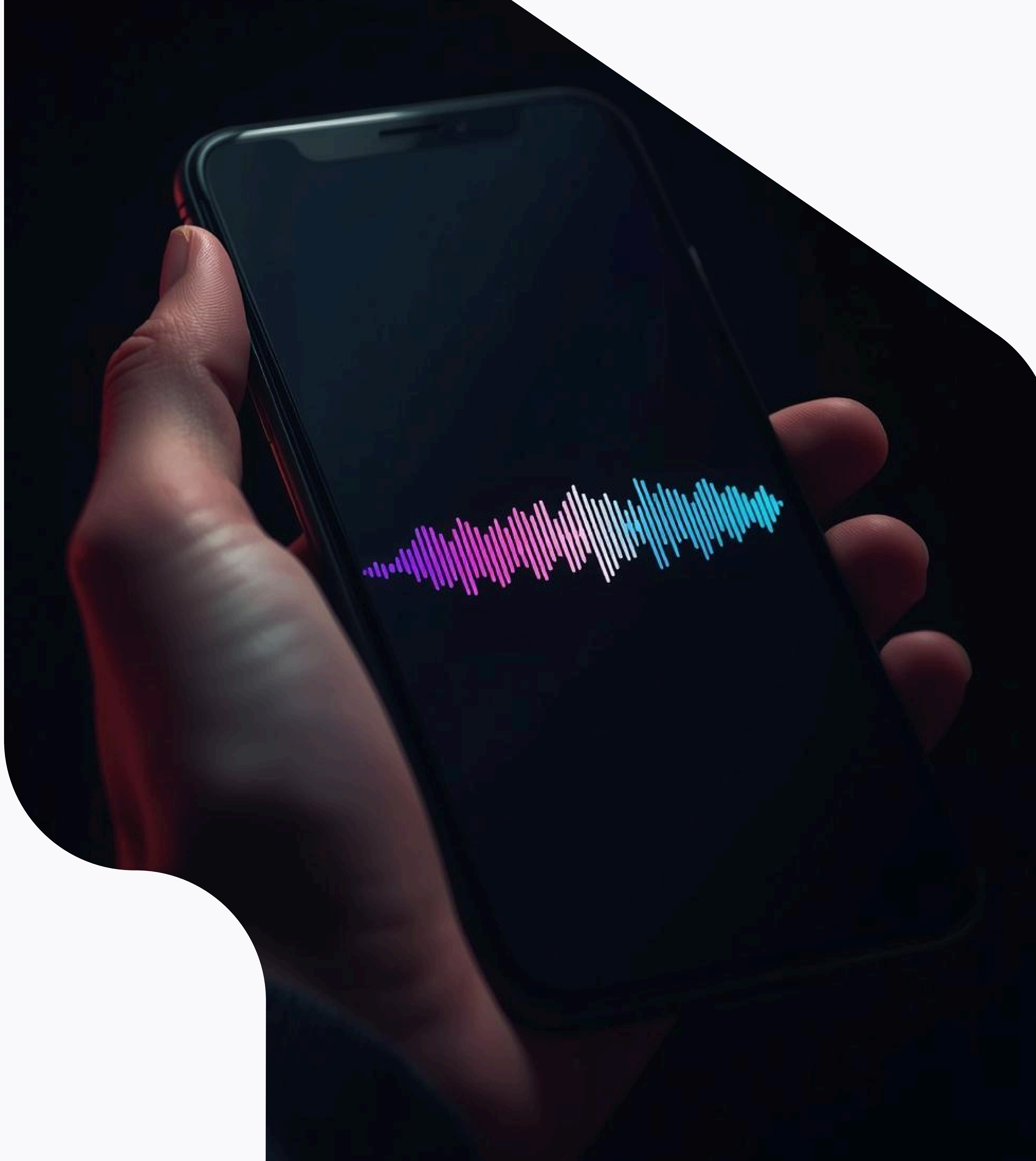
Haptic Assistant for Language Learning

Enhancing English Learning with Tactile Cues



Aman Paliwal
Angad Singh
Mudit Surana

Motivation for Haptic Learning

first watched the F1 haptic trailer on iPhone! 🏎️

haptics → evoke some emotion / feeling → singing or speaking?

enhancing language acquisition through tactile feedback for a richer, multimodal experience

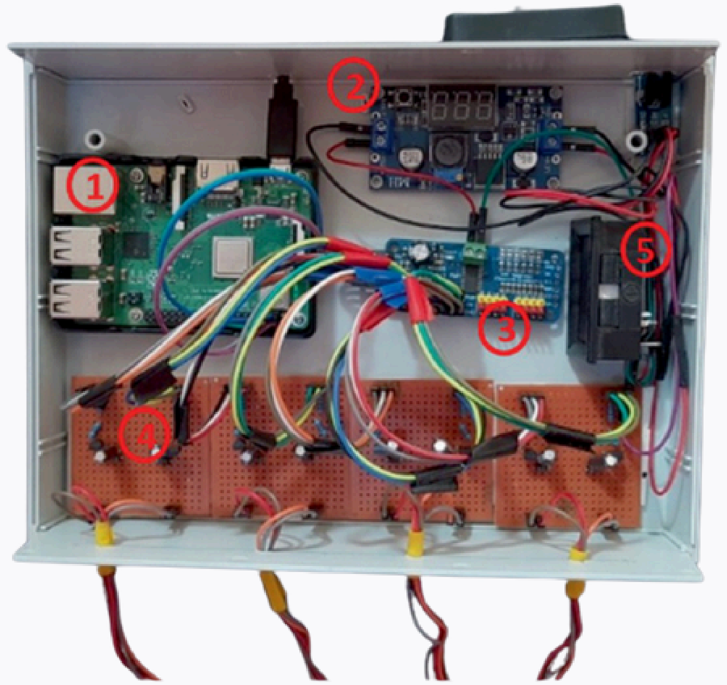
- prosody is often subtle and hard to perceive
- tactile cues provide immediate & intuitive sensory feedback for learners
- multimodal learning enhances memory and engagement

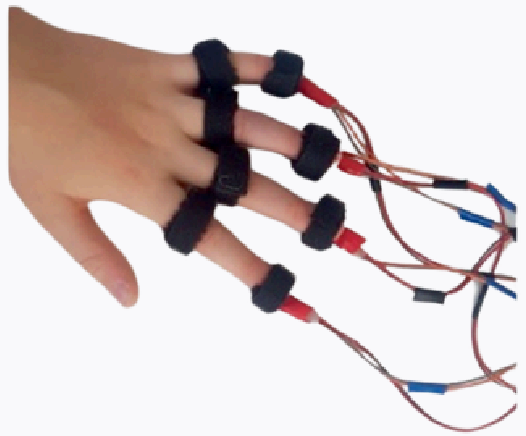
[1] https://tv.apple.com/us/clip/haptic-trailer/umc.cmc.5834l80x7lpxvb1wqiz7uvgj7?targetType=Movie&targetId=umc.cmc.3t6dvnnr87zwd4wmvpdx5came

Literature Review

- Touch to Speak (2025)
  - Wearable, real-time tactile feedback mapped phonemes to spatial vibrotactile cues for pronunciation training (speech/hearing-impaired use case). Three studies reported significant gains in articulation accuracy and engagement; closed-loop, phoneme-level feedback. Limitation: custom multi-motor hardware, not phone-based.

- HAPOVER (2024)
  - Eight-motor fingertip device compared learner audio to a native reference using MFCC + DTW, converting errors into “haptic codes.” Psychophysical evaluation reported ~80.7% improvement in word pronunciation after training. Limitation: bespoke hardware; requires users to learn code mappings.



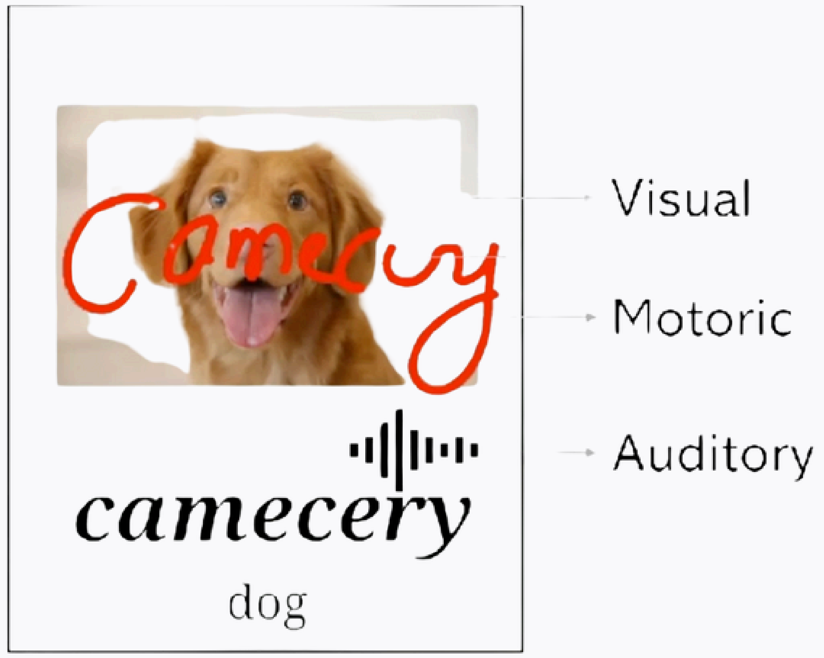


MDPI, CiteDrive

Literature Review

- Haptics in Mobile Learning UX (CHI 2020)
    - Mobile flashcard interface with vibrotactile feedback and free-form annotation improved vocabulary recall; “whole-word” annotation yielded +24% immediate and +30% 7-day recall. Effect of vibrotactile feedback was transient in delayed tests. Limitation: vocabulary (not pronunciation), Android/unspecified platform.

- Survey of Tactile Language Systems (IEEE ToH 2023)
    - Review of tactile language communication (text/phonemes) highlights design tradeoffs: spatial/temporal/intensity encodings, user training burden, and need for bi-directional systems. Gap: few phone-only, pronunciation-focused solutions.



ACM Digital Library, ACM Digital Library

Study (Year)	Goal	Hardware / Platform	Design & Task	Metrics / Findings	Limitations / Gaps
Touch to Speak (2025)	Real-time tactile pronunciation training	Wearable with multi-motor vibrotactile array	Phoneme→spatial haptic mapping; 3 user studies	Significant articulation accuracy gains; high engagement	Not smartphone-based; hardware complexity; transfer to single-actuator phones unknown. (MDPI)
HAPOVER (2024)	Improve L2 pronunciation via haptic codes	8 finger-mounted motors; MFCC+DTW	Compare learner vs native audio; convert errors→vibro codes	~80.7% pronunciation improvement post-training	Requires bespoke device and code learning; limited iPhone relevance
Mobile Haptics for Learning (CHI 2020)	Boost vocab recall with haptic-integrated UI	Smartphone app (vibrotactile + annotation)	Within-subjects vs baseline flashcards	+24% immediate, +30% 7-day recall (whole-word annotation); vibro effects mainly immediate	Focus on vocabulary (not pronunciation); platform not iOS-specific
Tactile Language Review (IEEE ToH 2023)	Synthesize methods for tactile language comms	Various (vests, wearables, arrays)	Survey of encoding strategies & performance	Shows feasibility with training; maps design space	Lack of smartphone-centric, pronunciation-feedback studies

MDPI, CiteDrive, ACM Digital Library, ACM Digital Library

Gap & Our Approach

Research into haptic-assisted verbal language learning shows significant potential, but the field remains nascent, with most studies confined to complicated hardware setups.

- Complex, inaccessible hardware like VR gloves or multi motor wearables
- Untapped potential of mobile devices that leverages modern smartphones for nuanced language learning

Our Approach: Bringing Haptic Feedback to the Learner's Pocket

- To use simple and accessible, but powerful haptic engines in everyday devices to enhance language learning.
- Study the qualitative aspects and quantitative degree to which haptics can elevate language speaking, listening & understanding skills.

Swift : Core Haptic

Hardware - Taptic Engine
Software - Core Haptics Framework

CHHapticEvent → .hapticTransient + .hapticContinuous

.hapticTransient : momentary tap - like sensations with intensity dependent duration good for discrete signals

.hapticContinuous : sustained vibrations with programmable intensity, duration and audio file (AHAP)

CHDynamicParameter → modify a pattern's parameters *while it is* playing

CHHapticParameterCurve → overlay multiple event instances key to creating smooth, expressive effects

Prosodic Feature/Feedback Purpose	Proposed Haptic Design	CHHapticEvent Type	Intensity (value)	Sharpness (value)	Duration (sec)
Rising Intonation (e.g., Question)	Smooth vibration that increases in intensity/sharpness	.hapticContinuous (with Parameter Curve)	0.3 -> 0.8	0.4 -> 0.9	0.8
Falling Intonation (e.g., Statement)	Smooth vibration that decreases in intensity/sharpness	.hapticContinuous (with Parameter Curve)	0.8 -> 0.3	0.9 -> 0.4	0.8
Stressed Syllable/Word	Single, sharp, prominent tap or short, strong pulse	.hapticTransient or .hapticContinuous	1	1	0.1
Unstressed Syllable/Word	Very brief, soft, and dull pulse	.hapticTransient	0.2	0.2	N/A
Speech Rhythm/Pacing	Series of transient events timed to match syllable cadence	.hapticTransient (multiple)	Varies	Varies	N/A
Correct Pronunciation Match	Short, satisfying "confirmation" buzz	.hapticContinuous	0.7	0.9	0.2

Experiment Design & Setup

Research Question: Does haptic feedback, synchronized with audio examples, improve a learner's ability to produce correct word-level pronunciation, intonation and stress?

Participants: 25 non-native English speakers with beginner-to-intermediate proficiency.

- **Control Group:** Uses the app with standard audio-visual feedback
- **Experimental Group:** Uses the same app, but with the addition of haptic feedback

Intervention: The experimental group will feel vibrotactile patterns on their iPhone that correspond to the correct intonation and stress of words as they listen to audio examples.

Data Collection:

- Objective Data: audio recordings from pre- and post-tests
- Subjective Data: User experience data via questionnaires

Analysis: Use of statistical tests to compare the performance improvement between the two groups and determine if the haptic intervention led to a significant difference in learning outcomes

[https://web.mit.edu/6.813/www/sp16/classes/11-experiment-design/]

Performance Metrics

1) GOP (Goodness of Pronunciation)
- evaluates the quality of a single phoneme (the smallest unit of sound)
- how closely a spoken sound matches the acoustic model of the target sound

2) Lexical Stress - Lexical Stress Ratio (LSR)
- quantifies how prominently a speaker stresses one syllable relative to another by combining three key acoustic correlates: duration, intensity (loudness), & pitch

3) Intonation Contour - F0 Root-Mean-Square Error
- quantifies the overall difference between the pitch contour of the learner's word and that of the native speaker's, providing a holistic measure of intonation accuracy
- **lower is better**

4) Intonation Consistency / DTW Score
- Measures how well the user's pitch contour aligns with the target, ignoring speed differences.
- Calculated using Dynamic Time Warping

5) Rhythm Score (Temporal Alignment)
- Measures the timing similarity between the user's amplitude envelope and the target rhythmic template.

6) Stress Score (Contrast)
- Checks if stressed syllables are actually louder and higher pitched than unstressed ones

User Survey

Metric (Survey Question)	**Mean Score**
"Would use again" (Retention)	**4.2 / 5.0**
"Overall Satisfaction"	**4.1 / 5.0**
"Haptic Helpfulness"	**4.0 / 5.0**
"Perceived Improvement"	**3.8 / 5.0**
"Haptic Clarity"	**3.6 / 5.0**

- Lower score for "Clarity" indicates that interpreting tactile vibrations has to be improved
- Despite the learning curve, the high "Retention" score suggests that users found the multimodal experience engaging and preferable to standard rote repetition.
- Even if the technical gains were moderate, the fact that users *want* to use the tool means they will practice more, leading to long-term fluency.

Results

Metric	Pre-Test (Baseline)	Post-Test (Audio Only)	Post-Test (Haptic + Audio)	Net Gain (Haptic vs Audio)
Final Score	45.00%	55.20%	**65.10%**	**9.90%**
LSR Score	35.50%	48.00%	59.20%	11.20%
Stress Score	40.00%	51.50%	61.00%	9.50%
Rhythm Score	42.00%	53.00%	62.50%	9.50%
DTW Score	50.00%	60.00%	64.50%	4.50%
GOP Score	65.00%	70.00%	71.50%	1.50%
F0 RMSE (Lower is better)	0.28	0.22	0.18	-0.04

1) Significant improvement in LSR & Rhythm (+11.2 % and +9.5%)

Haptic vibrations provide a direct physical cue for intensity (loudness) and duration (timing), making it easier for users to mimic stress patterns.

2) Minimal impact on segmental, phoneme wise pronunciation (GOP)

Our solution helps with Prosody, not Articulation

3) **Statistical Validity: paired t - test on final scores**

$p = 0.042$ (< 0.05) indicating the 9.9% overall improvement is statistically significant.

Potential Challenges

- **Designing Intuitive Haptic Cues:** Creating vibration patterns that intuitively map to features like pitch and emphasis and are not perceived as confusing or distracting by learners.
- **Participant Variability:** Individual differences in tactile sensitivity, learning styles, and prior language experience can introduce significant noise, variation into collected data.
- **Confounding & Hidden Variables:** Need to carefully consider experiment setup and ensure that no confounding factors or changes in environment that may induce deviations in results are present.
- **Feedback Synchronization:** Achieving perfect, real-time synchronization between the audio examples and the corresponding haptic feedback is vital; latency can reduce the intervention's effectiveness

Impact & Potential Applications

Why it matters

- Memory & engagement in mobile learning
  - Haptic-integrated mobile vocabulary study showed +24% immediate and +30% 7-day recall (whole-word annotation); supports adding touch for durable learning. ACM Digital Library
- Learning & engagement.
  - Synchronized haptics heighten salience of stress/intonation during model audio, adding a third channel beyond A/V.
- Social impact
  - 1.5B+ people live with hearing related impairments ➔ tactile cues can complement or substitute audition in learning/therapy. World Health Organization

Where it applies

- Pronunciation & Fluency Coach (mobile app)
  - Syllable-timed taps for rhythm; stress-strength taps for accent placement; error buzz for mispronounced phones. PNAS
- Speech Therapy & Assistive Learning
  - Tactile guidance for users with hearing impairment or CAPD; immediate vibrotactile cues mapped to phoneme or stress errors. MDPI
- Accessibility for hearing-impaired
  - Audio ➔ tactile vocoder on-device (wrist/handheld phone) for rhythm & envelope cues; robustness in noise.
- Immersive/media learning in the classroom
  - Trailer-style synchronized haptics for language listening lessons (beats, accents).

Thank You!

References

[1] https://tv.apple.com/us/clip/haptic-trailer/umc.cmc.5834l80x7lpxvb1wqiz7uvgj7?targetType=Movie&targetId=umc.cmc.3t6dvnnr87zwd4wmvpdx5came

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[8] https://aclanthology.org/2024.icon-1.73/