

# The Impact of Moving Sounds on Emotional Ratings and Postural Sway: Validating Real-Life Sounds for Virtual Reality Balance Retraining Algorithms

## Background

Virtual reality balance-retraining systems manipulate visual, somatosensory, and auditory cues to challenge individuals with vestibular dysfunction [1][2].

Validated real-life auditory stimuli and their associations with emotional appraisal, alertness, and postural control remain under-studied.

This study examined emotional responses and postural sway in **young adults with normal hearing and balance** when exposed to real-life sound stimuli.

## Study Design

A 2 (Motion: Looming vs Receding) by 6 (Sound Type) within-subject two-way repeated-measures ANOVA was used to calculate the mean differences for the motion effect, sound type effect and interaction effect of each dependent variable.

## Dependent Variables:

Mean COP sway (mm/s)  
Perceived Direction  
Perceived Valence  
Perceived Arousal  
Perceived Potency  
Perceived Intensity  
Perceived Salience  
Perceived Threat

## Methods

### Step 1

Eighteen real-life sound stimuli were grouped into six acoustical categories (Table 1).

### Step 2

Each stimulus was processed to simulate either looming or receding acoustical characteristics [3].

### Step 3

Sounds were presented via headphones to **16 participants** during quiet standing on a force plate.

### Step 4

Participants also filled out a visual analogue scale (VAS) questionnaire for perceived direction of each sound stimuli and perceived levels of alertness (Valence, Arousal, Potency, Intensity, Salience and Threat [4]).

**Table 1:** real-life sounds chosen form BBC Sound Effects grouped into their acoustical categories [5].

| Acoustical Categories | Tonal               | Low Frequency Tone                 |
|-----------------------|---------------------|------------------------------------|
|                       |                     | Mid Frequency Tone                 |
|                       |                     | High Frequency Tone                |
|                       | Amplitude-Modulated | Bee                                |
|                       |                     | Motorbike                          |
|                       |                     | Trimmer (Facial Electrical Shaver) |
|                       | Frequency-Modulated | Bicycle Bell                       |
|                       |                     | Truck Horn                         |
|                       |                     | Siren                              |
|                       | Impulse             | Scissors                           |
| Footsteps             |                     |                                    |
| Fireworks             |                     |                                    |
| Environmental Noise   | Waterfall           |                                    |
|                       | Forest              |                                    |
|                       | Rain                |                                    |
| Speech-related        | Market              |                                    |
|                       | Female Whisper      |                                    |
|                       | Crowd               |                                    |

**(Table 2):** Definitions of acoustical envelope characteristics for each acoustical category.

| Acoustical Category | Definitions                                                                                                                                                                  |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Tonal               | Sounds defined by stable, continuous frequencies with minimal modulation; Spectrally simple, typically consisting of a single harmonic component [6].                        |
| Amplitude-Modulated | Sounds characterized by periodic or irregular fluctuations in amplitude while frequency remains relatively stable. Characterized by rhythmic fluctuations in intensity [7].  |
| Frequency-Modulated | Sounds where frequency varies over time, producing sweeps, glides, or complex contours. Spectrally dynamic and often associated with motion or alerting functions [8].       |
| Impulse             | Short-duration, high intensity acoustic events with rapid onset [9].                                                                                                         |
| Environmental Noise | Broadband, often stochastic natural sound sources with complex, non-periodic structure. Often continuous and shaped by ecological processes such as water flow or wind [10]. |
| Speech-Related      | Human- generated vocal or crowd sounds with rich temporal-spectral variability [11][12].                                                                                     |

## Results

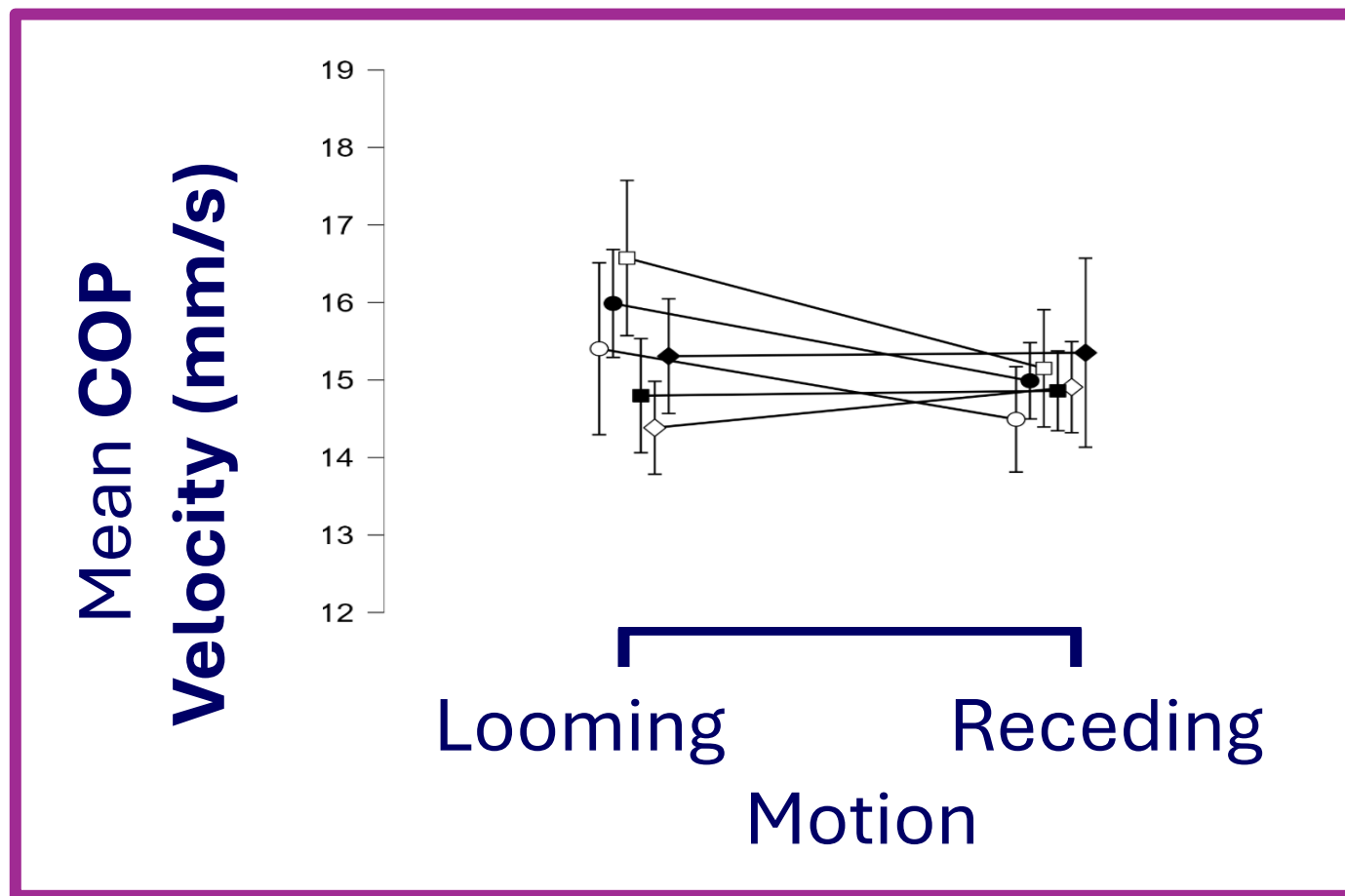
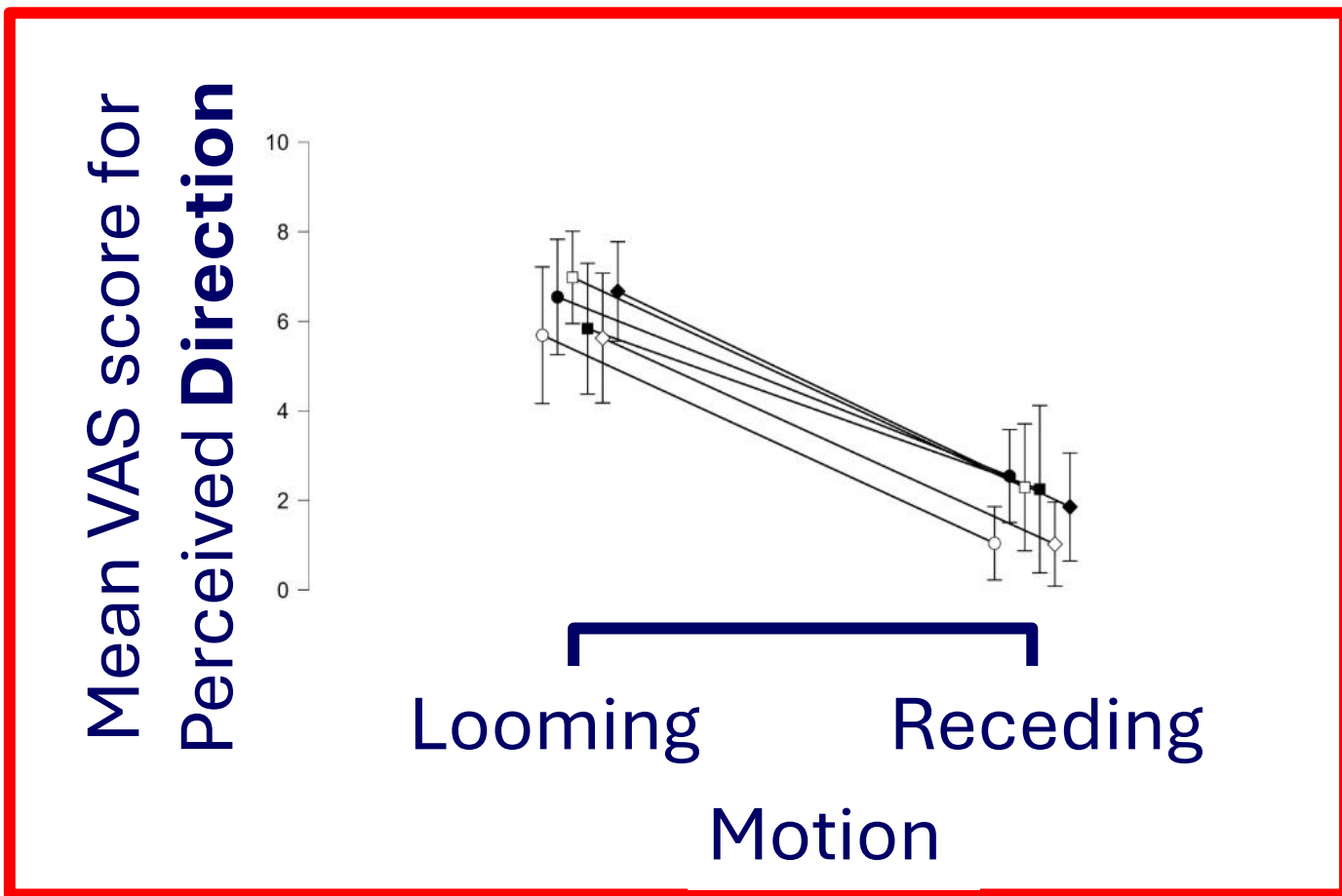
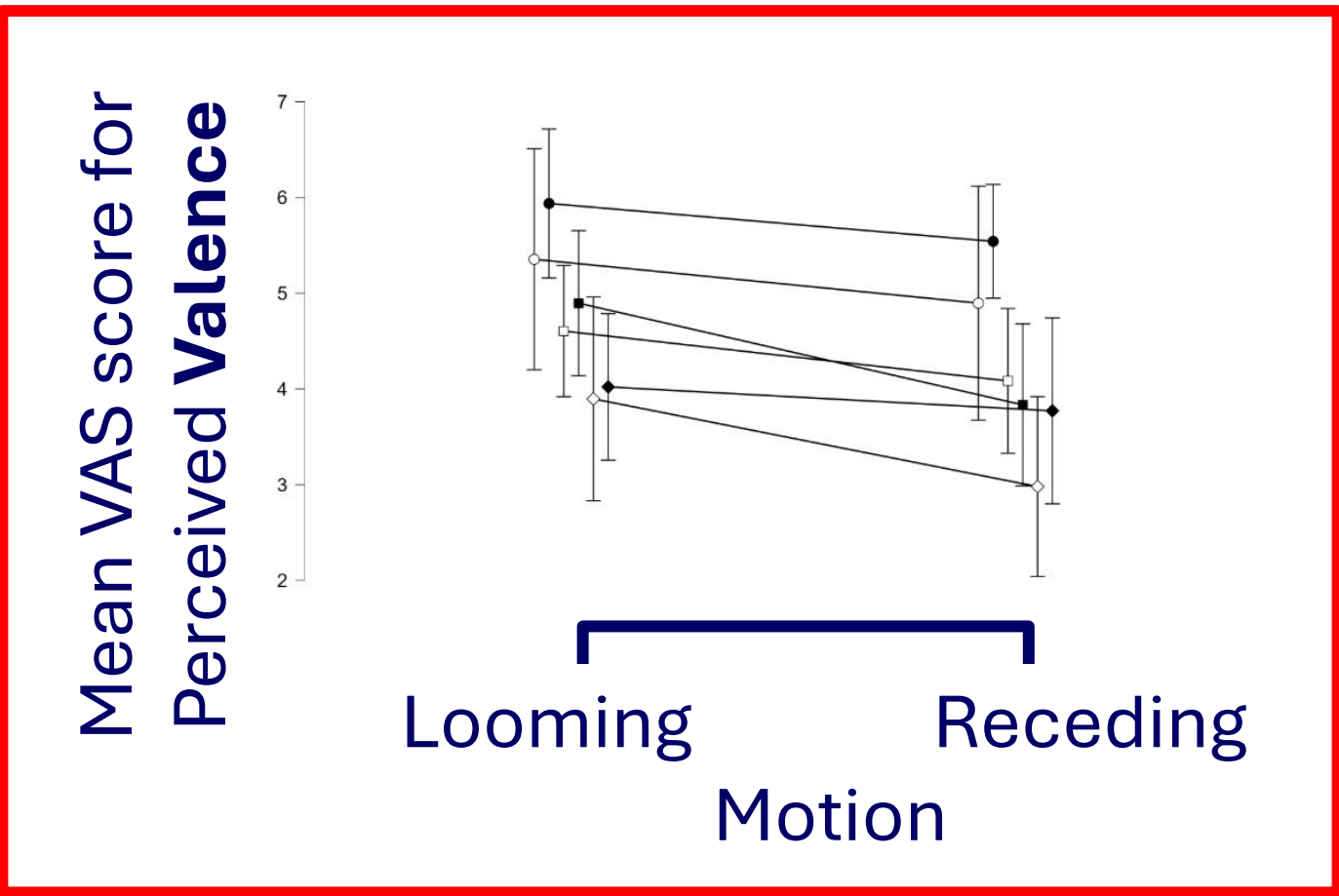
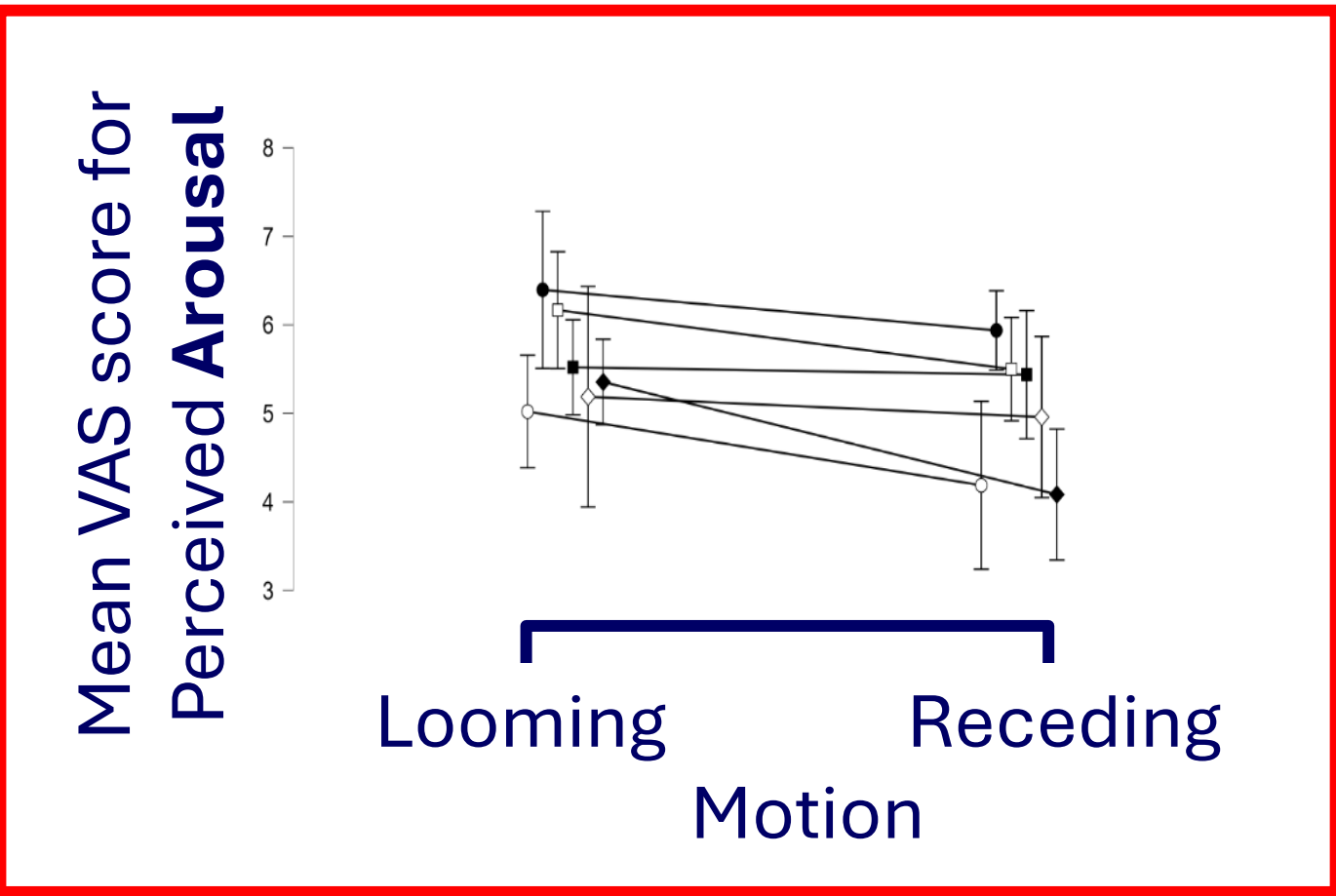
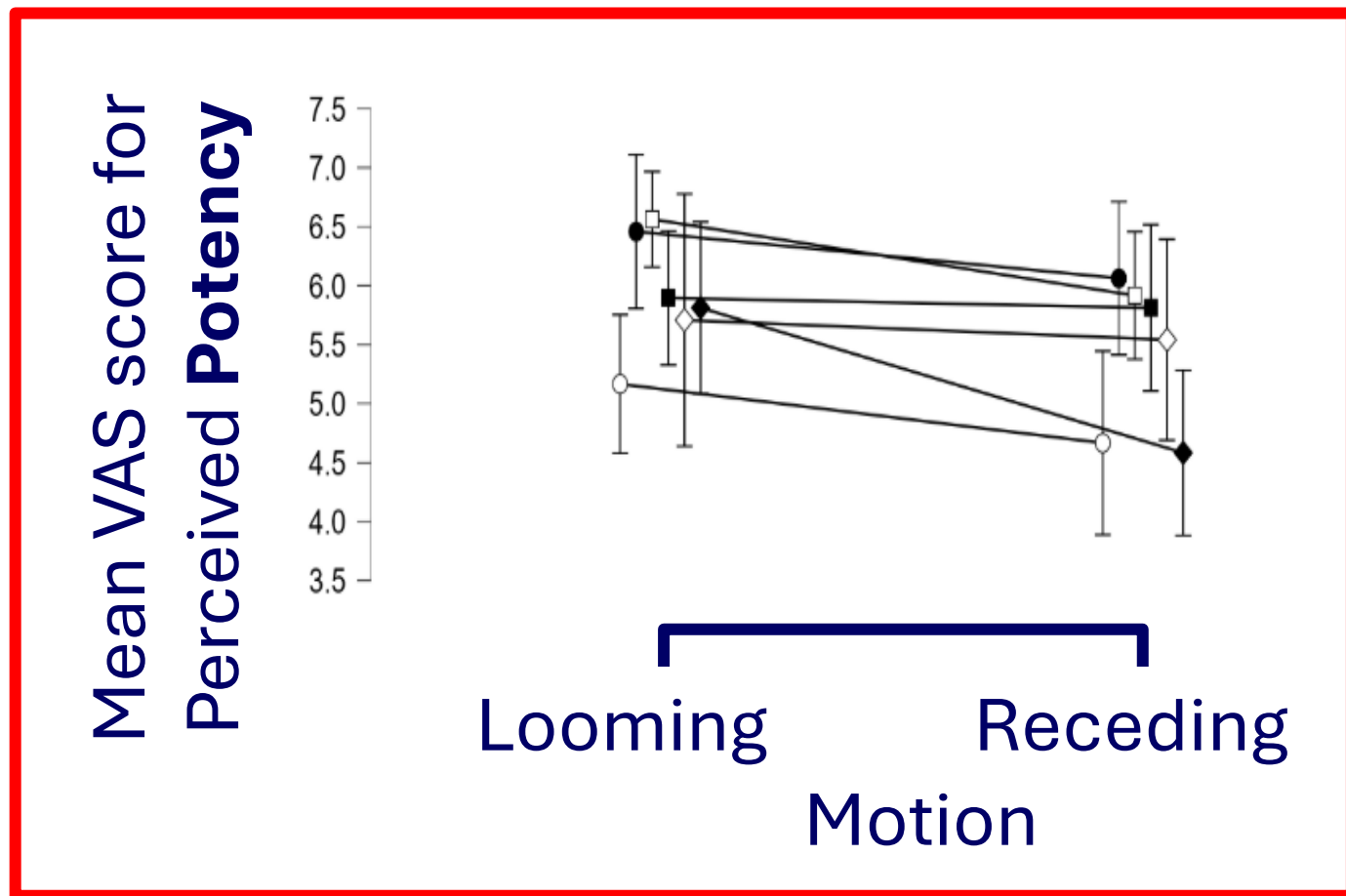
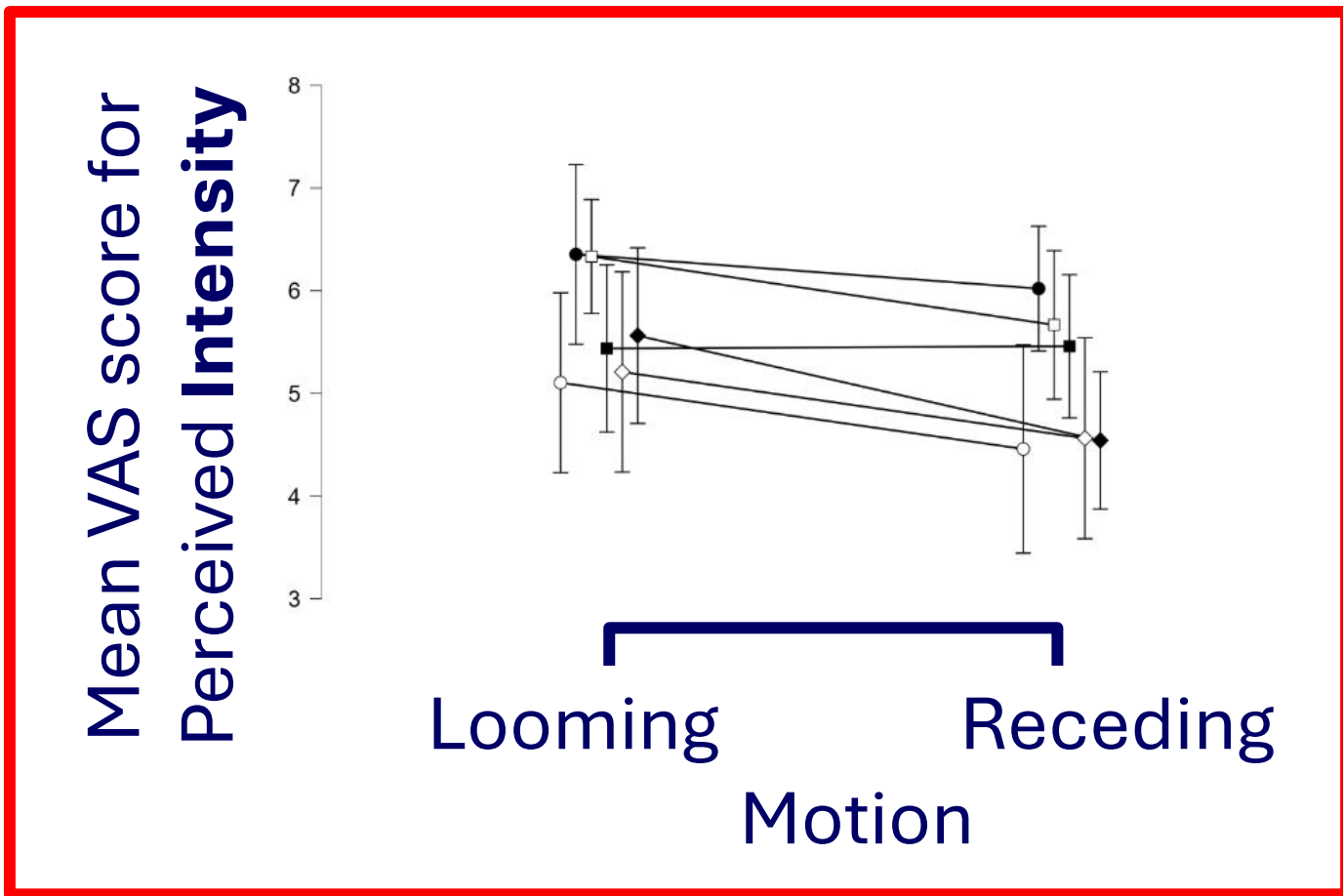
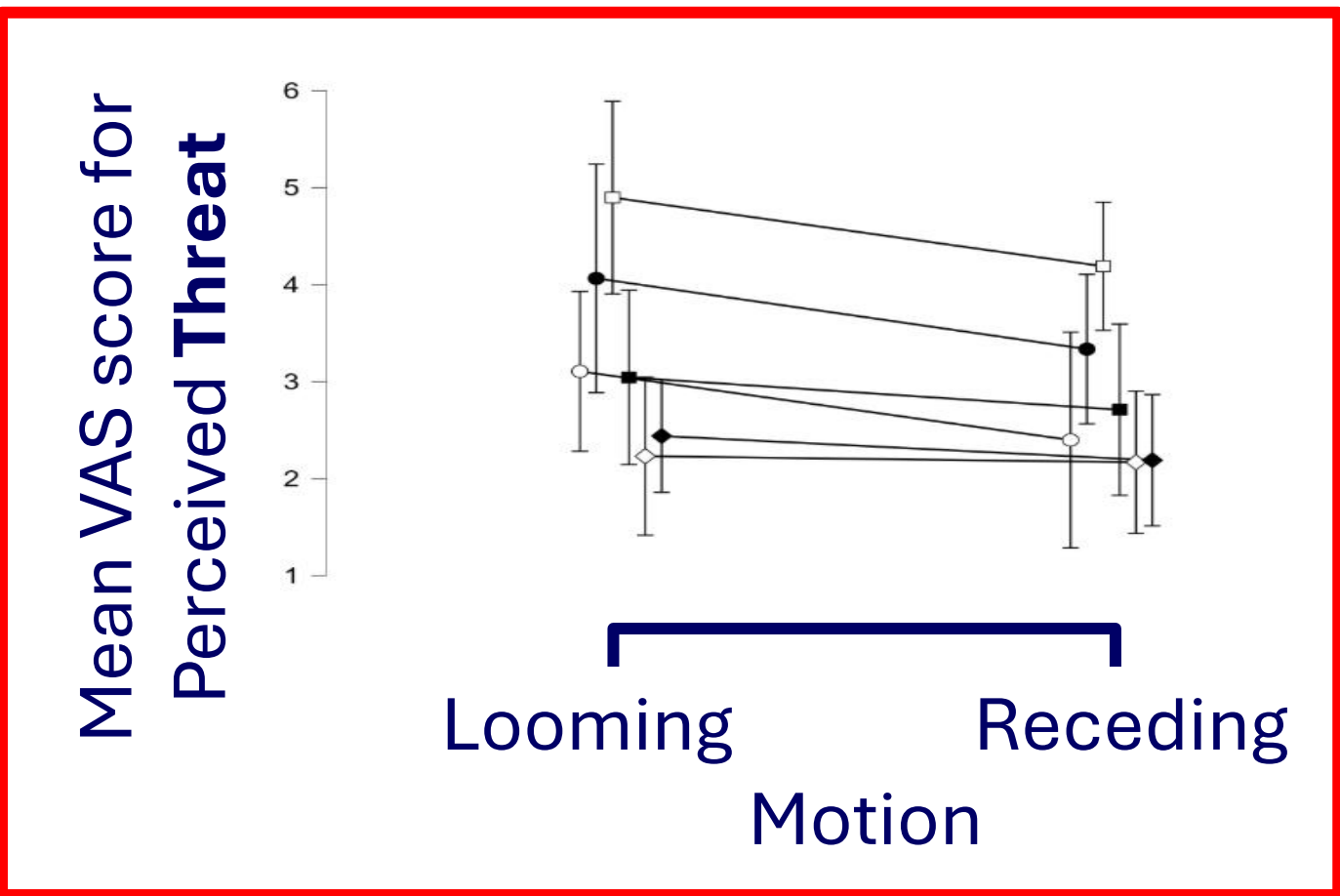
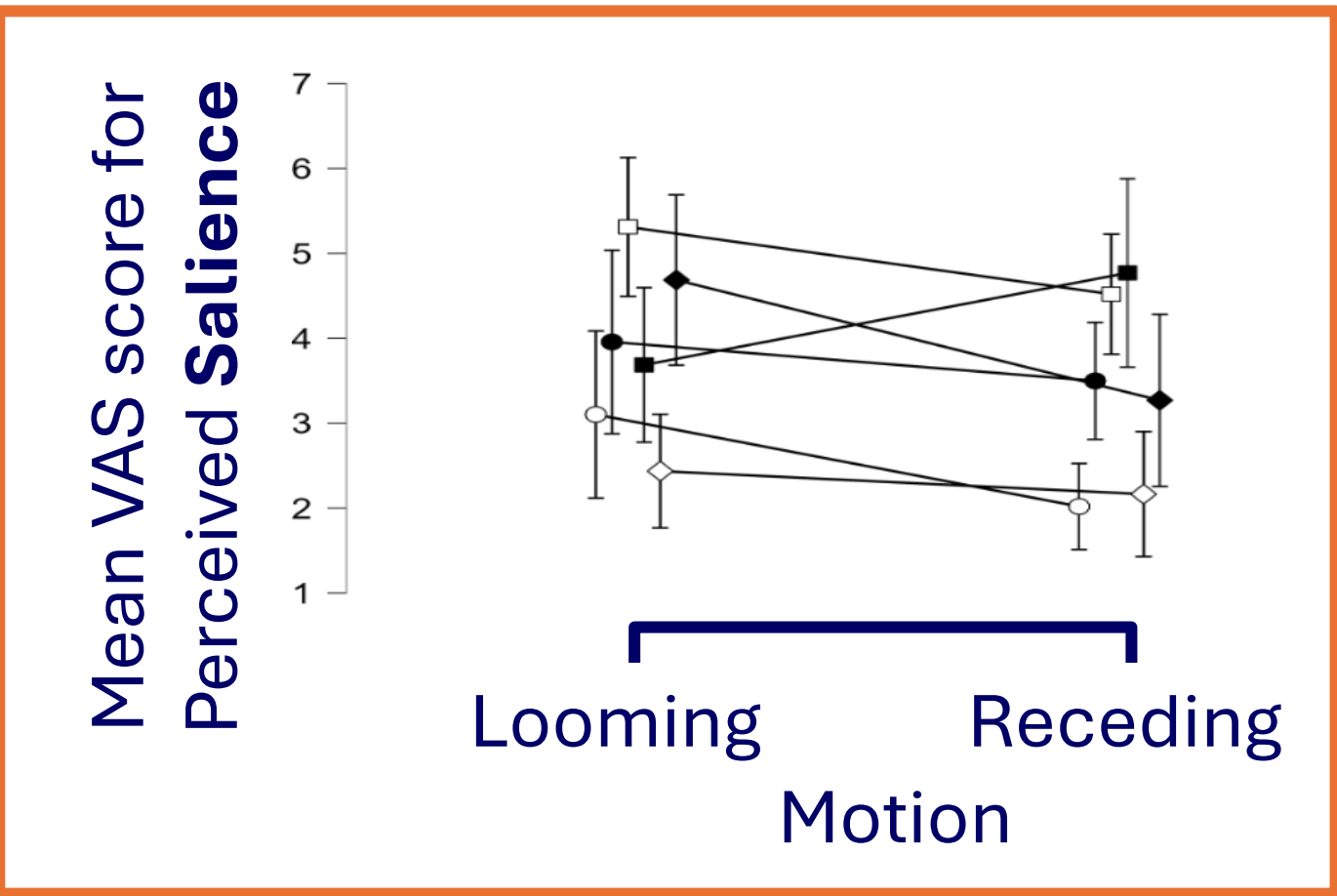
Postural sway did not differ significantly between motion conditions or sound categories.

However, both motion direction and sound type significantly influenced perceived direction of motion and emotional ratings (valence, arousal, potency, intensity, and threat), with no interaction effects.

For salience ratings, sound type and the interaction between sound type and motion were significant, whereas motion alone was not.

### Sound Type:

- Tonal
- Amplitude-Modulated
- Frequency-Modulated
- Impulse
- ◇ Environmental Noise
- ◆ Speech-Related



## Conclusions

Although auditory motion and sound category did not alter postural sway, they produced distinct subjective emotional and perceptual responses.

These findings suggest that real-life ecological auditory stimuli elicit meaningful differences in perceived motion and emotional appraisal, supporting their potential relevance for virtual-reality balance-retraining algorithms.

Longitudinal studies are recommended to determine whether these perceptual effects translate into measurable changes in alertness and postural control.

## References

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