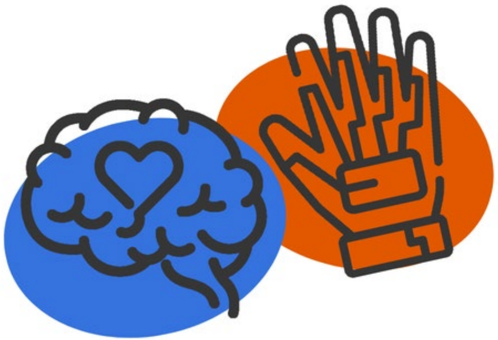
Mapping Vibrotactile Patterns to Emotions: An Experimental Study on Intuitive Tactile Communication



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Motivation

- Nonverbal cues such as facial expressions, gestures, and body language play an important role in emotional communication.
- People with visual impairments may have limited or no access to these visual affective cues.
- Vibrotactile wearables can provide discreet, body-worn feedback without requiring visual attention.
- The long-term goal is to support accessible affective communication through touch.

Research Context and Problem Statement

- Many haptic communication approaches rely on arbitrary or conventionalized tactile codes.
- These codes often require training, repetition, or prior agreement.
- In assistive contexts, this learning requirement can reduce immediate usability.
- Therefore, the key question is whether vibrotactile emotion patterns can be interpreted intuitively without prior training.

Study Focus and Added Value

This study investigates whether vibrotactile patterns can be intuitively associated with emotion labels without prior training.

It contributes:

- a structured evaluation framework
- empirical baseline evidence
- a winner-based approach for selecting robust tactile patterns

Theoretical Background

- Pattern design was guided by the Valence-Arousal Model (Russell's Circumplex Model of Affect)
  - Arousal was mainly operationalized through intensity, pulse density, rhythm, and dynamics
  - Valence was expected to be influenced more indirectly by qualitative signal characteristics
- Seven emotion labels were used: happiness, sadness, anger, fear, surprise, disgust, and contempt, based on Ekman's basic-emotions framework with contempt as an additional label.

Research Questions

- RQ1: Do individual vibrotactile patterns, without prior training, achieve assignment to the intended Ekman target emotion above chance level?
- RQ2: Which emotion category is selected as the dominant choice for each pattern, and how robust is this dominance?
- RQ3: Are trait empathy and experience with vibrotactile feedback associated with individual recognition rates? (exploratory)

Prototype

- Low-fidelity wrist-worn prototype
- Two vibration motors integrated into an elastic wristband
- Worn on the non-dominant wrist
- Controlled by an ESP32-based microcontroller
- Patterns triggered via laptop in a Wizard-of-Oz setup

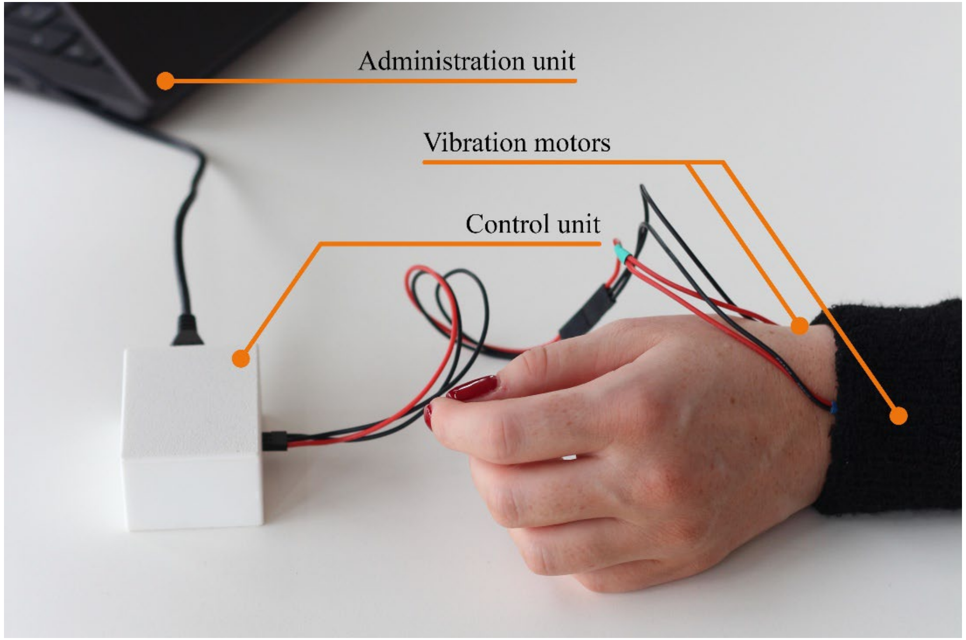

Figure 1. Wristband prototype with control unit, administration unit, and two vibration motors.

Stimulus Set / Vibrotactile Patterns

- 14 vibrotactile patterns
- 2 variants for each target emotion
- Parameters:
  - Intensity (low, medium, high)
  - Pulse duration
  - Pauses (short, medium, long)
  - Linear and exponential ramp profiles
- Pattern design was exploratory and guided by valence–arousal assumptions

Example Patterns

- **Sadness B**
  - Linear ramp-down from medium intensity to zero
  - Intended as low-arousal, fading signal
- **Surprise A**
  - Three short pulses with very short pauses
  - Ends in a high-intensity pulse
  - Intended as abrupt, high-arousal signal
- **Disgust A**
  - Three ramp-and-pulse segments
  - Medium–high–medium intensity structure
  - Intended as irregular rise–peak–decline profile

Study Design

- Controlled within-subjects experiment
- N = 33 sighted adult participants
- Each participant evaluated all 14 vibrotactile patterns
- Patterns were presented in randomized order
- Two neutral practice trials were excluded from analysis
- Each session lasted approximately 20–30 minutes

Trial Procedure and Measures

- After each stimulus, participants rated:
  1. **Emotion label** (seven-alternative forced-choice task)
  2. **Choice confidence** (5-point Likert-type scale)
  3. **Valence** (very unpleasant to very pleasant)
  4. **Arousal** (very calm/sleepy to very arousing/activating)
- Additional Measures:
  - Vibrotactile experience
  - Empathy
  - Demographics

Analysis Approach

- Recognition rate
  - Proportion of correct assignments to the intended target emotion
- Winner rate
  - Proportion of the most frequently selected emotion label per pattern
- Dominance Δ
  - Difference between the number of selections for the winner emotion and the runner-up emotion
- Statistical testing
  - One-sided exact binomial tests against chance level $p_0 = 1/7$
  - Holm correction across 14 patterns

Key Results

- **Target-consistent recognition:** Three patterns exceeded chance-level target assignment after Holm correction
  - Sadness A (ID 3): 51.52%
  - Sadness B (ID 4): 57.58%
  - Surprise A (ID 9): 36.36%
- **Emergent winner emotions:** Six patterns showed significant winner rates
  - IDs 2, 3, 4, 5, 8, 9
  - Sadness patterns showed strong dominance
  - ID 8 and ID 9 showed moderate dominance

Interpretation

- A purely intuitive one-to-one mapping to seven emotion categories appears difficult
- However, several patterns produced stable dominant emotion associations
- Sadness was the most robust target category in this dataset
- Arousal appeared easier to convey than valence
- Stable winner emotions may still be useful for building an initial tactile vocabulary, even when they differ from the intended target emotion

Limitations

- Exploratory baseline study with sighted participants
- Low-fidelity prototype in a controlled no-training setup
- Limited transfer to real-world assistive use
- Forced-choice format may amplify overlap between similar emotion categories
- No external actuator calibration

Conclusion and Future Work

Conclusion

- Some vibrotactile patterns can support stable, training-free emotion associations
- Winner rate and dominance Δ provide a practical screening approach for selecting robust patterns
- The current parameterization conveys arousal more clearly than valence

Future Work

- Retain robust patterns and redesign ambiguous ones.
- Reduce the pattern space and test simplified stimulus families.
- Validate the approach with people with visual impairments.
- Test minimal familiarization and context-relevant scenarios.

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