Scalability of the Size of Patterns Drawn Using Tactile Hand Guidance

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Brief Bio

Dhanya Nair

Education:

PhD. & M.S. in Electrical Engineering, Texas Tech University (2013)

B.Tech. in Electronics and Communication, CUSAT, India (2006)

Work Experience:

- Assistant Professor, Chapman University (2019 – Present)
- Assistant Professor, Weber State University (2016 – 2019)
- Fault Isolation Engineer, Blast Motion (2014 – 2015)
- Yield Analysis Engineering, Intel Corporation (2013- 2014)

Research Interests:

- Haptics, Assistive Technology, Handwriting Training, Braille Displays, Tactile Music.
- Website: **ndanya.wixsite.com/heartlab**

Motivation

- 2.4 million students in USA (between 3-21 years) had *specific learning disabilities*, during the 2019-2020 school year.
  - Specific learning disability: Disorders impacting the understanding or use of spoken or written language.[1]

- **Handwriting training helps** improve fine motor skills, general language skills and develops cognitive skills plus neural pathways for better reading and comprehension.[2]

- Assistive handwriting training devices help children with learning disabilities and rehabilitation of individuals with motor skill issues.[3][4]

Related Work

- Haptic assisted handwriting training
  - has gained interest recently.
  - has shown promise in developing strong visuo-motor skills.[2]-[6]

- Haptic assisted handwriting research utilize Phantom Omni/Novint Falcon primarily.[2]-[9]
  - Tethered, allocated space, expensive.

- *We have developed a wearable sleeve for providing corrective vibrotactile feedback.*
  - Untethered, and inexpensive.

Phantom Omni (above) and Novint Falcon are the primary sources of haptic feedback for handwriting training.

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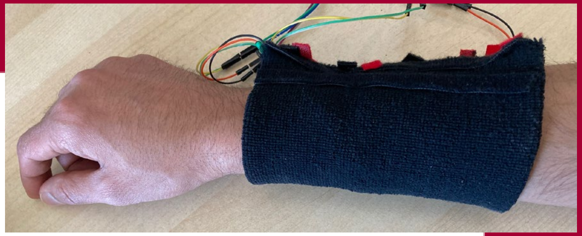

Objective

This study evaluates the feasibility of using the tactile sleeve for guiding the user towards the correct form (shape) and size/scale of different characters, *with the eventual goal of handwriting intervention***.**

Hence, it investigates the following:

1. Can the user respond to a vibration and **correct their hand movement in the desired direction**, while they are attempting to draw a pattern?

2. Can the user's hand **move a consistent distance** for identical vibrational cues (same vibrational intensity for the same time)?

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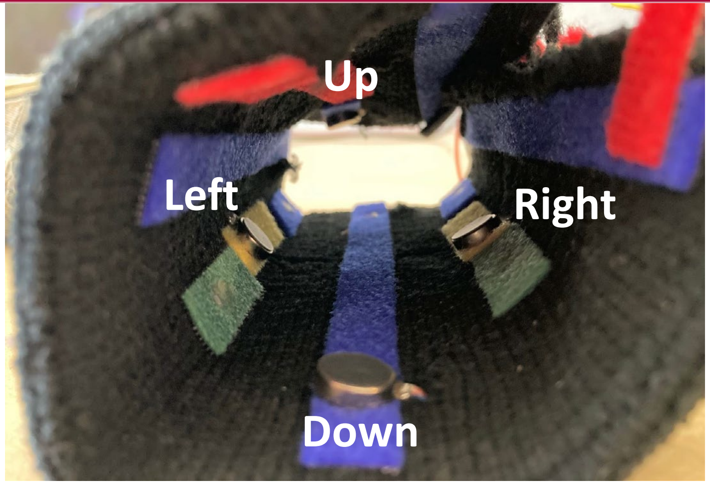
Sleeve Overview [10]

- Sleeve embedded with 4 vibrating motors.
- Only 1 motor activated at a time.
- The activated motor indicates the desired direction of movement (up, down, left, right).
- Hence, 90° directional cues only.

- The vibrotactile sleeve was used to guide participants through blind patterns/letters from different languages.



Sleeve embedded with 4 mini vibrating disk motors:
- up: near wrist on dorsal side.
- down: near proximal region on ventral side.
- left/right: midway on radial/ulnar sides.

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Hypotheses

- *Hypothesis 1:* Participants will be able to identify the vibrational direction provided by the sleeve and **trace these blind patterns with high accuracy.**

- *Hypothesis 2:* The **size** of the patterns drawn **will scale with the duration of vibration**.

- *Hypothesis 3:* **Shorter vibrational durations** (< 3 seconds) will show **higher variability** in the pattern size.
  - Average 1 second required for comprehending the direction to be moved in, hence the cognitive load might override the ability to maintain a steady size.

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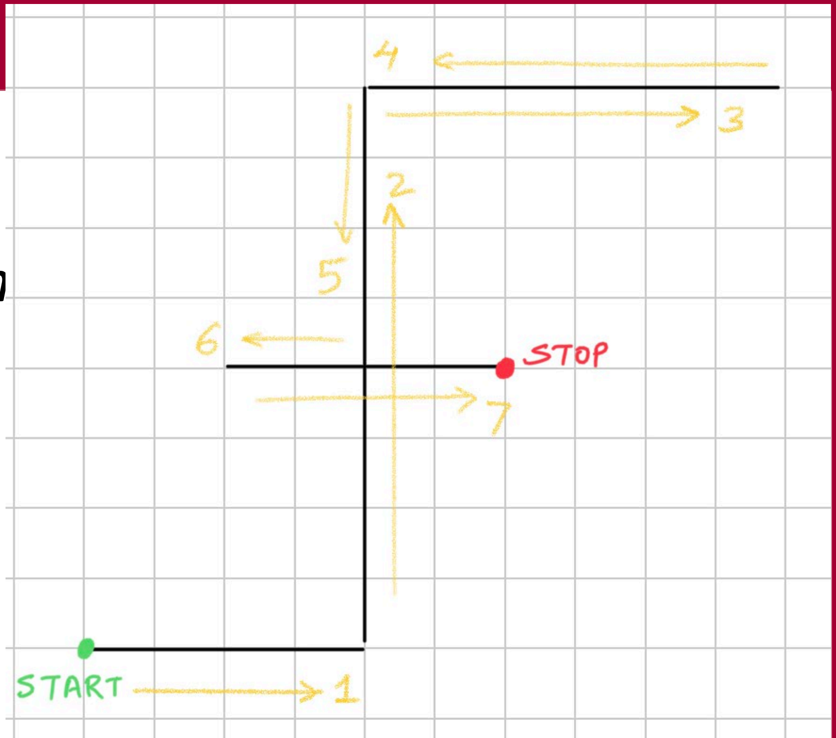
Methods: Training

- *On a graph paper, draw straight lines in the direction of the activated motor .*

Training: Practice tracing English letter f while receiving vibrations corresponding to the pattern through the sleeve.

- Each 1cm distance corresponds to 1s continuous motor vibration in that direction.
- Segment = Continuous movement in one direction.
- Change from one segment to next is continuous.
  - no break or cue to participants before segment changes.



Letter f in square font showing the 7 segments to be drawn in the order numbered.
Each grid is 0.5cm and each 1cm distance is encoded using a 1s vibrational duration/movement in that direction.

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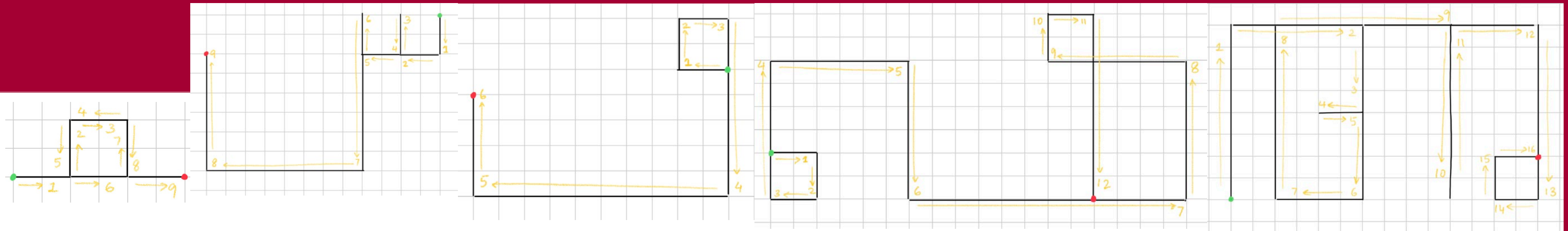
Methods: Testing



Left to right: English letter a, Arabic letters s and f, Malayalam letters sh, a respectively.

- 3 healthy adults participated in this pilot study.
- 5 patterns from different languages projected on participant's arm -> *To evaluate shape formation (form).*
- Letters presented at 3 different scales: 1s, 2s, 3s -> *To evaluate scaling.*
  - Each 1cm encoded as 1s continuous vibration for 1s scale
  - Each 1cm encoded as 2s continuous vibration for 2s scale, etc.
  - Only English and Arabic letters presented at different scales to avoid fatigue.
  - Malayalam letters were presented only at 1s scale.
- Hence, 11 patterns with 100 segments (directional changes) per participant.

Results: Pattern Shape

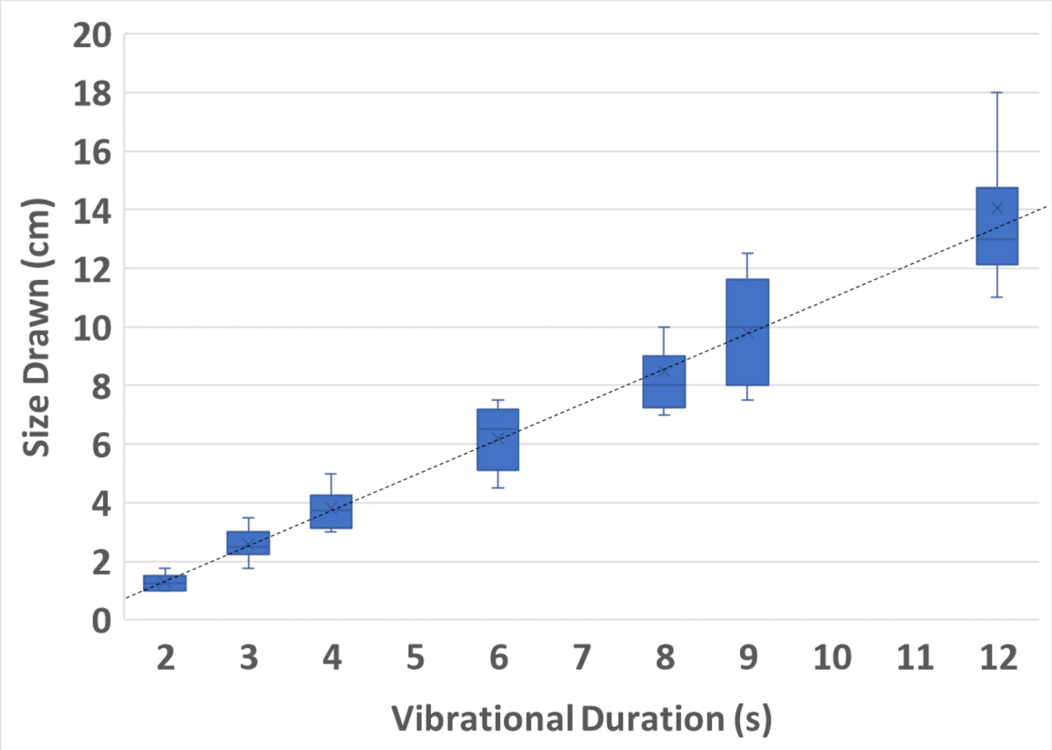
- The participants drew the blind patterns with high accuracy.
- Average accuracy: **95.67%**
    - individual accuracy of 96%, 95% and 96% per subject

- Hence, hypothesis 1 is supported:
    - ***Participants were able to distinguish the direction provided and trace the blind patterns with high accuracy.***

Results: Pattern Size and Scalability

- Size of the segments drawn by the subjects increases linearly with the increase in tactile duration.

- Hence, hypothesis 2 is supported:
  - ***The size of the patterns drawn does scale linearly as a function of the tactile duration.***



Cumulative data for the segment sizes drawn vs. the duration of continuous vibrational stimulation.

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Results: Pattern Size Variability

- Standard deviation
  - very low for small segments
  - increases with the segment length
- Hence, as the tactile duration increases, error in sizing increases.
- Contrary to expectation: hypothesis 3 is not supported.
  - ***When the vibrations provided continuously for a longer duration, it becomes more difficult to maintain the steady speed*.**

Duration (s)	**1**	**2**	**3**	**4**	**6**	**8**	**9**	**12**
Avg. size (cm)	0.982	1.281	2.595	3.818	6.163	8.536	9.800	14.068
Variance (cm ^ 2)	0.013	0.062	0.242	0.524	1.198	2.522	3.410	10.251
Std. dev. (cm)	0.114	0.248	0.492	0.724	1.094	1.588	1.847	3.202
Median (cm)	1	1.25	2.5	3.75	6.1	8.4	9.875	13
CV	0.116	0.194	0.189	0.190	0.178	0.186	0.188	0.228

Statistics of sizes drawn for different durations

Conclusion

- Tactile feedback shows promise for handwriting training, and shape/size of letters can be controlled.
- Three subjects drew blind patterns using the tactile feedback from the sleeve alone. Following conclusions were drawn:
  - **Patterns can be reproduced with high accuracy.**
  - **Segment lengths can be scaled linearly using vibrational durations.**
  - Hence, shorter segments (of less than 5cm) - provide using continuous vibrations.
  - If longer segments need to be drawn:
    - Break it into multiple small segments each with continuous vibrations of less than 5s with a small break (no vibration) between the segments.

<u>WIP and Future:</u>

- Test on larger number of participants, and individuals with visuo-motor skills issues / learning disabilities.

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THANK YOU!

Questions?

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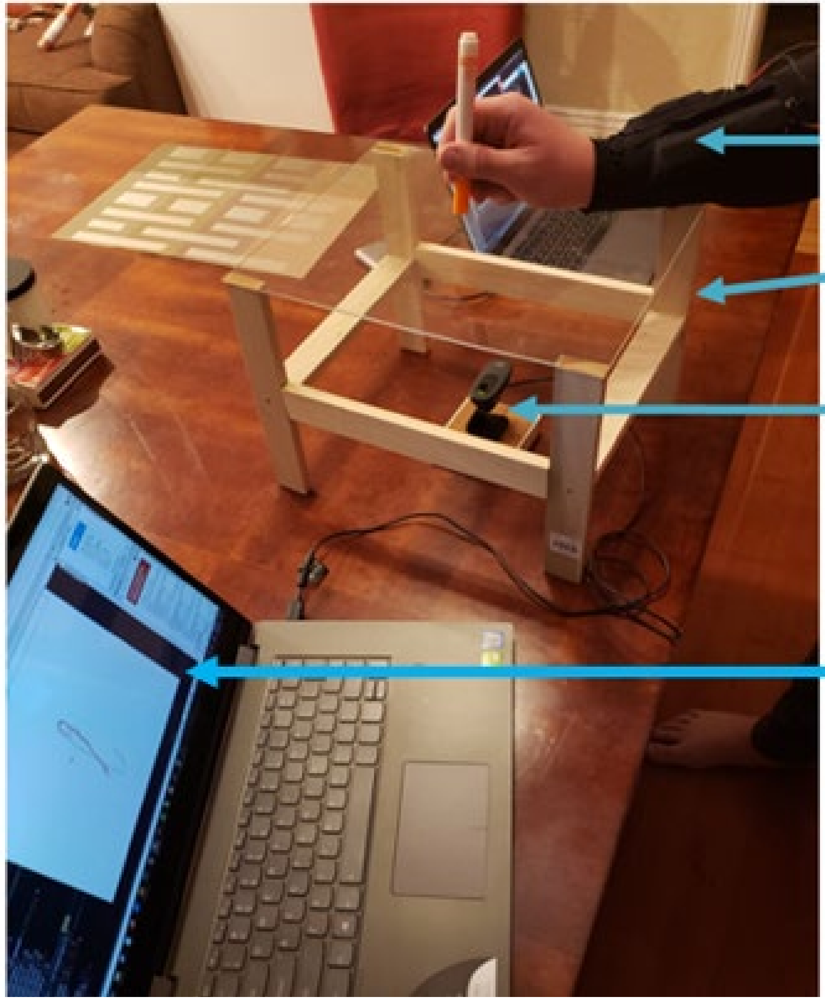
Prior Work [10]

Overall system consists of:

- Wrist worn sleeve
    - embedded with 4 motors.
    - ESP32 controller and battery.
- Webcam
- Learn-to-write software

System architecture and sleeve design was presented in [10].



Haptic sleeve (controller circuit, motors, batteries inside)

Transparent stand (to draw on)

Webcam (connected to laptop via USB)

Laptop with the Learn-to-write software program running

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