Smart Textiles that Teach: Fabric-Based Haptic Device Improves the Rate of Motor Learning

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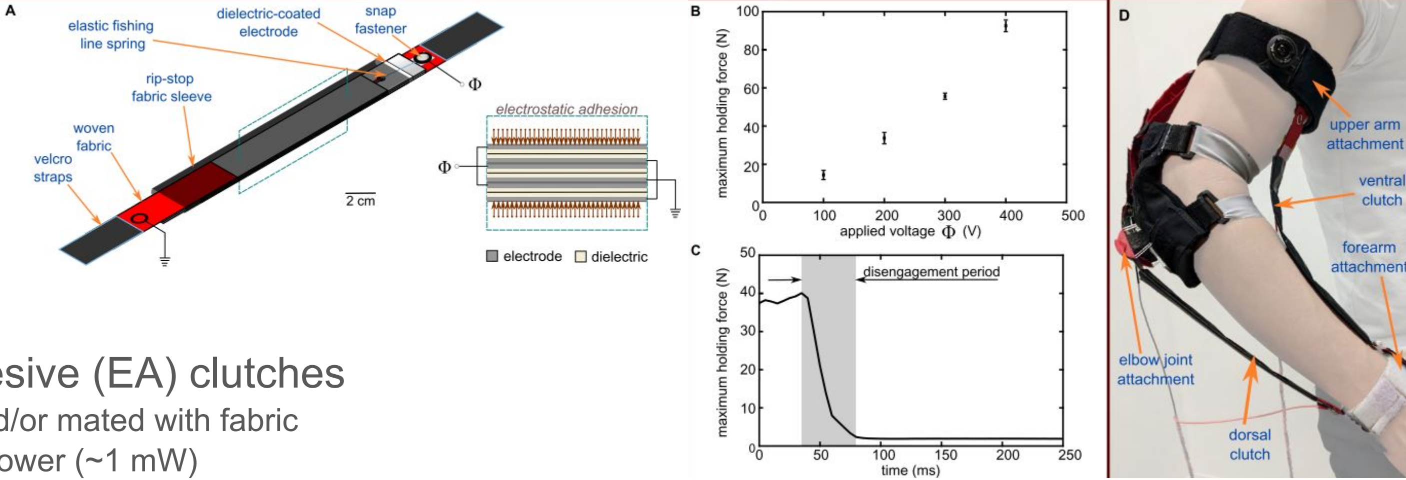
Introduction

- Motor learning is an error-driven process
  - Rate of learning depends on modality of feedback during training
- People rectify their errors based on a combination of visual, auditory, and haptic feedback.
  - Haptic interfaces allowsfeedback to be delivered to specific parts of the body which require corrective action
  - Existing haptic interfaces are often bulky and rigid
  - wearable interfaces becoming more standard while allowing a greater degree of mobility for the user

Haptic-based Training Methods

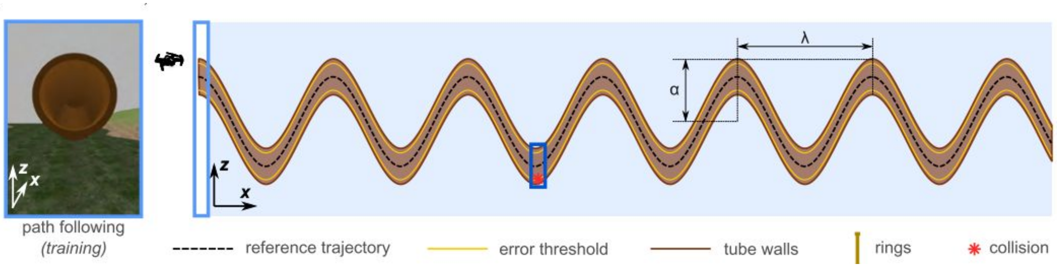
- Haptic guidance
  - System guides users to minimize errors
  - Increase to user performance during training
  - Performance levels precipitate when guidance is no longer provided
  - Best for novice users
- Error amplification
  - Amplifies user errors to increase task difficulty
  - Long periods of skill retention
  - Long training periods
  - Best for expert users

Haptic Interface

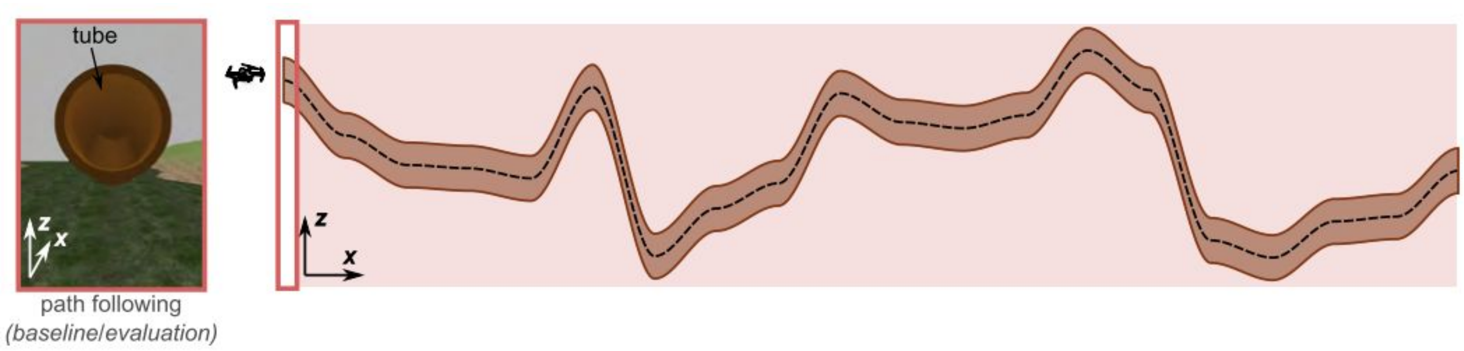


- Electrostatic adhesive (EA) clutches
  - Easily woven and/or mated with fabric
  - Operate at low power (~1 mW)
  - Rely on **movement braking** and **passive springs**
  - Can be designed in a task-agnostic manner
- EA haptic sleeve
  - Comprised of two clutches
    - Tested up to 400 V (applied), resulting in ~90 N holding force
    - Throttled to 200 V (applied), resulting in ~40 N holding force
    - Low-stiffness springs allow longitudinal deformation from rest length
  - Clutches oriented s.t. they respectively block the flexion and extension of the forearm about the upper arm
  - Sensorized with two IMU’s (mounted on forearm and upper arm attachments)

Tasks (1/3)

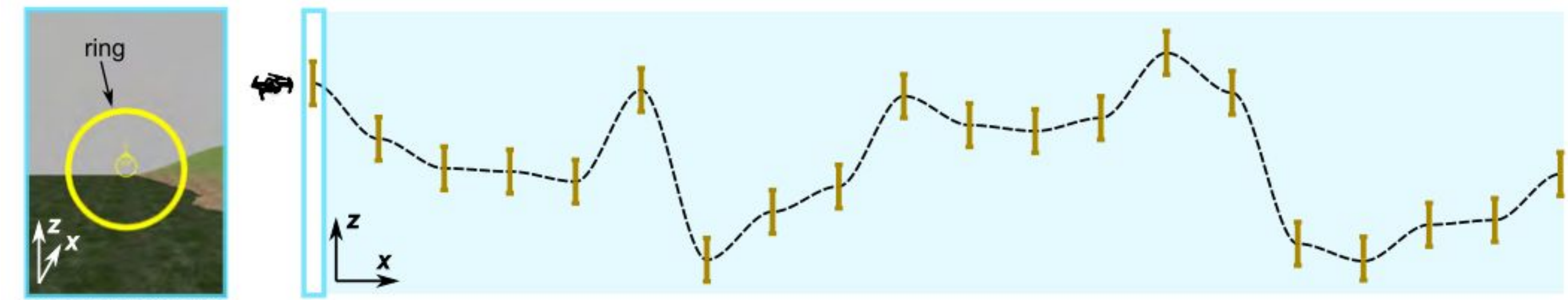


- Path following task
  - Control altitude of drone flying through a tube of constant radius and oscillating elevation
  - Avoid colliding the drone with any of the tube's walls
  - Performance measured by altitude error w.r.t. tube centerline
  - Three phases : baseline, training, evaluation



Tasks (2/3)

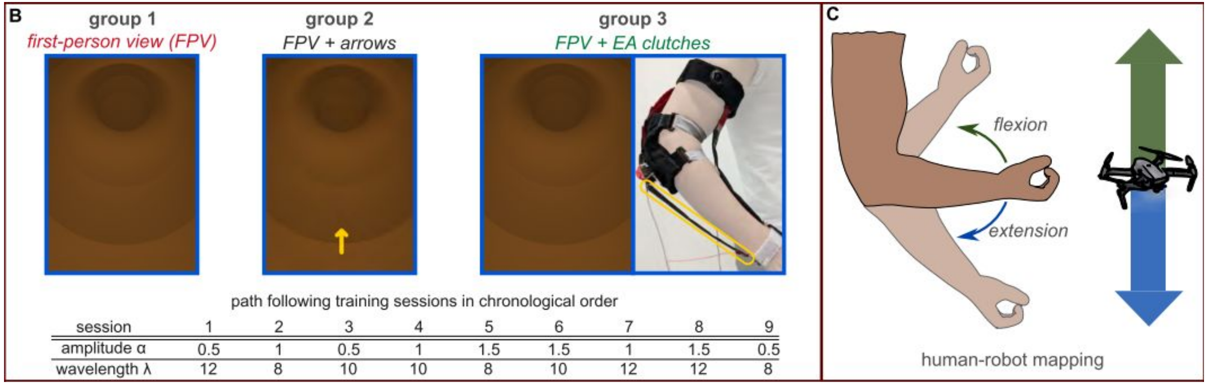
- Waypoint navigation task
  - Control the altitude of drone through a series of rings positioned at different heights
  - Performance measured by altitude error between drone and center of each ring
  - Two phases : baseline, evaluation



waypoint navigation
(baseline/evaluation)

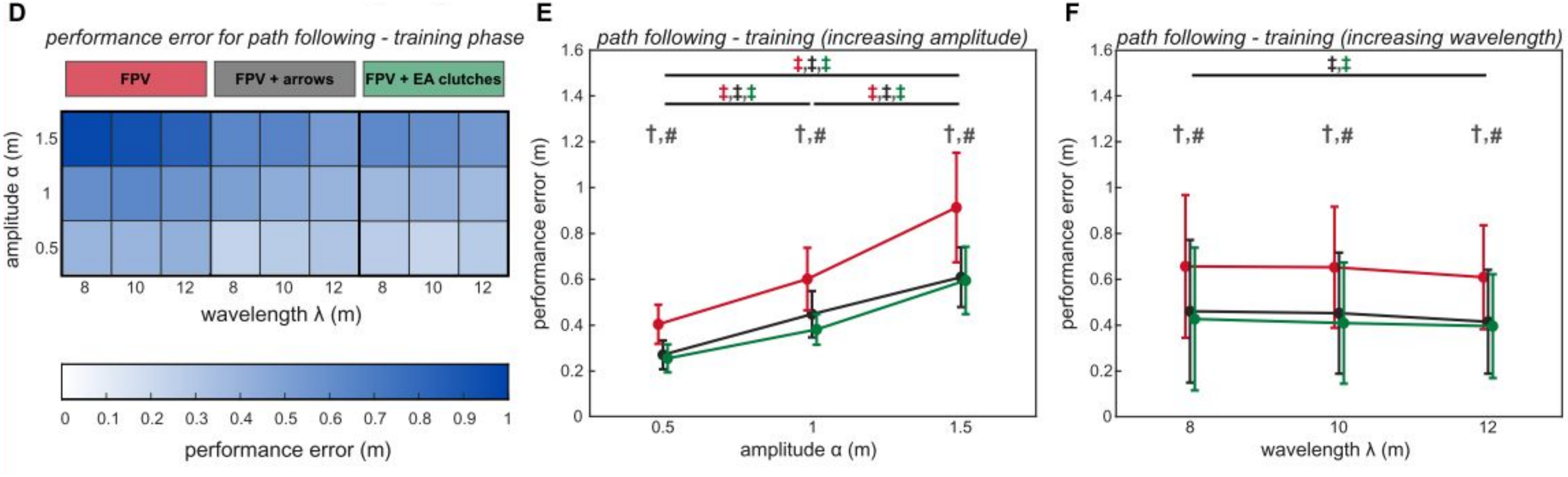
Tasks (3/3)

- 3 trial groups
  - Same interface
  - Different feedback
  - Groups 2, 3 received additional feedback when crossing error thresholds



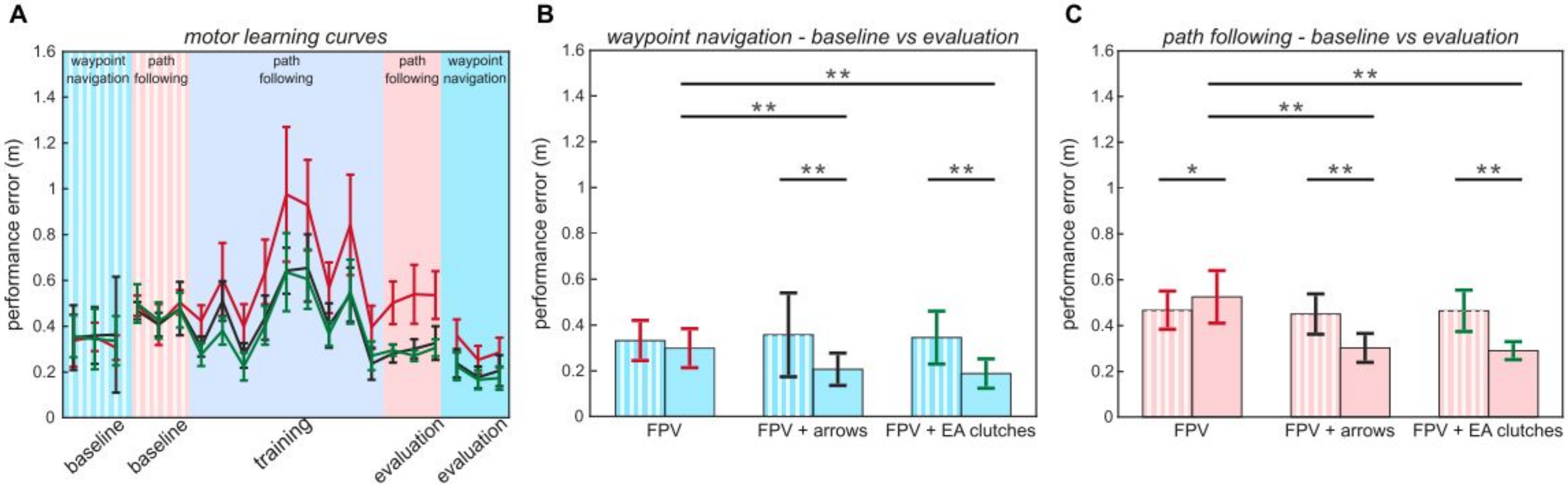
Acquisition & Retention of Motor Skills

- Path following task
  - Groups 2 (FPV + arrows) and 3 (FPV + EA clutches)
    - → fewer errors during evaluation
  - Group 1 committed 12.65% more errors during evaluation

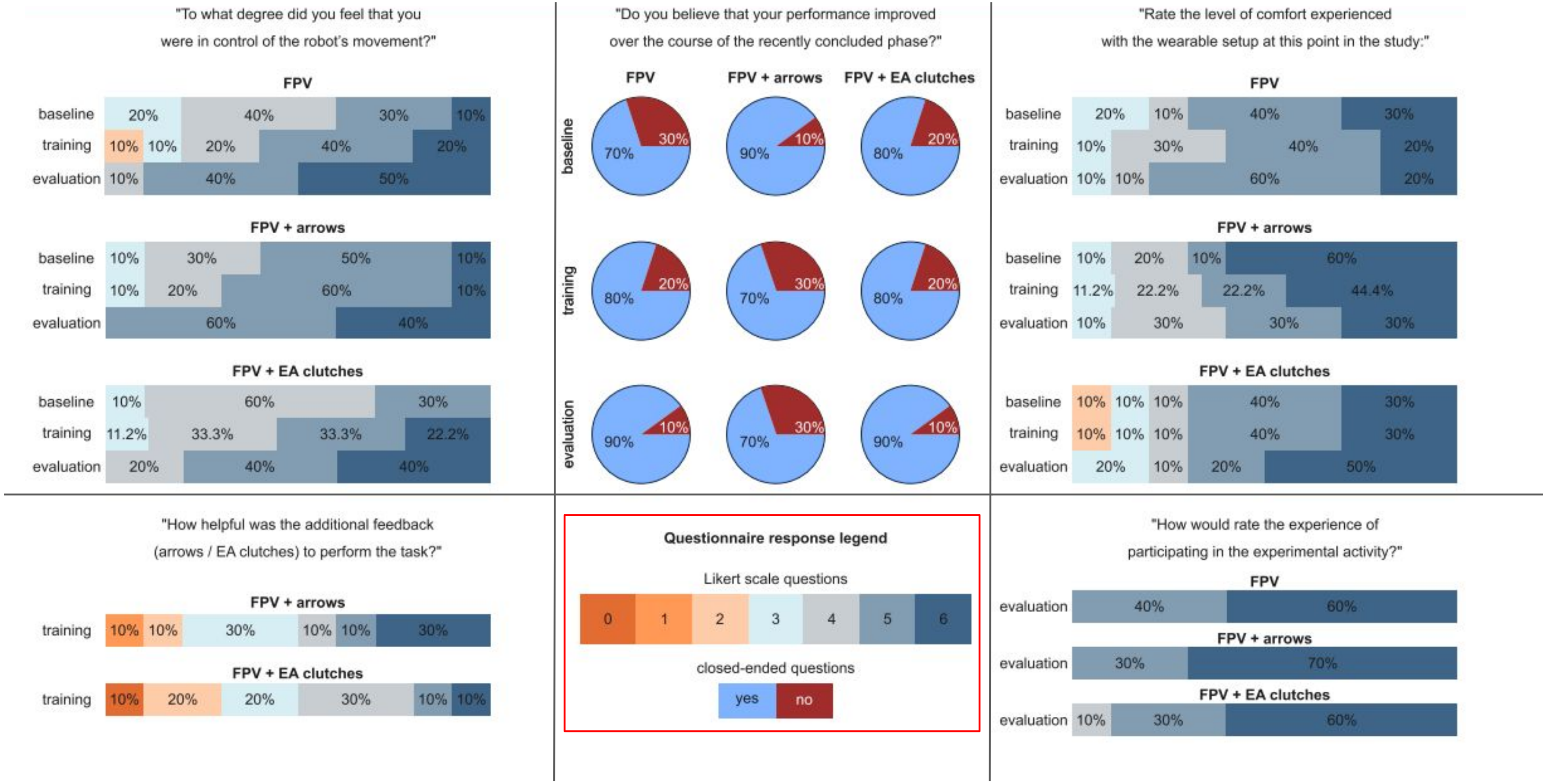


Transfer of motor skills

- Groups 2, 3 saw ~42-46% decrease in error
- Group 1 saw ~9.97% decrease in error



Subjective assessment



Conclusion

- Subjects without augmented feedback did not acquire and retain sufficient motor skills
- Subjects who received some form of augmented feedback displayed improved performance
  - Improved performance in evaluation phase suggests improved retention
  - “This shows that the subjects did not become overtly dependent on the additional feedback”
- “...there are no observable statistically significant differences between the two forms of additional feedback…”
  - Authors argue that additional (non-visual) feedback channels could be beneficial in reducing the risk of sensory overload
  - Authors make another case for haptic feedback as an alternative to visual feedback when a robot’s visual system is occluded (including signal drop-out scenarios), or for operators who themselves are visually impaired