QRTV, UN/ECE/WP.29, Berlin
27-29 Sep., 2010

An Examination on Required Sound Levels for Acoustic Warning Devices for "Quiet Vehicles"

Katsuya Yamauchi
Assistant Professor, Faculty of Engineering, Nagasaki University

Background

- Electric powered vehicles (EV) are becoming common. They are ***much quieter*** than the conventional internal combustion engine vehicles (ICEV).
- Suitable for the road noise environment

Background

- Electric powered vehicles (EV) are becoming common. They are ***much quieter*** than the conventional internal combustion engine vehicles (ICEV).
- Suitable for the road noise environment

- Danger of quietness has been indicated. The quietness reduces the sound cues to realize vehicle approaching.

➡ **installation of acoustic warning devices**

set up the committee concerning the action to the quietness, and published the guidelines (Jan., 2010)

Providing the Sound for Quiet-vehicles?

– My opinion.

- **Providing quieter sound environment** to make easy to hear the sound cues of quiet car is the most important on the long-term viewpoint.
  - ✓ Quiet vehicles are not completely silent in motion.
  - ✓ Quiet environment helps to aware bicycles etc.
  - ✓ Quiet environment is of benefit to whom using hearing aid.

Providing the Sound for Quiet-vehicles?

– My opinion.

- **Providing quieter sound environment** to make easy to hear the sound cues of quiet car is the most important on the long-term viewpoint.
  - ✓ Quiet vehicles are not completely silent in motion.
  - ✓ Quiet environment helps to aware bicycles etc.
  - ✓ Quiet environment is of benefit to whom using hearing aid.

Quiet = Hi-Fi soundscape

Providing the Sound for Quiet-vehicles?

– My opinion.

- **Providing quieter sound environment** to make easy to hear the sound cues of quiet car is the most important on the <u>long-term viewpoint</u>.
  - ✓ Quiet vehicles are not completely silent in motion.
  - ✓ Quiet environment helps to aware bicycles etc.
  - ✓ Quiet environment is of benefit to whom using hearing aid.

Quiet = Hi-Fi soundscape

- Installation of an **acoustic warning device (sound)** should be considered as a <u>short-to-medium term solution</u>.

Japanese Guideline

- Automatically emit sound when the vehicle runs at the speed of less than 20 km/h.
- Sound should be continuous sound that evokes the running condition of a vehicle. (such as an engine sound)
- Sound level is not clearly defined.

> *it should not exceed the sound level of the ICEV running at a speed of 20 km/h.*

Question

- Is this sound level the best for the sound cues?
- Is the engine sound the best to make pedestrians aware the running condition of vehicles?

Sound of conventional engine vehicle? Why?

Purpose of my study

clarify the psycho-acoustical relationship between

hearing impression and **acoustic properties**

awareness

annoyance

approaching/distancing

acceleration/deceleration

going forward/backward

...

sound level

pitch/frequency

timbre(tone color)

temporal pattern

...

Purpose of my study

clarify the psycho-acoustical relationship between

hearing impression and **acoustic properties**

awareness ←

annoyance

approaching/distancing

acceleration/deceleration

going forward/backward

...

sound level ←

pitch/frequency

timbre(tone color)

temporal pattern

...

Experimental Method (outline)

Environmental Sound (background)

External Acoustic Sign (target)

Participants:
adjust the sound levels of acoustic signs while listening both sounds simultaneously.

Experimental Method (outline)

Environmental Sound
(background)

External Acoustic Sign
(target)

Binaural Recording
Head and Torso Simulator (HATS)

Participants:
adjust the sound levels of acoustic signs while listening both sounds simultaneously.

Experimental Method; Background Stimuli

Recorded on the sidewalks in Fukuoka, Japan.

		(L_{Aeq} ; 5 min.)
Env.1	Two-lane busy street in downtown	65.9 dB
Env.2	Two-lane road in a residential area	67.8 dB
Env.3	Six-lane heavy traffic road	73.2 dB
Env.4	Narrow street in shopping area	60.4 dB

Env.1

Env.2

Env.3

Env.4

Experimental Method; Background Stimuli

Recorded on the sidewalks in Fukuoka, Japan.

		(L_{Aeq} ; 5 min.)
Env.1	Two-lane busy street in downtown	65.9 dB
Env.2	Two-lane road in a residential area	67.8 dB
Env.3	Six-lane heavy traffic road	73.2 dB
Env.4	Narrow street in shopping area	60.4 dB

Env.1

Env.2

Env.3

Env.4

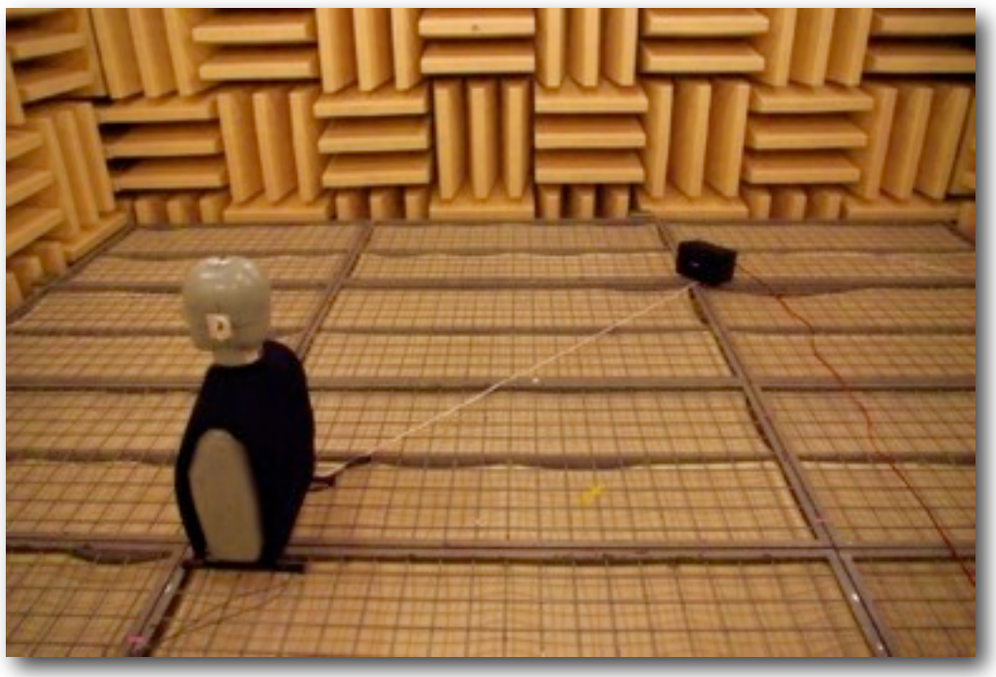
Experimental Method; Target Stimuli

(A) Chime	(B) Melody	(C) Broadband noise
(D) Horn	(E) Engine sound	(F) Female voice

Experimental Method; Target Stimuli

(A) Chime	(B) Melody	(C) Broadband noise
(D) Horn	(E) Engine sound	(F) Female voice

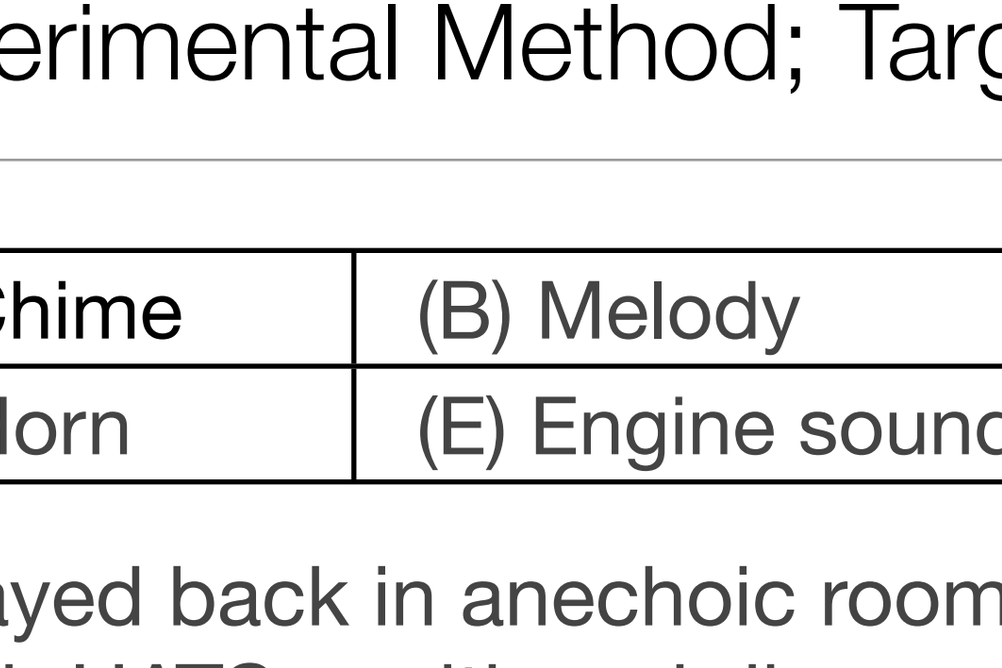
- Played back in anechoic room and recorded with HATS positioned diagonally forward left 2m from the loudspeaker.

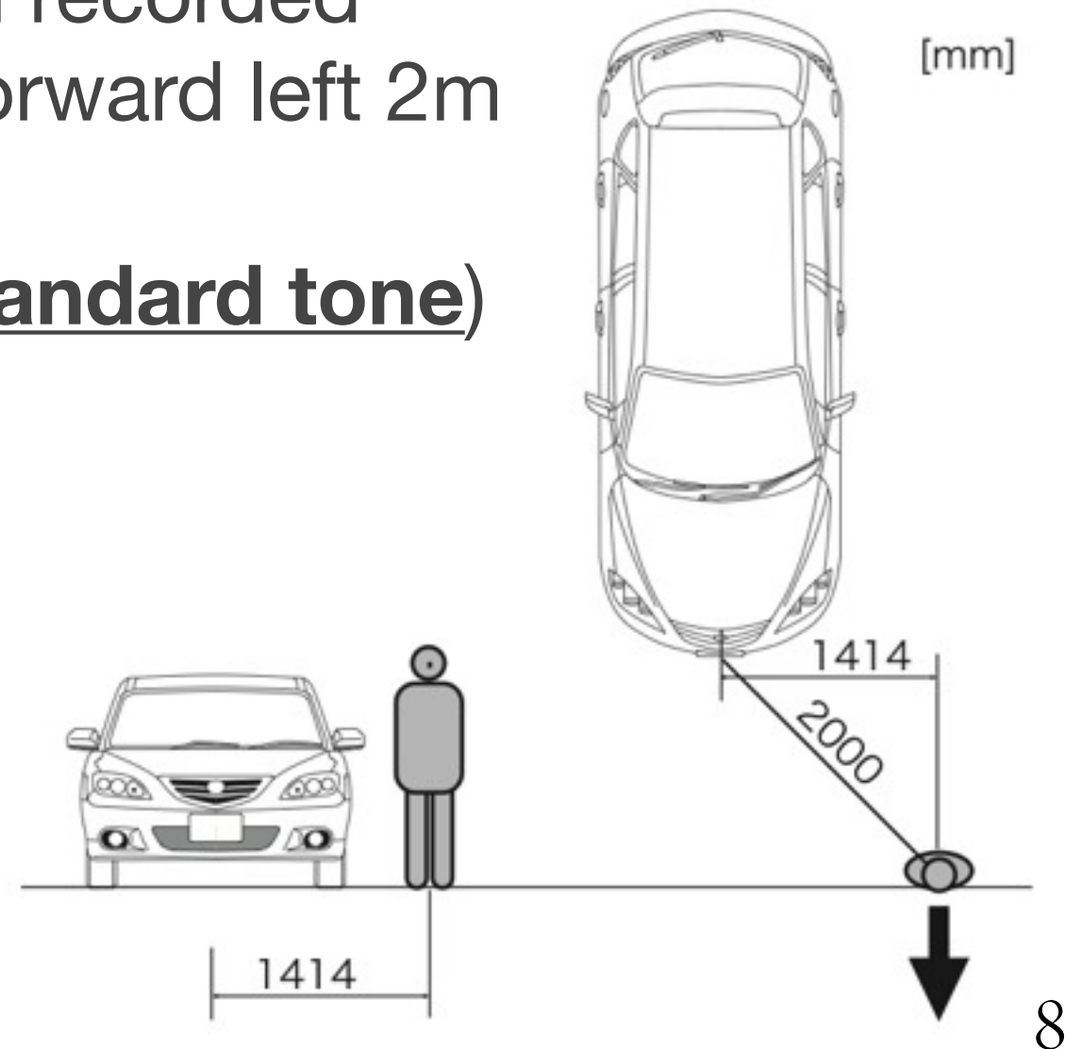


Experimental Method; Target Stimuli

(A) Chime	(B) Melody	(C) Broadband noise
(D) Horn	(E) Engine sound	(F) Female voice

- Played back in anechoic room and recorded with HATS positioned diagonally forward left 2m from the loudspeaker.
- equalized the L_{Amax} (all stimuli + **standard tone**)





Procedure (1)

- Target and background stimuli were presented simultaneously via headphones using a sound-mixer.
- Sound level of background was adjusted to the same level with the recording point.

Environmental Sound (background)

sound level; fixed

External Acoustic Sign (target)

sound level; changeable by the participant

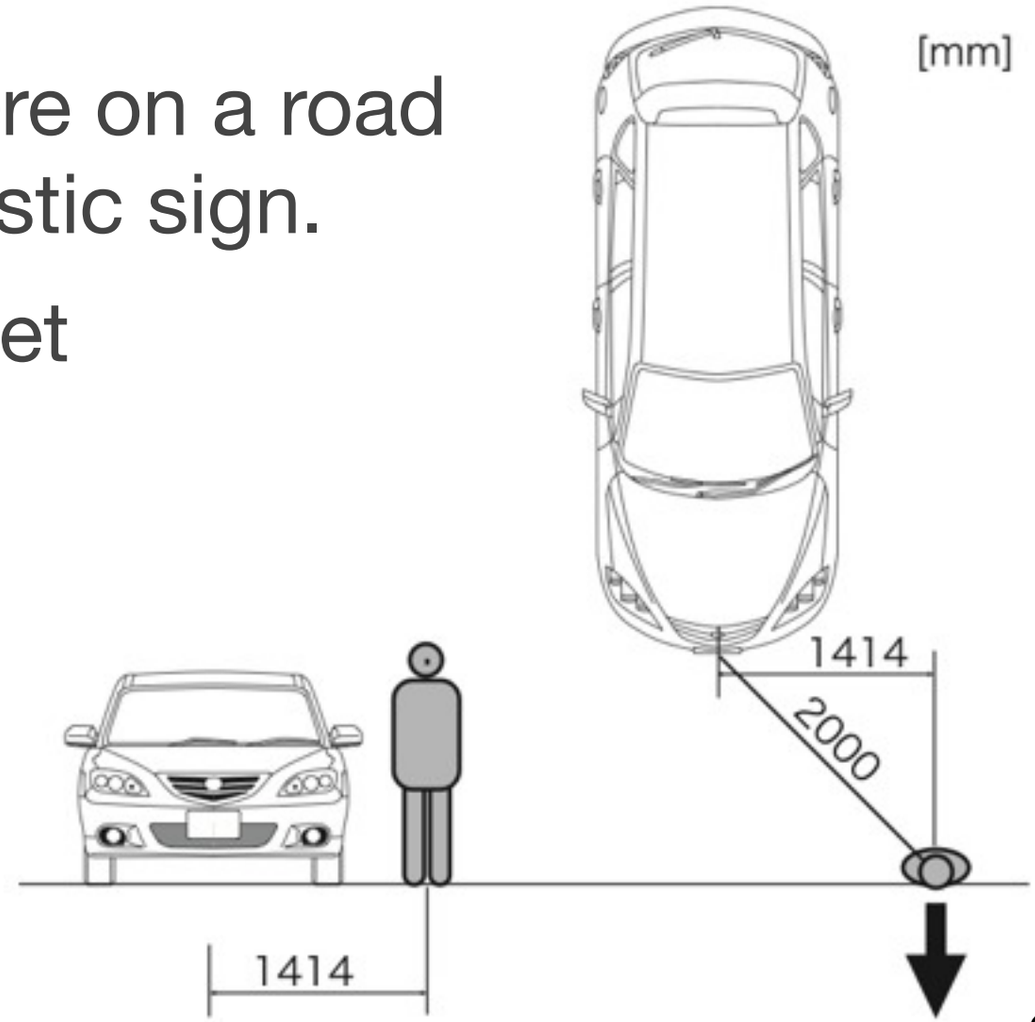
Procedure (1)

- Target and background stimuli were presented simultaneously via headphones using a sound-mixer.
- Sound level of background was adjusted to the same level with the recording point.
- Participants imagined that they were on a road and the vehicle providing the acoustic sign.

Procedure (1)

- Target and background stimuli were presented simultaneously via headphones using a sound-mixer.
- Sound level of background was adjusted to the same level with the recording point.
- Participants imagined that they were on a road and the vehicle providing the acoustic sign.
- Adjusted playback level of the target by using mixer fader.

adjust to “adequate level” and “lowest level”



Procedure (2)

- After the each adjusting trial, the standard tone was recorded at the position of the mixer-fader to which the participant adjusted.

Procedure (2)

- After the each adjusting trial, the standard tone was recorded at the position of the mixer-fader to which the participant adjusted.

- After all adjusting trials, the adjusted levels were measured by the comparison with the pre-recorded standard tone that the presenting sound had been measured.

Because the standard tone and all targets were equalized in A-weighted maximum sound level (L_{Amax}), the adjusted sound levels were measured in L_{Amax}.

Yamauchi et al., Intl. Congress on Sound and Vibration, 2005

Participants

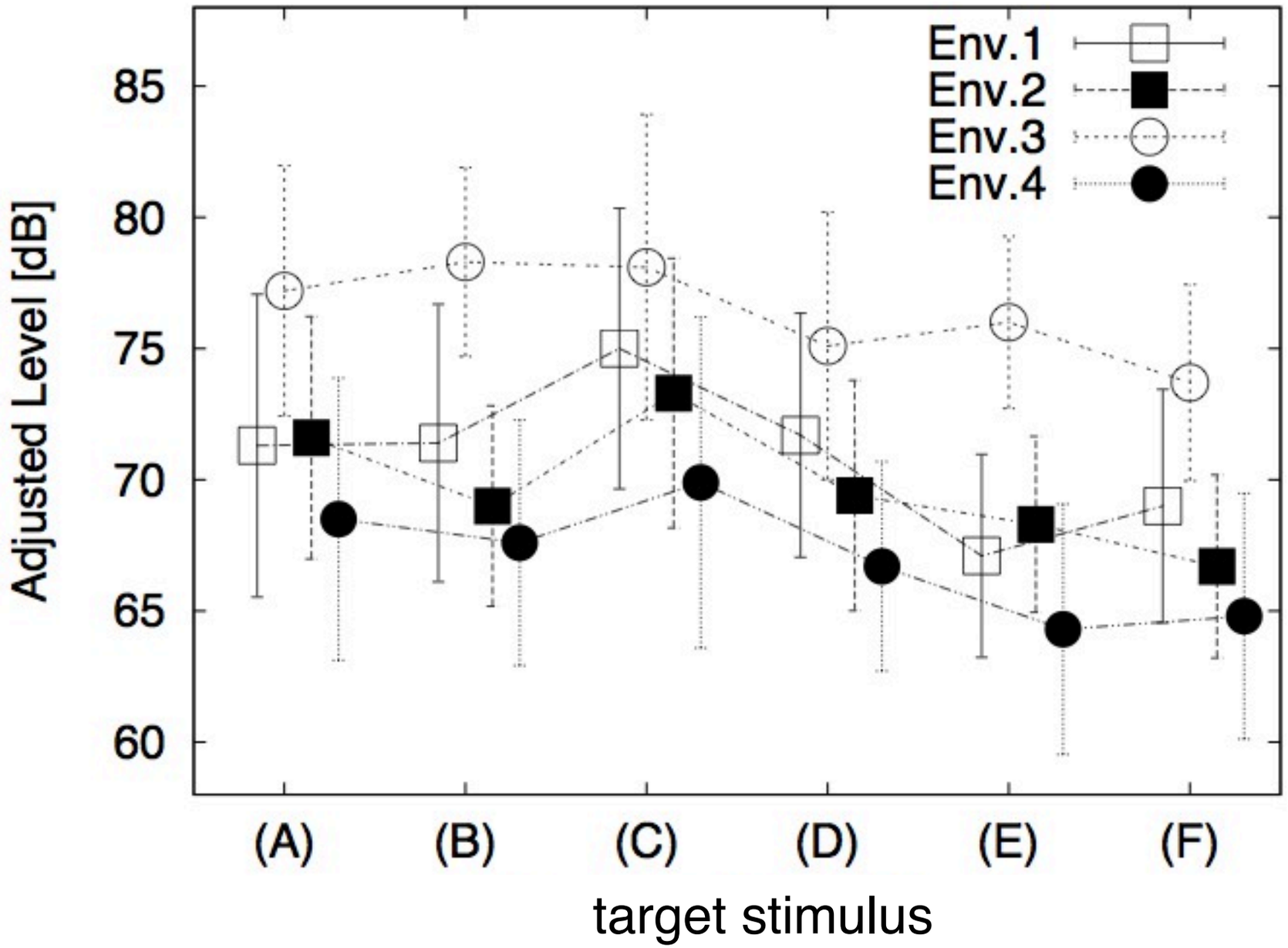
- student/staff of Fukushima University (4 male and 1 female)
- student/staff of Nagasaki University (7 male and 3 female)

11 male and 4 female
age: 21 to 39 (25.1 in average)

None of them has ever detected their hearing abnormalities by their routine physical examination.

Results

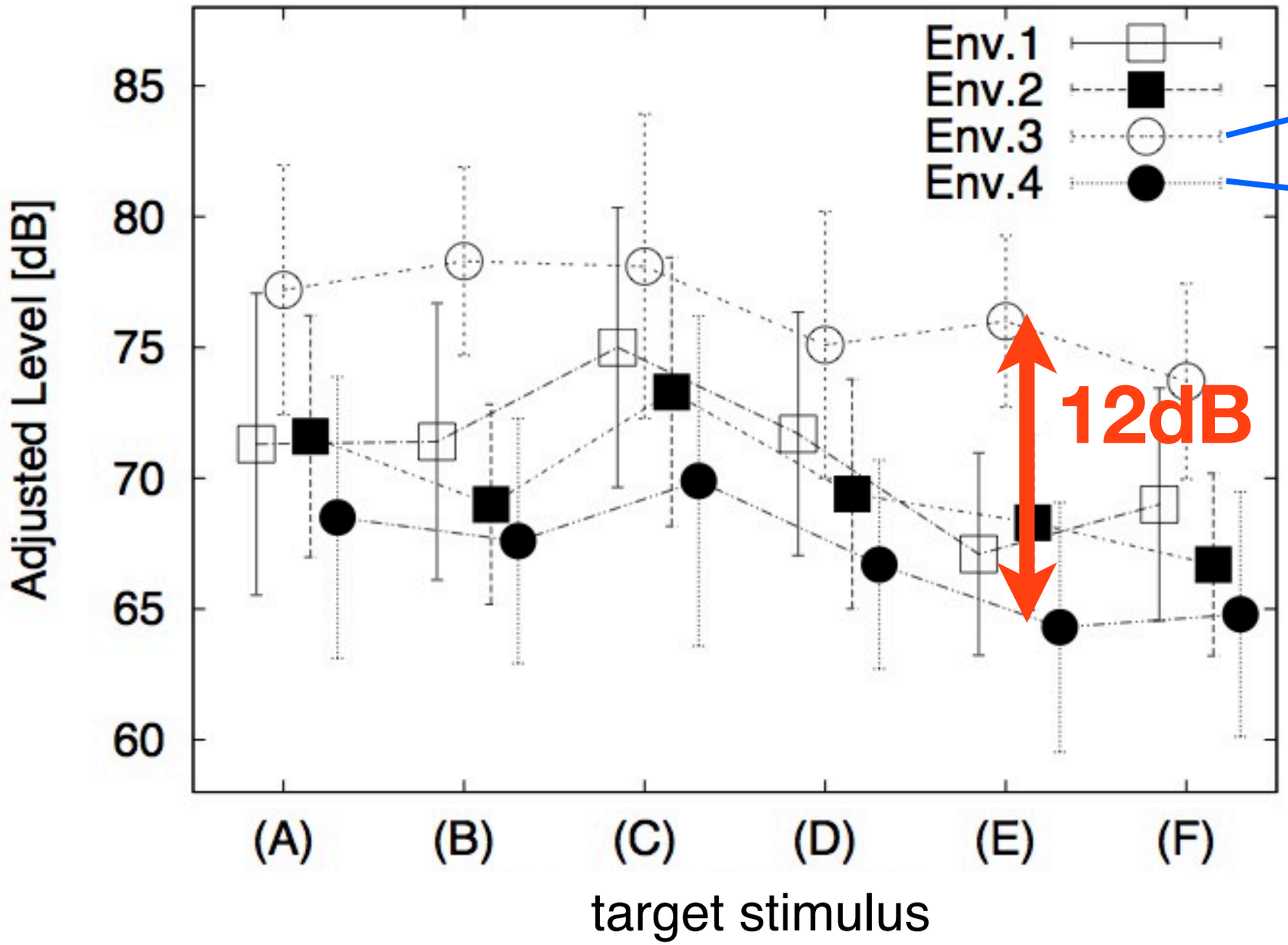
Adequate sound level



ANOVA:
both main effects are significant ($p<.001$)

Results

Adequate sound level

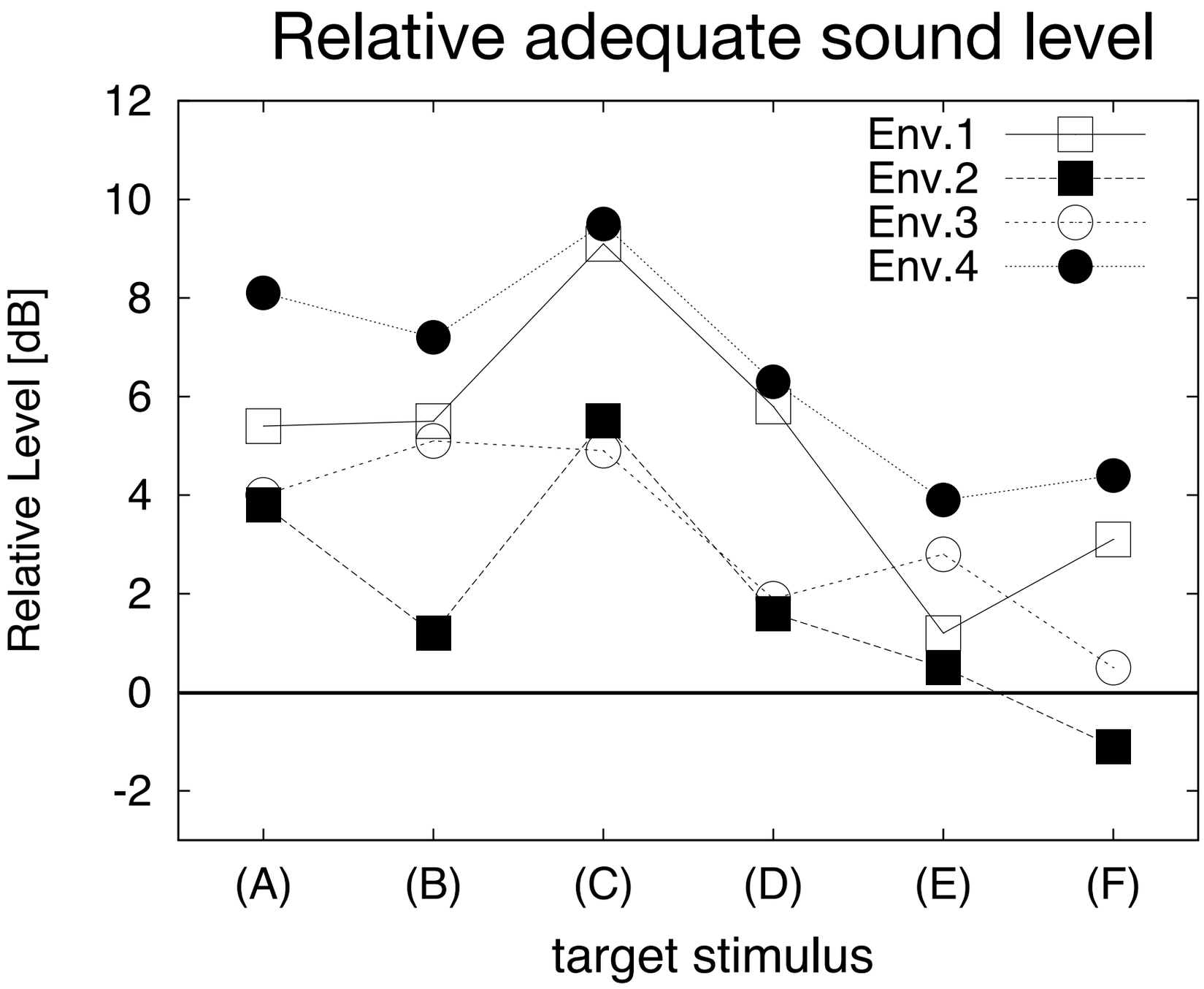


L_{Aeq}: 73.2dB

L_{Aeq}: 60.4dB

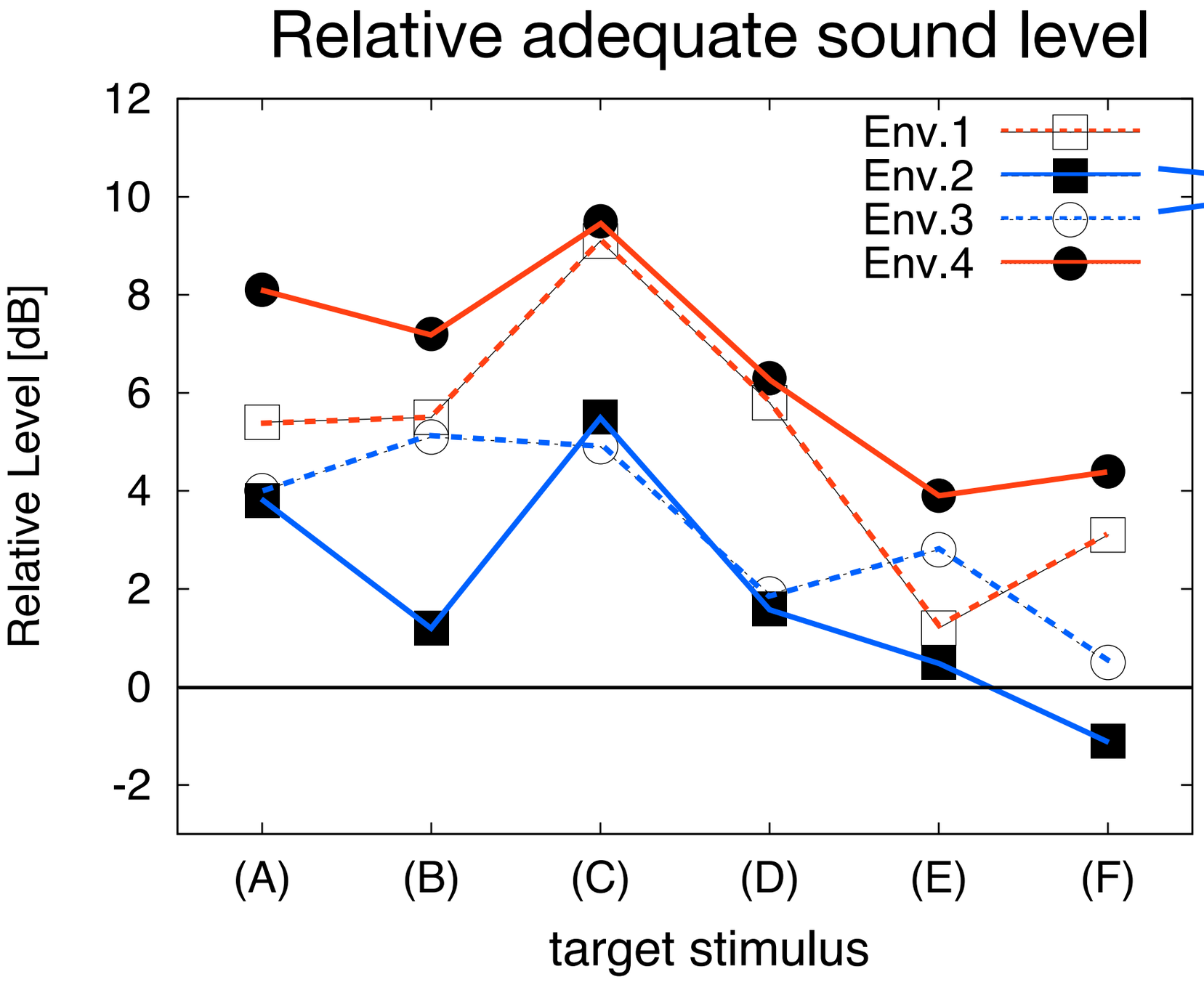
ANOVA:
both main effects are significant (p<.001)

Results



ANOVA:
both main effects are significant ($p<.001$)

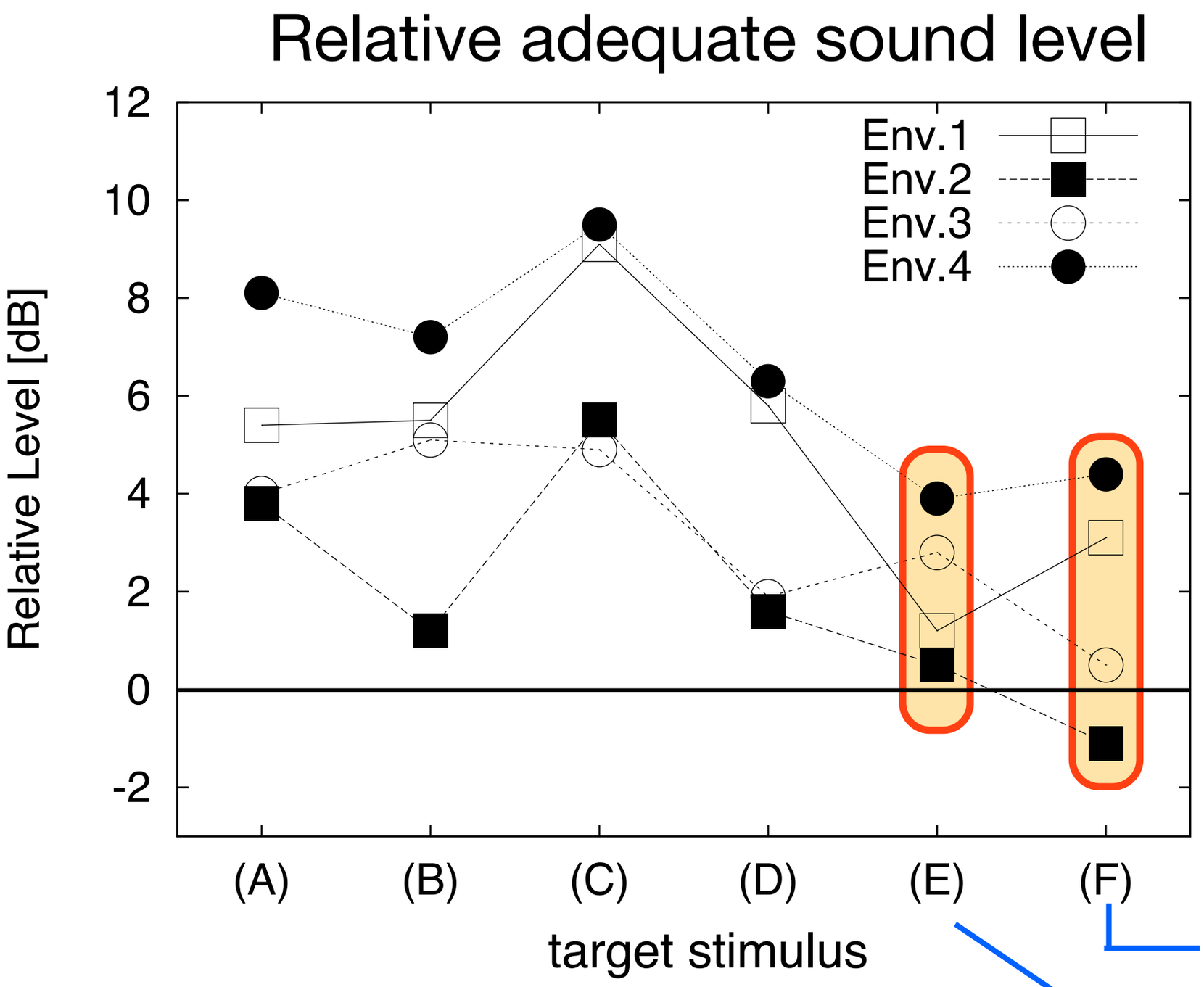
Results



road traffic noise

ANOVA:
both main effects
are significant
(p<.001)

Results

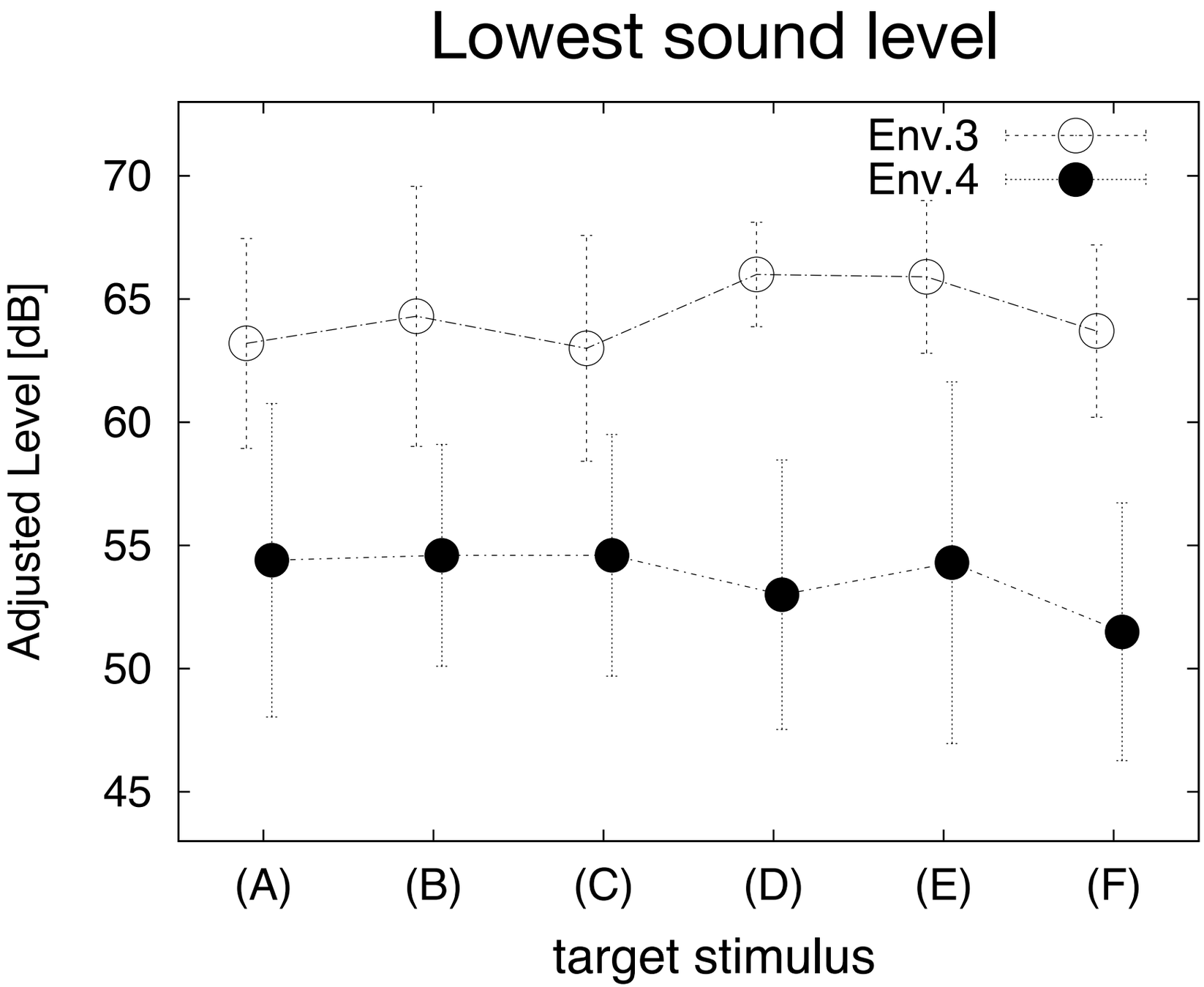


ANOVA:
both main effects
are significant
(p<.001)

Female voice

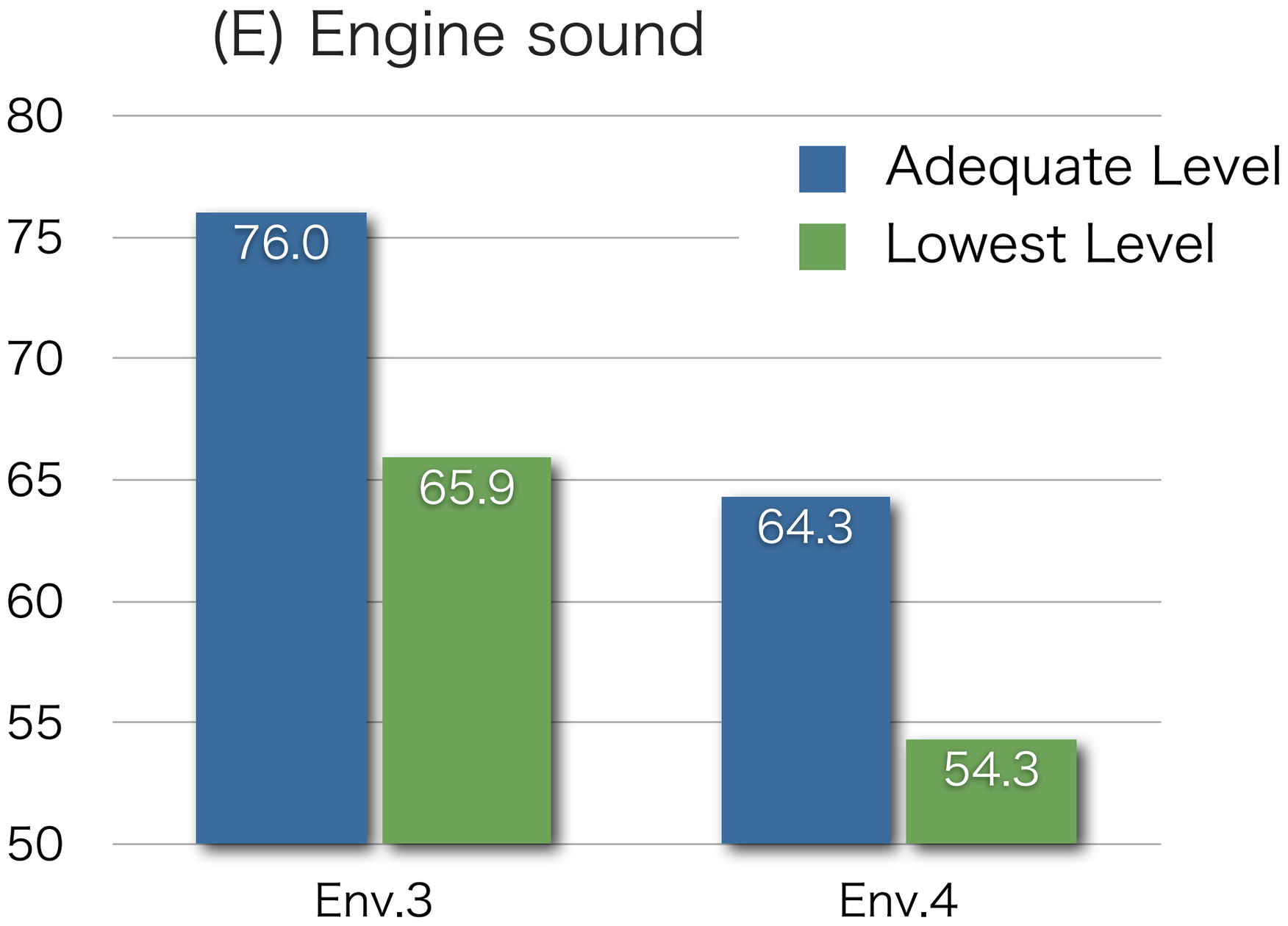
Engine sound

Results

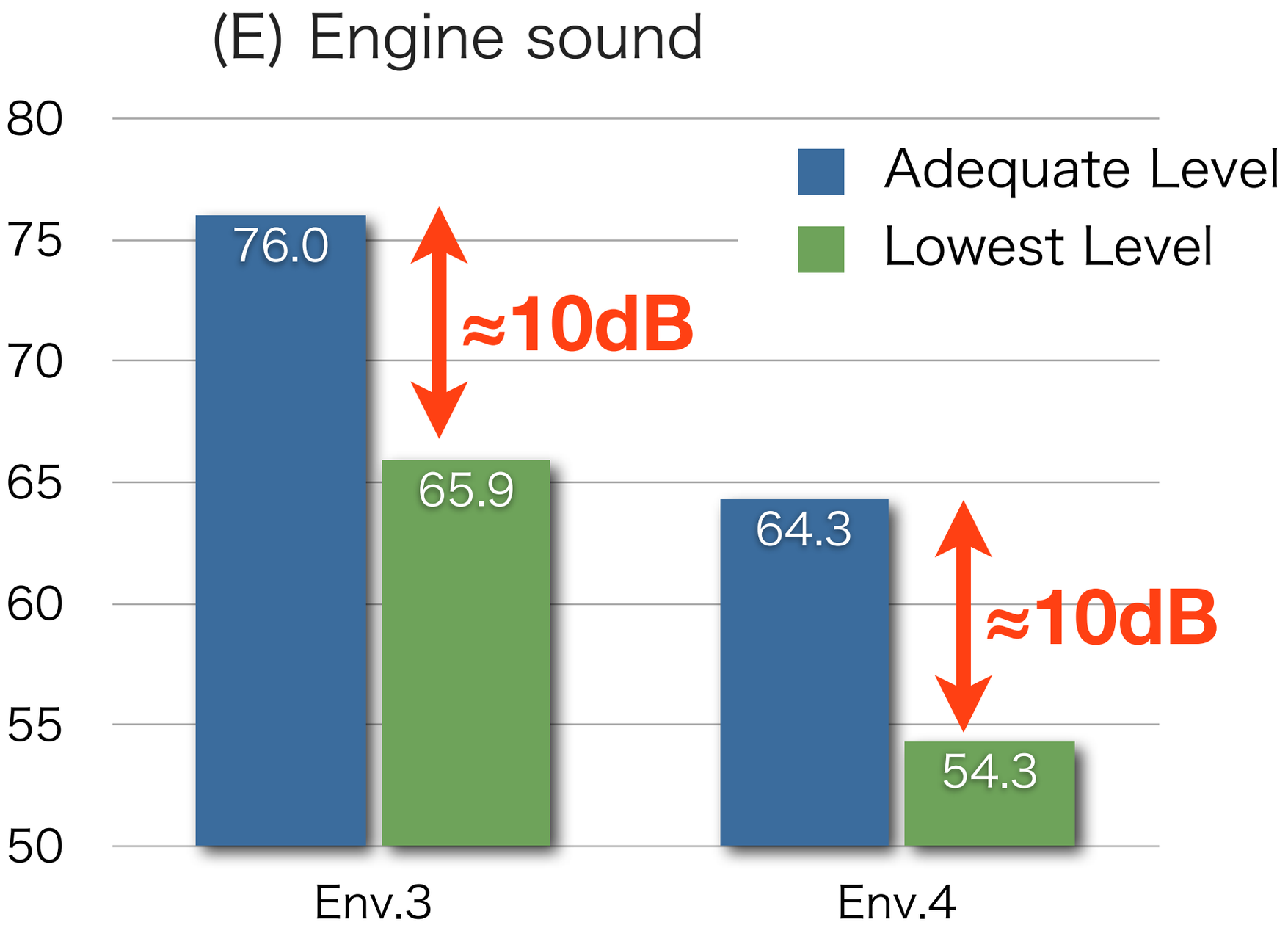


ANOVA:
main effects of background is significant ($p<.001$)

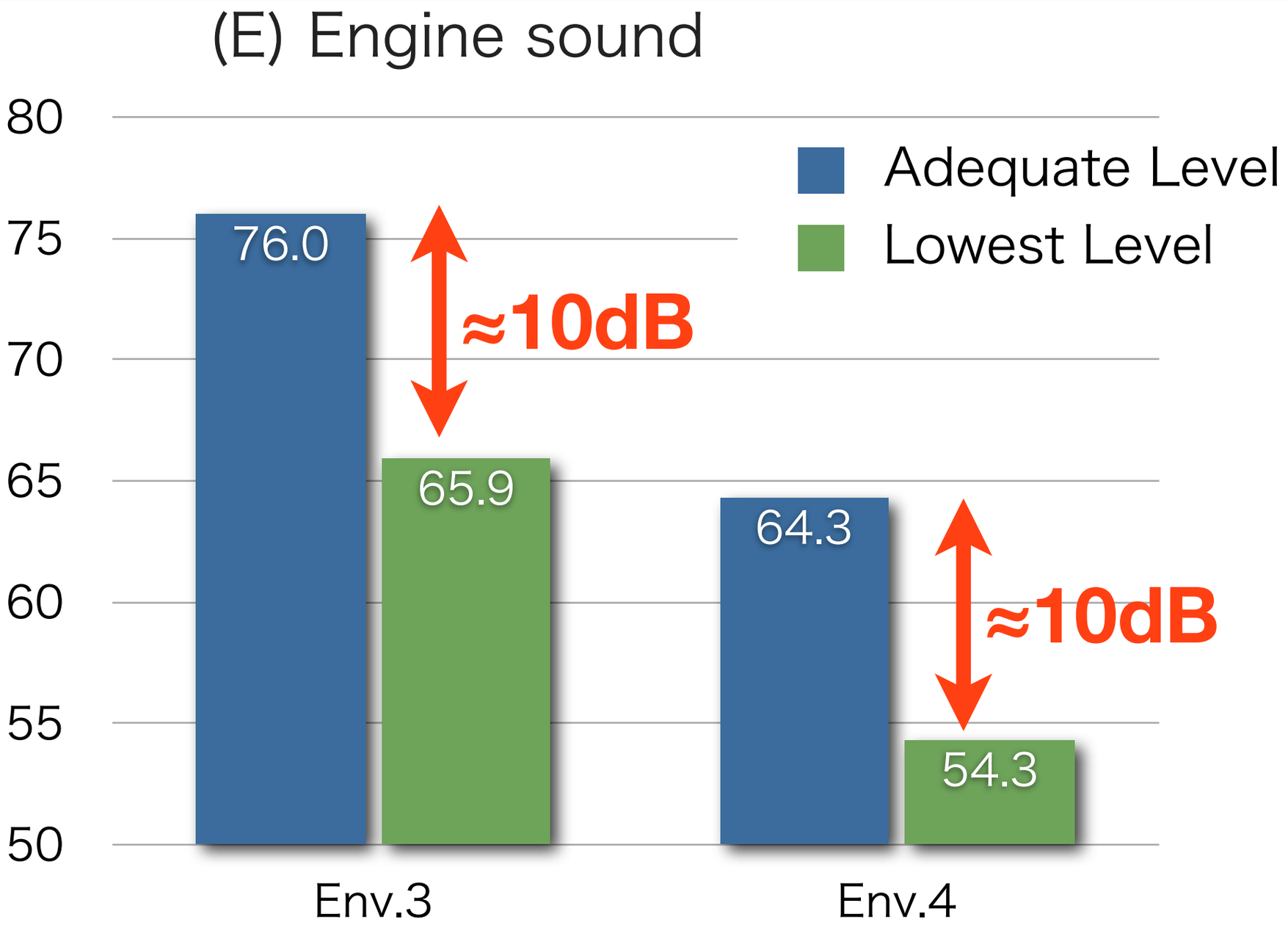
Results


(E) Engine sound
80
75
70
65
60
55
50
76.0
65.9
64.3
54.3
Adequate Level
Lowest Level
Env.3
Env.4

Results


(E) Engine sound
80
75
70
65
60
55
50
76.0
65.9
64.3
54.3
≈10dB
≈10dB
Adequate Level
Lowest Level
Env.3
Env.4

Adequate sound level for a quieter environment
is too small to be detected in 10 dB louder environment.



Conclusion of the results

- **Examined adequate sound level** for the acoustic sign through a psychoacoustic experiment.
- Both environmental sound and acoustic sign stimuli were recorded with HATS to simulate the relative position between the vehicle and the pedestrian.
  - Adequate sound level **depends on environmental condition**. (sound level, quality, characteristics)
  - Adequate sound level for a environment **cannot be detected in a 10 dB (or more) louder environment**.

- It is not easy to balance quietness and safety by adding sounds.

Our study ; Examination of Sound Level

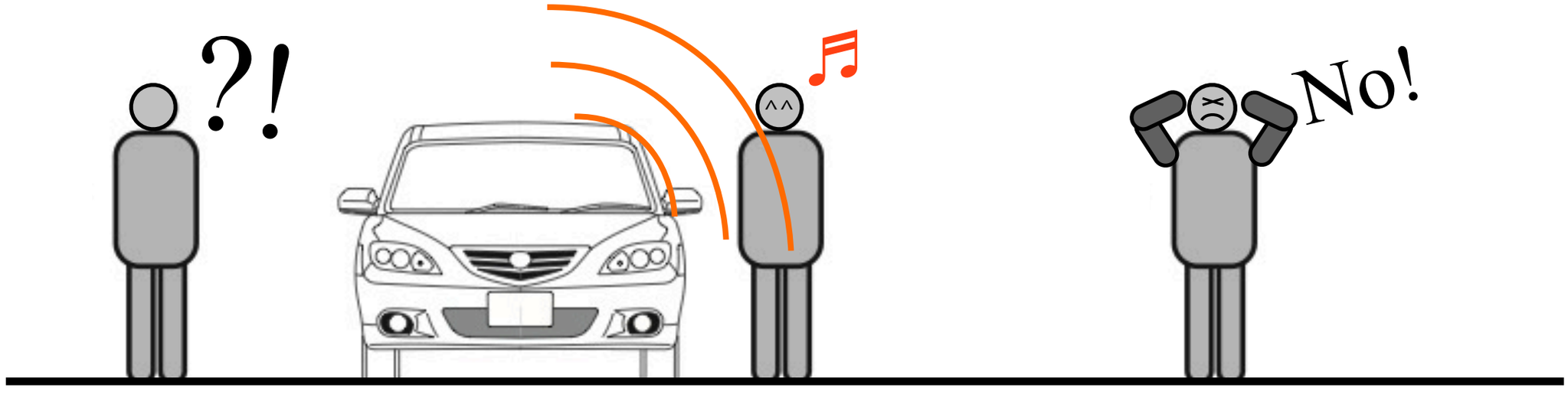
Examination of the **adequate sound level**
of external acoustic signs for “quiet vehicles”.

Dangerous for pedestrians

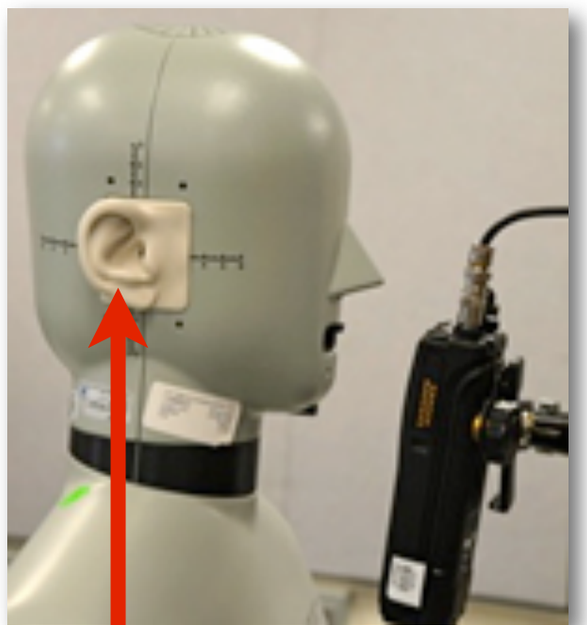
low

loud

Noise Problem

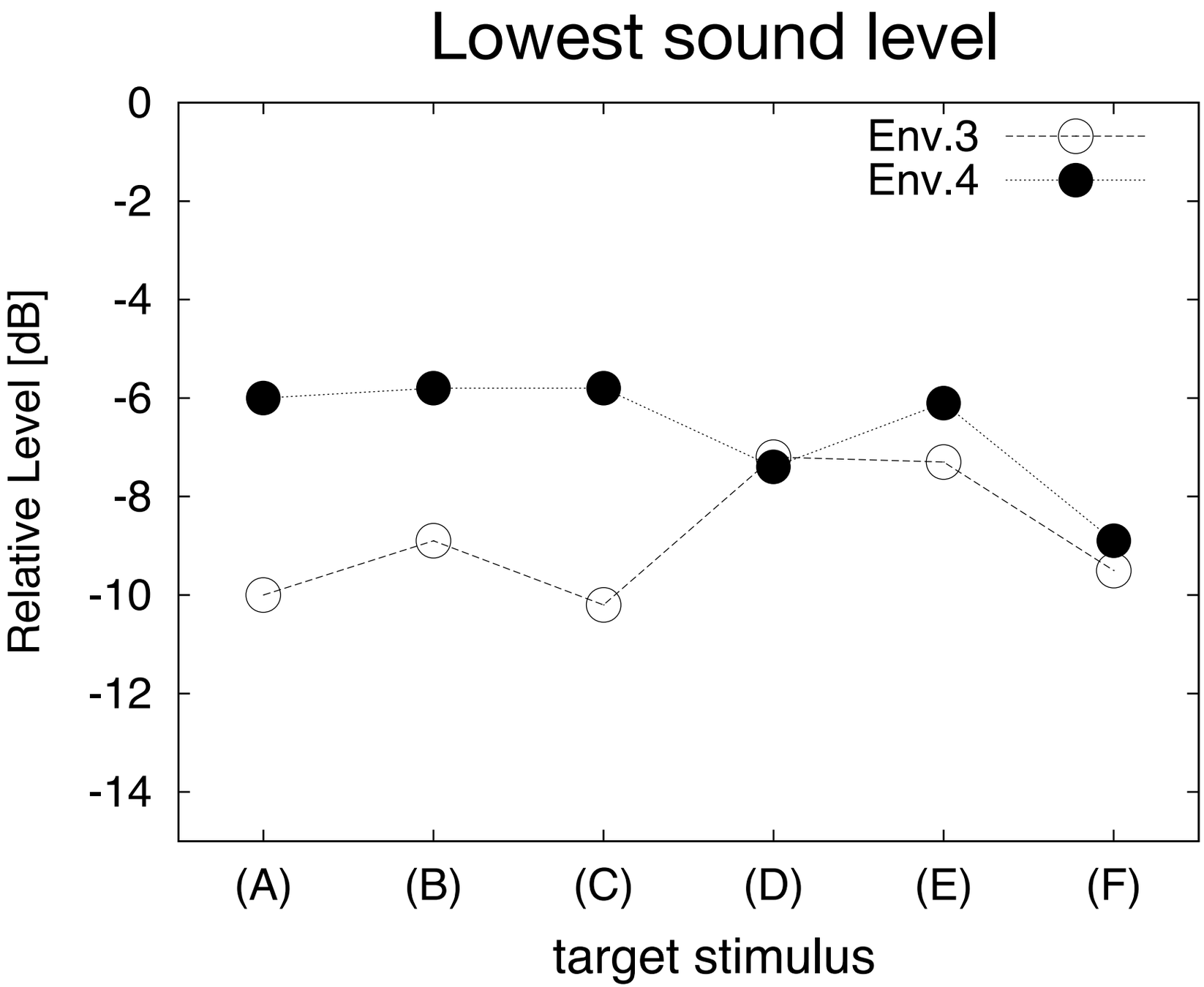


Head and Torso Simulator; HATS



Microphone

Results



ANOVA:
both main effects
& interactions are
significant ($p<.001$)