The Effect of Vibrotactile Feedback on VR Music Experiences

Jiwon Lee, Youjin Choi, Kyung Myun Lee

KAIST

MuBL
Music & Brain Lab

KSMPC

Research Background

- VR concert:
  - A new type of performance that allows audiences to enjoy concerts immersively using VR devices, without spatial or temporal constraints
  - From the audience's perspective, viewers can freely look around the stage and surrounding environment in 360°, providing a feeling of being at a real concert venue
  - With the emergence of platforms such as Amaze VR and YouTube VR, this format is also growing within the entertainment industry

Research Background

- Limitation of VR concerts
  - Compared to live concerts, VR concerts lack physical and emotional richness
  - Particularly, tactile dimension of music!!

  → In live concerts, audiences can feel vibrations through low-frequency sound and speakers, whereas these sensations are largely absent in VR concerts

Research Background

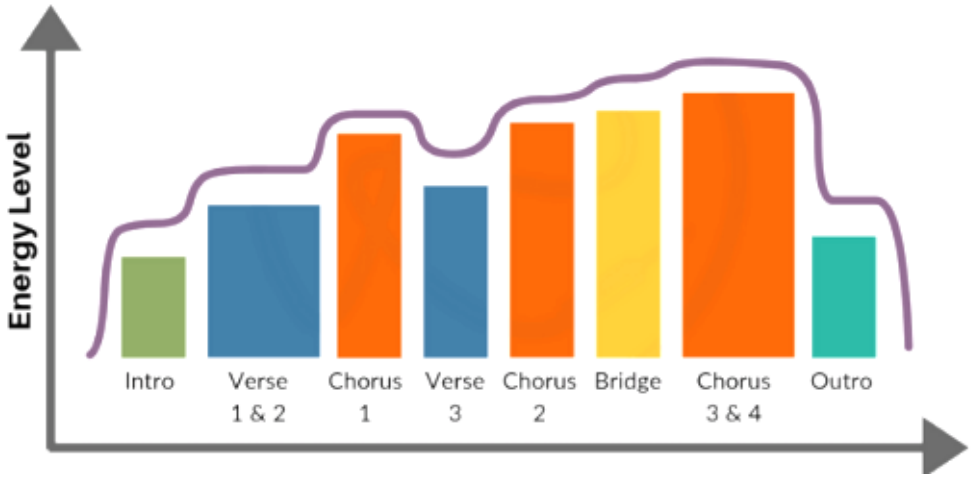
- Vibrotactile feedback
  - Compensating for the sensory limitations of VR concerts
  - A key factor in enhancing musical immersion and emotional responses
  - Previous research has primarily focused on audio signal–based mappings (e.g., pitch and rhythm)

Musical Features	Audio Signal → Vibration
Rhythm	Rhythm generated through short, strong stimuli
Pitch	Vibration frequency mapped to pitch
Loudness	vibration amplitude used to control loudness

Paterson & Wanderley (2023), Paisa et al. (2023), Remache-Vinueza et al.(2021,) Venkatesan & Wang (2023)

Research Background

- Music Structure: Chorus
  - A key section that forms the emotional and structural climax in music
  - Characterized by high energy and repetition, and the most memorable part
  - A section where listener attention and emotional responses reach their peak
- Research gap: Existing vibrotactile feedback studies have largely overlooked the role of structural highlights



Solberg & Dibben (2019), Von Balen et al., 2013

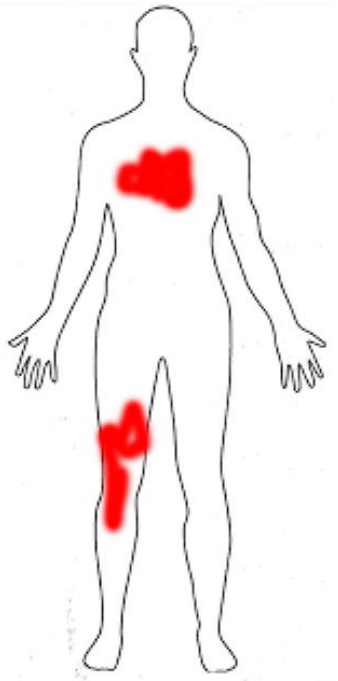
Research Questions

“How does musical structure-aligned vibrotactile feedback affect VR music experiences?”

“Does musical structure-aligned vibrotactile feedback enhance enjoyment and flow?”

Pre-study: Post-concert Field Survey

- **Goal**: to determine body location & sound features for vibration mapping
- **Location**: Seoul, after SHINee & Jay Park concerts (May 25, 2025)
- **Participants**:
  N = 17 (18–41 yrs)
- **Tasks**:
  "Mark body areas where vibration was felt (body map)"
  "List your top 3 body areas where vibrations felt strongest"
  "What kind of vibrations did you feel during the concert?"
  "While answering the questions above, which music genre(s) came to mind?"



Field Survey Results

- Analysis of Body Maps:
  - Body maps merged using ImageJ
  - Overlap intensity calculation & Heatmap visualization
- Strongest hotspot: Chest

Field Survey Results

- Top 1: Chest
- Participants described sensations as:

  "When the beat was intense, I could feel vibrations"

  "I felt vibrations when bass was deep and powerful"

- Associated genres: Hip-hop / Rock / EDM

VR Experiment

- **Goal**:
  to examine how vibrotactile feedback aligned with musical structure affects VR music experience, especially flow and enjoyment
- **Participants**:
  N = 23 (19–33 yrs)
- **Vibrotactile Conditions:**
  (a) Chorus-aligned: vibrations only during choruses
  (b) Random: same duration as the chorus-aligned condition, but unpredictably timed
  (c) Baseline: continuous vibrations throughout the entire song

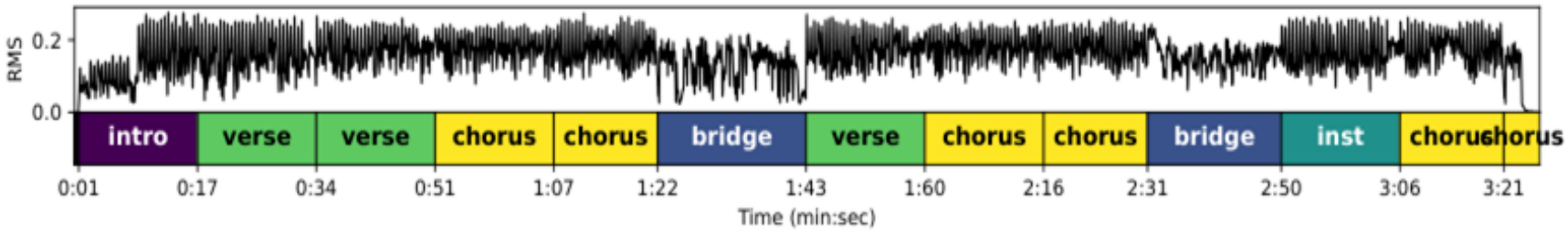
Stimuli

Singer	Song	**BPM**
ITZY	WANNABE	128
(G)I-DLE	TOMBOY	124
IVE	LOVE DIVE	118
APINK	DUM	130
STAYC	RUN2U	130
VIVIZ	BOP BOP	126
ELRIS	JACKPOT	116
OHMYGIRL	NONSTOP	125
Rocket Punch	BOUNCY	130

- Video: K-pop 180° VR concert videos from YouTube (3840 × 1920, 3–4 min each)
- Genres: dance / electronic (115–130 BPM)

Stimuli

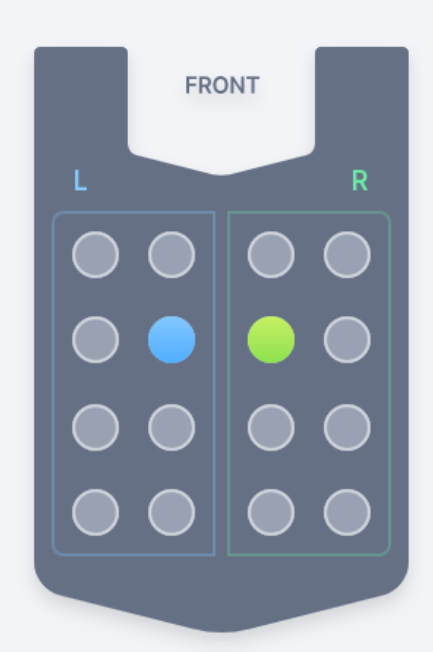
Remusic



- Chorus detection via Remusic AI + manual validation by two researchers who majored in music

Stimuli

- **Vibrotactile Feedback**
  - Audio extraction & preprocessing (Python, librosa)
    - Low-frequency filtering (< 200 Hz)
    - RMS-based thresholding (top 80%)
    - Beat extraction for rhythmic synchronization
  - Mapped to short pulses on chest actuators (bHaptics TactSuit Pro)
  - Synchronized video playback and vibration in VR setting



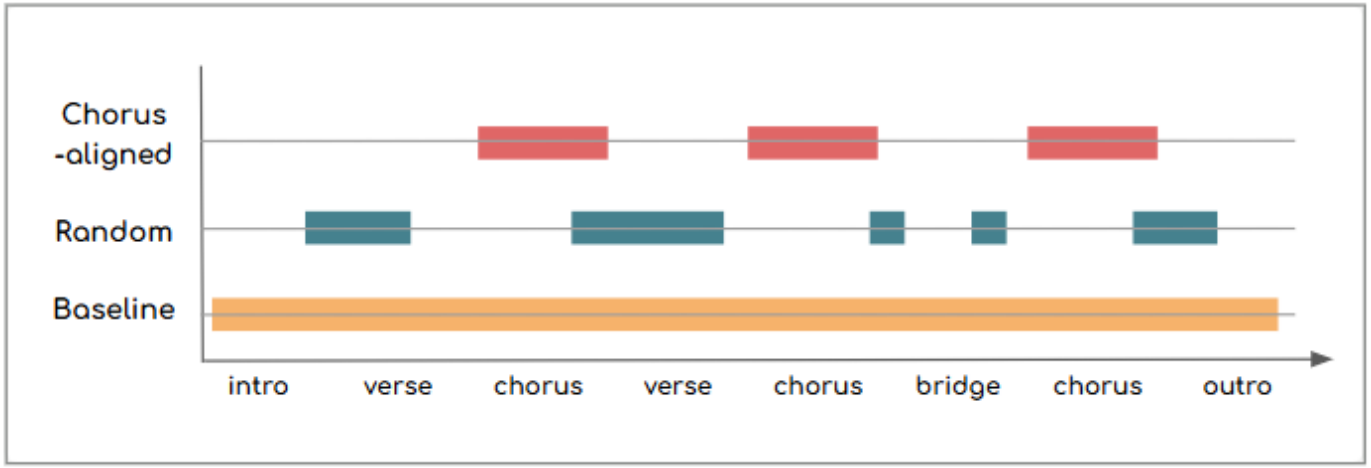
Vibrotactile Conditions

- **All conditions:** beat-synchronized vibrations

a. **Chorus-aligned**: vibrations only during choruses

b. **Random**: same duration as the chorus-aligned condition, but unpredictably timed (±1 bar around choruses excluded)

c. **Baseline**: continuous vibrations throughout the entire song



Procedure

- **Equipment:** Meta Quest 3 & bHaptics TactSuit Pro

- **Each trial:** Video viewing → Questionnaire response (7-point Likert scale)

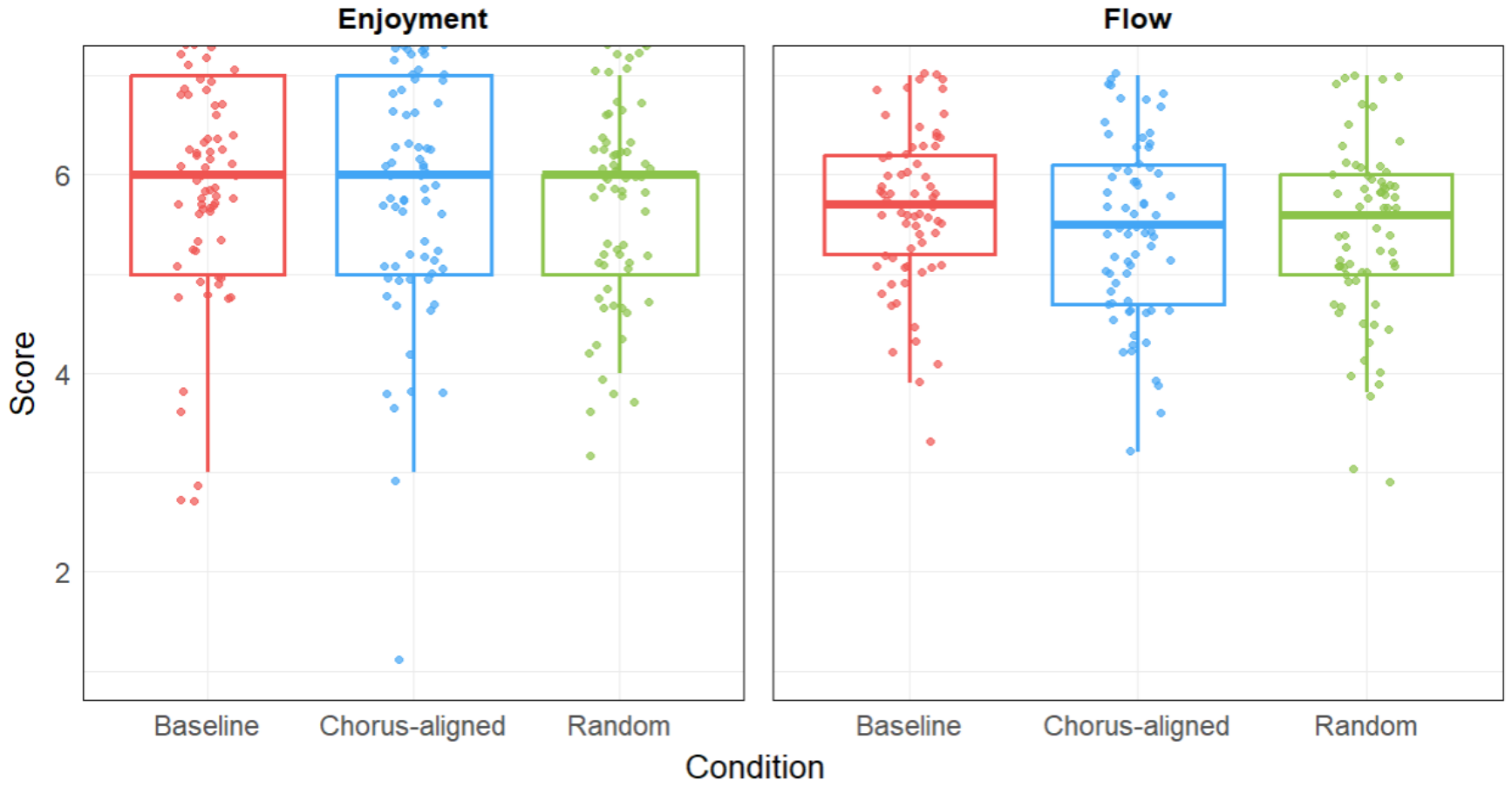
Flow (10 items)	"I am completely immersed in what I am doing right now.."
Enjoyment	"How enjoyable was this experience?
Familiarity	"How familiar are you with this song?"
Preference	"How much do you like this song?"

Procedure

- Experimental design (within-subject design):
  - Three songs per vibration condition, counterbalanced across song–vibration condition combinations → 9 songs presented per participant

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9
P1	**IVE Baseline**	STAYC Chorus-aligned	ELRIS Baseline	Rocket Punch Random	VIVIZ Chorus-aligned	ITZY Random	APINK Chorus-aligned	(G)I-DLE Random	OHMYGIRL Baseline
P2	APINK Baseline	Rocket Punch Baseline	VIVIZ Chorus-aligned	ITZY Chorus-aligned	STAYC Random	(G)I-DLE Baseline	OHMYGIRL Random	ELRIS Chorus-aligned	**IVE Random**

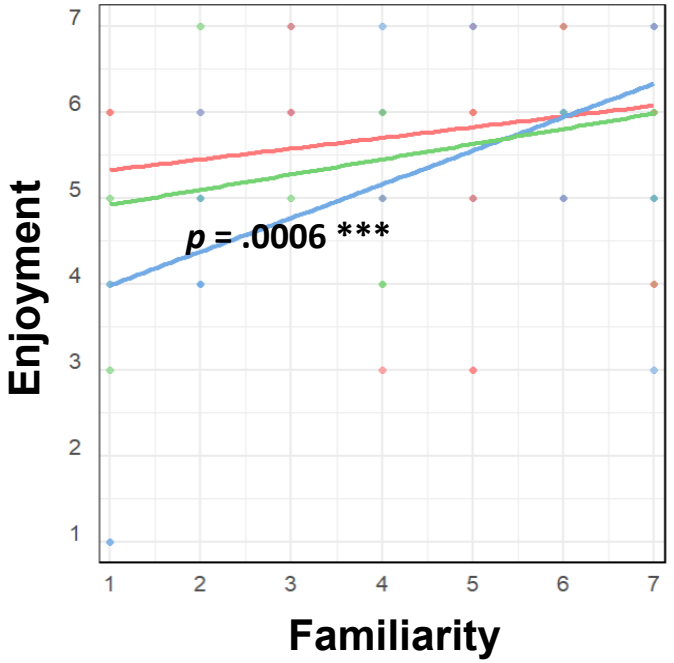
Results: Repeated One-way ANOVA



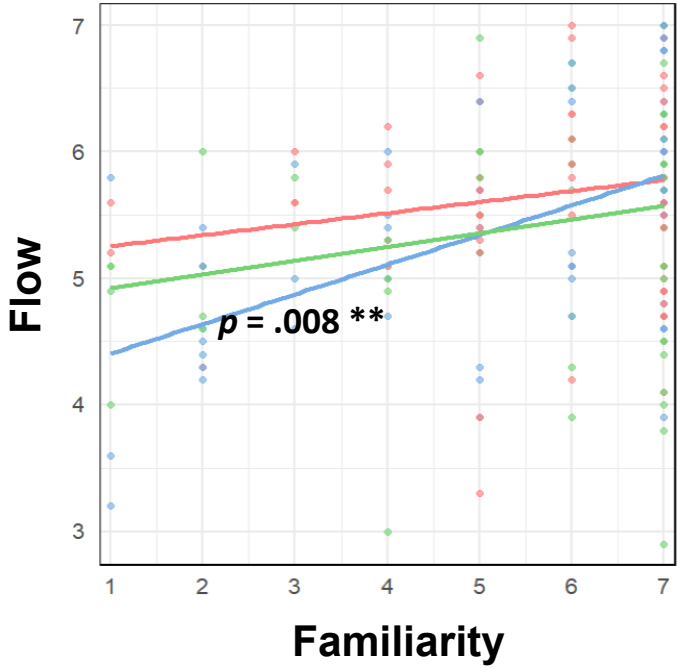
- No significant main effect of vibrotactile condition on enjoyment or flow

Results: Linear Mixed Effects Model

Enjoyment ~ Vibrotactile condition × Familiarity



Flow ~ Vibrotactile condition × Familiarity

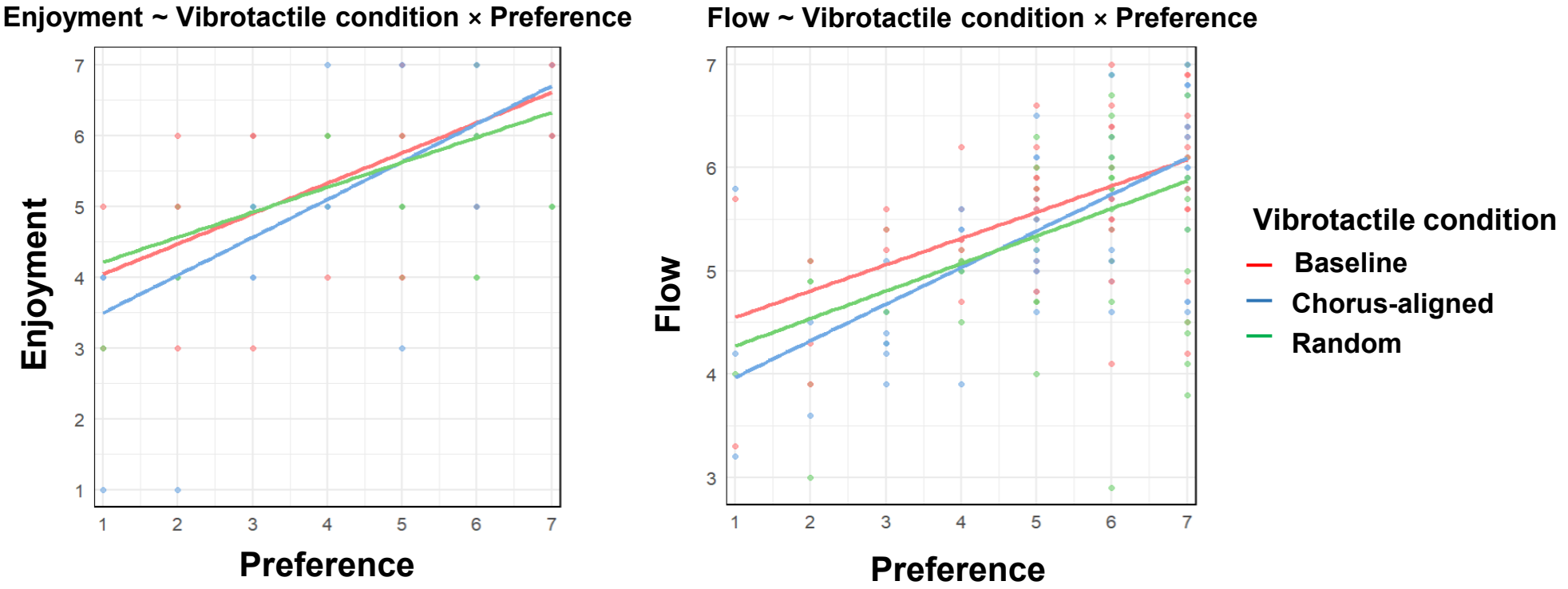


Vibrotactile condition
- Baseline
- Chorus-aligned
- Random

- Vibrotactile condition × **Familiarity**: significant interaction
  - Baseline vs. Chorus-aligned → Familiarity (p = .0006)
- Post hoc:
  Chorus-aligned – Baseline Δβ = 0.219, p = .0018,
  Chorus-aligned – Random Δβ = 0.144, p = .045

- Vibrotactile condition × **Familiarity**: significant interaction
  - Baseline vs. Chorus-aligned → Familiarity (p = .008)
- Post hoc:
  Chorus-aligned – Baseline Δβ = 0.153, p = .023,
  Chorus-aligned – Random Δβ = 0.137, p = .035

Results: Linear Mixed Effects Model



- **Preference**::
  - A significant positive predictor of enjoyment (β = 0.27, p < .001)
  - A significant positive predictor of flow (β = 0.22, p < .001)

    - Vibration condition × Preference: A trend approaching significance (Baseline vs. Chorus-aligned → Preference, $p \approx .051$)

Discussion

- When vibrations align with musical structure, enjoyment and immersion
  - When listening to familiar songs, listeners can better predict the location of the chorus
  - When vibrations are delivered in sync with this predicted climax, stronger emotional responses occur

  → Familiarity enables structural prediction, and vibrations delivered at predicted moments enhance the musical experience

- Across all vibration patterns, enjoyment and immersion increase for more preferred songs
  - Regardless of the vibration pattern, liked music leads to a more positive musical experience

Limitation & Future Works

- Studies using a wider range of musical genres
- Research involving listeners with hearing impairments
  - Exploring how music-structure-based vibrotactile feedback can complement music listening experiences

Conclusion

- Vibrotactile feedback aligned with musical structure enhances VR music experiences, particularly for more familiar songs
- These findings suggest that future VR concert vibrotactile designs should incorporate musical structure
- This may be especially effective for fan-oriented VR concert experiences

Thank you!

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