

Pedestrian awareness of the approach of quiet vehicles: Effect of approach informing sound and designing awareness

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ABSTRACT

Hybrid and electric vehicles are quieter than combustion-engine vehicles. To prevent accidents resulting from such quietness, an acoustic vehicle alerting system generates an approach informing sound (AIS). However, the recognition rate of the AIS is not high (~40%) and it might be difficult for pedestrians and others to notice the approach of quiet vehicles via hearing alone. To improve AIS recognition, we designed an AIS based on onomatopoeic sounds. A subjective evaluation experiment using these sounds revealed that people tended to evaluate noisy and rough sounds, such as those similar to the sound of a car traveling or an engine, as a good indication of a car traveling. Another experiment investigated the sounds that pedestrians actually use to recognize the approach of quiet vehicles. It was found that most participants recognized the approach of a quiet vehicle not by AIS but by sounds emitted from the vehicle, such as road and wind noise. This tendency was also observed after participants correctly recognized the AIS. However, some participants reported that their awareness of AIS changed and they became more aware of AIS in daily life after the experiments. Designing awareness is effective and necessary for the design of AIS.

Keywords: Quiet vehicles, Approach informing sound, Designing awareness

1. INTRODUCTION

Quiet vehicles such as hybrid vehicles and electric vehicles emit less noise than vehicles having internal-combustion engines, particularly when traveling at low speed. Although such quietness results in less environmental noise, it may cause accidents in which pedestrians are unaware of approaching vehicles. To address this issue, the Ministry of Land, Infra-structure, Transport and Tourism in 2011 established for the first time in Japan guidelines for the installation of acoustic vehicle alerting system (AVAS) in quiet vehicles. An international standard was established on the basis of these guidelines (1). However, the recognition rate of the AVAS has not been high (i.e., approximately 40% (2)). To improve the recognition of the AVAS, studies on designing an approach informing sound (AIS) have been conducted (3–6). In a previous study, we proposed a method of designing an AIS based on onomatopoeia sound that reflects the pedestrians' image of AIS (7). In addition, to reveal factors affecting the evaluation of "the sound indicates a car traveling", a subjective experiment was conducted using sound stimuli designed according to provided onomatopoeic sound and an evaluation grid method (8). This experiment revealed that "engine sound", "wind noise", and "road noise" remain dominant in the evaluation of sound that indicates a car traveling while quiet vehicles have been widespread.

The above results suggest that pedestrians might become aware of the approach of quiet vehicles by listening to the sound emitted from the road or car body rather than the AIS. A previous study (7) reported that it is difficult for pedestrians to notice the AIS without recognizing the sound, whereas providing the opportunity to hear the AIS helped pedestrians notice the sound. This approach of providing the opportunity to recognize the AIS is referred to as the design of awareness. On that basis, the present paper reports an experiment aimed at clarifying the sounds that pedestrians actually use in

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noticing the approach of quiet vehicles. In addition, a survey was conducted to examine the long-term effect of designing awareness according to a previous study (7).

2. EXPERIMENT 1: SOUND USED IN RECOGNIZING THE APPROACH OF A QUIET VEHICLE

An experiment was conducted to clarify the sound that pedestrians actually use in noticing the approach of quiet vehicles. Participants were required to report the sound that they heard and used in noticing the approach of a quiet vehicle.

2.1 Experimental conditions

The experiment was conducted on a traffic comprehensive test road at Nihon University on 16 October 2017 using a Prius (TOYOTA) as an example of a quiet vehicle. The positions of the quiet vehicle and participants are shown in Fig. 1. The quiet vehicle traveled from line AA' to line BB' at a constant speed of 15 km/h, which was within the operational speed range of the AVAS and ensured the safety of participants. The vehicle speed was measured using a speed gun.

The participants stood 2 m from the center line of the quiet vehicle near line PP' in Fig. 1, forming a line with 1-m intervals. The experimental scene is shown in Fig. 2. So that the participants paid attention to the sound emitted from the quiet vehicle, the participants stood with their backs to the vehicle and closed their eyes during the experiment. The quiet vehicle passed behind the participants three times. The participants were 11 male students and one female student attending Nihon University and having an average age of 21.7 years. The experiment was recorded using a video camera.

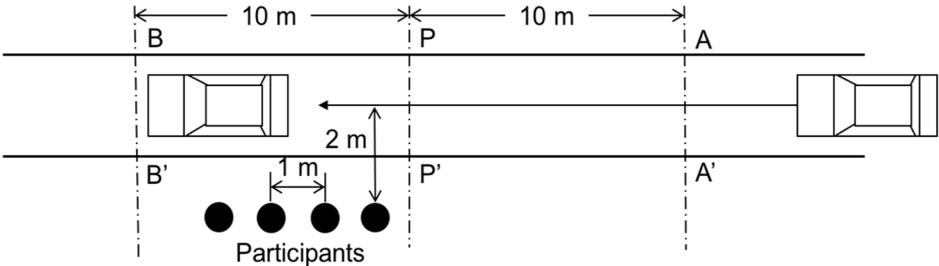


Figure 1 – Positions of participants and the quiet vehicle



Figure 2 – Experimental scene

2.2 Experimental method

To avoid the participants intentionally directing their attention to the AIS, the experimenters explained that “This experiment aims to measure the distance at which pedestrians sense the danger of an approaching vehicle”. The participants were required to raise their hand when they felt they were in danger from the approaching vehicle. The experiment was conducted twice with the emitting of AIS. The experimenter then conducted an interview in which participants were asked what sound they used in noticing the approach of the vehicle and feeling danger.

2.3 Experimental results

Experimental results obtained from the interview are given in Table 1. Each participant is indicated by a letter. Those who knew about AIS before participating in the experiment are indicated by colored cells. Table 1 shows that no participant answered that he or she noticed the approach of the quiet vehicle and felt danger because of the AIS, and rather, they used other sounds, such as the sound of the motor, road noise, and wind noise. One participant referred to an “engine sound” even though the quiet vehicle did not drive with an engine. The sounds listed by participants are emitted from not only quiet vehicles but also vehicles with internal-combustion engines. The results suggest that the participants might use these familiar sounds as clues to the approach of the quiet vehicle.

Participants who did not notice the AIS reported that “I did not recognize the sound as a notification sound” and “I noticed sounds such as road noise and running noise other than the AIS”. As reported in a previous study (7), it might be difficult for people to notice the AIS without recognizing the sound. However, participants who knew about AIS before participating in the experiment also reported that they did not use AIS in noticing the approach of the quiet vehicle but other sound emitted by the vehicle. The recognition of the AIS might not affect the use of sound in noticing the approach of vehicles and feeling the danger posed by vehicles. To address this point, the same experiment was conducted after providing the opportunity for participants to recognize and hear the AIS as Experiment 2.

Table 1 – Results of an interview conducted after the experiment

	What sound did you use in noticing the approach of the vehicle and feeling danger?	Did you notice AIS? (Yes/ No)	What did you feel about AIS (if you noticed AIS)
A	Sound like that of a motor and road noise	Yes	It needs a louder volume to be noticed
B	Sound pressure of sound	Yes	It hardly induces a feeling of danger
C	Sound unique to the PRIUS	No	–
D	Road noise and sound of a motor	Yes	It is difficult to notice
E	Driving noise	No	–
F	Driving noise	No	–
G	Car approaching sound and wind sound	No	–
H	Increasing in the sound pressure level, low- and high-frequency sound	No	–
I	Engine sound and sound emitted from tires	No	–
J	Increasing sound pressure level	Yes	It can be heard in a quiet area but might be difficult to hear in a noisy area
K	Increasing sound	No	–
L	Driving noise	No	–

3. EXPERIMENT 2: EFFECT OF DESINGING AWARENESS

3.1 Experimental conditions and method

The experimental conditions and method were the same as those in Experiment 1. The experimenters explained the AIS to the participants and the participants heard the AIS repeatedly until they could recognize it before the experiment began.

3.2 Experimental results

Experimental results are given in Table 2. As in Table 1, each participant is assigned a letter and those who knew about the AIS before participating in the study are indicated by colored cells. Half of the participants answered that they used the AIS in noticing the approach of the quiet vehicle and feeling danger, and three of them (participants G, H, and I) did not know about the AIS before participating in the study. This result suggests that providing the opportunity to hear and recognize the AIS (referred to as the design of awareness in a previous study (7)) can contribute to the use of the AIS in noticing the approach of a vehicle. In Experiment 1, physical quantities such as the volume of sound and abstract sounds such as driving noise were reported as factors used in recognizing the approach of a quiet vehicle and feeling danger. Meanwhile, specific sounds such as the AIS and sound of tires were reported as factors in Experiment 2.

As observed in Experiment 1, other participants in Experiment 2 did not use the AIS. These participants reported that the AIS did not notify them of the approach of a vehicle enough to feel danger. They therefore use familiar sounds such as road noise rather than the AIS in noticing the approach of a quiet vehicle. Further studies on various aspects of the design of AIS are required.

Table 2 – Sounds that participants used to notice the approach of a quiet vehicle

	What sound did you use in noticing the approach of the vehicle and feeling danger?
A	AIS and road noise
B	AIS
C	Rubbing noise of tires
D	Road noise
E	Sounds other than AIS
F	Sound of tire slipping
G	AIS or the sound of tires
H	AIS and the sound of tires
I	AIS
J	Sound of tires
K	Rubbing noise of tires
L	Sounds other than AIS

4. SURVEY FOLLOWING EXPERIMENTS 1 AND 2

The results of Experiments 1 and 2 reveal that the design of awareness is effective in improving the recognition of AIS and changing pedestrians’ attitude toward sound. To discuss the long-term effect of this design of awareness, the following survey was conducted 1 and 3 months after the experiments.

4.1 Method

The questionnaire survey was conducted using Google Form provided by Google. The experimenters sent the URL of the Google Form by e-mail and required participants to complete the questionnaire survey via the Internet. The survey questions are given in Table 3. Up to nine questions

were asked according to the answers given.

Table 3 – Questions asked in the follow-up survey

	Question
1	Did you notice the AIS in daily life after participating in the experiments?
1-1	How many times did you notice AIS?
1-2	What were the road conditions when you noticed AIS?
1-3	Where did you notice AIS?
2	Did your attitude toward AIS change after participating in the experiments?
3	Did you talk to someone about AIS?
3-1	Who did you talk about AIS?
3-2	Why did you talk about AIS to someone?
3-3	What content did you discuss when talking about AIS?

4.2 Results

Results of the questionnaire survey completed 1 month after the experiments are given in Table 4. Each participant is indicated by a letter and those who knew about the AIS before participating in the study are indicated by colored cells. The table shows that six participants (A, B, C, D, K, and L) noticed and heard the AIS in daily life (i.e., under noisy conditions), whereas the experiment was conducted under quiet conditions. However, only some reported that their attitude toward the AIS changed and that they consciously listened to the sound. A change in attitude toward the AIS might not necessarily affect the participants' awareness of the AIS. Meanwhile, participants who were not aware of the AIS in daily life reported that their attitude toward the AIS changed after participating in the experiment (participants E, G, H, and J). Their participation in the experiment and opportunity to recognize and hear the AIS affected the participants' attitude toward the AIS. Furthermore, three participants (B, E, and H) reported that they had talked to friends or someone about AIS after participating in the experiment. A previous study (7) showed that information from other people is most effective in terms of recognizing AIS. Therefore, participating in the experiment and the effect of designing awareness could improve the recognition of AIS. These results again confirm the effect of designing awareness on AIS reported in a previous study (7). The design of awareness contributed to improving the recognition of and changing the attitude toward AIS.

Results of the questionnaire survey completed 3 months after the experiments are given in Table 5. Again, each participant is indicated by a letter and those who knew about the AIS before participating in the study are indicated by colored cells. Three participants (E, H, and J) reported that they noticed AIS in daily life even though they did not 1 month after the experiments. The number of times that five participants (C, E, H, J, and K) noticed AIS increased from that reported 1 month after the experiment. As observed in Table 4, more than half the participants stated that their attitude changed in that they consciously heard AIS. The design of awareness thus has a long-term effect.

In the interview conducted after Experiment 2 and described in Chapter 3, few participants answered that they noticed the approach of the quiet vehicle and felt danger through AIS. However, six participants (C, D, E, J, K, and L) reported that they noticed AIS in daily life 1 or 3 months after participating in the experiment. Two of them (participants C and E), who did not know about AIS before participating in the study, also reported that their attitude toward AIS changed after the experiments. The results show that providing the opportunity to recognize and hear AIS, or in other words, the design of awareness, can change the participants' recognition of and attitude toward AIS over the long term and contribute to improving others' recognition of AIS.

Table 4 – Results of the follow-up questionnaire survey: 1 month after the experiment

	Did you notice AIS in daily life after participating in the experiments? (Yes/No)	How many times did you notice AIS?	Did your attitude toward AIS change after participating in the experiment?	Did you talk to someone about AIS? (Yes/No)
A	Yes	More than 10 times	I think neither	No
B	Yes	5 or 6 times	I think somewhat so	Yes
C	Yes	1 or 2 times	I think so	No
D	Yes	1 or 2 times	I think neither	No
E	No	–	I think somewhat so	Yes
F	No	–	I don't think so much	No
G	No	–	I think somewhat so	No
H	No	–	I think somewhat so	Yes
I	No	–	I don't think so much	No
J	No	–	I think somewhat so	No
K	Yes	1 or 2 times	I don't think so much	No
L	Yes	5 or 6 times	I think somewhat so	No

Table 5 – Results of the follow-up questionnaire survey: 3 months after the experiment

	Did you notice AIS in daily life after participating in the experiments? (Yes/No)	How many times did you notice AIS?	Did your attitude toward AIS change after participating in the experiment?	Did you talk to someone about AIS? (Yes/No)
A	Yes	More than 10 times	I think somewhat so	No
B	Yes	1 or 2 times	I think so	Yes
C	Yes	5 or 6 times	I think so	No
D	No	–	I think so	No
E	Yes	1 or 2 times	I think neither	No
F	No	–	I don't think so much	No
G	No	–	I think neither	No
H	Yes	1 or 2 times	I don't think so much	Yes
I	No	–	I think somewhat so	No
J	Yes	5 or 6 times	I think somewhat so	No
K	Yes	5 or 6 times	I don't think so much	No
L	Yes	3 or 4 times	I think somewhat so	No

5. CONCLUSIONS

The two experiments conducted in this study revealed that pedestrians who did not recognize AIS noticed the approach of a quiet vehicle and felt danger not through AIS but through other, familiar sounds, such as wind noise and road noise, which are also emitted by vehicles having internal-combustion engines. After providing the opportunity to hear and recognize AIS (in the design of awareness), half the participants began using AIS in noticing the approach of quiet vehicles. However, others reported that AIS was not enough to inform them of the approach of quiet vehicles, and they thus did not use it. Further studies on the design of a more noticeable AIS are needed. Surveys conducted 1 and 3 months after the experiments showed the long-term effect of designing awareness. About a half of participants noticed AIS in daily life and recognized that their attitude toward AIS had changed such that they listened to the sound consciously after participating in the experiments. Further studies on the design of AIS, including designing awareness, would contribute to and improve

the recognition of AIS.

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