Vibrotactile feedback for postural adjustment during fine sensorimotor tasks: Two studies investigating optimal algorithms and stimulus parameters

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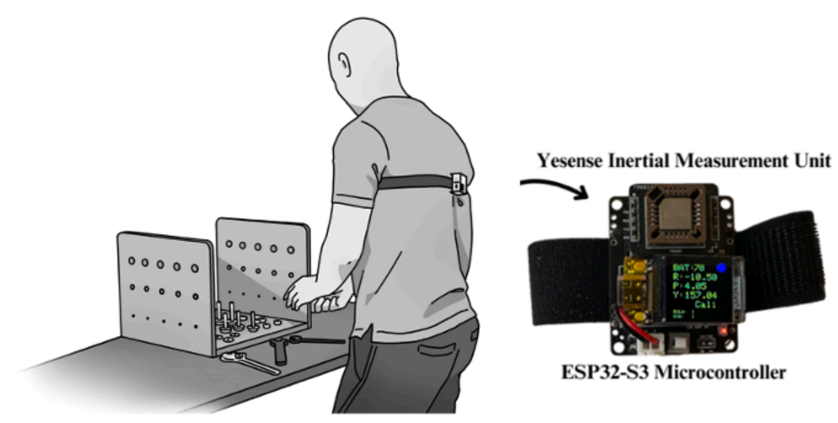
Background

- Healthcare workers have high rates of musculoskeletal injuries due to poor posture[1]
- A wearable biofeedback device could reduce injury, if used effectively and safely[2]
- Sensors can detect when posture is maladaptive, while vibrotactile stimulation can inform the user and prompt corrective action
- Study 1 tested two algorithms for delivering feedback, while Study 2 is investigating optimal stimulation parameters for use during motor tasks

Experiment 1 - Methods

30 Participants (14M, 16F, age 22.9 ± 1.7 years)



Score	Level of MSD Risk
1-2	negligible risk, no action required
3-4	low risk, change may be needed
5-6	medium risk, further investigation, change soon
6+	very high risk, implement change now

Three feedback conditions:

1. No feedback
2. Rapid Upper Limb Assessment (RULA) category feedback; automatic stimulation at Category 5+
3. Exposure Variation Analysis, which weighs scores by RULA category and duration of exposure

$$\mathbf{TWE} = \sum_{m=1}^{M} \mathrm{R_m} \sum_{i=1}^{7} T_{m,i} * 2^{E_i}$$

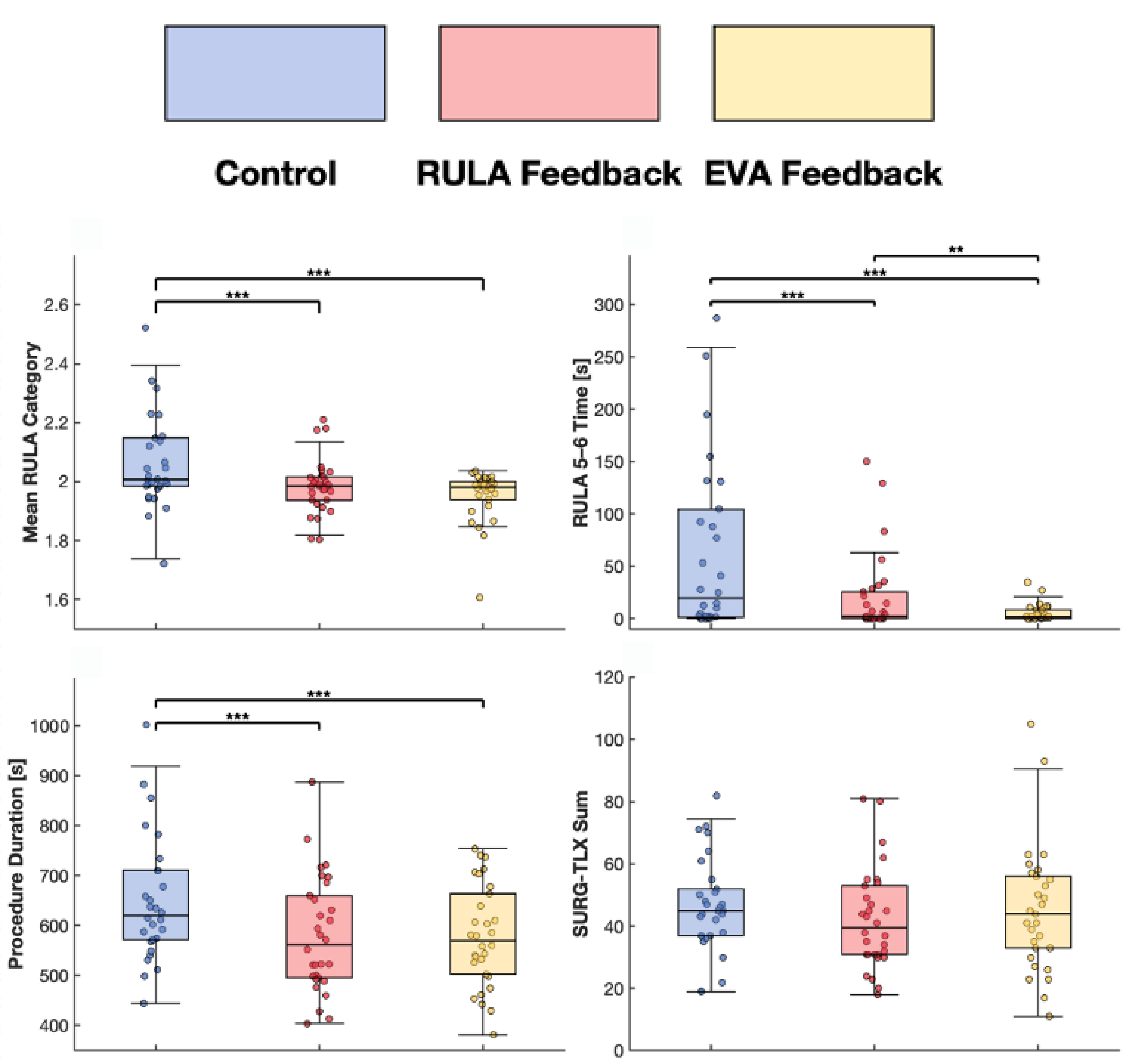
where:

- M = Number of RULA categories (3-4, 5-6, 6+),
- R_m = RULA multiplier (1, 1.5, 2 for increasing RULA categories),
- i = index for time period lengths (i = 1,2...,7),
- $T_{m,i}$ = time spent in RULA category m at the time period i,
- E_i = exponent for each time period (E_i = 0, 0.5, 1.5, 2, 2.5, 3).

SURG-TXL questionnaire to measure cognitive workload[3]

Experiment 1 - Results

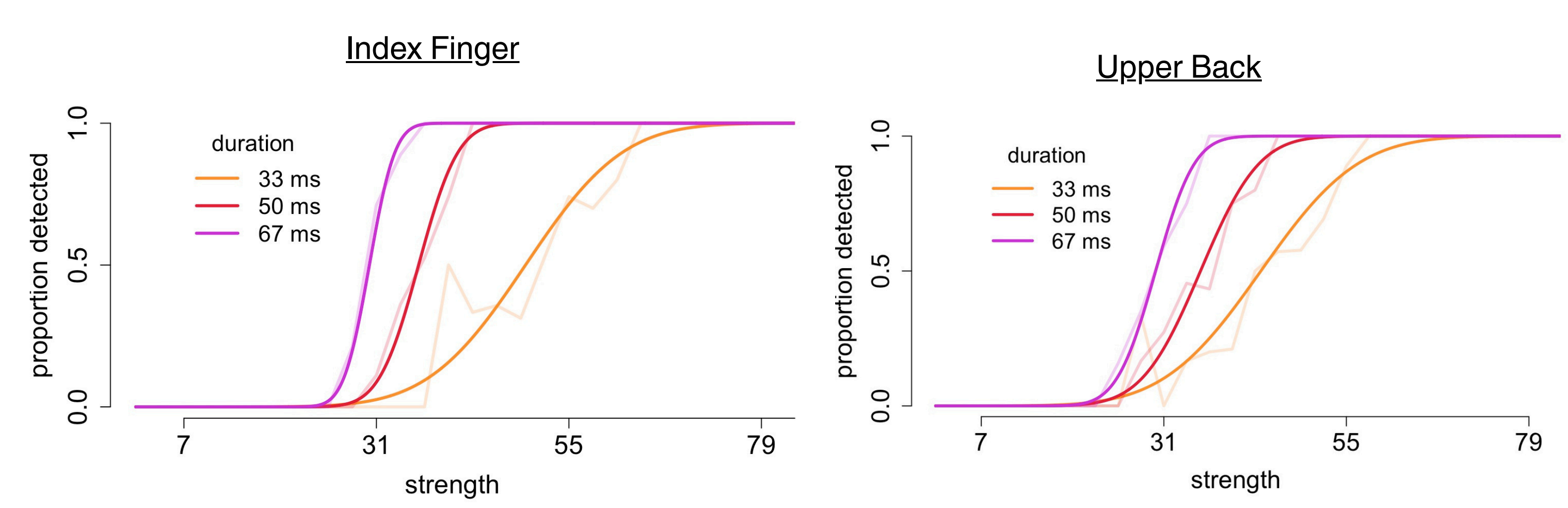
EVA feedback significantly reduces time in maladaptive posture vs. RULA feedback and no feedback. Neither feedback increases task duration or cognitive workload



Condition	RULA 1-2 *[s]*	RULA 3-4 *[s]*	RULA 5 *[s]*	RULA 6 *[s]*
Control	20.08 ±6.13	496.75 ±34.13	74.22 ±21.02	0.00 ±0.00
RULA-based Feedback	22.39 ±4.71	454.42 ±25.79	20.35 ±6.91	0.03 ±0.03
EVA-based Feedback	23.29 ±5.80	470.24 ±21.53	5.47 ±1.50	0.06 ±0.06

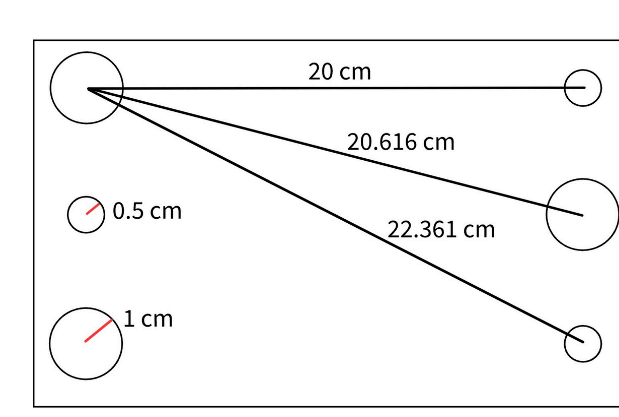
Experiment 2

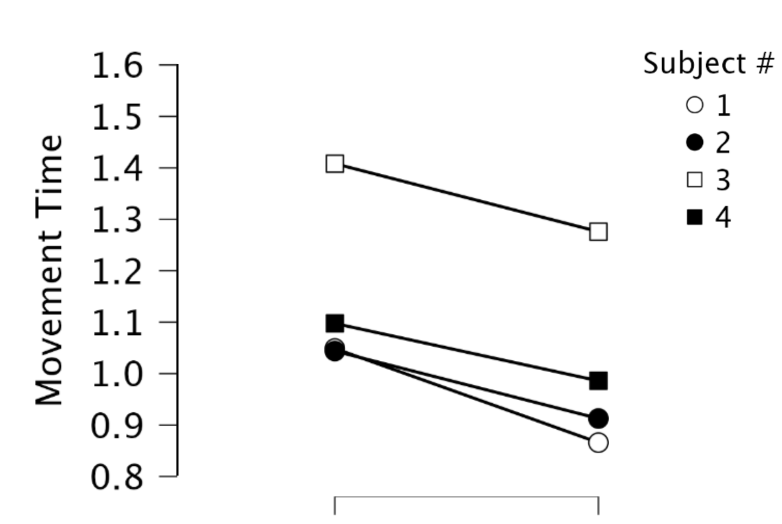
- Still in pilot stage – goal is a dual-task paradigm combining vibrotactile stimulation and an aiming task – does dual-task slow movement and / or reduce detction rates?
- Vibrotactile Detection Task (N = 4):
  - 3 stimulus durations (33, 50, 67ms) delivered to the index finger or upper back
  - Varied intensity and fit psychometric curves to detection rates

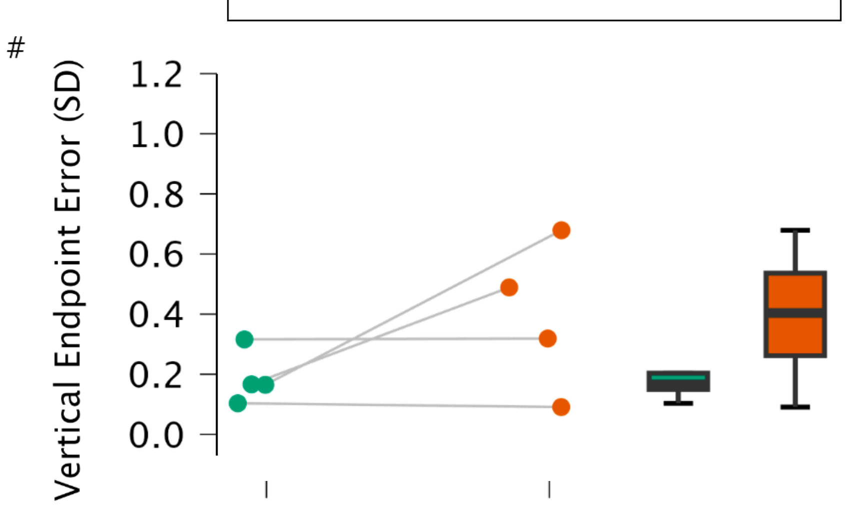


Duration	PSE (Index	PSE (Upper Back)
33 ms	49.59 ± 9.55	43.76 ± 10.05
50 ms	36.26 ± 3.88	35.83 ± 6.07
67 ms	30.13 ± 2.52	29.92 ± 4.02

- Aiming Task (N = 4):
  - 2 target sizes, 6 locations -->
  - Measured movement time and endpoint error
- As expected, small targets result in less variable but slower movements







Conclusions and Future Directions

- EVA-based feedback with an integrated sensor-motor can significantly reduce maladaptive posture during manual tasks.
- Duration and strength of vibrotactile stimulus affects detection rate; target size affects movement time and endpoint variance on manual aiming task.
- Does combining the vibrotactile detection task with the aiming task impair performance on either task? Higher PSE? Slower movements, or less precise movement endpoints?

References:
1. Xu AL, et al. (2023). *JBJS Review.* 2. Kim W et al. (2022). *IEEE Trans Haptics* 3. Wilson MR et al. (2011). *World J Surg*