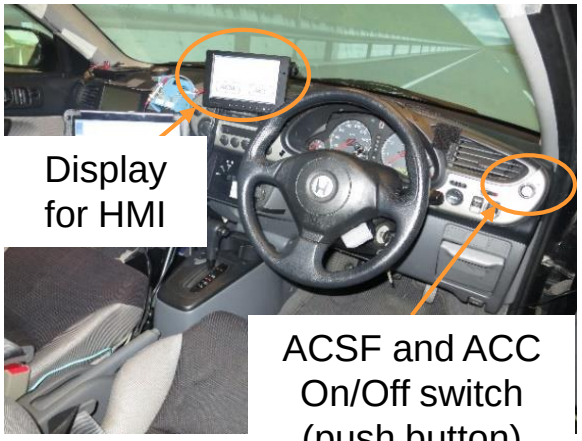
1. To achieve the above objectives, testing was conducted using a driving simulator (DS) with normal drivers driving the vehicle, equipped with a system where ACSF and ACC are combined, for 25-40 min per test, each test being performed for multiple times per driver.
2. For the system to be used continuously, button-pushing at given intervals was included in the test conditions of some test scenarios.
3. Testing was conducted on 30 subjects aged between 20s and early 70s.

Test Conditions

- Test subjects drove on a motorway driving lane using a system where category E of ACSF (lane keeping and automatic lane change for overtaking) is combined with ACC.
- Drivers did not operate the vehicle manually; they kept their hands away from the steering wheel. However, they were instructed to take over the operation (to drive manually) when they detect any danger or when the system gives warning that urges them to operate the vehicle manually.
- To simulate situations where ACSF is used continuously for a long period of time, the vehicle was driven for at least 25 min and at most 40 min per test (various driving times were used, with each difference being about 5 min). An event where the system fails and transition to the driver's manual operation takes place was programmed to occur at the end of each test. Each test was deemed to have ended upon the completion of the transition to the manual operation.

Test Conditions

- In some test scenarios, for the system to be used continuously, drivers were instructed to push the system on/off button at given intervals (1-min-intervals and 5-min-intervals were used in separate scenarios).
- No sub task (action irrelevant to driving) was performed during testing.

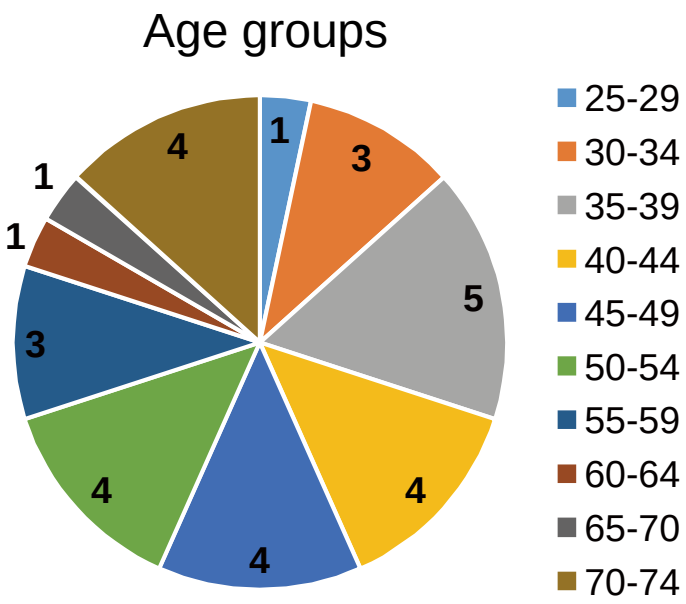


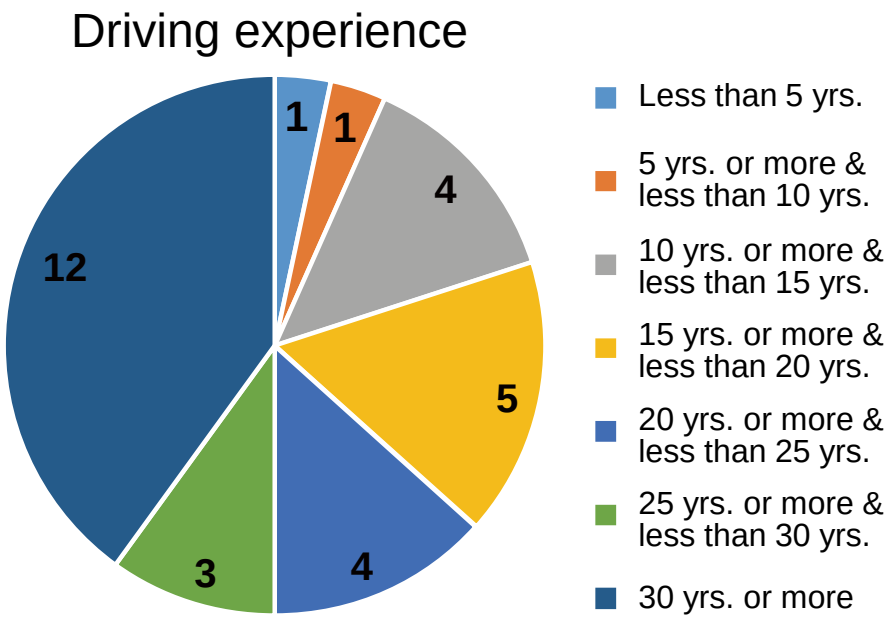
How We Observed Awakeness Reductions

- We observed the drivers' eyes and faces in videos of their faces taken by a compact camera during testing.
- The results of our observation found that the drivers, after they started driving and a certain period of time elapsed, began to repeat closing their eyelids (eye-closure state) for a longer duration than the normal blinking (in these tests, the duration was 0.4 sec or longer). Thus, in this study, we chose to extract the eye-closure state as a way to verify how the awakeness reduces.
- To measure the time between the start of the driver's driving in the awake state and the onset of eye-closure, the first test scenarios performed after the rest were subjected to verification.

Breakdown of Test Subjects

- A total of 30 normal drivers were subjected to testing (17 male drivers and 13 female drivers), as shown below:





Number of Test Scenarios Subjected to Verification

Composition of test subjects		Number of test scenarios subjected to verification*		
Age group	**Driving experience (Nos. in parentheses = nos. of drivers)**	**No button-pushing**	**With button-pushing action (1-min-intervals)**	**With button-pushing action (5-min-intervals)**
25–29	5 yrs. or more & less than 10 yrs. (1)	3		1
30–34	10 yrs. or more & less than 15 yrs. (2) 15 yrs. or more & less than 20 yrs. (1)	9	2	1
35–39	10 yrs. or more & less than 15 yrs. (1) 15 yrs. or more & less than 20 yrs. (3) 20 yrs. or more & less than 25 yrs. (1)	17	3	
40–44	10 yrs. or more & less than 15 yrs. (1) 15 yrs. or more & less than 20 yrs. (1) 20 yrs. or more & less than 25 yrs. (2)	12	2	2
45–49	25 yrs. or more and less than 30 yrs. (1) 30 yrs. or more (2)	12		1
50–55	20 yrs. or more & less than 25 yrs. (1) 25 yrs. or more & less than 30 yrs. (2) 30 yrs. or more (2)	13	2	1
55–59	30 yrs. or more (3)	11		1
60–64	30 yrs. or more (1)	4		
65–69	30 yrs. or more (1)	3	1	
70–74	Less than 5 yrs. (1) 30 yrs. or more (3)	13		3

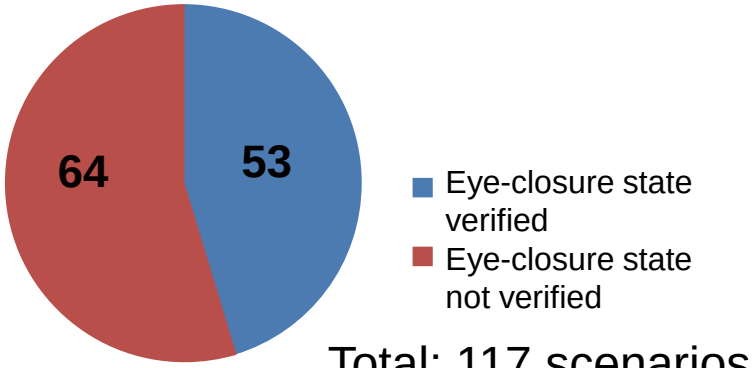
* The first test scenarios performed after the rest were subjected to verification.

→Total: 117

Test Results

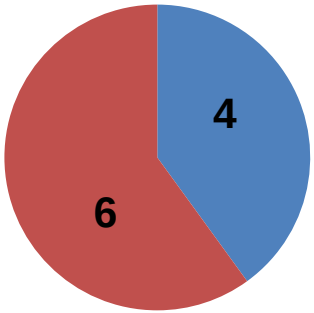
Number of test scenarios where the eye-closure state was verified

- The eye-closure state was verified in 53 scenarios, which account for about 45% of the test scenarios subjected to verification (117 in total).
- At least 1 eye-closure movement was verified in 20 out of the 30 test subjects.

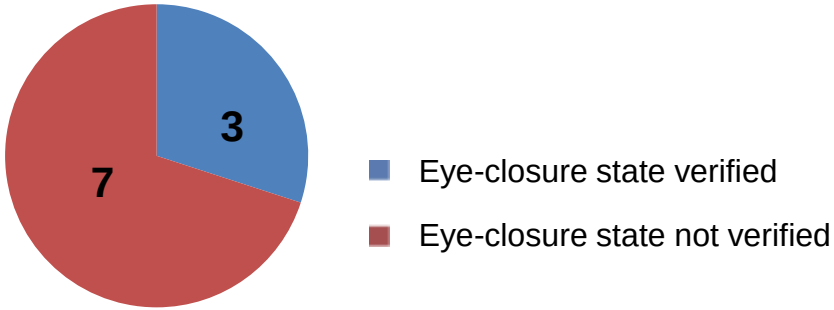


Total: 117 scenarios

- The eye-closure state was also verified in 30–40% of the test scenarios where the button was pushed at given intervals.



Scenarios with button-pushing at 1-min-intervals (10 scenarios)



Scenarios with button-pushing at 5-min-intervals (10 scenarios)

Test Results

Next, the verification results for the test scenarios where the eye-closure state was verified (53 scenarios in total) will be shown from the following 3 perspectives, respectively:

(1) Distribution of the time elapsing between the start of driving and the onset of eye-closure;
(2) Distribution of the time elapsing until the occurrence of each eye-closure (for all eye-closures);
(3) Intervals of eye-closure occurrences (for all eye-closures).

In addition, the verification results for the test scenarios where the button was pushed (20 scenarios in total) will also be shown:

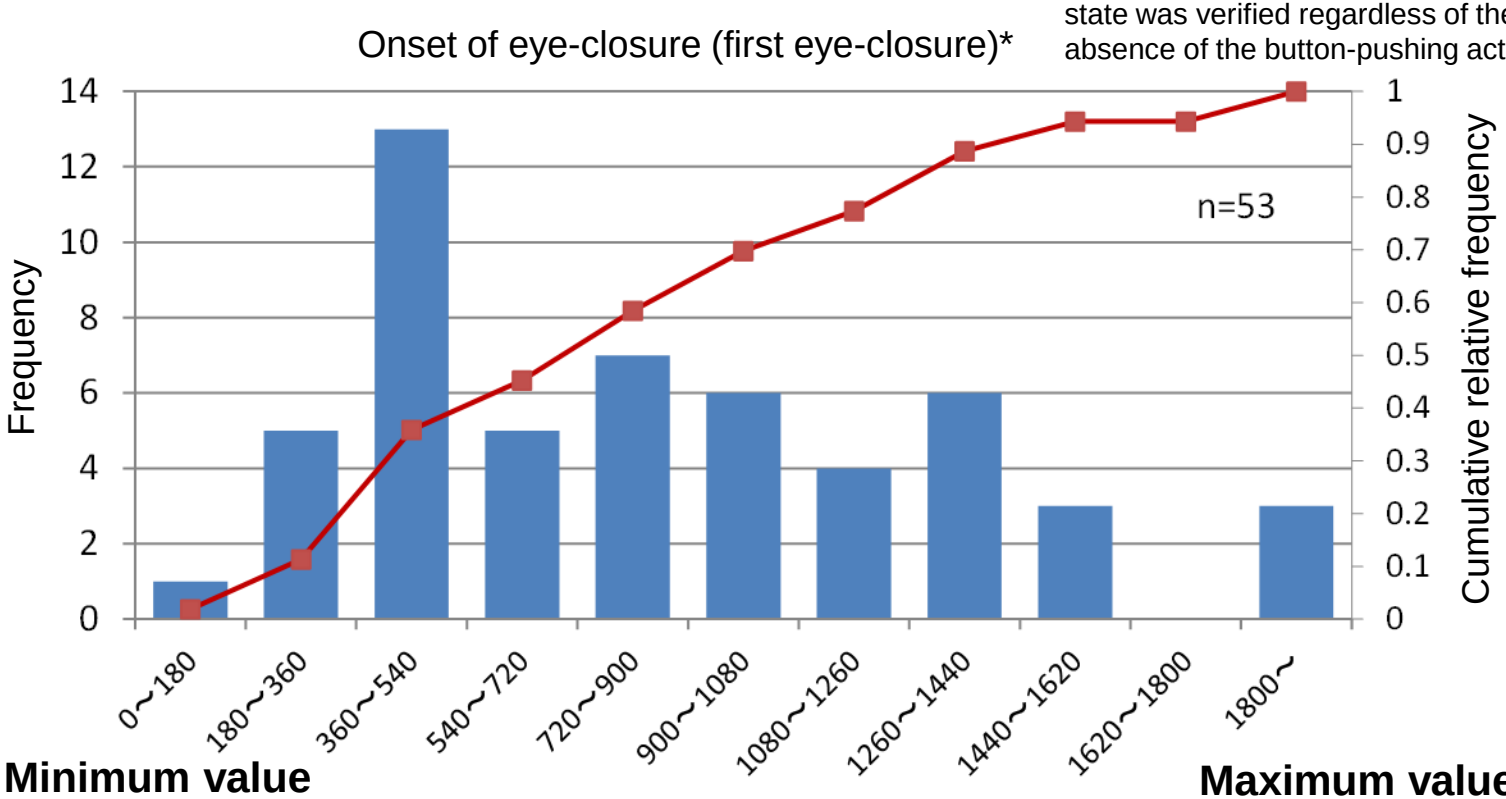
(4) Verification results for the test scenarios with button-pushing actions (“Distribution of the time elapsing until the occurrence of each eye-closure” and “Intervals of eye-closure occurrences”)

Test Results

(1) Distribution of the time elapsing between the start of driving and the onset of eye-closure

- The earliest onset (first eye-closure) took place 180–360 sec (3–6 min) after the start of driving.
- About 60% of all onsets occurred within 900 sec (15 min).

* Distribution for all scenarios where the eye-closure state was verified regardless of the presence or absence of the button-pushing action

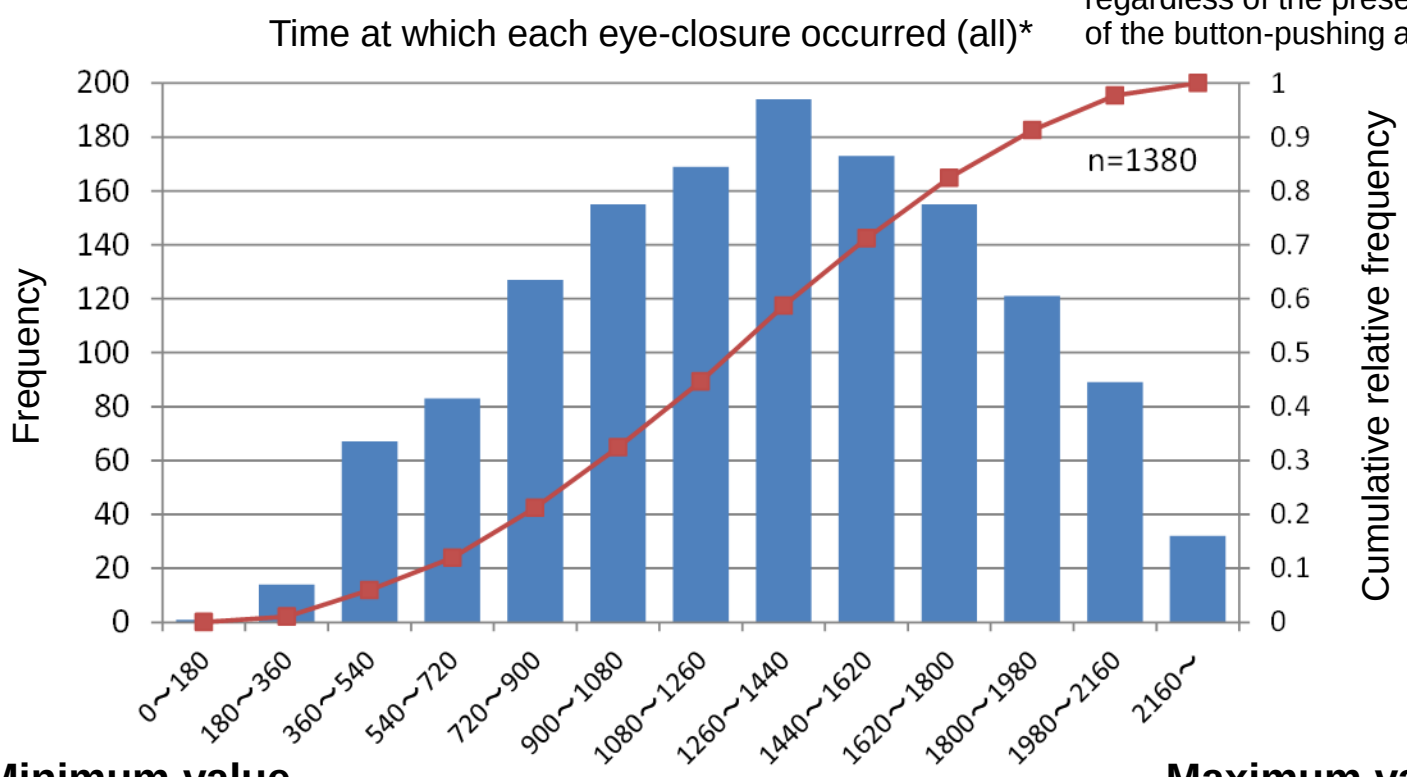


Test Results

(2) Distribution of the time elapsing until the occurrence of each eye-closure (for all eye-closures)

- Most of the eye-closures occurred at the 1260–1440 sec (21–24 min) range. Fewer eye-closures occurred farther away from this range.

* Distribution for all scenarios where the eye-closure state was verified regardless of the presence or absence of the button-pushing action



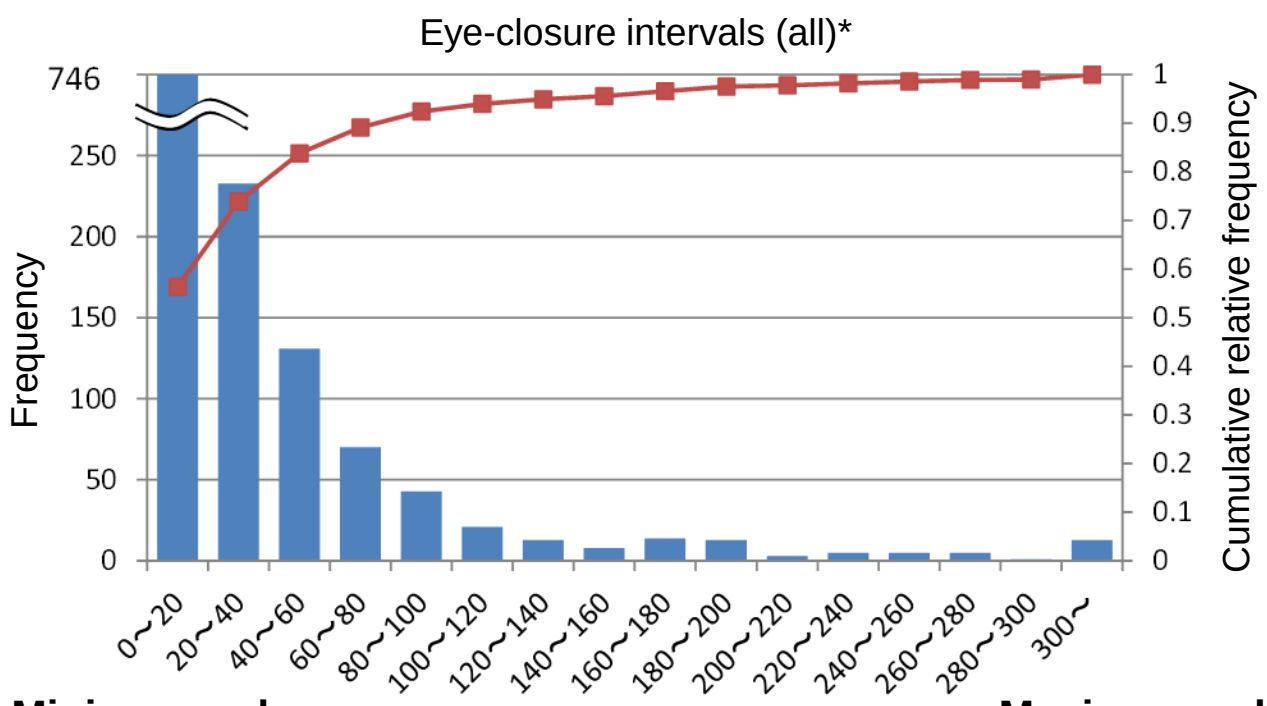
Minimum value = 162 [sec]

Maximum value = 2336 [sec]

Test Results

(3) Intervals of eye-closure occurrences (for all eye-closures)

- Most of the intervals were less than 20 sec, accounting for about 60% of all intervals.
- Many of the test subjects whose eye-closures were verified were found to have closed their eyelids repeatedly at relatively short intervals.



* Distribution for all scenarios where the eye-closure state was verified regardless of the presence or absence of the button-pushing action

Minimum value = 1.5 [sec]

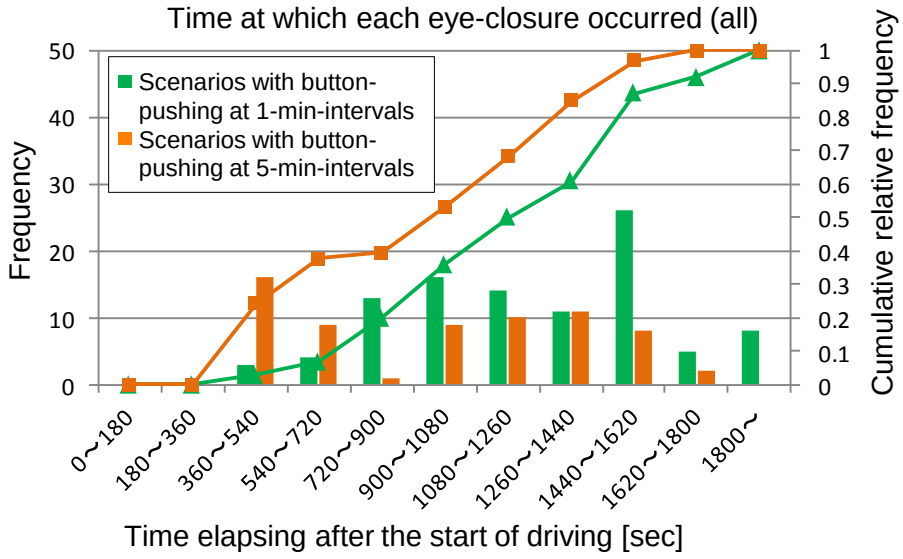
Maximum value = 881 [sec]

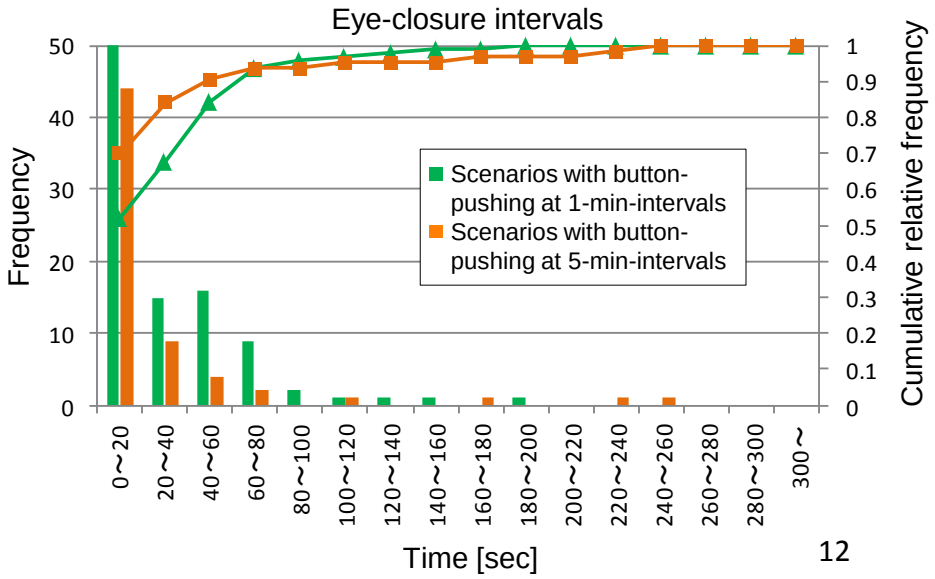
Test Results

(4) Verification results for the test scenarios with button-pushing actions

- The distribution of time elapsing until the occurrence of each eye-closure (left chart) shows eye-closures occurring widely. Furthermore, compared with the 5-min-interval distribution, the 1-min-interval distribution has more eye-closures occurring at higher time ranges.
- As regards the eye-closure intervals (right chart), most of the intervals were less than 20 sec in both the 1-min-interval distribution and the 5-min-interval distribution, although the 1-min-interval distribution has more eye-closures occurring at slightly longer intervals.

⇒ **In relation to eye-closure occurrences, no significant difference between presence and absence of the button-pushing action was seen.**





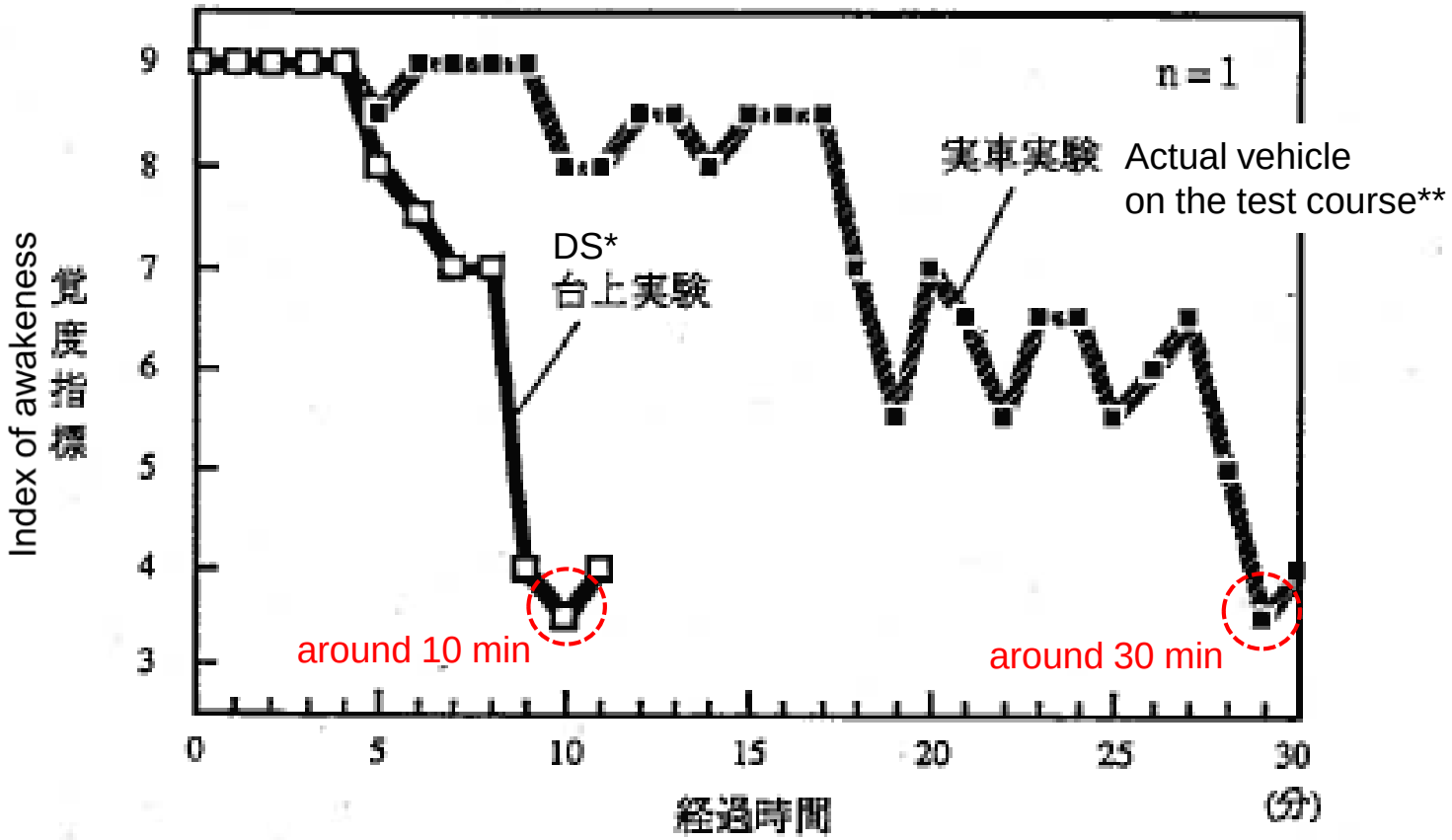
Summary

- Many of the drivers whose awakeness reduces while driving on motorways using ACSF tend to close their eyelids for a few sec repeatedly at relatively short frequencies of less than 20 sec.
- The earliest onset of eye-closure after the start of driving took place within 3–6 min, and about 60% of all onsets occurred within 15 min.
- While it is necessary to take into account the fact that this study was conducted using DS which is different from the real-world driving environment*, we would like to propose, based on the above results, that the time until the onset of warning should occur in the event where the driver availability recognition system is unable to confirm the driver activity be specified to be 3 min.
- As for the repeated button-pushing actions for the system to be used continuously, the results of this study indicate that such actions would not be sufficient as a measure against the awakeness reduction in drivers using ACSF.

* There is a Japanese industry's research which shows that awakeness of a driver who drives on a DS tends to reduce in shorter time compared to actual vehicle.(see next Appendix) Therefore, the above test results should be treated carefully.

Appendix-Example of research-

Hiramatsu, Kasai, Taguchi: A study of Effects of Odor on Relieaving Drowsiness, (JSAE Paper 9533901(1995))



* A stational type DS was used, and all windows were covered to make the room dark. The task of the driver was monotonous work to track a course on a monitor screen.

** Monotonous driving with manual operation by the driver on the test course.