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:
- 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.\textsuperscript{[2]}-\textsuperscript{[6]}

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

• \textit{We have developed a wearable sleeve for providing corrective vibrotactile feedback.}
  • Untethered, and inexpensive.

\begin{center}
\textbf{Phantom Omni (above) and Novint Falcon are the primary sources of haptic feedback for handwriting training.}
\end{center}
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)?
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.
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.
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.
Methods:

Testing

• 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.
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.*
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.

WIP and Future:
• Test on larger number of participants, and individuals with visuo-motor skills issues / learning disabilities.
References

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THANK YOU!

Questions?
Contact:
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Prior Work \cite{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 \cite{10}.