System for Automatically Detecting the Driver's Abnormal Conditions

Basic Design Document

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ASV (Advanced Safety Vehicle)
Promotion Study Group,
Road Transport Bureau,
Ministry of Land, Infrastructure,
Transport and Tourism

History

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1.　Introduction
1.1.　Positioning of the Basic Design Document

This Basic Design Document provides for technical requirements to be met, matters to be taken into consideration, etc. when designing a system for automatically detecting the driver's abnormal conditions to be used for the driver's abnormal condition response system.

Explanatory Note:

This system will be used in combination with the driver's abnormal condition response system, which is a system capable of stopping the vehicle for the driver as an emergency measure when it suddenly becomes difficult for the driver to continue driving safely due to sudden changes, etc. in his/her physical condition. This document first defines requirements for those detection items whose early practical application is expected, and will be revised and include additional detection items in line with the progress of technological developments in the future.

1.2.　Definition of Terms

(1)　"Driver's abnormal condition" means a sudden change in one's physical condition that is difficult to predict in advance. The driver's abnormal conditions do not include predictable poor physical conditions or abnormalities.

(2)　"Driver's abnormal condition response system" means a system capable of detecting the driver's abnormal conditions and stopping the vehicle for the driver.

(3)　"System for automatically detecting the driver's abnormal conditions" means a system capable of detecting the occurrence of the driver's abnormal conditions using sensors, etc. (hereinafter referred to as the "System").

(4)　"Abnormal condition detection" means to predict the driver's abnormal condition, i.e., a sudden change in one's physical condition that is difficult to predict in advance, based on facts obtained from a single detection item or a combination of two or more detection items.

(5)　"Confirmed abnormal condition" means a situation where the

System has detected an abnormal condition, causing the driver's abnormal condition response system to turn on the activation start alarm, and the activation is not cancelled even after 3.2 seconds, in principle, have elapsed.

(6)   "Driver status" means the driver's external condition such as his/her posture, facial expression, and hand/foot motion, or the driver's internal condition such as his/her hemodynamics and cranial nerve response.

(7)   "Driving behavior" means operation of the steering wheel, accelerator, brake, etc. as well as an action necessary for safe driving such as a visual check.

(8)   "Driving operation" means operation of the steering wheel, accelerator, brake, etc.

(9)   "Vehicle behavior" means the vehicle's motion such as wavering and speed-changing.

(10)   "Detection item" means a specific item of a driver status, driving behavior, vehicle behavior, etc. that is used to detect abnormal conditions.

(11)   "Index" means the physical quantity that describes the state of a detection item.

(12)   "Threshold" means a specific value or qualitative requirement based on which the occurrence of the driver's abnormal condition is determined.

(13)　　"Response check actuation" means the System requesting the driver to perform some kind of response operation so as to enable the System to determine whether or not the driver can continue driving.
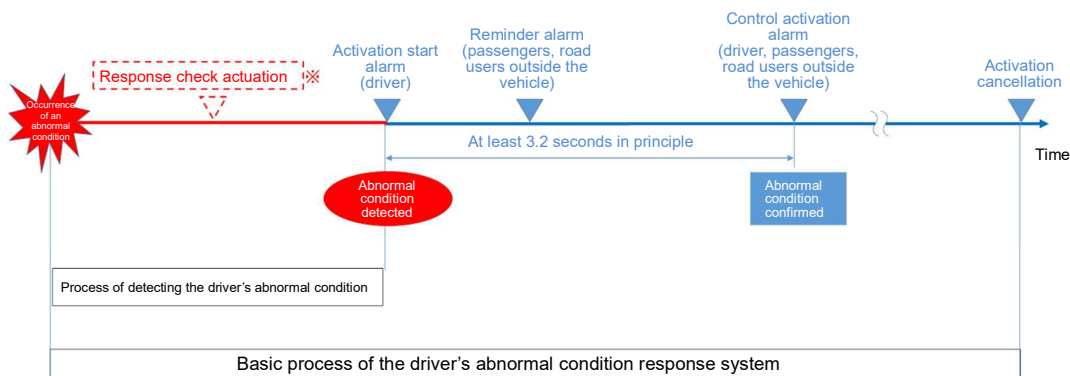
1.3.　　Driver's Abnormal Conditions to Be Detected

The driver's abnormal conditions to be detected by the System shall be those abnormal conditions that make it difficult for the driver to drive safely once they occur, such as sudden symptoms of vascular brain diseases, cardiac diseases, digestive system diseases, fainting, etc. The System is not intended to detect predictable poor physical conditions or abnormalities due to drinking alcohol, poor management of one's physical condition, fatigue, sickness, drugs, etc. However, it does not preclude detection of such predictable poor physical conditions or abnormalities.

2.　　Process of Detecting the Driver's Abnormal Condition

2.1.　　Method for Detecting an Abnormal Condition

An occurrence of the driver's abnormal condition is detected when the index reaches the threshold or when, in addition to this, there is no response from the driver for a certain period of time after the start of the response check actuation. As the "certain period of time", appropriate time shall be set so as to enable the driver who can continue driving to respond to the response check actuation. The driver shall be deemed to be capable of continuing driving if the index does not reach the threshold or if it is determined that the driver has operated properly the steering wheel, accelerator, brake, switch, etc.

It should be noted that, for reducing accident risks, it is desirable to detect the occurrence of an abnormal condition as quickly as possible.

※ Whether the response check actuation is required or not depends on the target detection item, index, and threshold.

Figure 1: Process of Detecting the Driver's Abnormal Condition

2.2.   Detection Items

Events that occur due to symptoms of vascular brain diseases, cardiac/aortic diseases, diabetes, and epilepsy include "Collapsed postures", "Closed eyes", and "No steering wheel operation". As the detection items for these events, the statuses "Collapsed postures" and "Closed eyes" are considered to increase the degree of dangerous driving due to the continued lack of forward attention, whereas the status "No steering wheel operation" is considered to increase the degree of dangerous driving due to the continued loss of consciousness. When the detection is difficult using one of these detection items alone, the detection accuracy may be improved by using it in combination with other detection items or the response check actuation.

Appendix Tables show the relations between diseases/disorders and symptoms, between symptoms and detection items, and between detection items and indices.

See the Attachments for specific detection methods for each detection item.

i.e., "Collapsed postures" status, "Closed eyes" status, and "No steering wheel operation" status.

The "Collapsed postures" status is easy to be expressed in physical quantities (e.g., angle, joint position, etc.), and it is also possible to define thresholds using numerical values. Similarly, the "Closed eyes" status is relatively easy to be expressed in physical quantities, which is an advantage. As for the "No steering wheel operation" status, although it is difficult to predict it based solely on this detection item, the detection accuracy can be improved by combining it with the response check actuation or other detection items. In addition to the above, other items such as the "Open eyes" status and "Gazes / eye movements" status could also be used to detect the driver's abnormal conditions, and it is also considered possible to determine whether the driver is conscious or unconscious by using saccades, which are said to be correlated with the visual fixation and the function of attention. However, since there are individual differences in the "Open eyes" status and because detection technologies based on gazes or eye movements are not fully developed yet, we have decided to continue the discussion on these possibilities along with the discussion on the driver monitoring (prediction of signs of driving conditions and abnormal conditions, etc.).

As regards the matrices (Appendix Tables) showing the relations between diseases/disorders and symptoms, between symptoms and detection items, and between detection items and indices, although we created these tables based on the information obtained from medical practitioners as well as the information obtained from manufacturers participating in the ASV Promotion Project, this does not mean that other symptoms, detection items, indices and their respective relations will be excluded.

In the future, we will consider including more detection items in accordance with the progress of technologies for detecting the driver's abnormal conditions and will specify detection methods for detection items to be added to the Attachments.

2.3.　Response Check Actuation Method

The sense of vision must be used, and at least one of the physical senses that include the sense of hearing, sense of touch and gradual deceleration must be used as well.

The response check actuation shall be started at an appropriate timing to verify whether or not the driver is being capable of continuing driving. The timing to start the response check actuation shall be set appropriately, taking into account the detection accuracy of the detection items used. It may also be made variable in response to the vehicle speed and/or the activation status of driver assistance systems (lane keeping assist system,

cruise control/adaptive cruise control, etc.).

3. Measures to Be Taken When the System Fails

The System shall have measures to make the driver aware of any system malfunction detected by the System.

4. Items to Be Known to the Driver

The following items shall be made known to the driver appropriately by means of the instruction manual, indication, etc.:

  (1)   Purpose, kind and effects of the System;
  (2)   Conditions for activating the System and conditions for not activating the System;
  (3)   The System's sounds, indications, etc. as well as their meanings;
  (4)   Limit of the System's function;
  (5)   Other instructions for use.

Explanatory Note:

The above items to be known to the driver are listed as the information necessary for the driver to understand and use the System correctly. Documenting the fact that an adequate explanation was given to the driver or the vehicle operator, etc. is significant to a certain degree as the evidence that accountability has been fulfilled.

Explanatory Note:

   We referred to the following literatures to develop this Basic Design Document:

(1) Motozawa, Y. et al., "Analysis of Sudden Death Cases during Driving," *Proceedings of the JSAE Annual Congress (Spring)*, No.41-04: 9-12, 2004.

(2) Yasukawa, A. et al., "Reconstruction of Driving Posture Based on Autopsy Examples," *Journal of the Japanese Council of Traffic Science*, 11(2), 2011.

(3) Hitosugi, M., "Investigation of Accidents Caused by the Sudden Onset of a Disease While Driving a Taxi—Analysis of Dashcam Data," *The Japanese Council of Traffic Science*, 2013.

(4) Kawachi, S. et al., "Vehicle Driving Posture at Drivers' Unconsciousness and Accident Prevention," *Japanese Journal of Occupational Medicine and Traumatology (JJOMT)*, 61(2):144-147, 2013.

(5) Hitosugi, M., "Analysis and Preventive Measures of the Vehicle Collisions due to Drivers' Health Problems", *Journal of Society of Automotive Engineers of Japan*, 70(3), 2016.

(6) Hitosugi, M.,"Disease and Vehicle Driving: For the Prevention of Health-related Vehicle Collisions," *Journal of Society of Automotive Engineers of Japan*, 71(12), 2017.

Specific detection method for each detection item

	Item number	Detection item
Driver Status	DS-1	Collapsed postures
	DS-2	Closed eyes
	DS-3	No steering wheel operation
Driving Behavior	DB-	
Vehicle Behavior	VB-	

Explanatory Note:

   "Collapsed postures", "Closed eyes" and "No steering wheel operation", as indicated in the present version of the Attachments, are all classified into the "Driver Status" category. In the future, if we consider including more detection items in accordance with the progress of technologies for detecting the driver's abnormal conditions and add them to the Attachments, they will be classified into one of the three categories of "Driver Status", "Driving Behavior" and "Vehicle Behavior", and appropriate item numbers will be assigned.

   The item number consists of the following:

   ○○-X

- ○○ can be DS (Driver Status), DB (Driving Behavior), or VB (Vehicle Behavior).
- X is a sequential number for DS, DB, or VB.

DS-1　Collapsed Postures

Brief description:
The driver's abnormal condition is detected based on his/her posture.
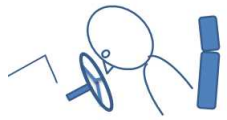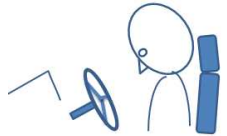
1.　　Classification
Driver Status

2.　　Detection Items
　Collapsed postures status

　The driver's possible collapsed postures due to the loss of consciousness, etc. and their possible combinations are shown in Table 1.

Table 1: List of Collapsed Posture Patterns

Collapsed posture pattern	Illustration	Description	Related diseases/dis-orders & symptoms
Slumped forward		The driver is slumped forward with his/her face close to the steering wheel and remains in this posture.	Factor A
Facing downward		The driver is facing downward and remains in this posture.	Factor A
Tilted backward		The driver's upper body is tilted backward with his/her face looking up and remains in this posture.	Factor A
Bent backward		The driver's upper body is bent backward with his/her face looking up and remains in this posture.	Factor B
Tilted to the side (neck only)		The driver's head is tilted to the left or right side, and the upper body remains in this posture.	Factor A
Tilted to the side		The driver's upper body is tilted to the left or right side with his/her face tilted in the same direction and remains in this posture.	Factor A
Leaned to the side		The driver's upper body is leaned to the left or right side and remains in this posture.	Factor A

Factor A: The posture occurs due to muscle relaxation resulting from the loss of consciousness caused by vascular brain diseases, cardiac/aortic diseases, etc.
Factor B: The posture occurs due to stiffening of the body caused by epilepsy.

Explanatory Note:
    While there are a variety of possible collapsed posture patterns, we developed the above table based on our interviews with medical practitioners, etc., in which the possibility of the occurrence of these postures was confirmed. As the human body has a complex skeleton, as well as complicated joint motion ranges and muscle arrangements,

we aimed to define collapsed postures as deviations from the normal driving posture based on posture patterns and use the collapsed posture duration as the index. To this end, we defined the minimum collapsed posture patterns. Hence, we neither exclude other collapsed posture patterns to be detected, nor assume that each pattern will be detected independently.
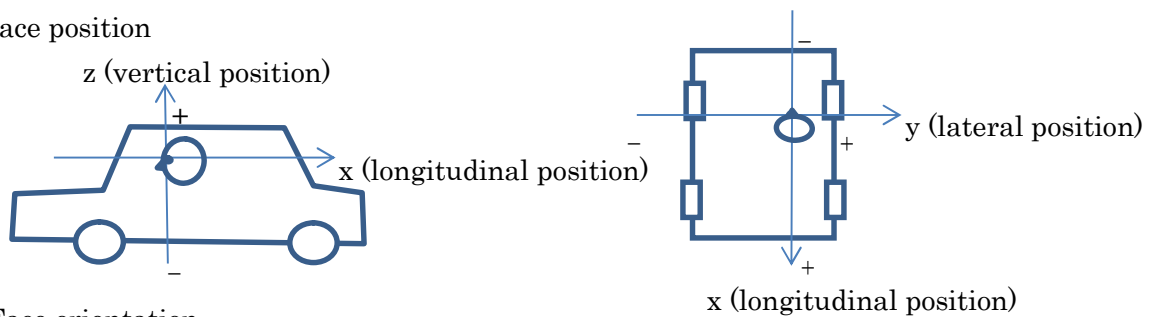
3.　　　Related Diseases/Disorders and Symptoms

　For the diseases/disorders and symptoms related to each collapsed posture pattern, see Table 1.

4.　　　Indices
- Deviation of the face position (x, y, z) from the reference position
- Angles of the face orientation (yaw, pitch, roll)
　　　　(See Figure 1 for the definitions of the axes.)
- Duration

■Face position

z (vertical position)

x (longitudinal position)

y (lateral position)

x (longitudinal position)

■ Face orientation

Yaw (left/right)

z (vertical position)

x (longitudinal position)

y (lateral position)

Roll (tilt to the side)
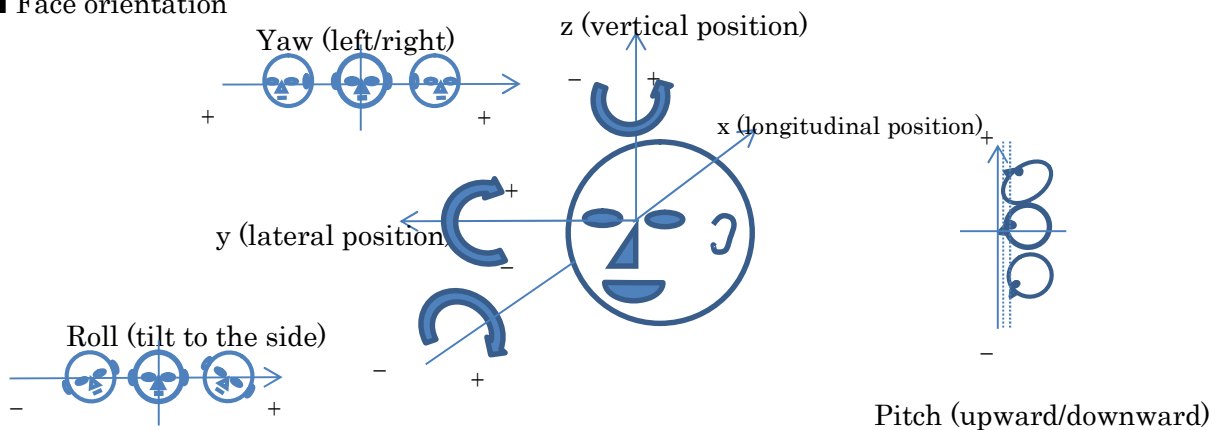
Pitch (upward/downward)

Figure 1: Definitions of the Axes of the Face Position and Orientation

Explanatory Note:

　The reference position is defined as the face position in a posture where the driver is driving in a stable manner for a certain period of time prior to the occurrence of a
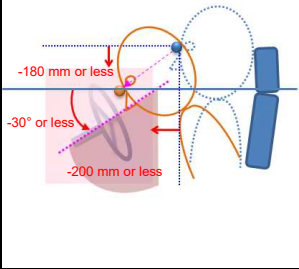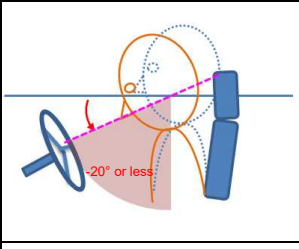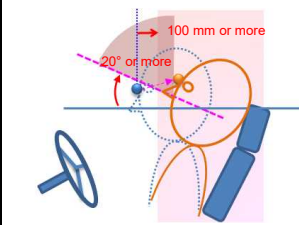
5.　　Thresholds

Thresholds for each collapsed posture pattern are shown in Table 2.

Table 2: Thresholds for Each Collapsed Posture Pattern (1/2)

| Collapsed posture pattern | Thresholds illustrated | Thresholds（reference values） | | | | | | |
		x (longitudinal)	y (lateral)	z (vertical)	Yaw	Pitch	Roll	Duration
Slumped forward		-200 mm or less	-	-180 mm or less	-	-30° or less	-	Appropriate value equal to or more than 2 seconds to be set
Facing downward		-	-	-	-	-20° or less	-	
Tilted backward		+100 mm or more	-	-	-	+20° or more	-	

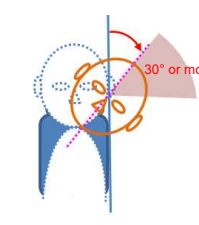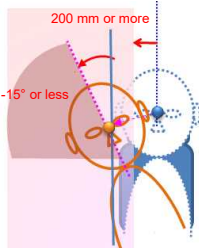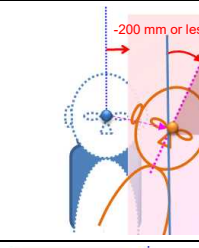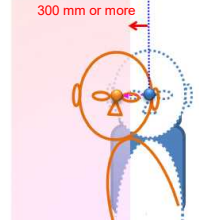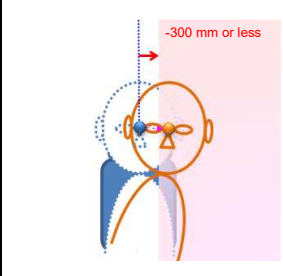| Col-lapsed posture pattern	Thresholds illustrated	Thresholds（reference values）						
		x (longi-tudinal)	y (lateral)	z (vertical)	Yaw	Pitch	Roll	Duration
Bent back-ward		-	-	-	-	+25° or more	-	

Table 2: Thresholds for Each Collapsed Posture Pattern (2/2)

Collapsed posture pattern	Thresholds illustrated	Thresholds（reference values）						
		x (longitudinal)	y (lateral)	z (vertical)	Yaw	Pitch	Roll	Duration
Tilted to the side (neck only)		-	-	-	-	-	-30° or less	Appropriate value equal to or more than 2 seconds to be set (*)
		-	-	-	-	-	+30° or more	
Tilted to the side		-	+200 mm or more	-	-	-	-15° or less	
		-	-200 mm or less	-	-	-	+15° or more	
Leaned to the side		-	+300 mm or more	-	-	-	-	

Col-lapsed posture pattern	Thresholds illustrated	Thresholds（reference values）						
		x (longi-tudinal)	y (lateral)	z (vertical)	Yaw	Pitch	Roll	Duration
		-	-300 mm or less	-	-	-	-	-

-: No value specified (Any value can be set.)

*: Special consideration is needed to ensure distinction from similar behaviors observed in normal driving conditions.

Explanatory Note:

The thresholds for face positions and orientations were set based on the values obtained from simulations that used the skeleton/muscle model for the standard body type, with margins added taking into account the variation factors such as the body type, posture, etc. The simulation results, which reflect typical collapsed postures of the applicable patterns, may differ from the results of measuring the human body with a complex skeleton as well as complicated joint motion ranges and muscle arrangements. For this reason, we provided the margins to offset these differences. It should be noted that we have confirmed that the postures based on these thresholds are considered as abnormal postures that are usually impossible to occur if the driver is driving in the normal condition, i.e., postures with no forward vision. (For example, when the thresholds for the "Slumped forward" posture are reached, the driver will have no forward vision, which is impossible in the normal driving posture.)

As regards the duration threshold, with a view to determining whether safety checks necessary for driving can be performed appropriately by the driver in the target postures, we set the duration for the "Slumped forward", "Facing downward", "Tilted backward" and "Bent backward" postures based on the duration of the "driver not gazing forward" which is unlikely if the driver is driving in the normal condition, as well as by referring to similar driver assistance systems (distracted driving alert, eye closure alert, etc.), time required for the driver to operate a switch while driving, etc. On the other hand, the "Tilted to the side (neck only)", "Tilted to the side" and "Leaned to the side" postures are not necessarily related to the "driver not gazing forward" and can occur for a short duration while the driver is driving normally. Therefore, to reduce detection errors, it will be effective if an appropriate (longer) duration is set as the threshold, if the threshold is

specified in combination with driving behaviors, vehicle behaviors, etc., or if the threshold is made variable. The thresholds specified in this Basic Design Document may be adjusted, as appropriate, when data that can serve as new evidence is obtained or when the postures are restricted due to differences in driving position, seat type and/or seatbelt type of different vehicle models.

6. Response Check Actuation
Optional

Explanatory Note:

The detection accuracy can be improved if the detection is combined with the response check actuation. If the driver remains in a collapsed posture for a long duration, it is highly probable that the driver's abnormal condition has occurred. In this case, since it is desirable to detect such abnormal condition as quickly as possible to reduce accident risks, the response check actuation may be omitted.

7. Special Instructions
Nothing in particular

Explanatory Note:

The reference position of the driver's posture for designing and making evaluations can be set by taking statistics of the driver's eye positions when looking straight ahead and using an "eyellipse" (composite term of "eye" + "ellipse"; JIS D 0021) that defines a distribution range.

DS-2　Closed Eyes

Brief description:
　The driver's abnormal condition is detected based on the duration of the eyes-closed period.

1.　　　Classification
Driver Status

2.　　　Detection Items
Closed eyes status

3.　　　Related Diseases/Disorders and Symptoms
Loss/lowering of consciousness caused by vascular brain diseases, cardiac/aortic diseases, diabetes, and epilepsy

4.　　　Indices
Duration of the eyes-closed period

5.　　　Thresholds
　Duration of the eyes-closed period shall be 2 seconds or more.
The threshold may also be made variable in response to the vehicle speed, the activation status of driver assistance systems, the characteristics of the detection method used, etc.

We set the above threshold by referring to the value set for the eye closure alert that has already been put to practical use, information on technologies currently being developed by manufacturers, the Distraction Guidelines of NHTSA (National Highway Traffic Safety Administration), and so on.

6. Response Check Actuation
Optional

Explanatory Note:
The response check actuation can be performed to determine whether the driver can operate the vehicle based on his/her consciousness level. If the driver's eyes remain closed for a long duration, it is highly probable that the driver's abnormal condition has occurred. In this case, since it is desirable to detect such abnormal condition as quickly as possible to reduce accident risks, the response check actuation may be omitted.

7. Special Instructions
Nothing in particular

DS-3　No Steering Wheel Operation

Brief description:
　The driver's abnormal condition is detected based on the duration of no steering wheel operation.

1.　Classification
Driver Status

2.　Detection Items
No steering wheel operation status

3.　Related Diseases/Disorders and Symptoms
Loss/lowering of consciousness and/or paralysis of the body (hand, foot, etc.) caused by vascular brain diseases, cardiac/aortic diseases, diabetes, and epilepsy

4.　Indices
Duration of no steering wheel operation

wheel operation duration" can be combined with indices related to the operation of the accelerator, brake, etc.

5.　　　Thresholds
The threshold shall be set, but no values are specified in this document.

Explanatory Note:
　As a dangerous situation can occur due to the driver's inability to keep driving in the straight forward direction if the duration of no steering wheel operation is detected for a certain period of time or longer, it is preferable to set an appropriate threshold to detect the driver's abnormal condition. However, at the present moment, since it is affected by various factors such as the vehicle speed and the activation status of driver assistance systems (lane keeping assist system, cruise control/adaptive cruise control, etc.), it is difficult to set the reliable and uniform threshold. Thus, considering that motor vehicle manufacturers will set an appropriate threshold to ensure safety, we decided not to specify any threshold this time. In the future, we will continue discussing this issue in line with the progress of developments of technologies that predict abnormal conditions from driving operations.

6.　　　Response Check Actuation
Mandatory

Explanatory Note:
　The response check actuation shall be performed to determine whether the driver can operate the vehicle based on his/her consciousness/paralysis level.

7.　　　Special Instructions
Nothing in particular

Appendix Tables