Relationship between Acceleration Impression and Frequency Shifting of Vehicle Sound

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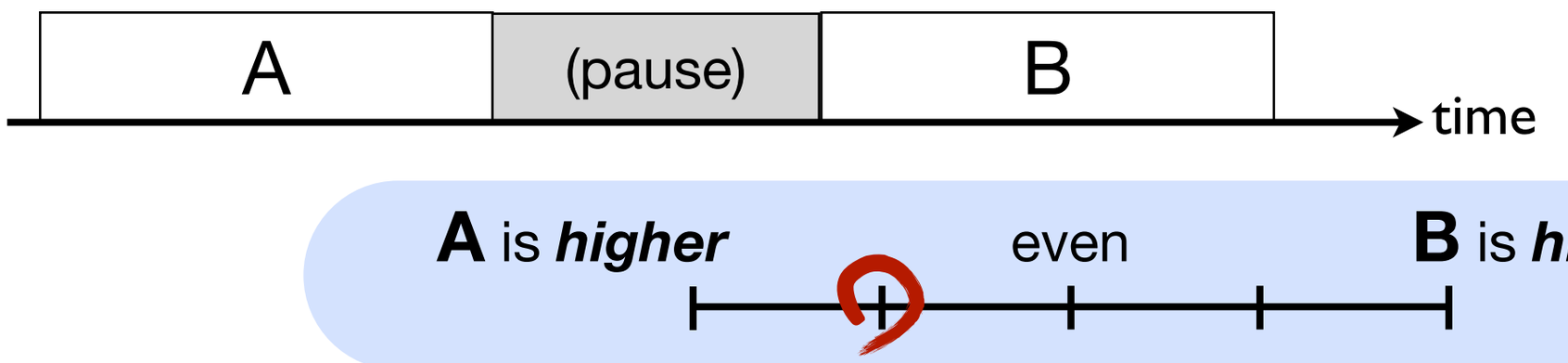
Acceleration Impression and Frequency Shifting

- Pedestrians can ***hear*** information of a vehicle behavior
- **variation of frequency contents** as a function of the vehicle speed shall make pedestrians easier to recognize the vehicle acceleration.
  - *e.g.* ??% for 10km/h acceleration
- The additional sounds can be designed independent form the vehicle propulsion mechanism.
- Need to reveal the knowledge of relationship between **acceleration impression** and **frequency shifting** of vehicle sound

Experiment Design

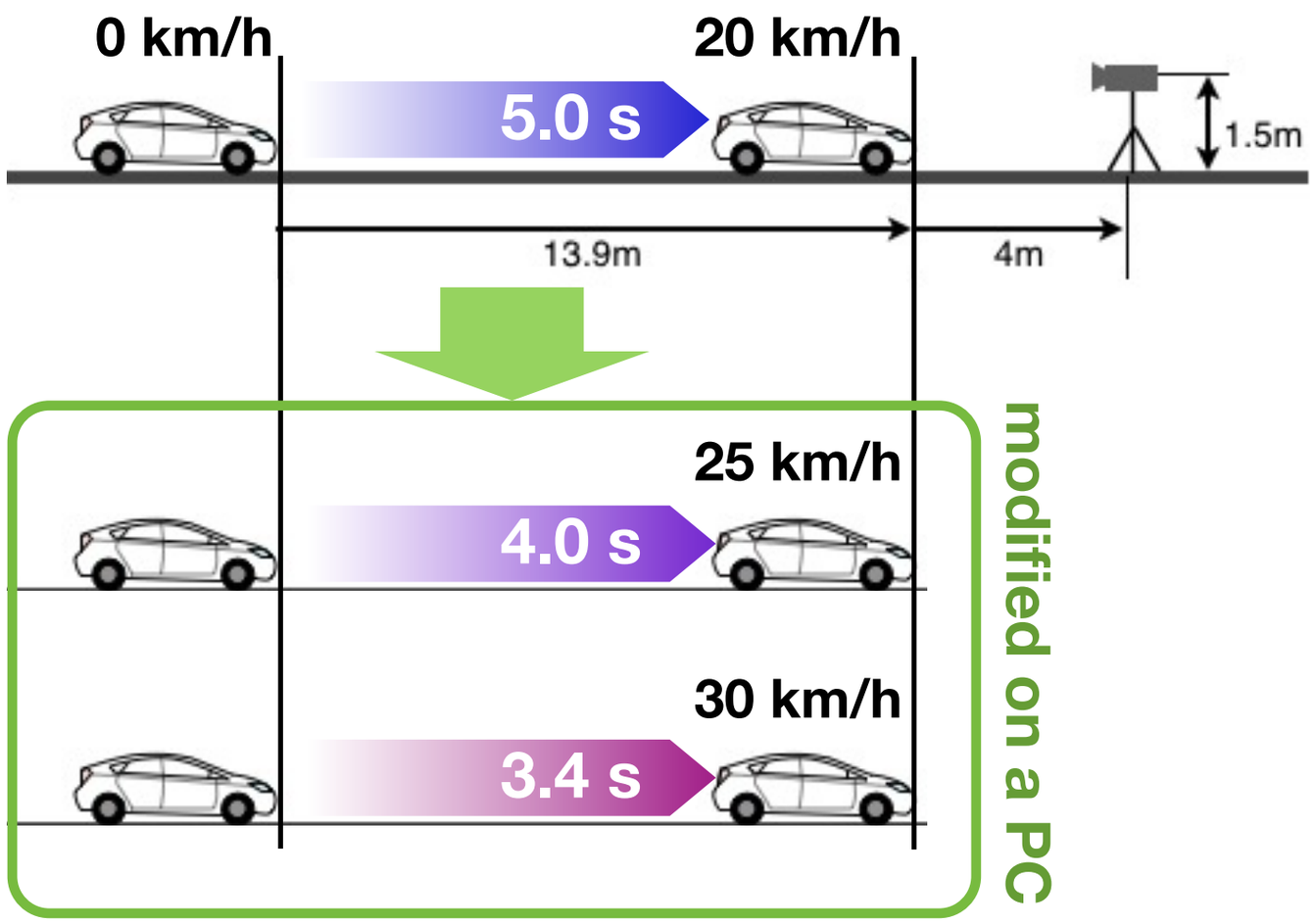
- Scheffe's paired comparison test
- using Audio-Visual stimuli in a laboratory

- a pair of audio-visual stimuli was presented across a pause
- subjects were asked to rate the impression of the second stimulus compared to the first on a five-points scale



Visual Stimuli Conditions

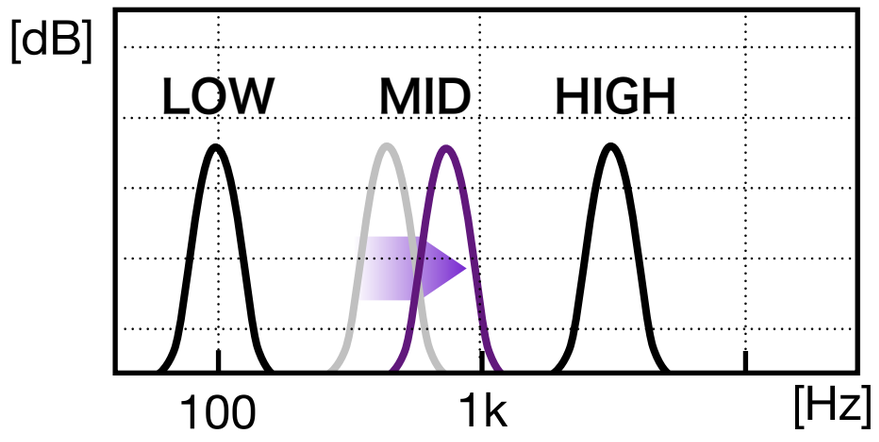
- movie of a traveling vehicle monotonically accelerated from stopping to 20 km/h (in 5 sec.)
- movie duration was modified on a PC to emulate different vehicle acceleration



ID	duration	acceleration
V1	5.0 s	0—20 km/h
V2	4.0 s	0—25 km/h
V3	3.4 s	0—30 km/h

Audio Stimuli Conditions

- mix of three 1/3oct. band noises (100, 400 & 2k Hz)
- all or one of the band noises were **independently shifted** while the others were stable

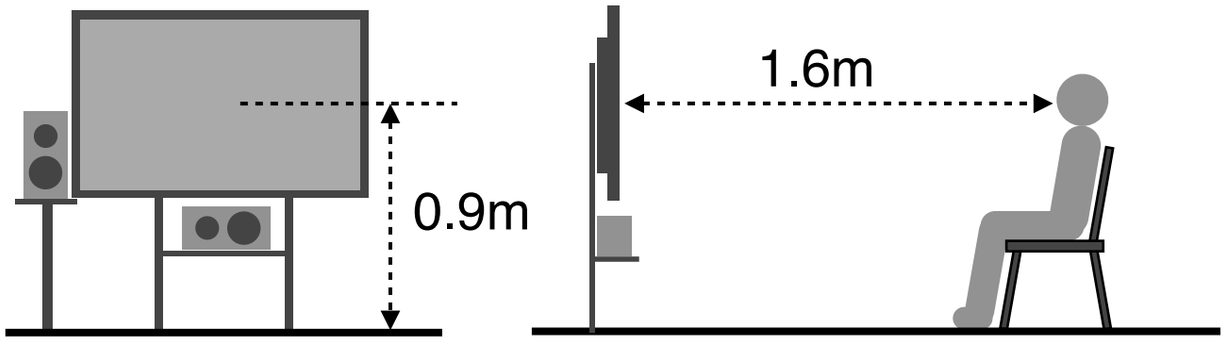


- center frequencies were shifted to be **120/150/180% higher** at the end of the stimuli

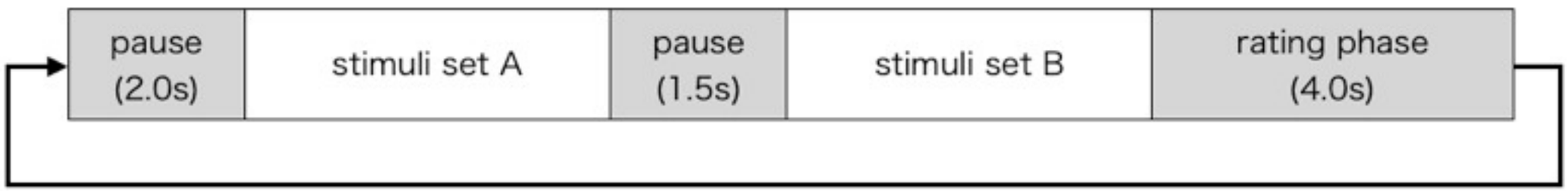
ID	shifting band	rate
A0	no shifting (control)	
A1	**LOW** only shifting (100 Hz)	120%
A2		150%
A3		180%
A4	**MID** only shifting (400 Hz)	120%
A5		150%
A6		180%
A7	**HIGH** only shifting (2kHz)	120%
A8		150%
A9		180%
A10	**ALL** shifting (100, 400 and 2k Hz)	120%
A11		150%
A12		180%

✳ attenuated -23.5 dB at the beginning to 0 dB at the ending to emulate a geometrical attenuation in a free sound field.

Experiment Procedure



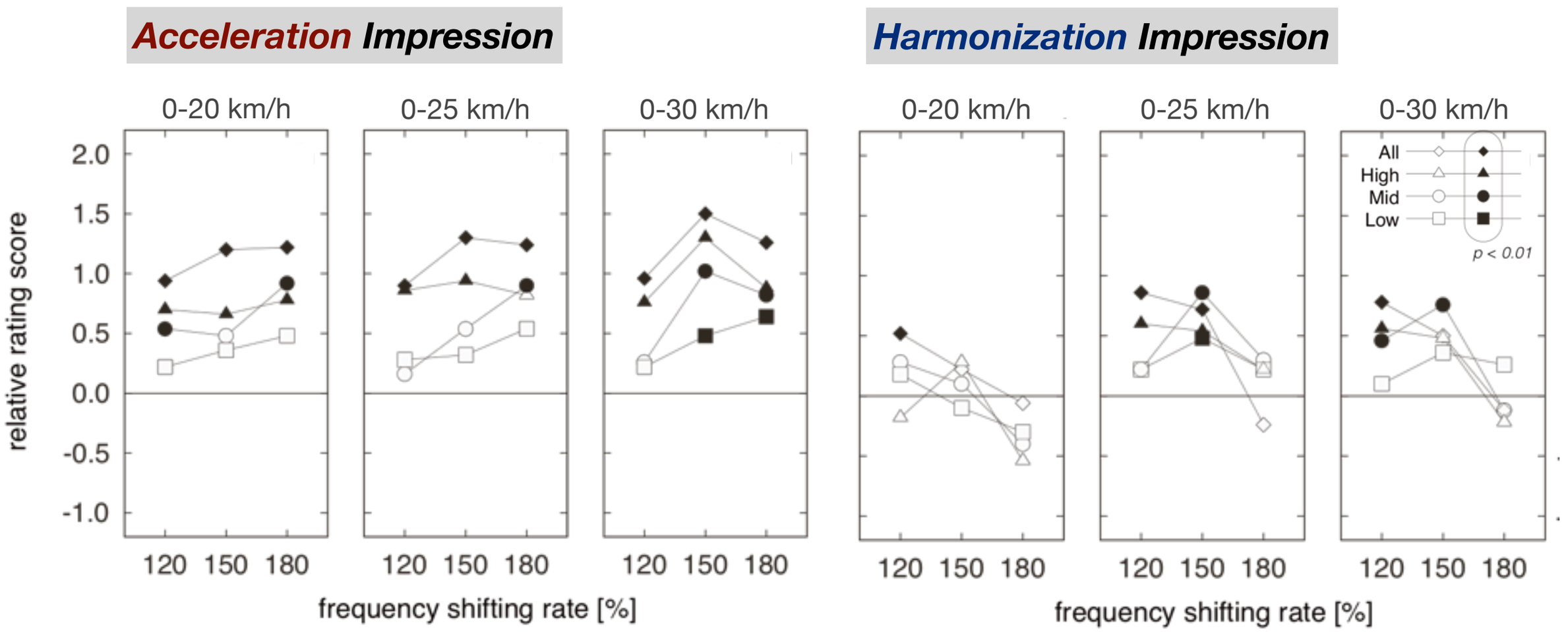
- 55 dB at the subject's head position
- pair of audio-visual stimuli was presented across a pause



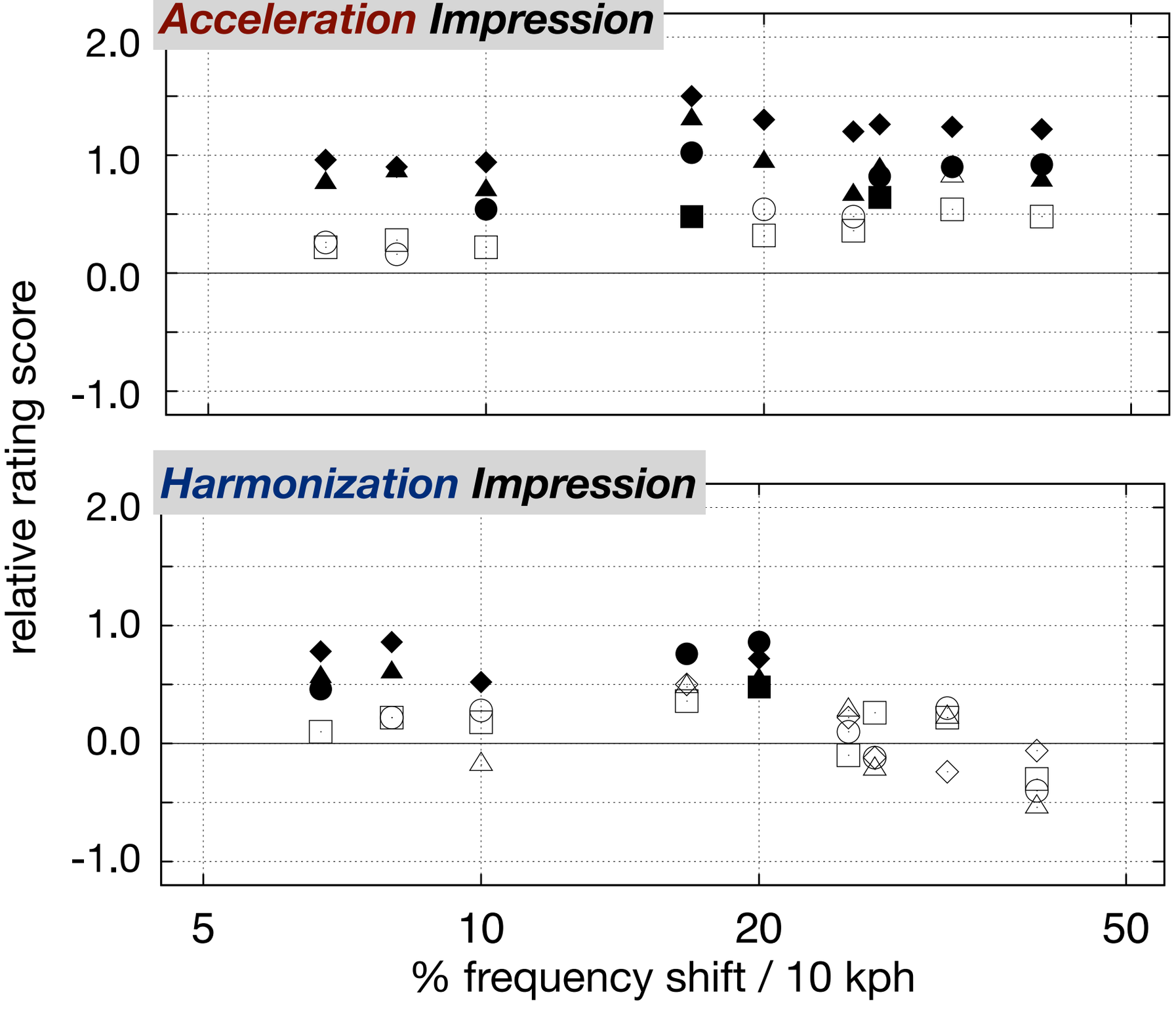
- subjects were asked to rate the impression of the second stimulus compared to the first on five-points scale
  - **acceleration** / **harmonization** impression of A-V stimuli
- Subjects: 5 male and 5 female (age between 19-48)

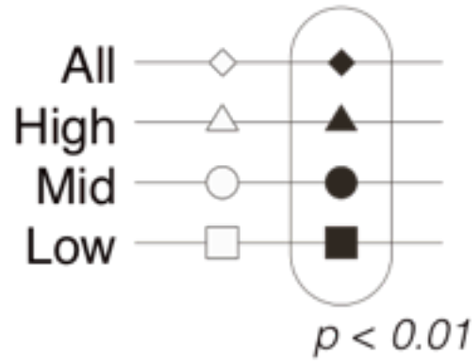
Result

- analyzed using the Scheffe's method with Nakaya's variation.
- relative rating score for each duration and shifting rate condition were estimated. Then, the relative rating scores were calculated as differences from the control (*i.e.* no shifting) condition.



Acceleration Impression





Harmonization Impression