# Effects of vibrotactile stimuli on perception of voiced and unvoiced bilabial stop consonants in noise

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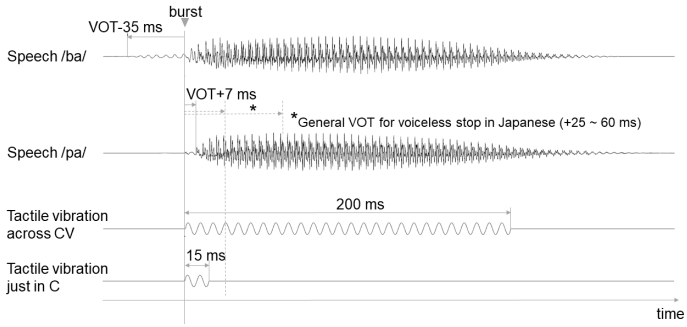
## Introduction

-Vibrotactile cues of speech have been used by people with vision-and-hearing impairments [1].
-Vibrotactile stimulation generated from speech has been reported to improve discrimination between degraded voiced and voiceless consonants [2,3].
-Such stimulation has been applied to an entire speech segment, but the effect of vibrotactile stimulation given to unvoiced consonants was unknown.
-The relationship between this effect and auditory efficacy was not tested.
-Our hypothesis was (1) vibrotactile stimulation in a consonant region biases an unvoiced consonant toward voiced and (2) this effect depends on speech efficacy.

## Methods

Subjects: 21 native Japanese speakers (6 female).

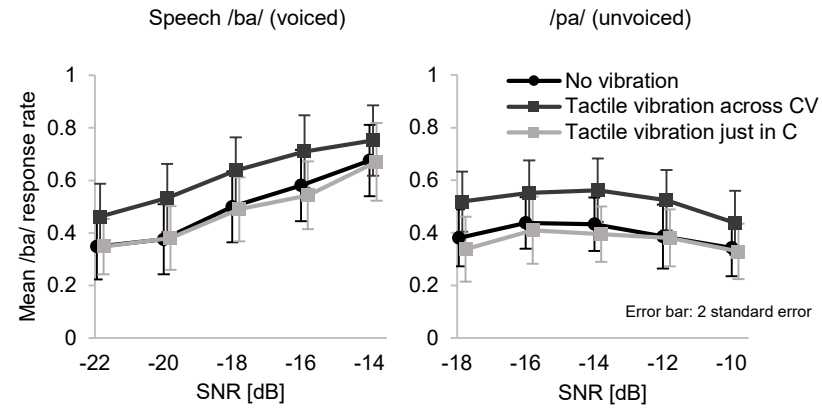
Stimuli: speech stimuli /ba/ and /pa/ in Japanese* were presented with and without vibrotactile stimuli.
*Japanese voiceless stops are not aspirated.

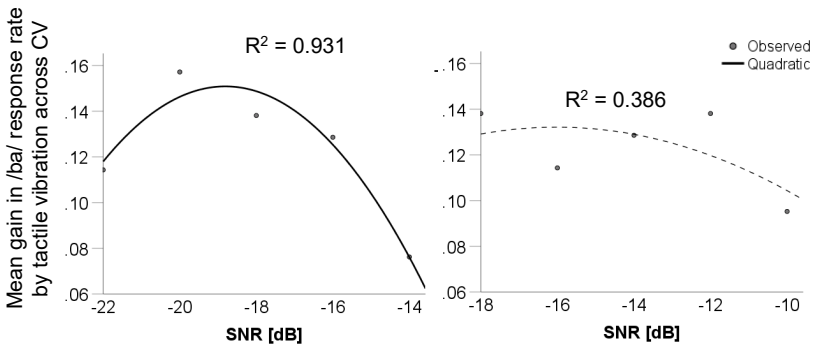



-Speech stimuli were degraded in 5 SNR steps.
-Vibration on backs of both hands[4] .

Experimental protocols:
-Participants selected one of the alphabetic keys on a PC representing Japanese consonants.
-Repeated 10 times.


## Results & Discussion




(1) Vibrotactile stimulation across the consonant-vowel region (across CV), not just in the consonant region (just in C), biased the consonant perception toward voiced for not only voiced consonant [2] but also for unvoiced consonant.

- tactile vibration across CV x voiced consonant → yes: replicated [2].
- tactile vibration across CV x unvoiced consonant → yes: indicate that vibrotactile stimulation biased the perception of unvoiced consonant toward voiced even though the vibration and the voiced region of speech were inconsistent.
- tactile vibration just in C → no:
  - implies that to alter perception for a consonant region, vibrotactile stimulation in a vowel region is assumed necessary. Just a vowel region will most likely alter perception for a consonant region(cf.[3]).
  - or just in C was not long enough to induce pre-voicing perception in Japanese voiced stop.

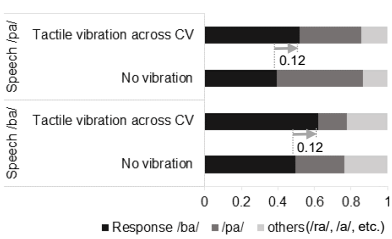
(2) There was a non-linear effect of vibrotactile stimulation across CV while speech efficacy changed for /ba/.

-suggests that there is a hot spot of auditory efficacy for vibrotactile and auditory integrated speech.

## Conclusion

We examined whether consonant perception is biased toward voiced by (1) giving /pa/ vibrotactile stimulation just in an unvoiced consonant region or across a consonant-vowel region, and (2) giving different speech efficacy. Our result showed (1) vibrotactile stimulation across a consonant-vowel region, not just in an unvoiced consonant region biased the consonant perception toward voiced, and (2) this had non-linear effect on speech-efficacy change. Even though the present research has some limitations, it will contributes to understanding how to improve intelligibility under noisy conditions and for people with hearing impairments.

## Appendix




## References

[1] Alcorn, "Development of the Tadoma Method for the Deaf-Blind", 117–119.
[2] Marino et al., "Single-Channel Vibrotactile Feedback For Voicing Enhancement In Trained And Untrained Perceivers", 44–45.
[3] Chu et al., "Testing Symmetry Of Temporal Window Of Integration In Vibrotactile And Auditory Speech Information On Phoneme Perception", 46–49.
[4] Gick and Derrick, "Aero-tactile integration in speech perception," 502–504.