Evaluating Wrist-Based Haptic Feedback for Non-Visual Target Finding and Path Tracing on a 2D Surface

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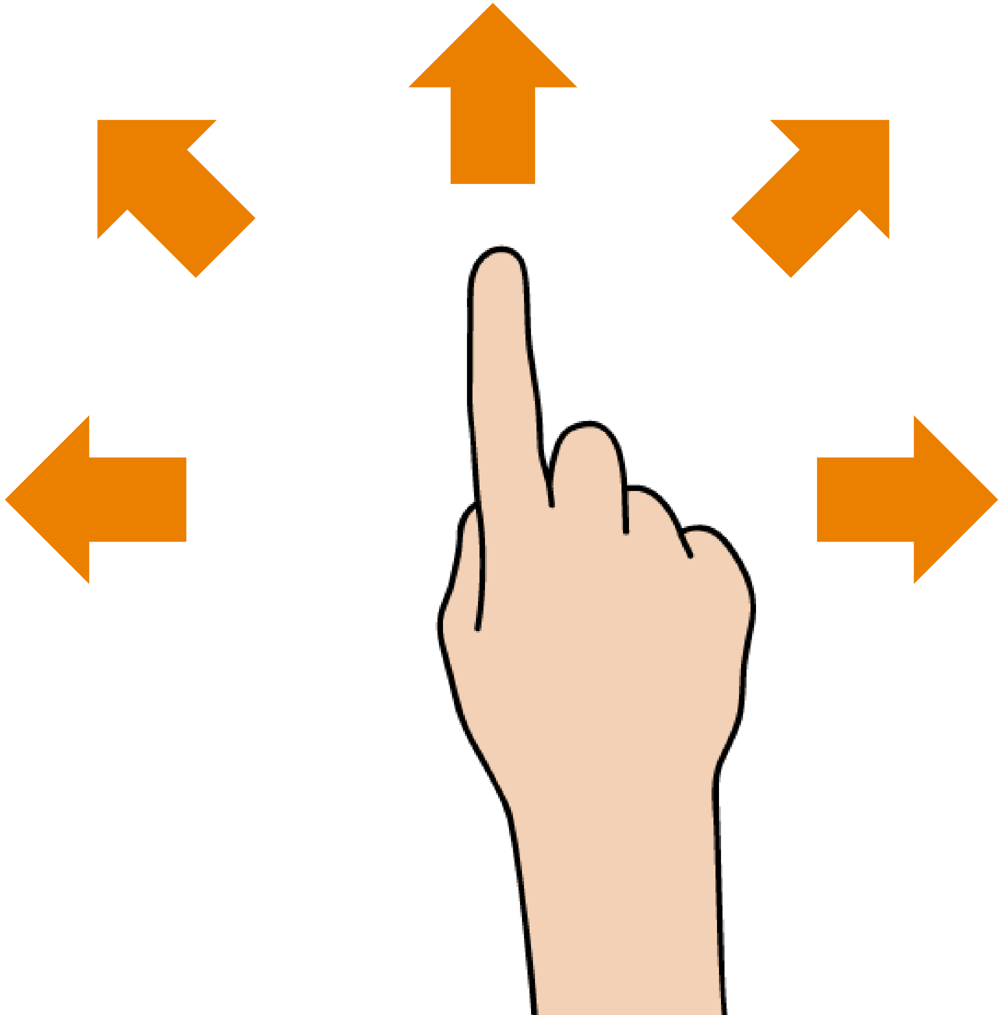
What is hand guidance?



Ex. 1) tracing a text with finger-mounted camera

Ex. 2) Learning touchscreen gestures

Ex. 3) Learning handwriting

Approach

Audio or **haptic feedback** have been used to provide visually impaired people with the hand guidance.

Smartwatches present new opportunities for directional hand guidance that is proximal to the hand.

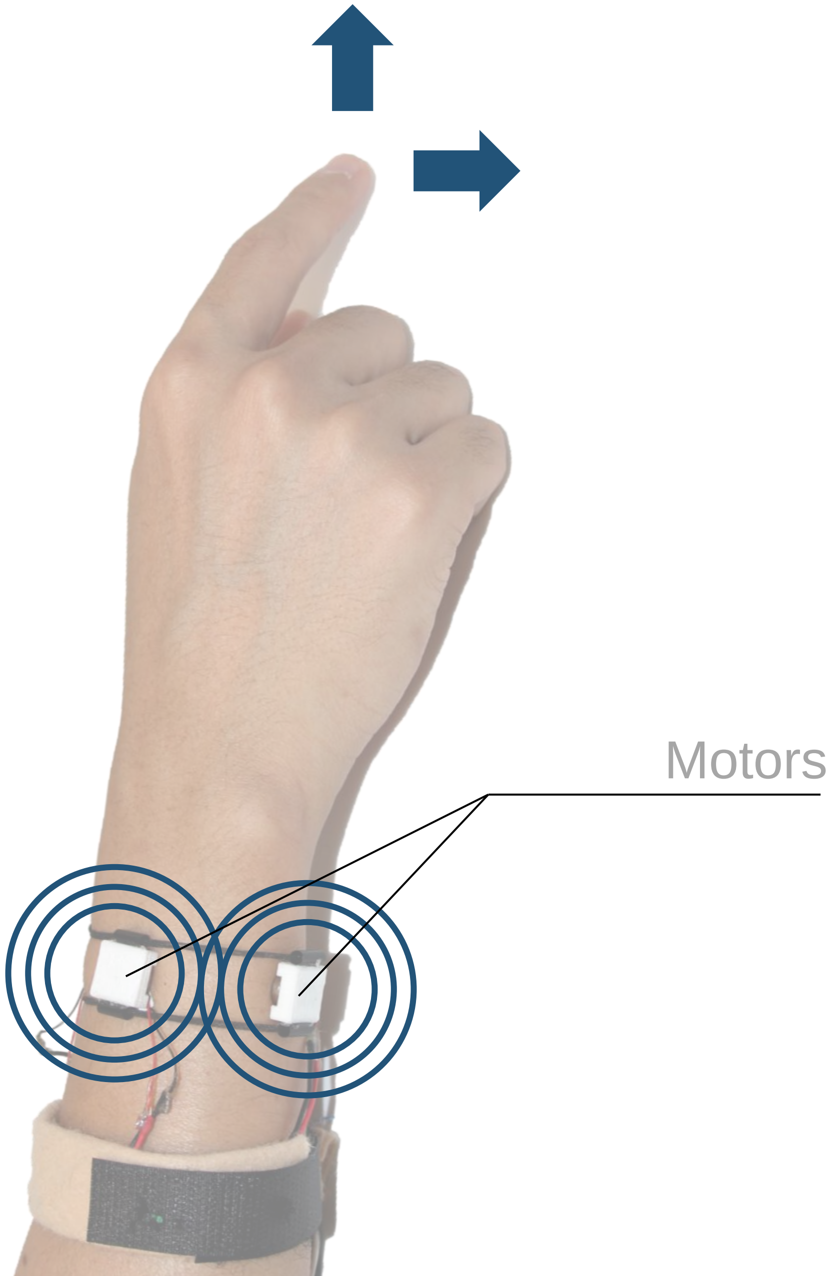
Problem

How should the haptic feedback around a wrist be designed?

How many haptic actuators do we need?

Is **interpolated vibration** stimulation able to provide more precise directional guidance?

Haptic feedback around a wrist



Number of Motors

4 motors

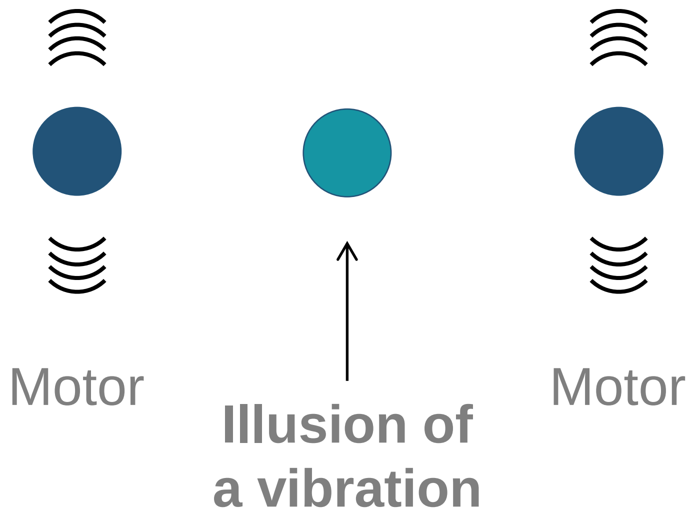
8 motors

Interpolated Feedback (Phantom Sensation)

Two vibrotactile actuators placed closely together on the skin create the **illusion of a single vibration** between the two actuators.

The location of the phantom sensation is determined by the amplitude of the two vibrations.

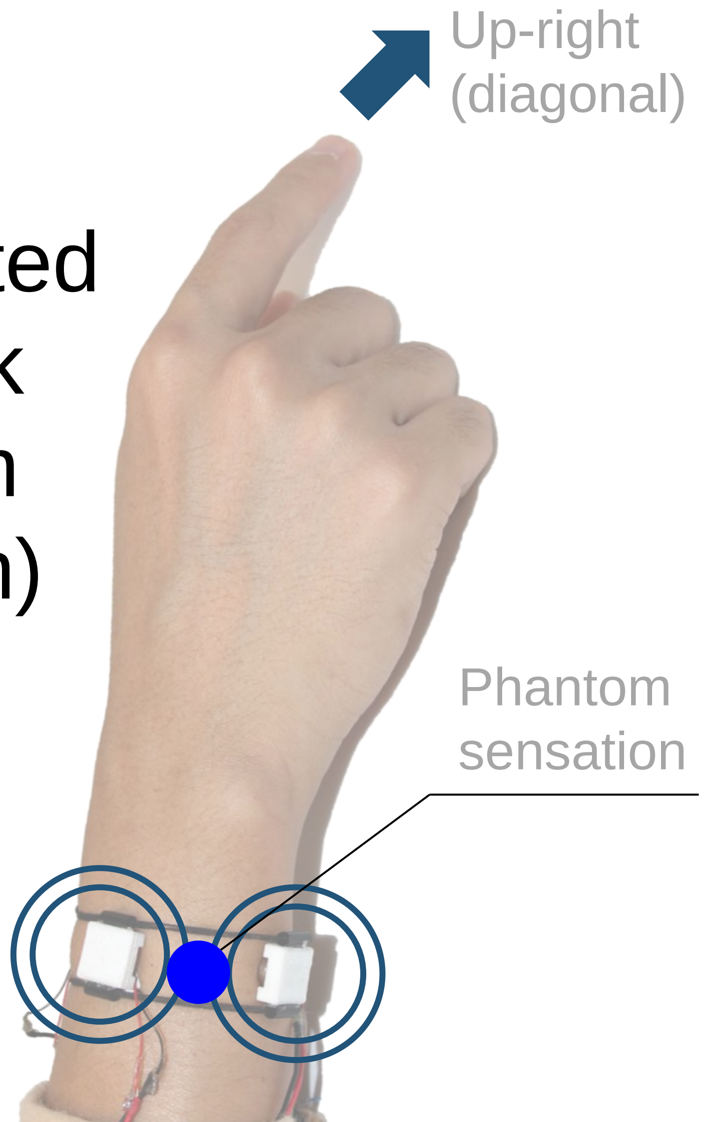
[Alles, 1970]



Single-motor and Interpolated Feedback

Single-motor
Feedback

Interpolated
Feedback
(Phantom
sensation)



Research Questions

4 motors
Simplicity

vs.

8 motors
High fidelity

Single-motor feedback
Clear/discrete guidance

vs.

Interpolated feedback
Continuous guidance

Overview of Two Studies

Study 1 – Interpolation and Number of Motors

Comparing 4 and 8 motors as well as single-motor and interpolated feedback with 11 sighted and 2 blind participants.

Study 2 – Evaluating with Blind Participants

Comparing 4 and 8 motors using single-motor feedback with 14 blind participants.

Related work

Haptic Feedback for Assistive Applications

Sensory Substitution of Visual Information

BrainPort by Sampaio *et al*., 2001

Optacon by Schoof, Loren, 1974

Whole Body Navigational Support

4x4 grid of tactile actuators on the back of a vest by Ertan *et al*., 1998

Wrist-worn haptic devices by Scheggi *et al*. 2014

Non-visual Directional Hand Guidance

Haptic Directional Guidance on a Hand

Vibromotors mounted on a smartphone by Kim *et al*., 2016

Haptic actuators on the finger by Stearns *et al*., 2016

Wrist-worn Directional Haptic Guidance

Haptic wristband for sighted users in virtual space by Weber *et al*., 2011

Haptic wristband using phantom sensation by Hong *et al*., 2016

User study 1

Comparing 4 and 8 motors as well as single-motor and interpolated feedback for haptic feedback around a wrist with sighted and blind participants.

4 conditions

1. 4-motor + single-motor feedback
2. 8-motor + single-motor feedback
3. 4-motor + interpolated feedback
4. 8-motor + interpolated feedback

Participants

11 sighted participants (6 female, 5 male)

25.3 years old on average

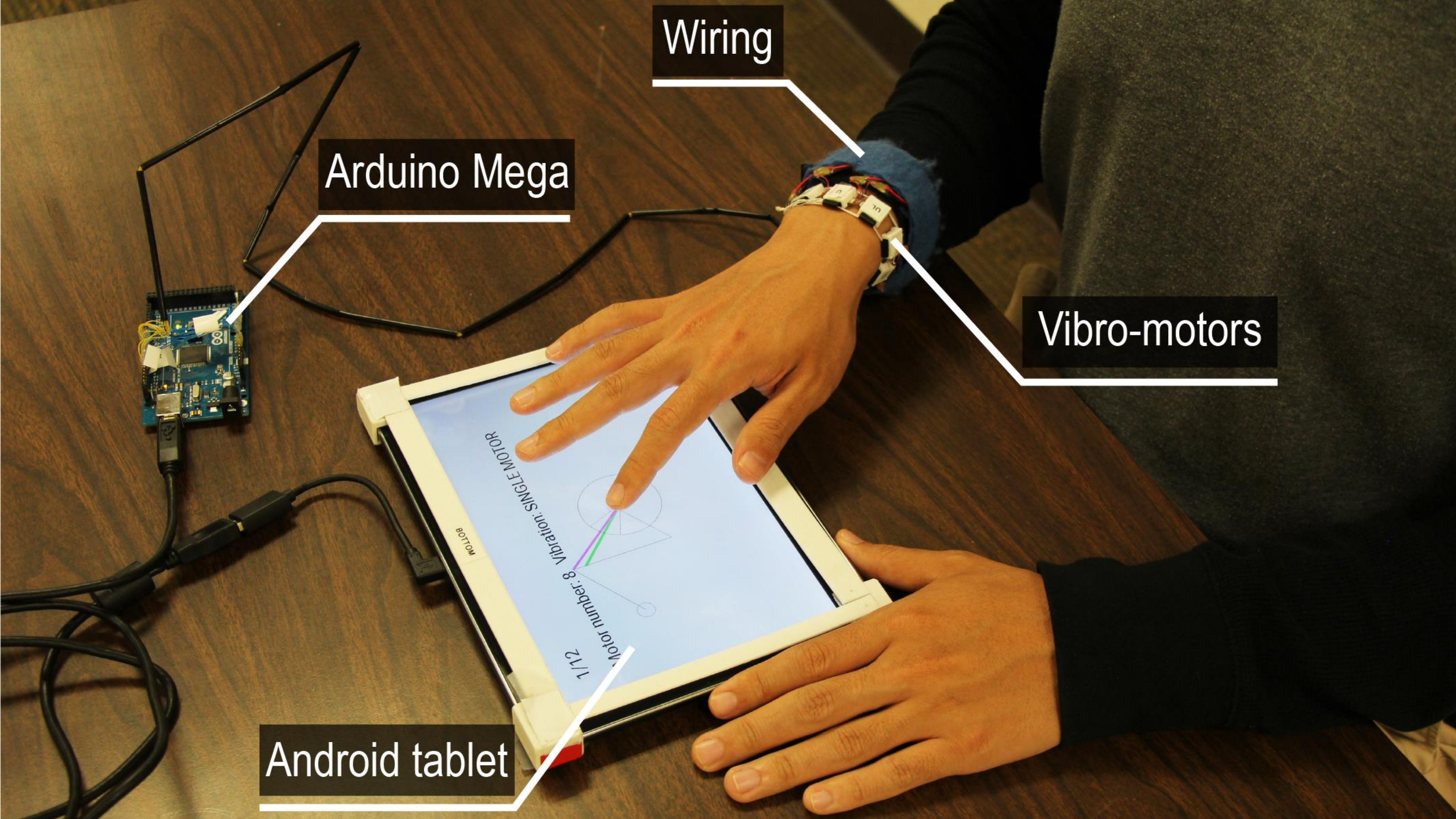
Blindfolded during the task

All right-handed

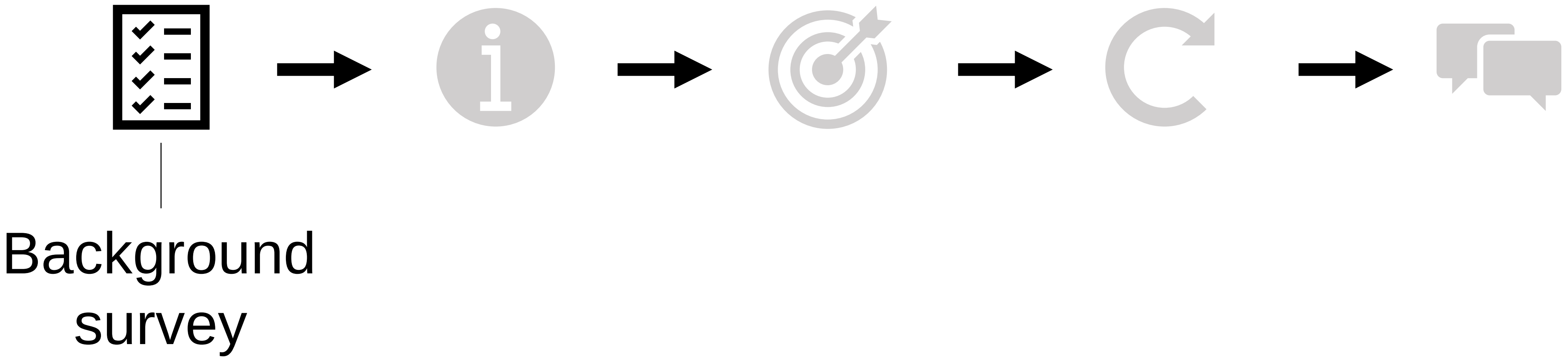
2 blind participants (1 female, 1 male)

53 years old male, right handed

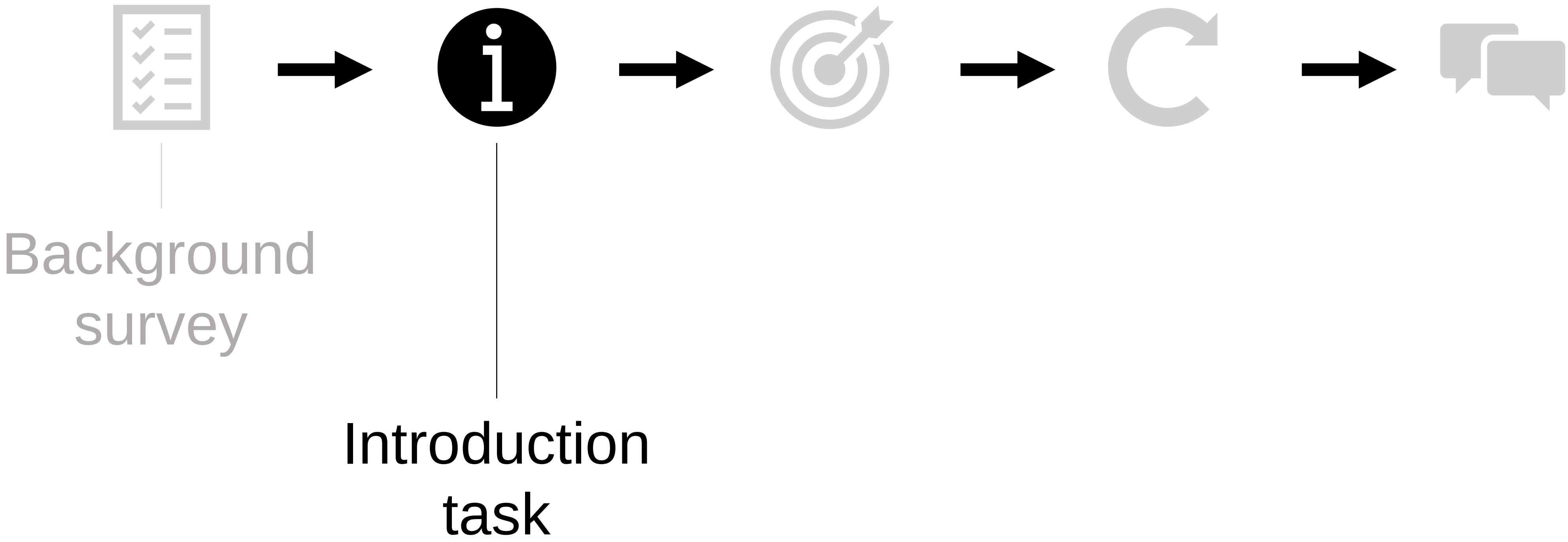
63 years old female, left handed


Wiring
Arduino Mega
Vibro-motors
Android tablet
Vibration: SINGLE MOTOR
Motor number: 8
1/12
BOTTOM

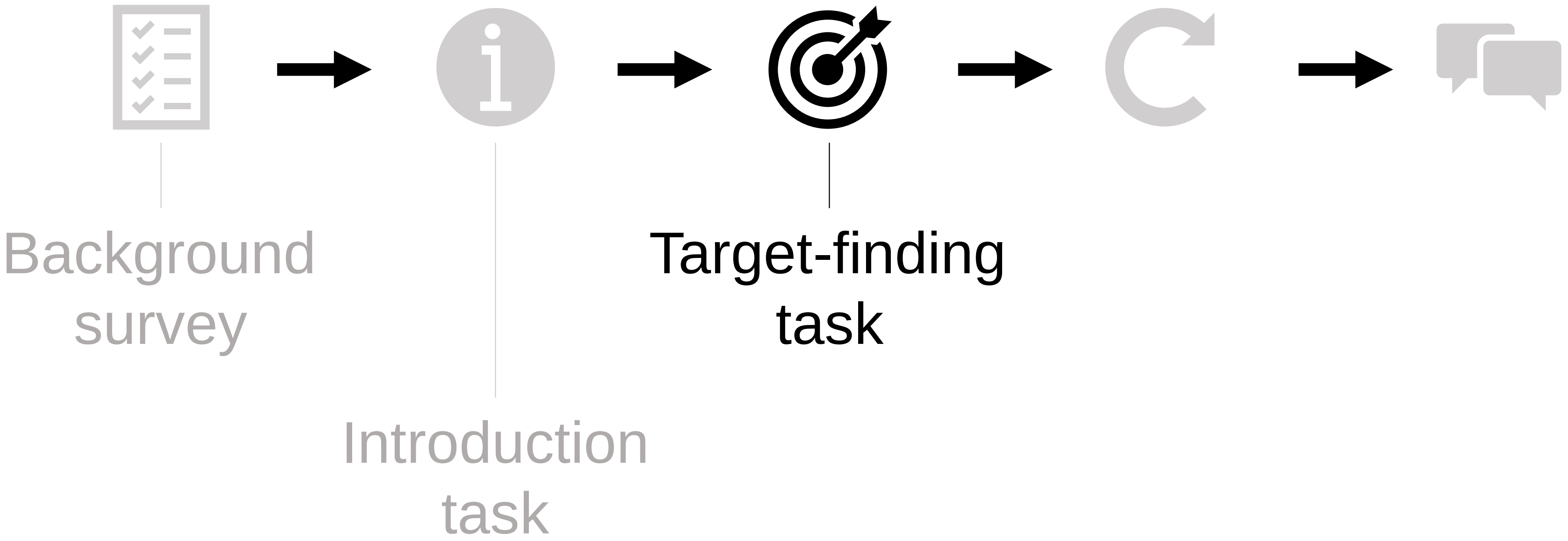
Procedure



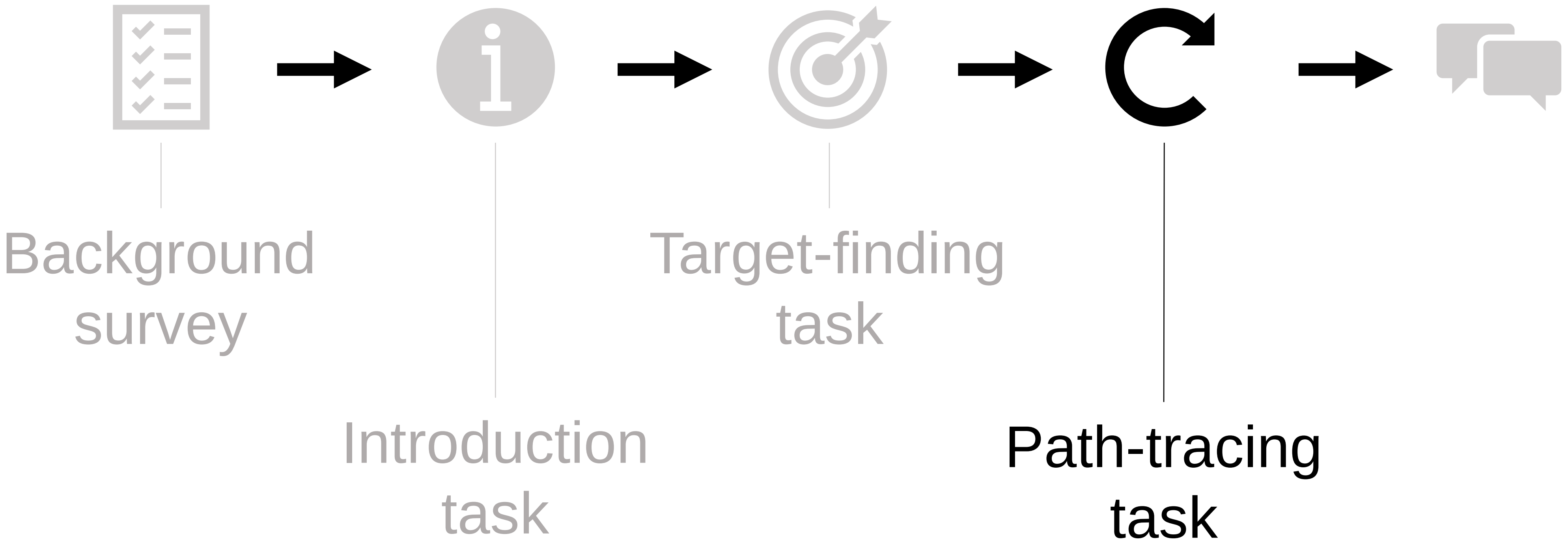
Procedure



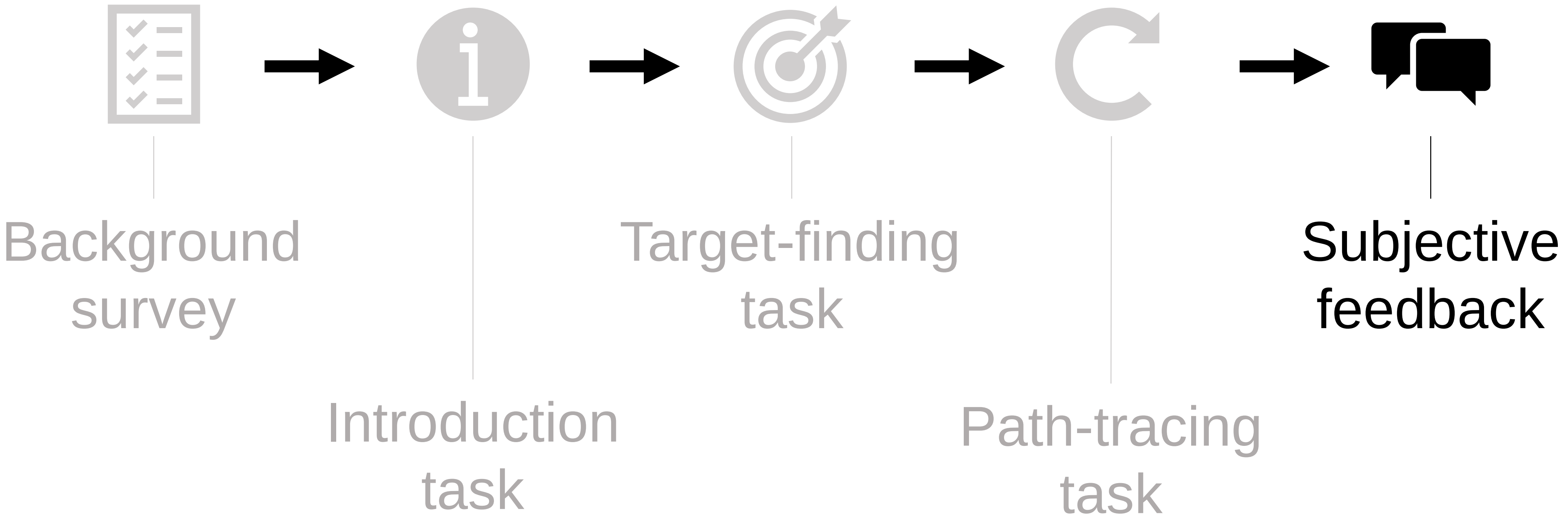
Procedure



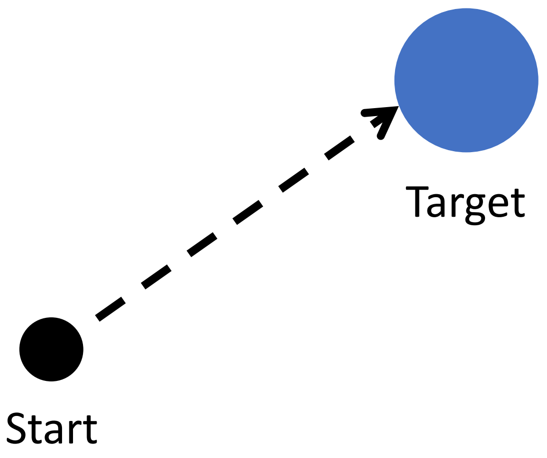
Procedure

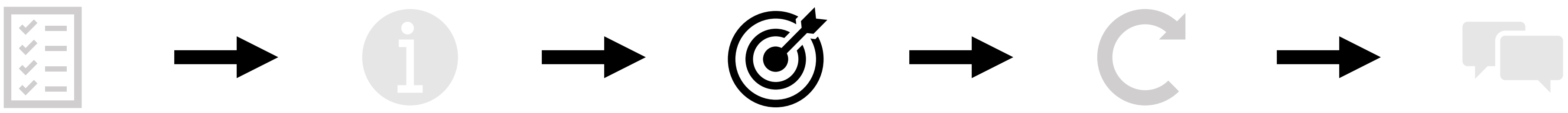

Background survey
Introduction task
Target-finding task
Path-tracing task

Procedure


Background survey
Introduction task
Target-finding task
Path-tracing task
Subjective feedback

Target-finding Task





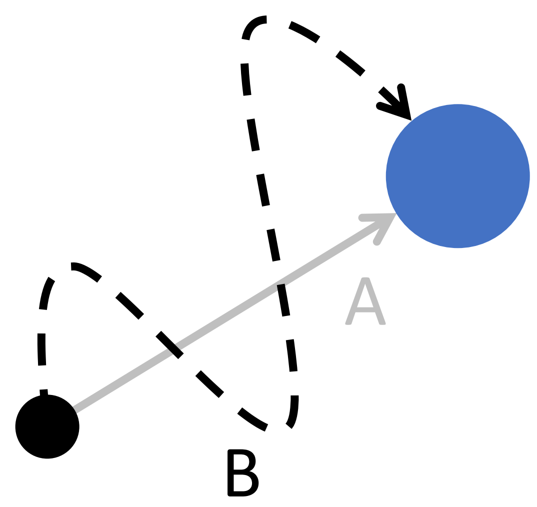
Measures

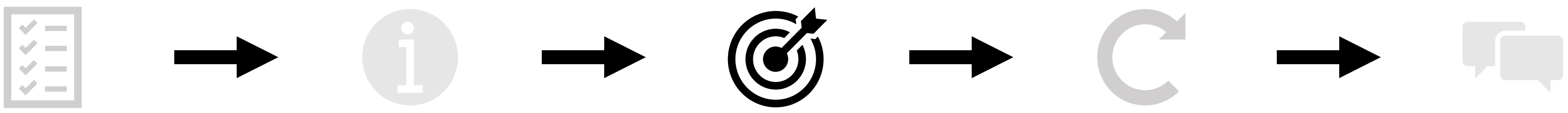
Trial completion time

The time from the time a trial started until the finger entered the target bounds.

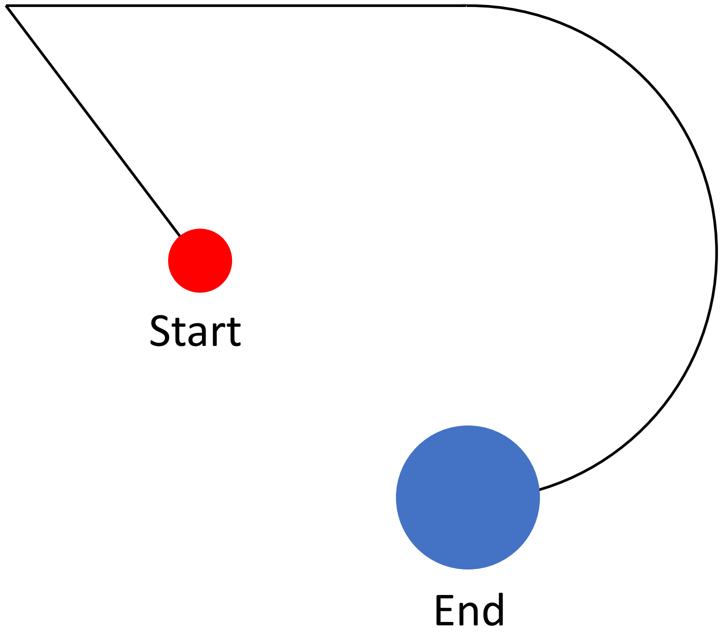
Movement error

$$= \frac{\boldsymbol{Actual\ distance\ the\ finger\ moved\ (B)}}{\boldsymbol{Euclidian\ distance\ (A)}}$$

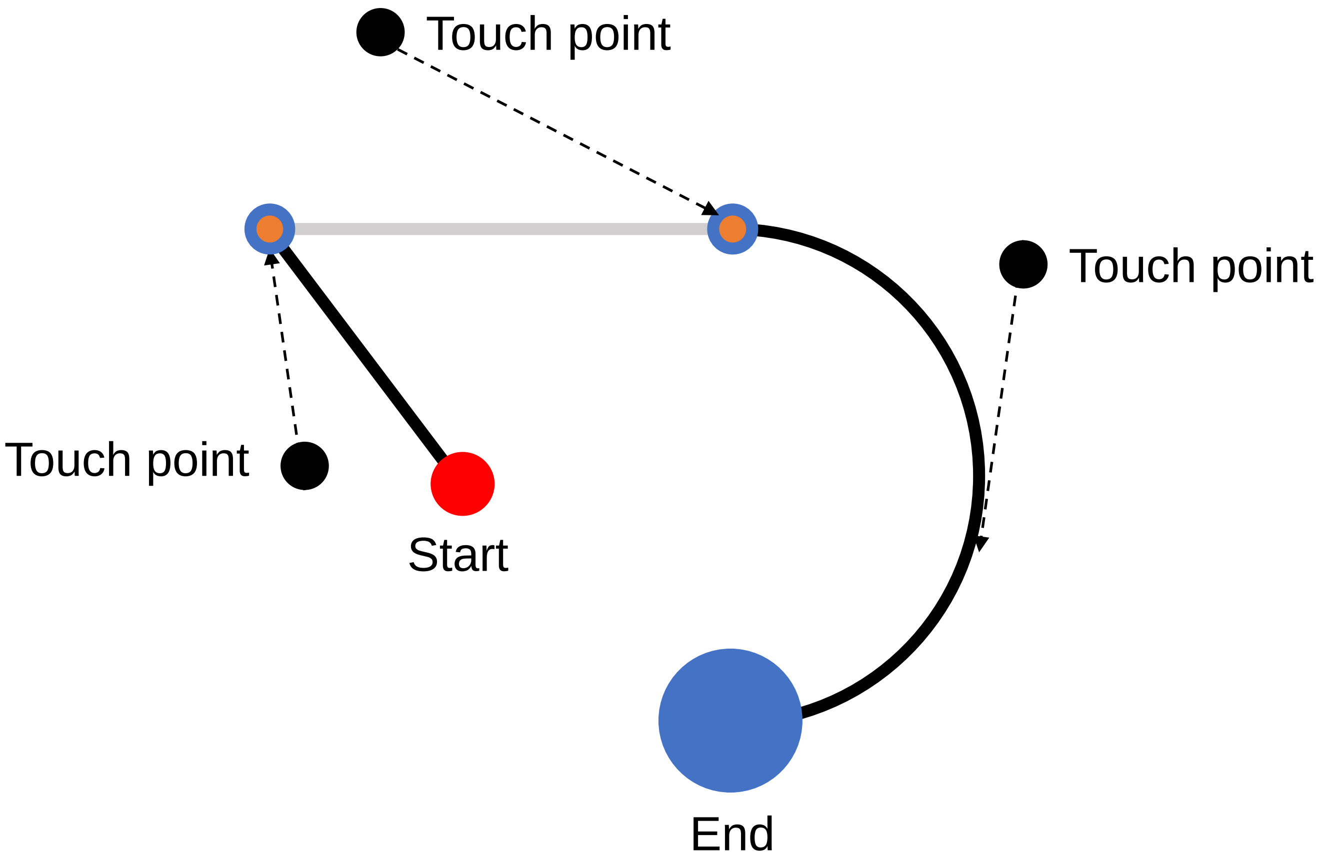




Path-tracing Task



Path-tracing Task



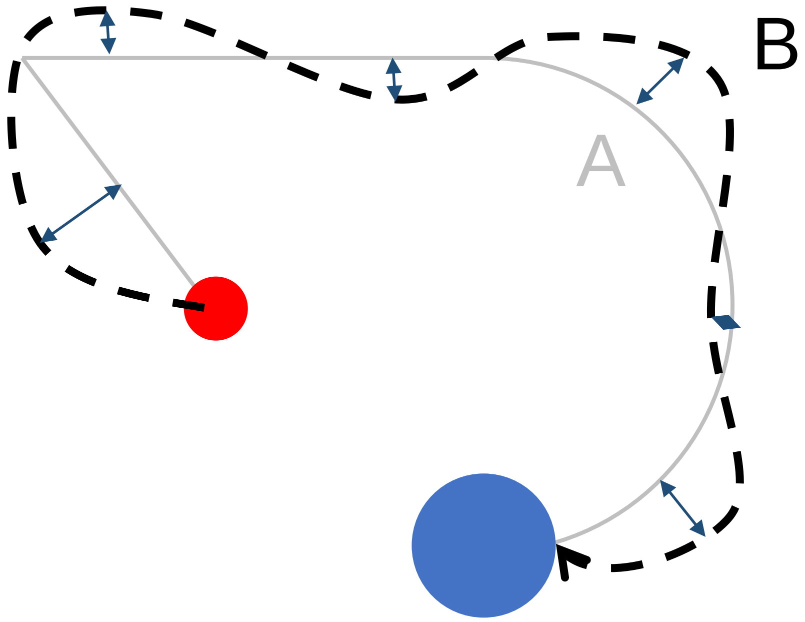
Measures

Trial completion time

The time from the time the vibration started until the finger reach the last segment.

Movement error

Distance between the path (A) and **the trace that finger moved (B)** computed by dynamic time warping (DTW)



Results of User Study 1

Target-finding task

Interpolated feedback was **slower** than single-motor feedback (*p* = .005)

Interpolated feedback resulted in **higher** error rate than single-motor feedback (*p* = .023)

Path-tracing task

Interpolated feedback was **slower** than single-motor feedback (*p* = .007)

Movement error was **higher** with interpolated feedback (*p* = .038)

Subjective feedback

Participants consistently rated the wristbands with interpolation worse than other conditions.

Results of User Study 1

Single-motor feedback was faster and more accurate than interpolated feedback in both tasks

The clear vibration from 4-motor wristband resulted in better performance than 8-motor wristbands with higher fidelity.

There was no significant difference between 4 and 8-motor wristbands

User study 2

Comparing 4 and 8 motors of single-motor feedback with blind participants.

Participants

14 visually impaired participants (8 female, 6 male)

- 7 totally blind
- 2 blind with light perception
- 5 legally blind

25.3 years old on average

Handedness

- 12 were right handed
- 1 was left handed
- 1 reported using her left hand for writing and right hand for touchscreen devices (she used her right hand for study tasks)

Procedure

The same tasks as Study 1

Only 2 experimental conditions

Single-motor feedback with 4 motors

Single-motor feedback with 8 motors

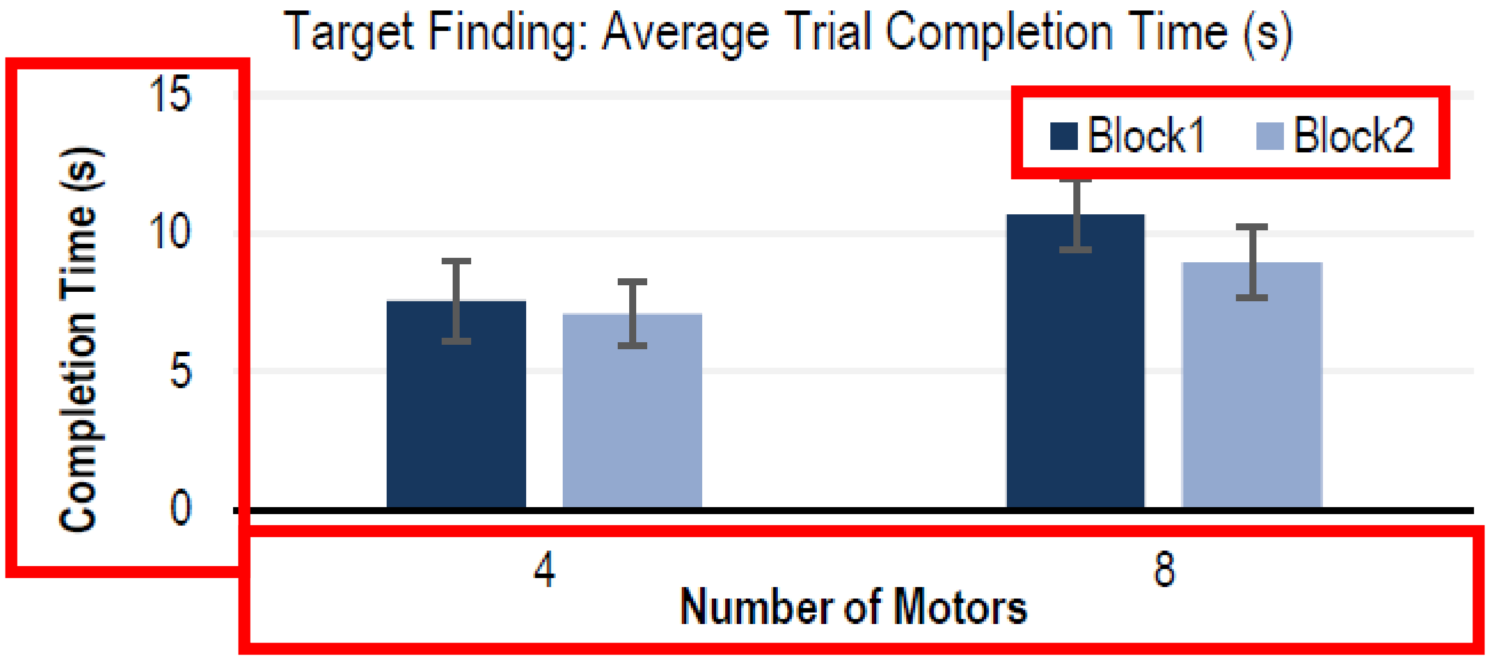
More trials were provided in three tasks

Target-finding task 30→ 36 (2 blocks, 18 trials each)

Path-tracing task 10 → 12

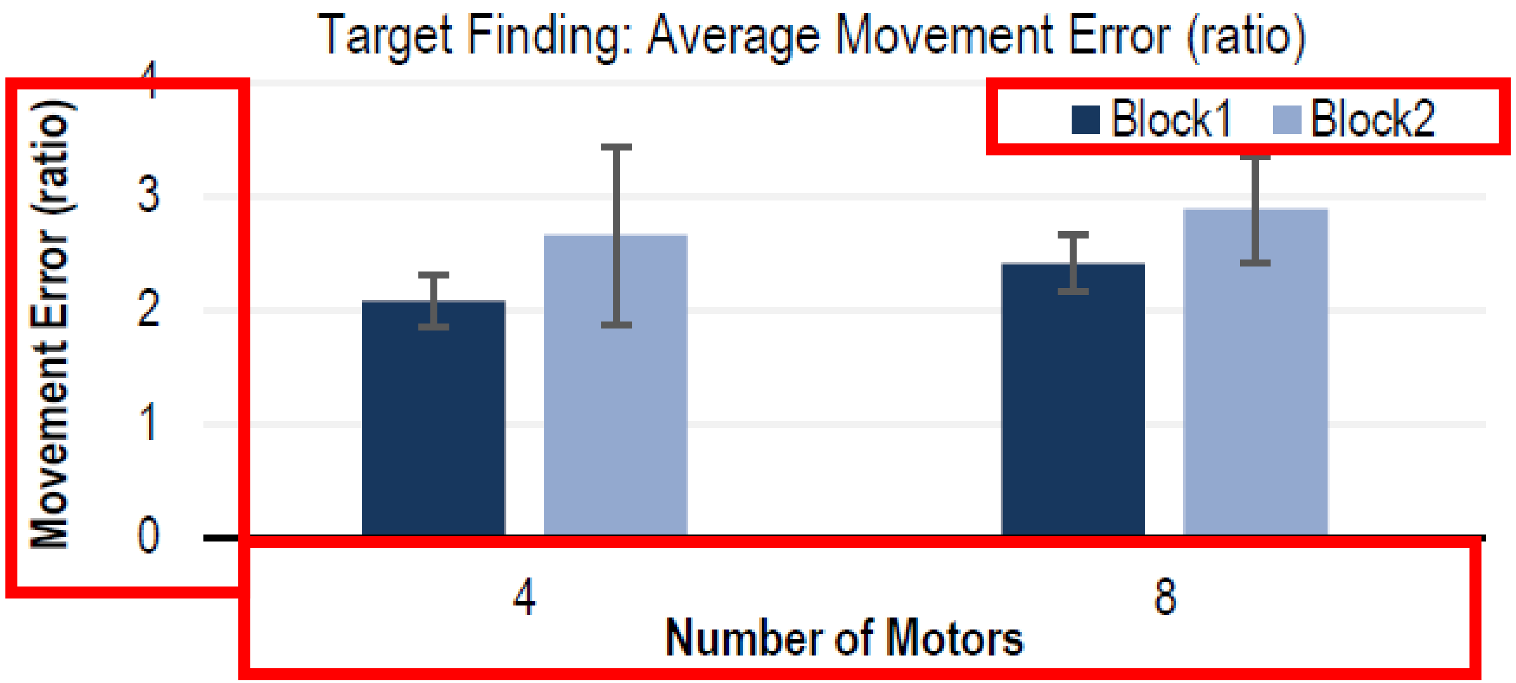
Results of User Study 2

Target-finding Task



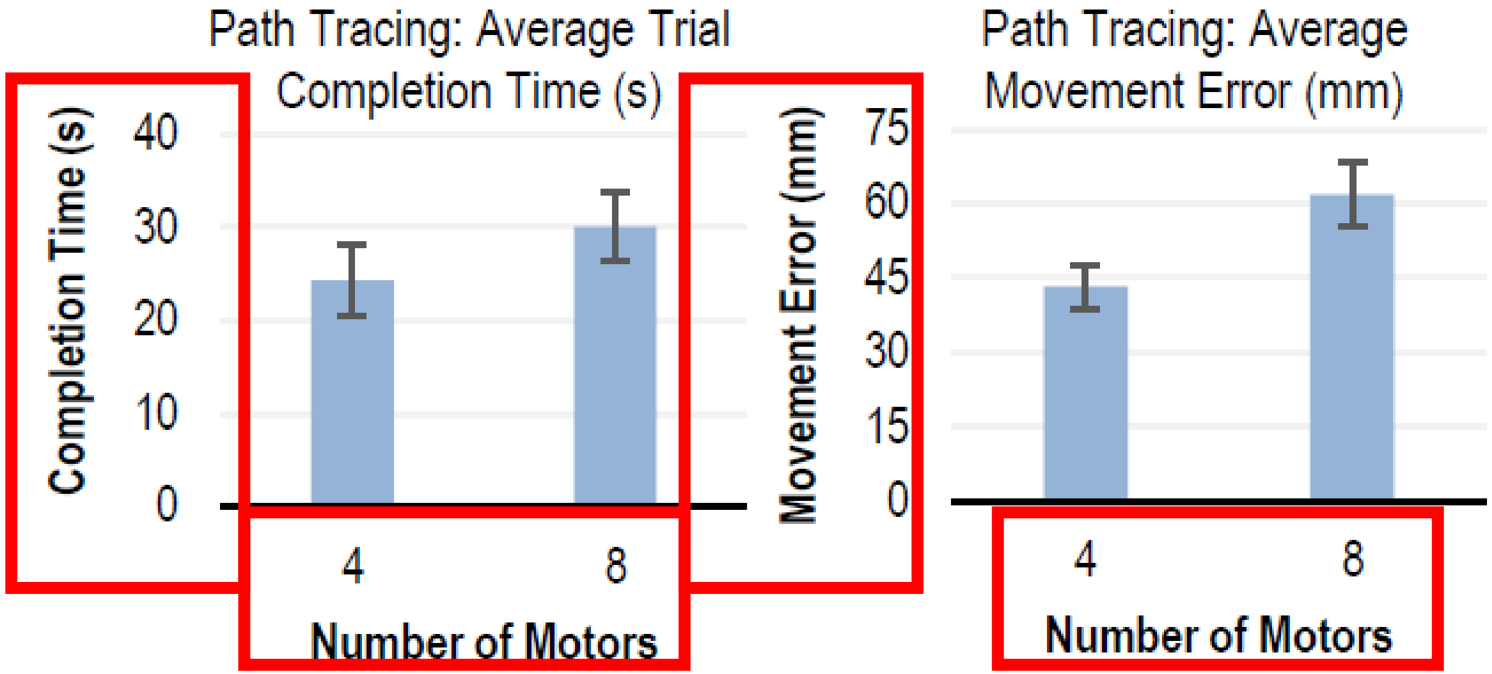
- Participants were **faster** with the 4-motor wristband than 8-motor one (p < .001)
- The main effect of *Block* was not statistically significant (p = .119).

Target-finding Task



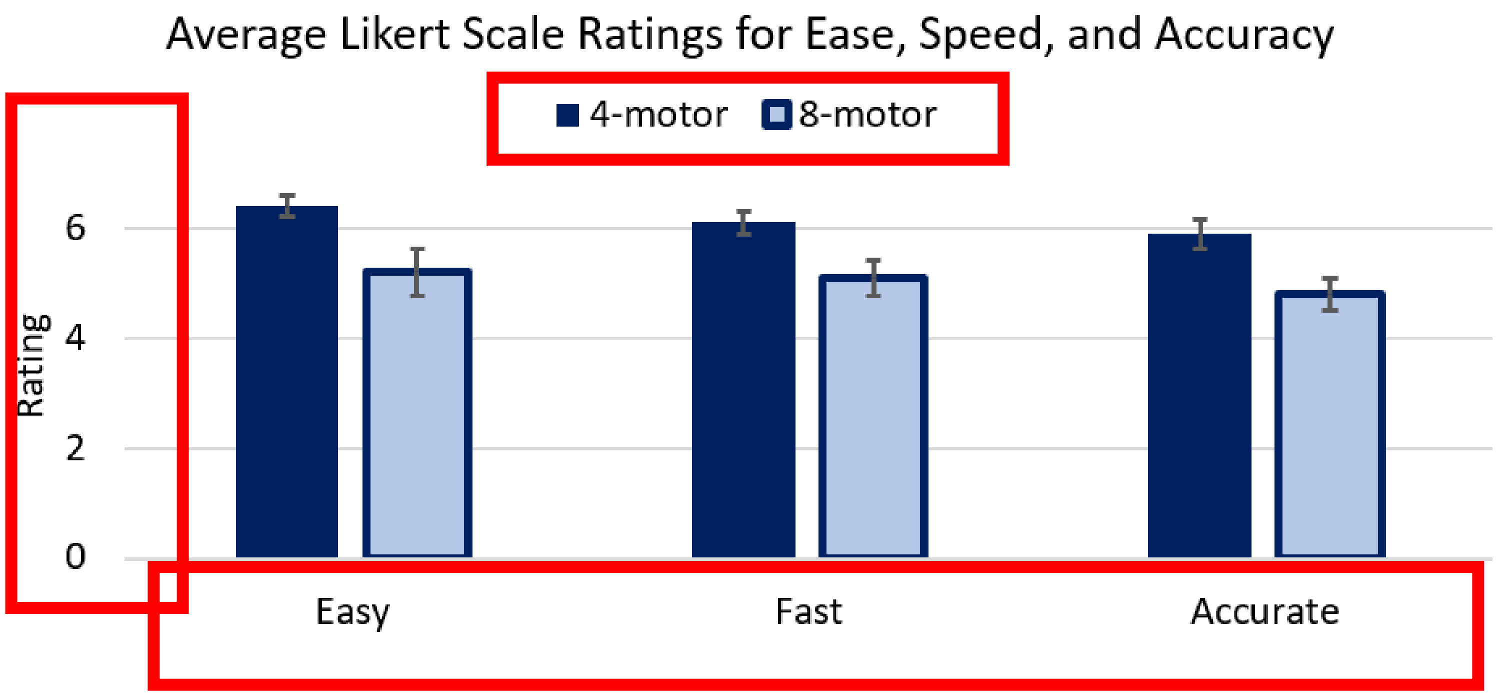
- They were **more accurate** with the 4-motor wristband than 8-motor wristband (*p* = .029)
- The main effect of *Block* was not statistically significant (*p* = .560).

Path-tracing Task



- Participants were not faster with either wristband (*p* = .091)
- They were **more accurate** with 4-motor wristband than 8-motor wristband (*p* = .009).

Subjective Feedback



- Participants perceived the 4-motor wristband to be **easier** to understand and **more accurate** than the 8-motor wristband.
- No differences were found in perceptions of speed.

Subjective Feedback

The most common reason cited for preferring 4-motor feedback was that it was easier to understand (6 participants).

“[4-motors] was easier to use and I felt less frustrated. I felt like I did better. I was more sure of […] which one was vibrating.”

Subjective Feedback

Reasons for preferring 8-motor feedback included higher perceived accuracy and increased precision.

“The feedback is more fine-grained and I like that [...] Instead of a general direction I like precision.”

Summary of Study 2

4-motor wristband outperformed 8-motor wristband in both tasks.

The subjective evaluation supported the performance results with positive feedback about the 4-motor wristband.

Discussion

1. Why does 4-motor outperform 8-motor?

2. Designing wristband haptics

3. Effect of age and technology experience

Limitations and Future Work

1. Fatigue from using the haptic feedback

2. Learning to use the wristband

3. Performance in practice

Questions?

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