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agenda item 10(b))

A Study on Approach Warning Systems for hybrid vehicle in motor mode

JASIC, JAPAN

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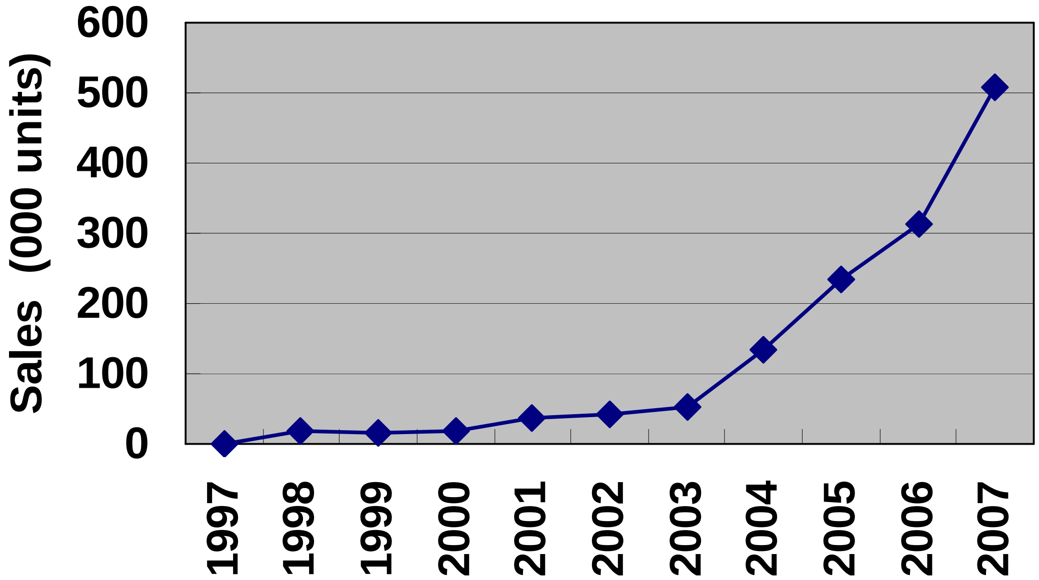
Background to the Study

- Hybrid vehicles (HV) and Electric vehicles (EV) increasing;



Sharp increases in annual sales since 2004

- Those vehicles are very quiet and difficult to be noticed by pedestrians
- However, no reported accident has been confirmed.

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Assessing the Situation

- **No reported accident by vehicles to be quiet has been confirmed.**
- **It is not even known how quiet hybrid vehicles in motor mode are.**
- **We compared the noise level between hybrid vehicles in motor mode (HV (EV mode)) and the gasoline engine vehicles (GE) to determine how difficult they are to notice.**

Method for Assessing the Situation

(1) Comparison of Equivalent Sound Level (L_{Aeq}) Between HV (EV mode) and GE

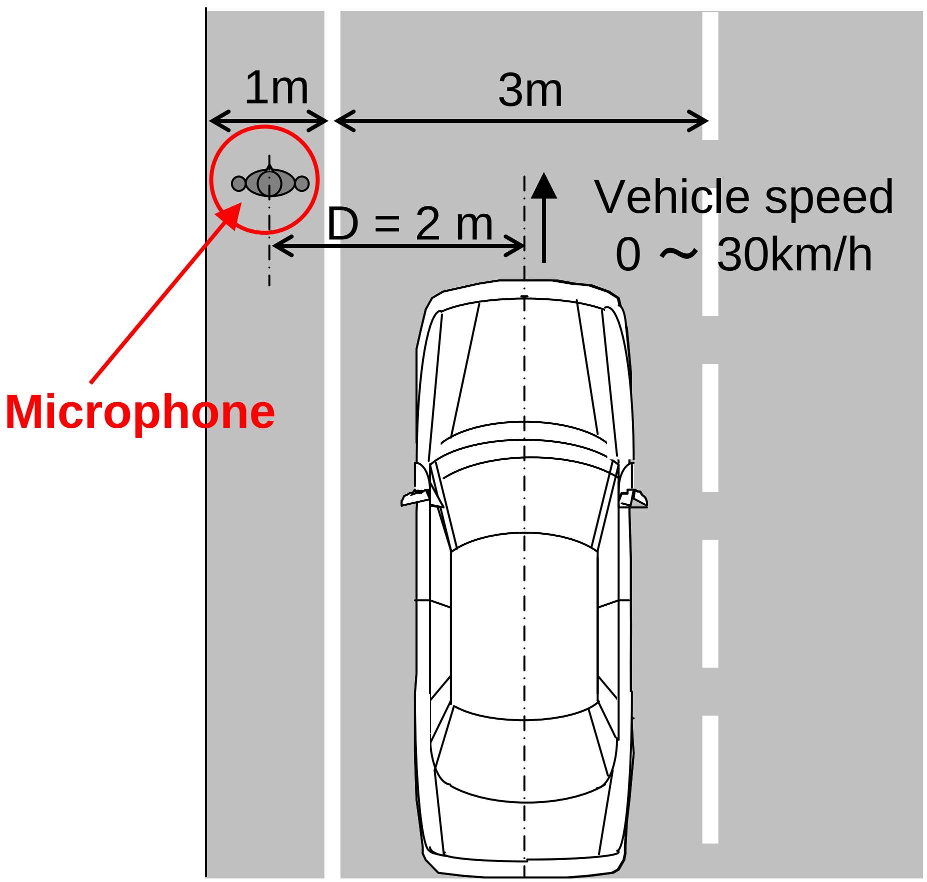
To eliminate the effect of background noise, vehicle noises of HV (EV mode) and GE was recorded in the special environment resembling an anechoic chamber (i.e., at a test course in a mountain with no insect), and L_{Aeq} of them were compared.

(2) Perception of Pedestrians Evaluated

Under a specific environmental condition (indoor), those vehicle noises mixed with background noise were played to subjects, and their perception was evaluated.

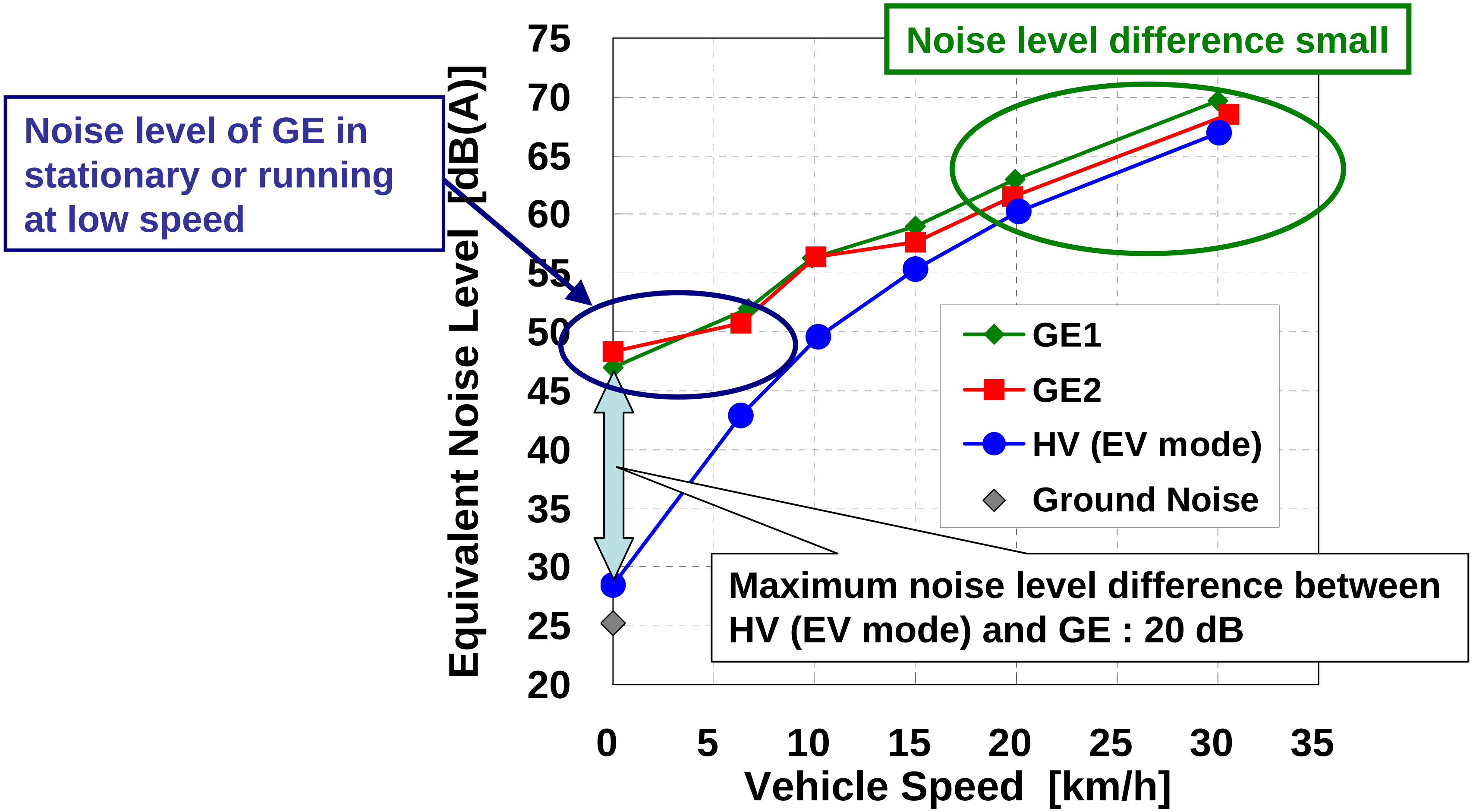
(1) Comparison of Noise Level (L_{Aeq}) Between HV (EV mode) and GE

♦ **Noise level of HV (EV mode) and GE at 2 m to the side**



Measurement schematic

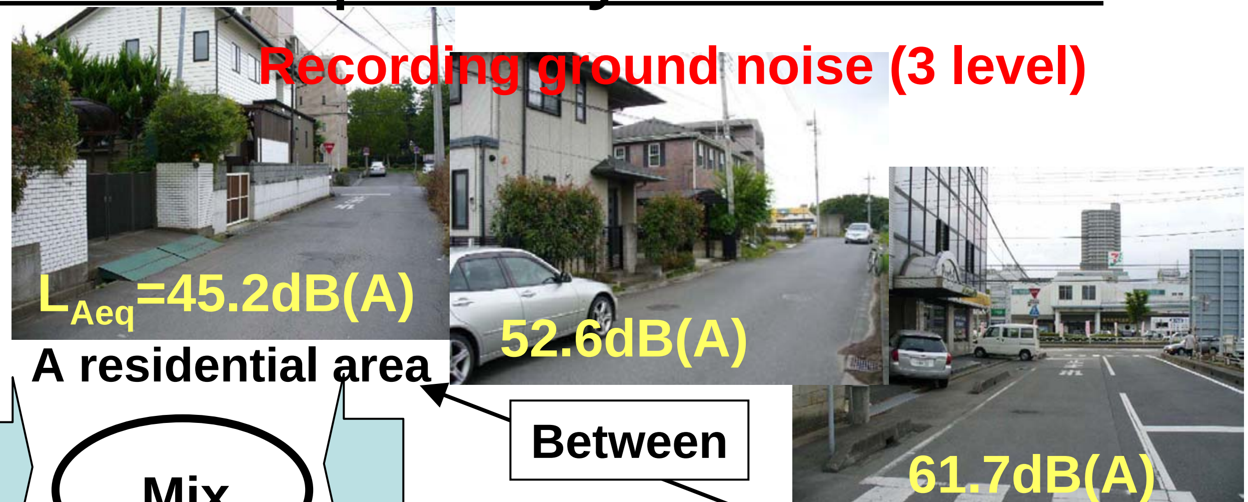
(1) Comparison of Equivalent Sound Level (L_{Aeq}) Between HV (EV mode) and GE



- The slower the speed of HV (EV mode), the bigger the noise-level difference from GE.
- Noise level difference maximum at about 20dB when stationary.
- Noise level difference smaller at speed 20 km/h or above.

(2) Evaluation of Perception by Pedestrians

Recording vehicle noise

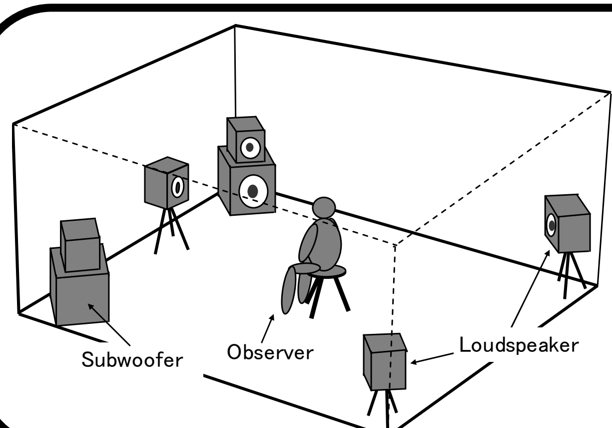


A residential area

Between

A bustling street

Mix

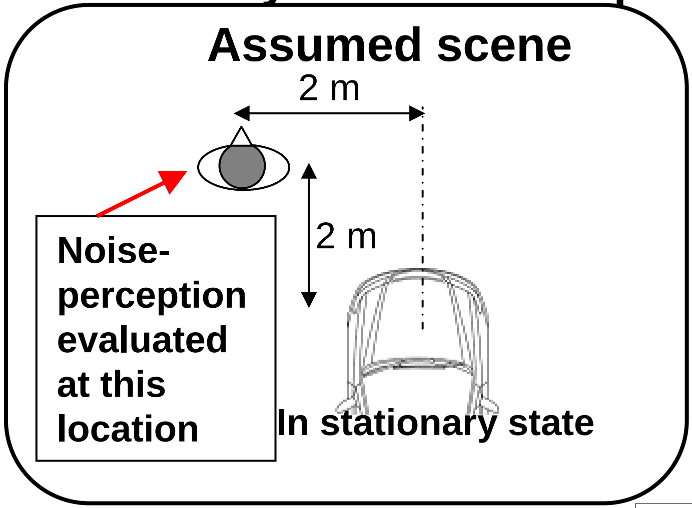


Setup of noise hearing experiment

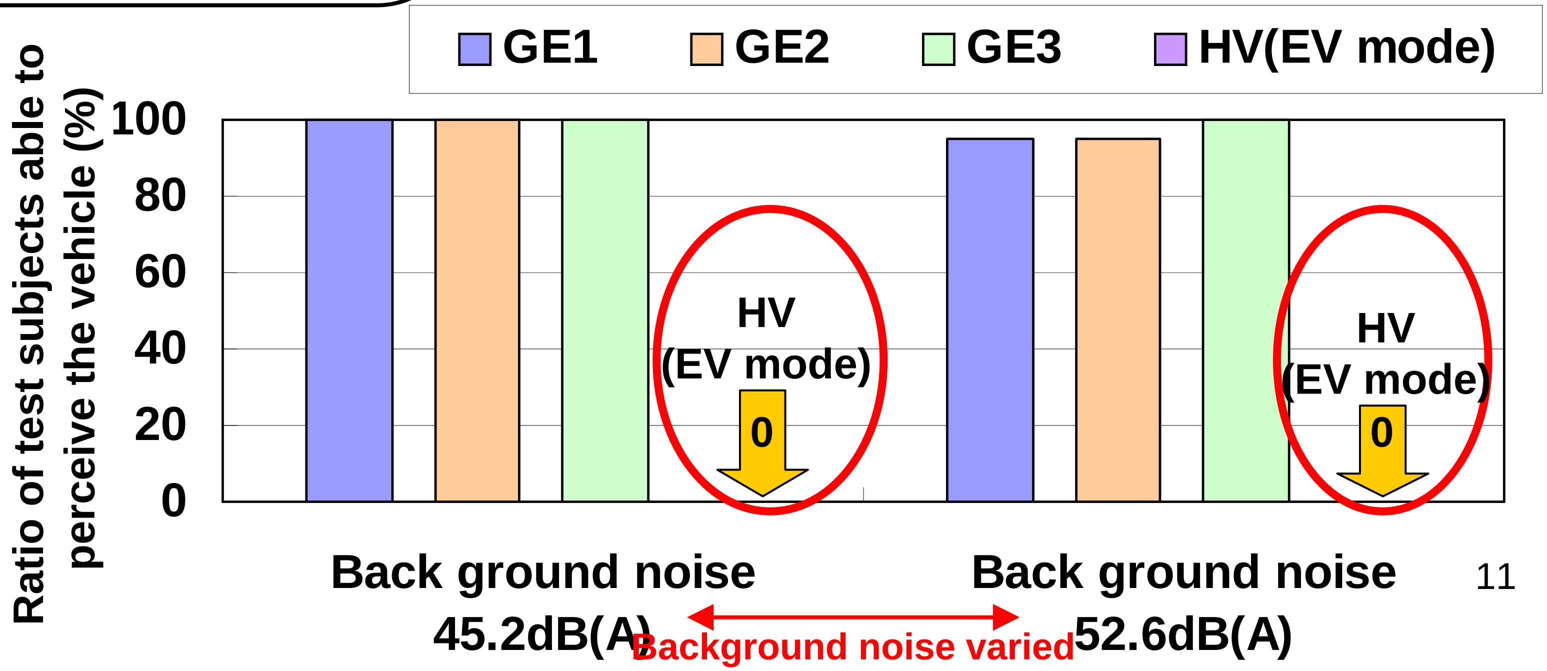
•Evaluation of perception using recorded vehicle noises and 3 ground noises by 20 subjects.

(2) Evaluation of Perception by Pedestrians

◆ **Stationary Vehicle Perception Results**

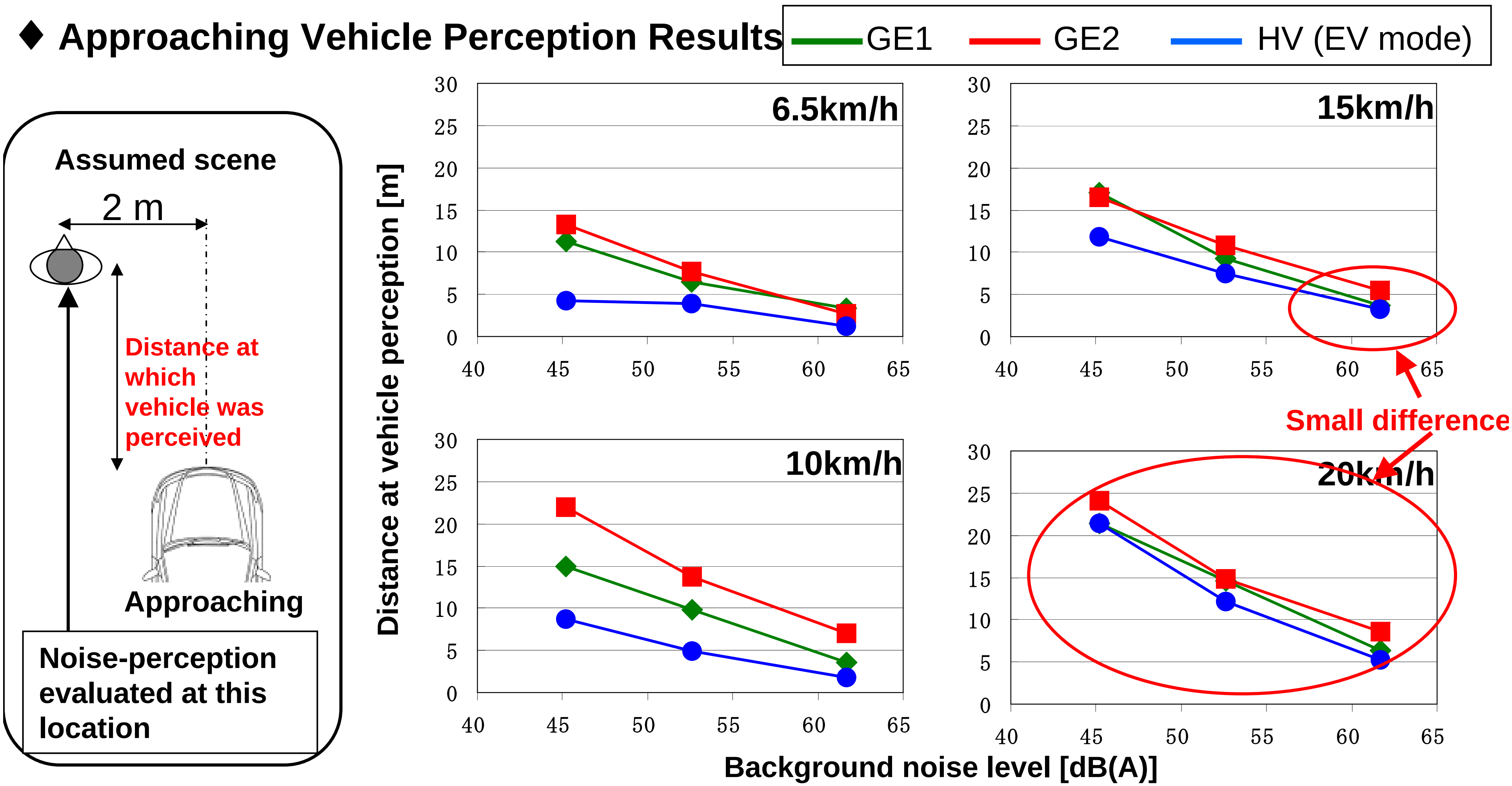


•Perception of HV (EV mode) in stationary lower than GE
•Subjects able to perceive the HV (EV mode) : 0%



(2) Evaluation of Perception by Pedestrians

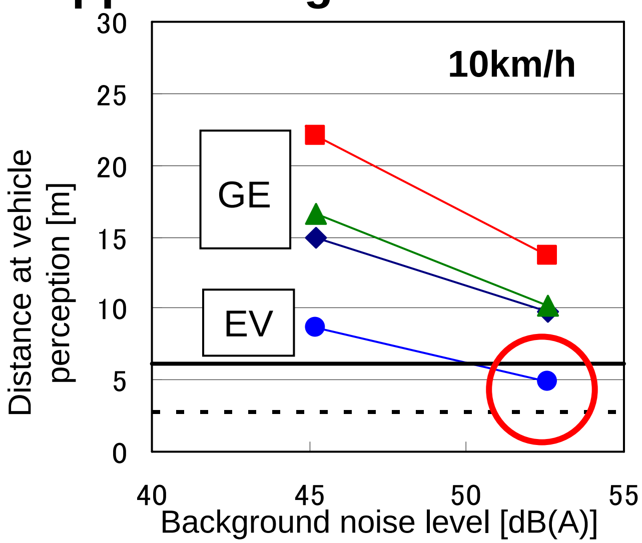
◆ **Approaching Vehicle Perception Results**

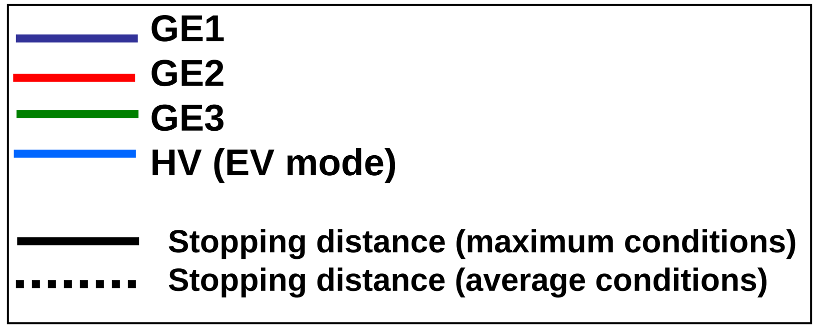


•Perception of HV (EV mode) is lower than GE when the background noise level is low and the speed is 15 km/h or below.
•The noise level difference became smaller as the vehicle speed exceeded 20 km/h.

(2) Evaluation of Perception by Pedestrians

♦ Approaching Vehicle Perception Distance and Stopping (braking) Distance





Pedestrian's HV (EV mode) perception distance may measure shorter than the stopping distance of maximum conditions.

The stop distance of vehicles was calculated from the following theoretical formulas and test results.

1.Calculation of Stop Distance.

Stop distance = free running distance + braking distance

= speed x reaction time + speed^2/(2x9.8x coefficient of friction)

2. Free running distance (speed x reaction time).

The running-out reaction time test result in a public road .

(Japan Safe Driving Center carried out in 2000)

Reaction time: Average =0.82 (second), an average of+3sigma=1.966 (second)

3. Braking Distance

Braking distance = speed^2/(2x9, 8x coefficient of friction).

A coefficient of friction is the following (from Ichiro Emori "automobile accident engineering").

・It is 0.6 in case of the worn-out tire on dry asphalt

・With the ordinary tire on dry asphalt, it is 0.7.

However, more study is necessary for this issue by the safety experts.

<u>(3) Summaries</u>

1. **Perception of the stationary HV (EV mode) was significantly lower than GE. Hence, *there could be the case where it is useful and therefore necessary for preventing contact with the pedestrians to improve the perception, by audible means, of HV vehicles before they are in forward motion.***

2. **The distance between HV (EV mode) and pedestrian measured when the pedestrian perceives the vehicle is shorter than GE when the vehicle is run at low speed. Hence, *there also could be the case where it is useful and therefore necessary for preventing contact with pedestrians to improve the perception of HV (EV mode) in the low-speed range.***

3. **No major difference in perception between HV (EV mode) and GE above 20 km/h.**

4. **As there used to be no concerns related to perception of GE at this stage, we can focus on HV (EV mode) at low speed.**

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Experiments Using Sample Sounds

Purpose and Method

Since the noise of HV (EV mode) at low speed is difficult to be perceived because it is too quiet, the vehicle was experimentally driven while playing sample sounds to study its perception and acceptability by pedestrians.

Procedures

Sample sounds selected (11 sounds, including existing sounds, created sound, simulated engine sound)

↓

Test vehicle created

↓ ↓

Perception by pedestrians evaluated

Acceptability by residents/pedestrians evaluated

↓ ↓

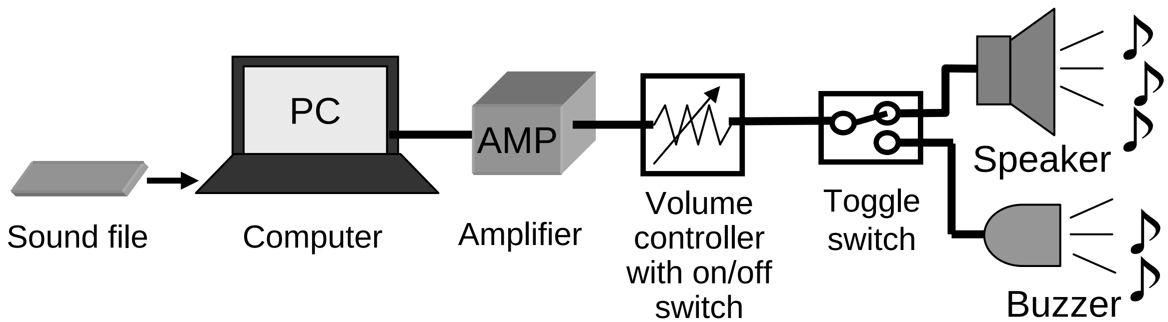
Overall evaluation

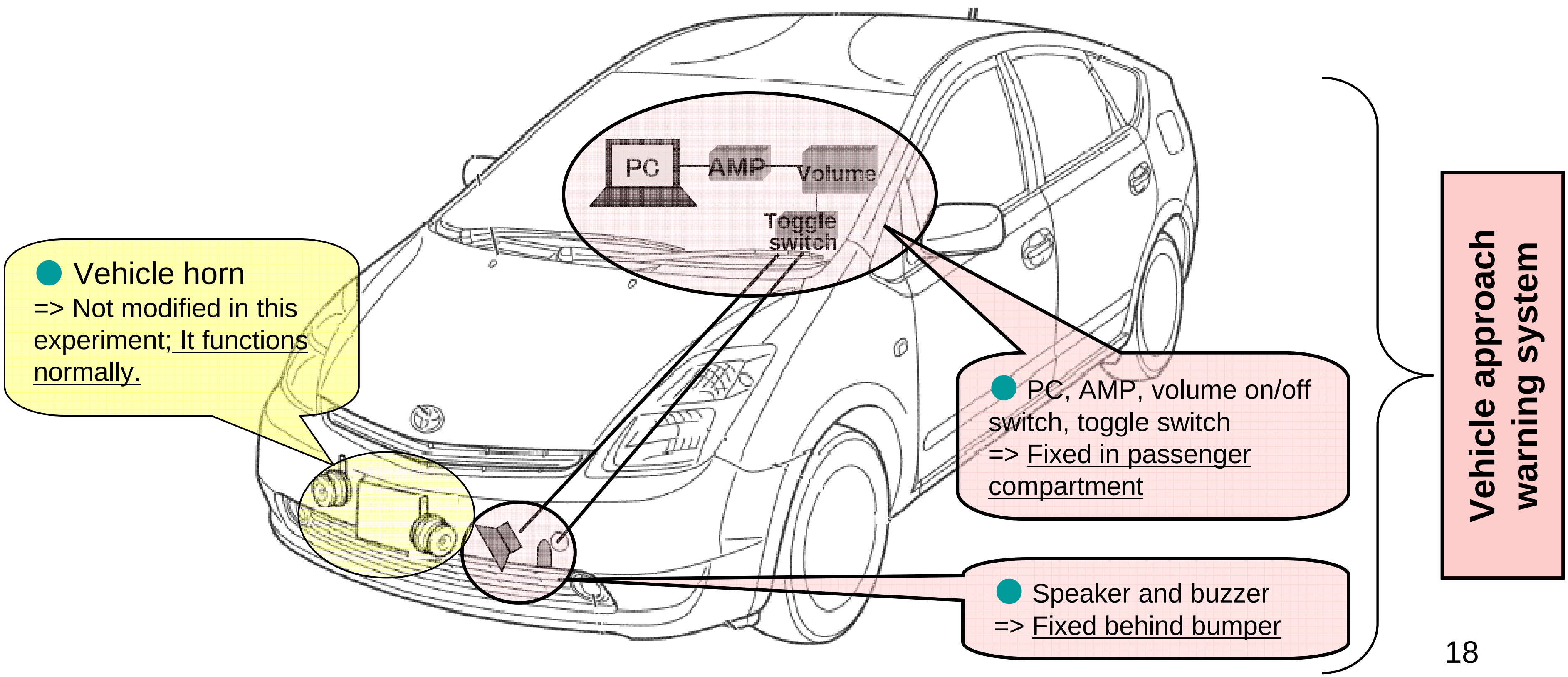
(1) Selection of Sample Sounds

9 sounds selected out of the pre-selected 20 sample sounds, plus 2 actual engine noises

No.	Sound type	Remarks
(1)	Non-steady sound	Existing sound
(2)	Non-steady sound	Existing sound
(3)	Non-steady sound	Existing sound
(4)	Non-steady sound	Created sound
(5)	Non-steady sound	Created sound
(6)	Steady sound	Created sound
(7)	Steady sound	Created sound
(8)	Steady sound	Created sound
(9)	Steady sound	Simulated engine sound
(10)	Steady sound	Actual engine sound (L4, 1496 cc)
(11)	Steady sound	Actual engine sound (V8, 4292 cc)

(2) Creation of Test Vehicle





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(1) Experiment for Evaluating Perception by Pedestrians

- **Purpose**

To evaluate perception of sample sounds by using test subjects

- **Procedures**

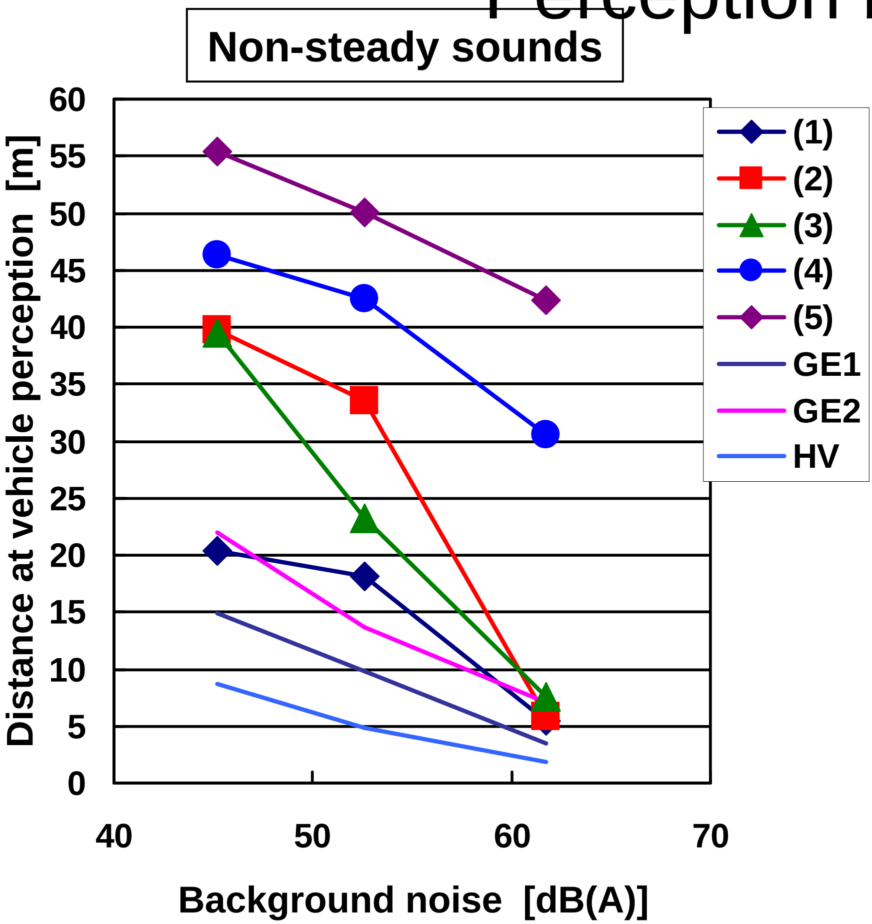
1. The volume of the selected sample sounds was set at around the same level as GE (L_{Aeq}=50 dB at 2 m in front).

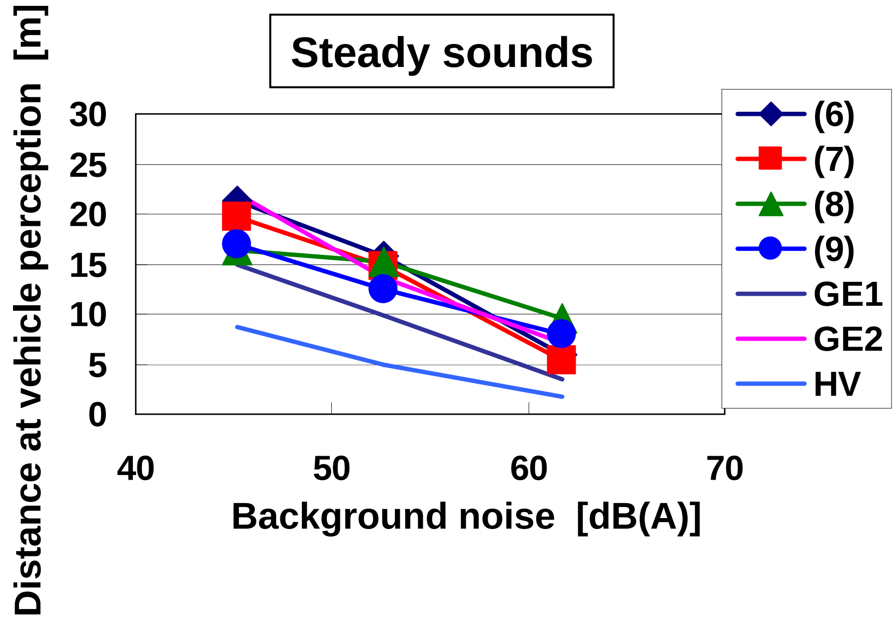
2. Under specific environmental conditions (indoor experiment), a vehicle approaching at 10 km/h was simulated; the three background noises mixed with the sample sounds were played for 20 subjects; the following was evaluated:

(1) Distance required to perceive the sound at L_{Aeq}=50 dB

(2) L_{Aeq} of sample sounds when they were perceived at around the same distance as GE

(1) Result of Experiment for Evaluating Perception by Pedestrians





Vehicle speed 10 km/h

- **Even at the same L_{Aeq}, perception largely differs for each sample sound type (frequency).**
- **Perception is higher for non-steady sounds.**

(1) Result of Experiment for Evaluating Perception by Pedestrians

- **In additional test result, L_{Aeq} of the sample sounds for which almost the same perception as GE was listed below.**
- **Some of these sample sounds had lower L_{Aeq} than GE noise and yet had almost the same perception.**

No.	Sound type	L_{Aeq} (dB(A)) at 2 m
(1)	Non-steady sound	50.0
(2)	Non-steady sound	42.6
(3)	Non-steady sound	42.9
(4)	Non-steady sound	41.1
(5)	Non-steady sound	39.3
(6)	Steady sound	50.0
(7)	Steady sound	50.0
(8)	Steady sound	50.0
(9)	Simulated engine sound	50.0

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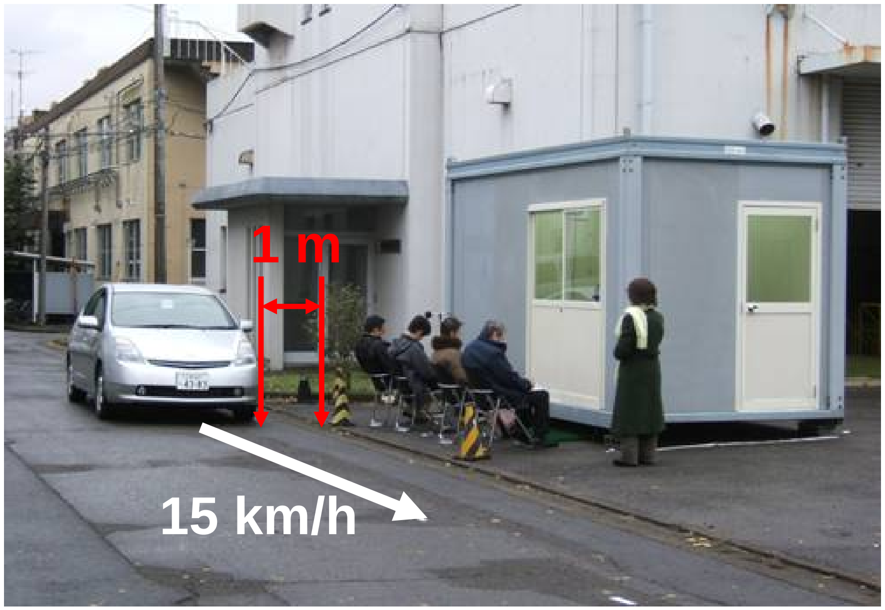
(2) Experiment for Evaluating Acceptability by Residents/Pedestrians

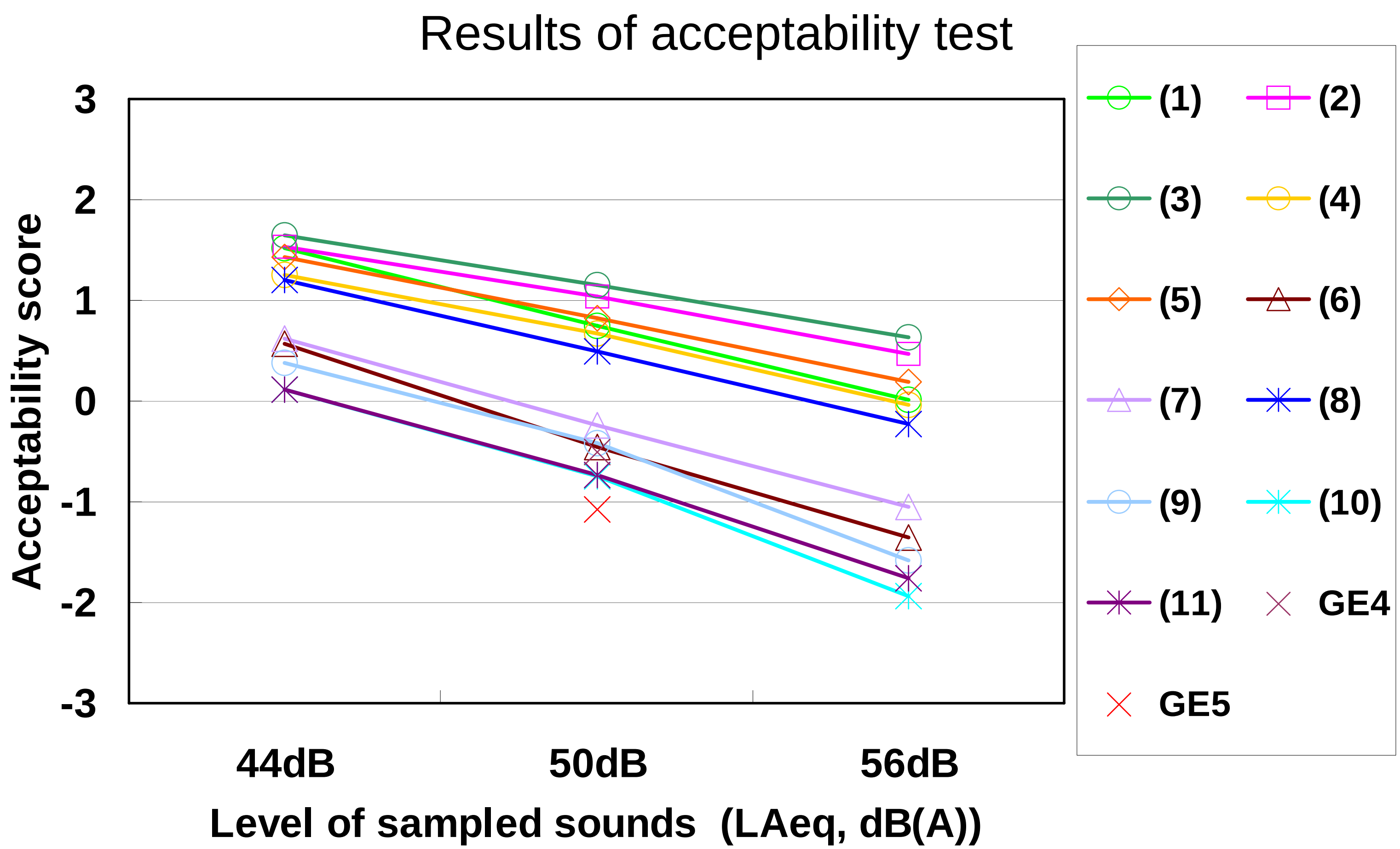


Prefabricated building simulating a Japanese wooden house

*** Test conducted with sample sounds at 3 different volumes**
*** 59 subjects**

Solving crossword puzzles to take their mind off the vehicle

(2) Experiment for Evaluating Acceptability by Residents/Pedestrians



- Even at the same L_{Aeq}, acceptability differs for each sample sound type.
- For any sample sound, acceptability is higher at lower volume.
- Acceptability tends to be higher for non-steady sounds.

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(3) Overall Evaluation

- Purpose

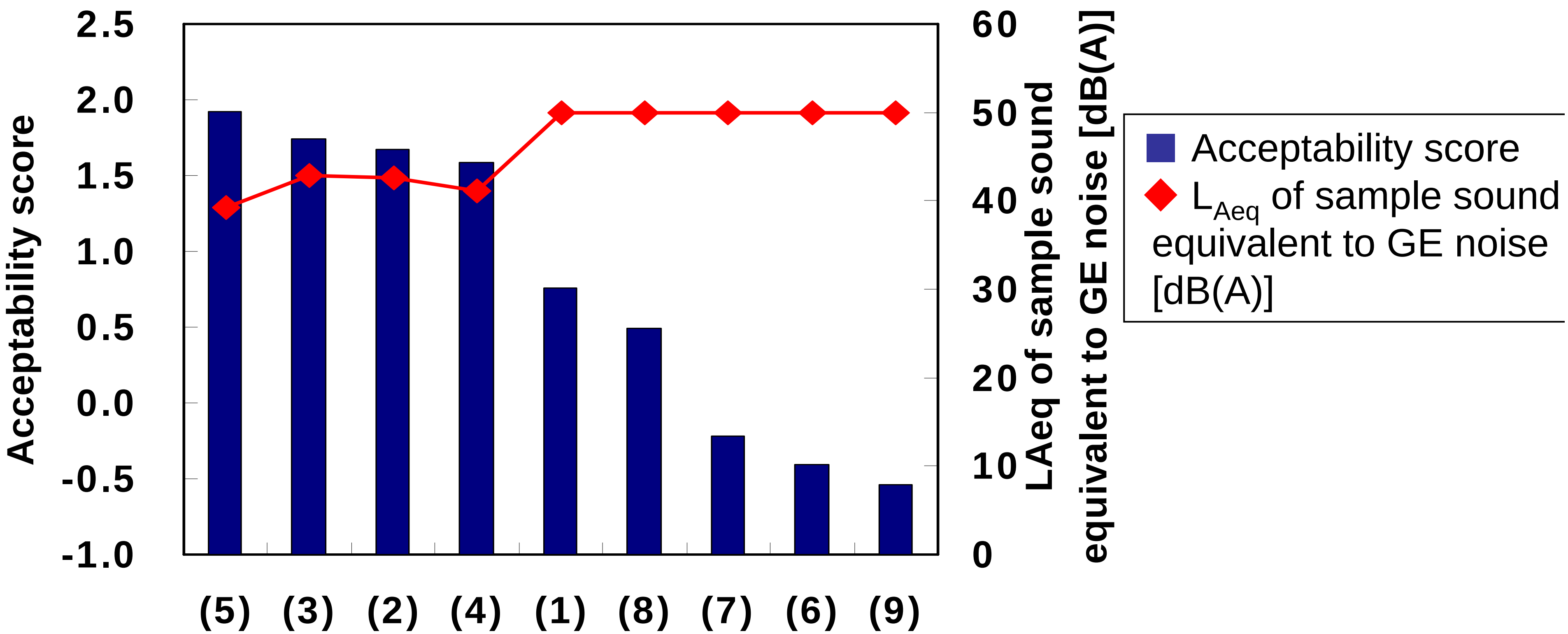
  To study, based on the results of evaluating perception and acceptability, the acceptability of those sample sounds which showed almost the same level of perception as GE.

- Procedures

  1. From the results of perception experiment, sample sounds that had almost the same perception level as GE vehicle and whose L_{Aeq} was particularly low were selected.
  2. For these selected sample sounds, the acceptability score was calculated. The score was also evaluated for the actual vehicle.
  3. The results were compared and evaluated.

(3) Overall Evaluation

Comparison of acceptability between engine noise and sample sounds with almost the same perception level as engine noise



•Some sample sounds have higher acceptability than GE noise even at equivalent noise level (L_{Aeq}) lower than GE noise by about 10 dB(A) and have almost the same perception level as GE noise.

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At various locations on public roads, the engine idling noise and sample sounds were emitted from the test vehicle and the “distance required for perception” was investigated.

(1) Main investigation

•Locations:

Parking lots, expressway service areas, commercial facilities, parking lots for employees;

Straight ways in residential areas, intersections with poor visibility;

•Interviews to visually-impaired people.

(2) Main results:

- **Many people were unaware of the sample sounds being emitted from the vehicle and didn’t turn their heads.**
- **At intersections with poor visibility, the “distance required for perception” of the sample sounds was better than for engine sound.**
- **Some visually-impaired people didn’t realize the sounds were coming from the vehicle even when they heard them.**
- **A request from visually-impaired people: either a sound that is obviously coming from vehicles or a uniform warning sound is desirable.**

(3) Conclusions

- **When it was obvious to pedestrians that the sound was coming from vehicles, the “distance required for perception” of the sample sounds was more favorable than the engine noise.**
- **As the warning sound of an approaching vehicle, it is important to use a sound that is obviously coming from vehicles or a uniform sound that is widely known as such sound.**

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Conclusions

1. **This study was conducted because of the concern that the increasing number of hybrid vehicles could cause accidents due to their excessive quietness, such as hitting pedestrians who are not aware of their approach.**
2. **To date, no accidents caused by vehicles being too quiet have been found in the database on accidents statistics.**
3. **Comparisons made to assess the situation also showed that there was no significant difference in the perception between HV (EV mode) and GE when traveling above 20km/h.**
4. **Although the relationship between quiet vehicles and accidents is not known, indoor experiments and investigations on public roads were conducted to examine the vehicle approach sounds that can be considered at this stage.**

Conclusions

5. Results of experiments and investigations

(1) Even at the same L_{Aeq}, the perception largely differs for each sound type (frequency or sound quality).

(2) Some sample sounds have higher acceptability than GE noise even at equivalent noise level (L_{Aeq}) lower than GE noise by about 10 dB(A) and have almost the same perception level as GE noise. (L_{Aeq}=50dB at 2 m)

(3) When it is obvious to pedestrians that the sound is coming from vehicles, the sample sounds was more perceptible than the GE noise.

(4) As the vehicle approach warning sound, a sound that is obviously coming from vehicles or that is widely promoted as such sound.

For the future

(1) Since safety is closely involved in this issue; therefore, it is difficult to for the issue to be discussed by GRB alone.

(2) Further discussions are necessary based on reported accidents and complaints.

(3) For this reason, more information from GRB members is expected.

Thank you very much
for your attention