Nottingham Trent University

Vibration sensing textiles for personal protective applications

Theo Hughes-Riley, Kalana Marasinghe, Malindu Ehelagasthenna, Zahra Rahemtulla, Carlos Oliveira, Harry Riley, and Tilak Dias

Advanced Textiles Research Group, Nottingham School of Art and Design,
Nottingham Trent University (United Kingdom)

13/09/2024

Overview

- This presentation will focus on the development of a glove designed to monitor hand transmitted vibrations.
- Overview the problem and existing solutions.
- Discuss the development and validation of a vibration sensing electronic yarn.
- Present continuing work in this area.
- Briefly discuss noise monitoring textiles.

Hand transmitted vibration

- Over-exposure to vibration entering the hand can lead to serious musculoskeletal, neurological, and vascular injuries.
- Common conditions could by hand transmitted vibration (HTV) are Hand Arm Vibration Syndrome (HAVS) and Carpal Tunnel Syndrome (CTS).
- Injury occurs after cumulative, prolonged over-exposure to vibration.
- Therefore, monitoring vibration exposure can prevent serious injury.

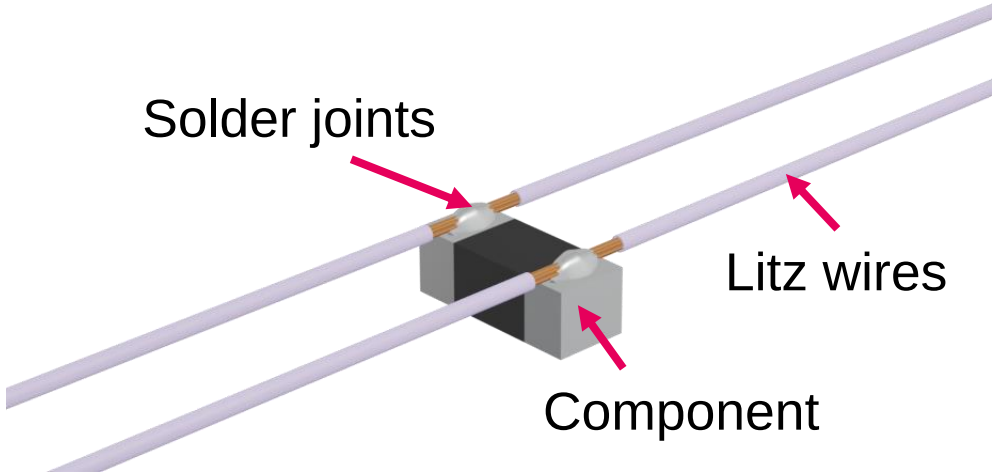
Factors to monitor

- Current health and safety practise take the sum of a weighted vibration magnitude and exposure duration.
- Tool vibration magnitudes can come from a manufacturer, legislators, or from recording the vibration patterns of the tool.
- Research has shown that the critical physical variables relevant to HTVs are: magnitude, frequency, duration, direction, area of contact, contact force, posture, and environment[1].

[1] Griffin, M.J. Measurement, Evaluation, and Assessment of Occupational Exposures to Hand-Transmitted Vibration. Occup. Environ. Med. **1997**, *54*, 73–89.

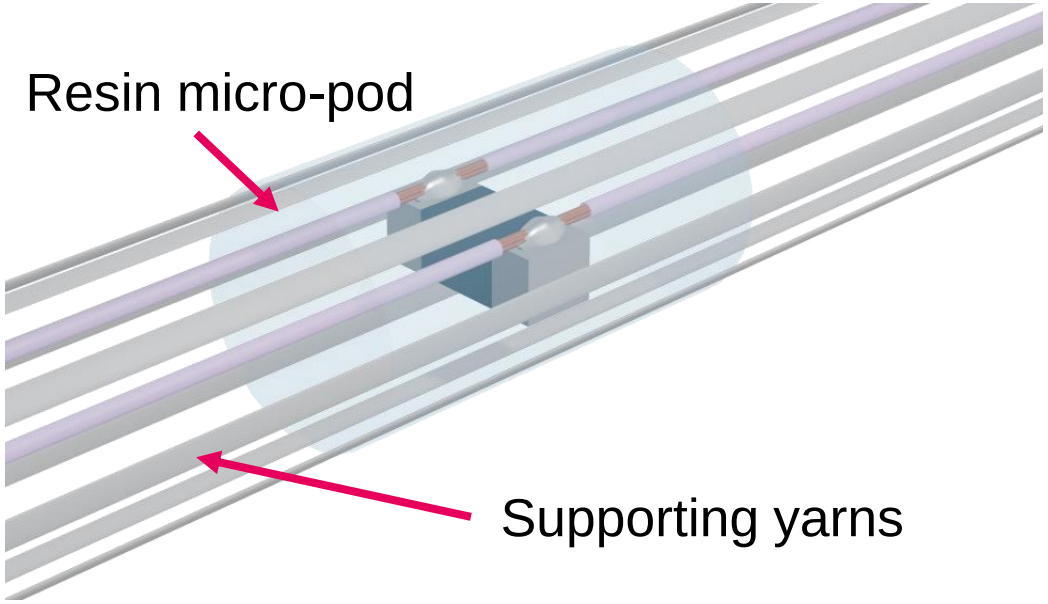
E-yarn fabrication process - Soldering

- A small electronic component is soldered onto thin, multi-strand, Litz wires.
- This creates a robust mechanical and electrical connection between the wires and the component.

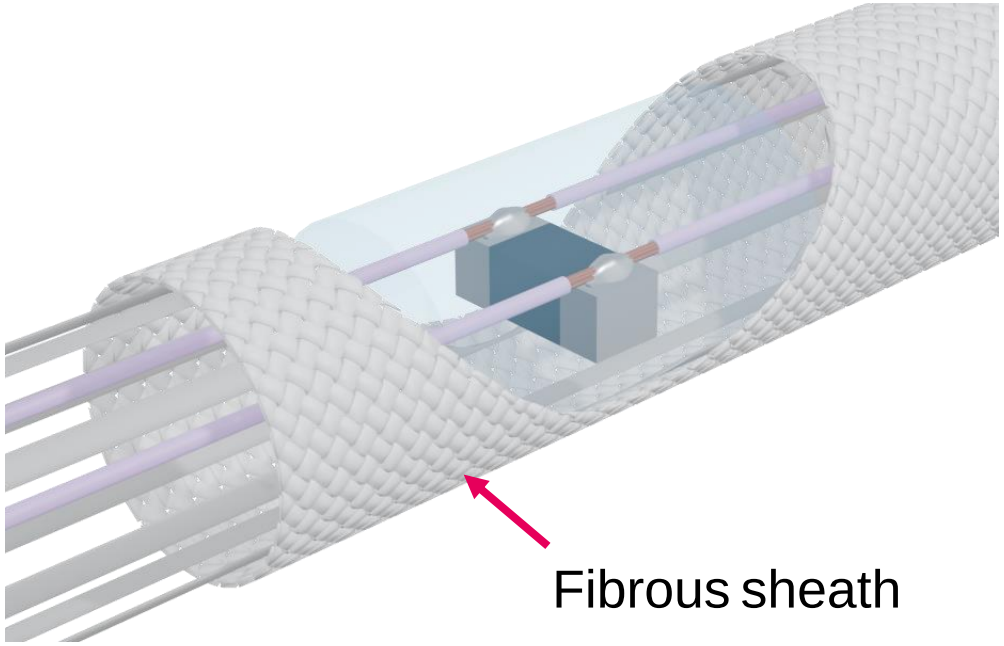


E-yarn fabrication process - Encapsulation

- The solder connections and chip are encapsulated within UV cured resin pod along with a reinforcing yarns.
- This ensures that the component and solder joints are fully protected from external mechanical and chemical stresses.



E-yarn fabrication process – Fibre covering



- The ensemble is covered in a fibre sheath.
- The final yarn is thin, soft, flexible, drapable, and comfortable to wear.

Normal textile properties

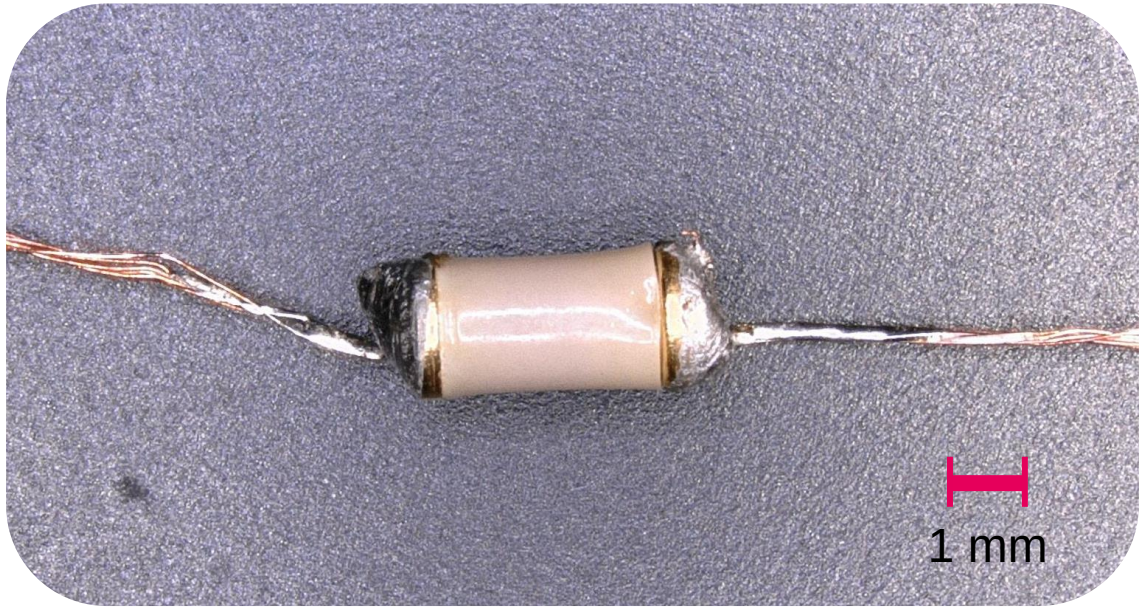
Electronic textiles made using E-yarns

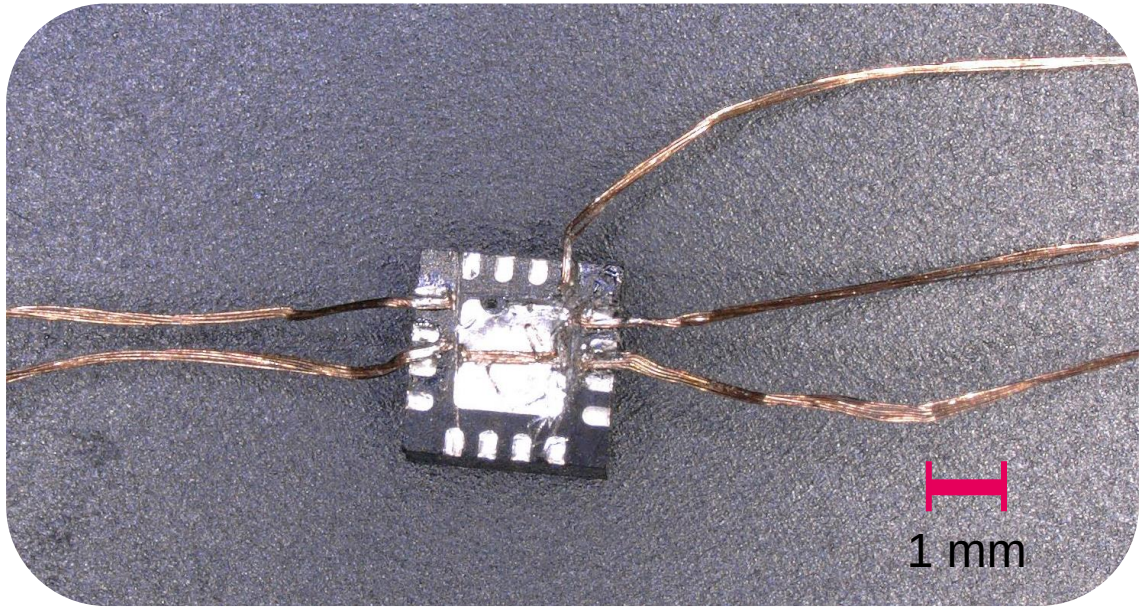
Fall detecting sock

Textile solar panel

Haptic feedback glove

Early attempts at a vibration sensing E-yarn

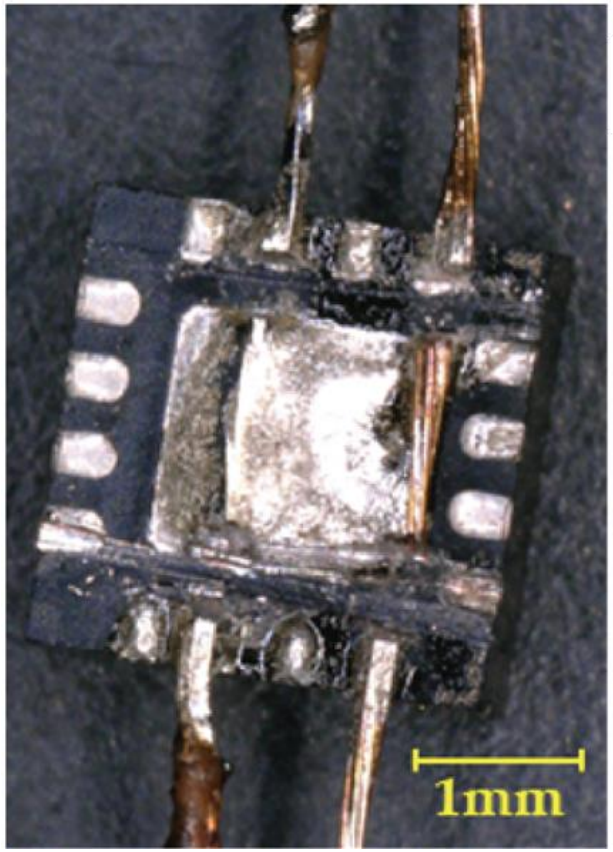




NTU

Vibration sensing E-yarn

Soldered

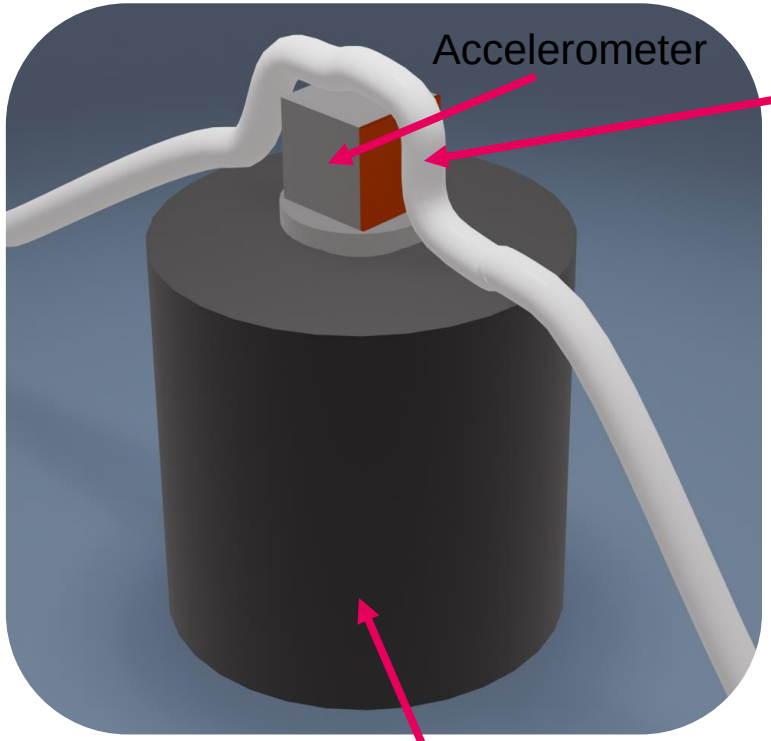


Encapsulated

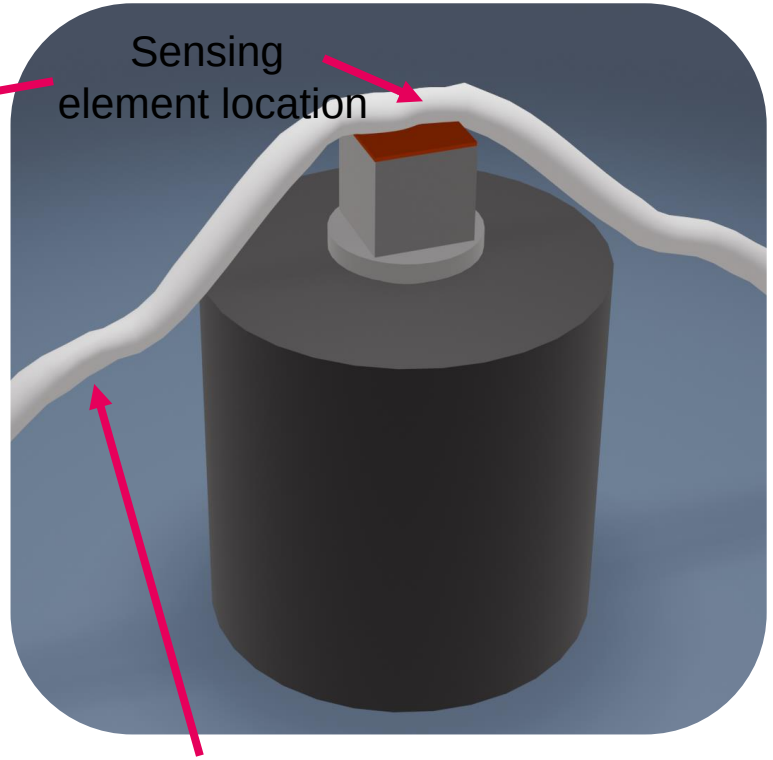
Final E-yarn

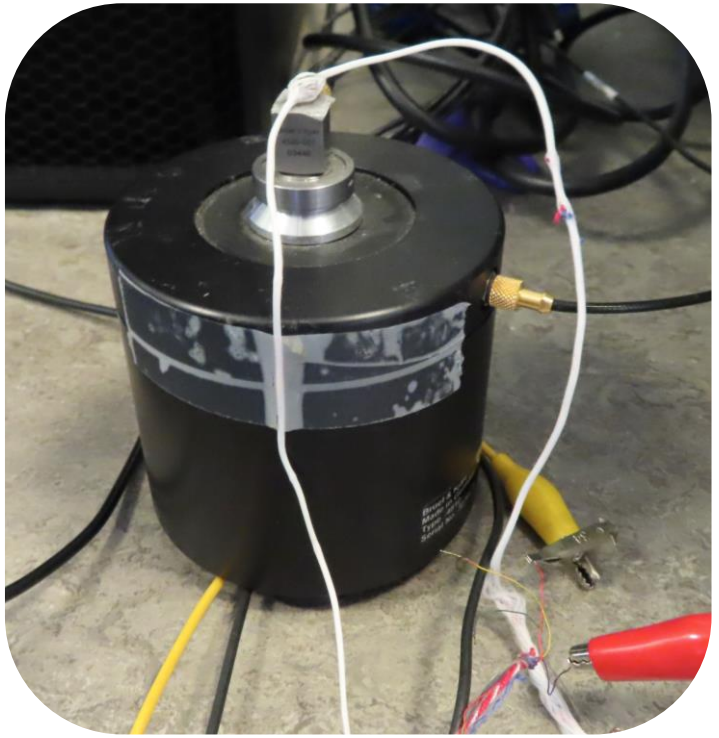
Characterisation of vibration sensing E-yarn

X-axis characterisation

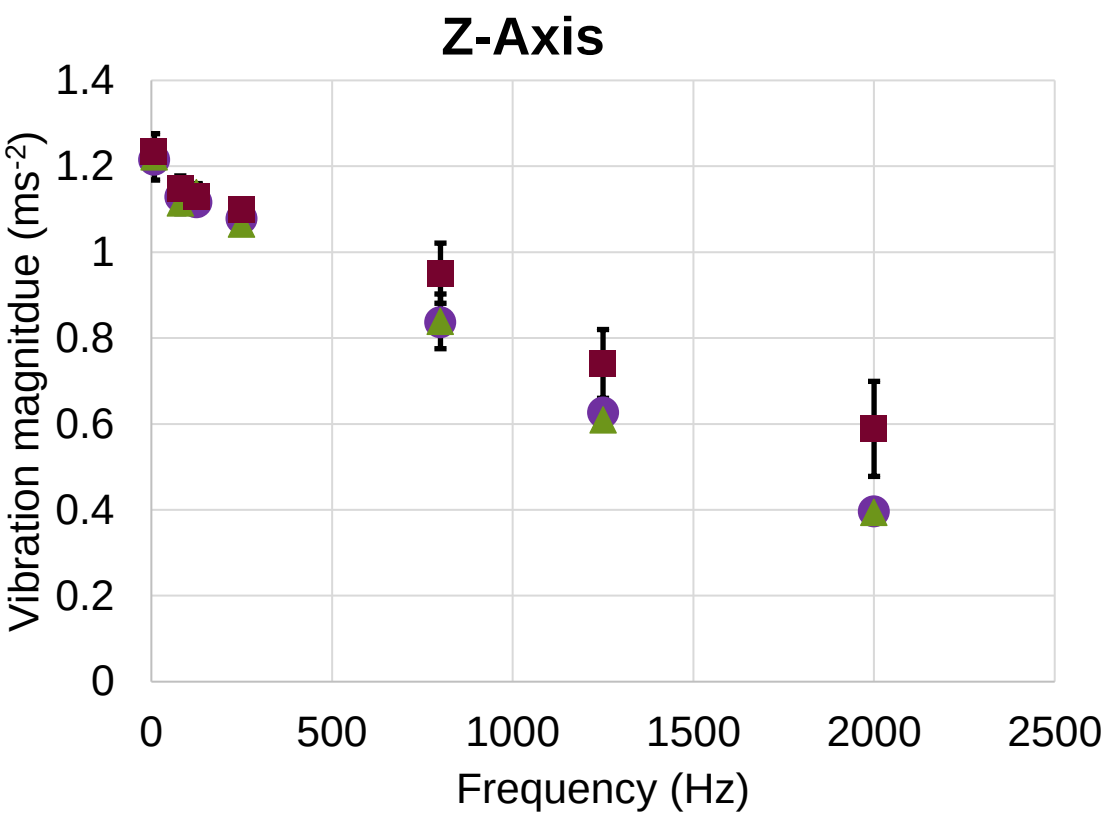


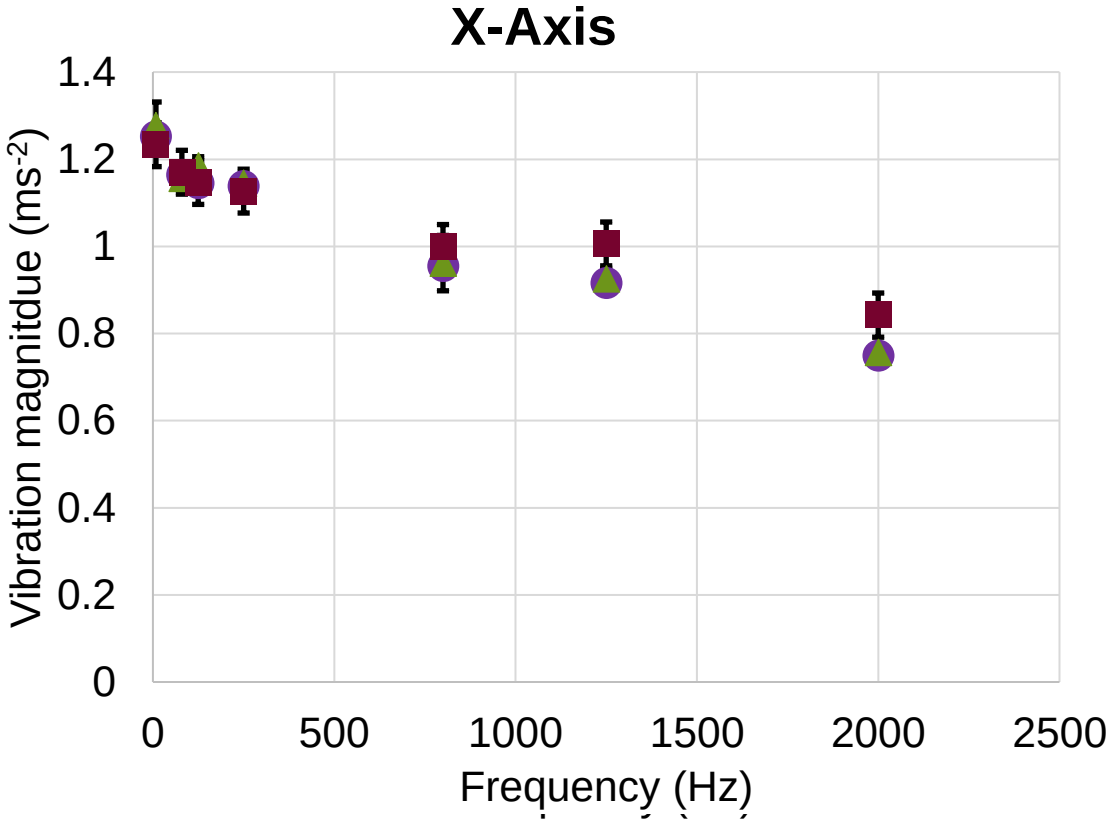
Z-axis characterisation





Frequency response

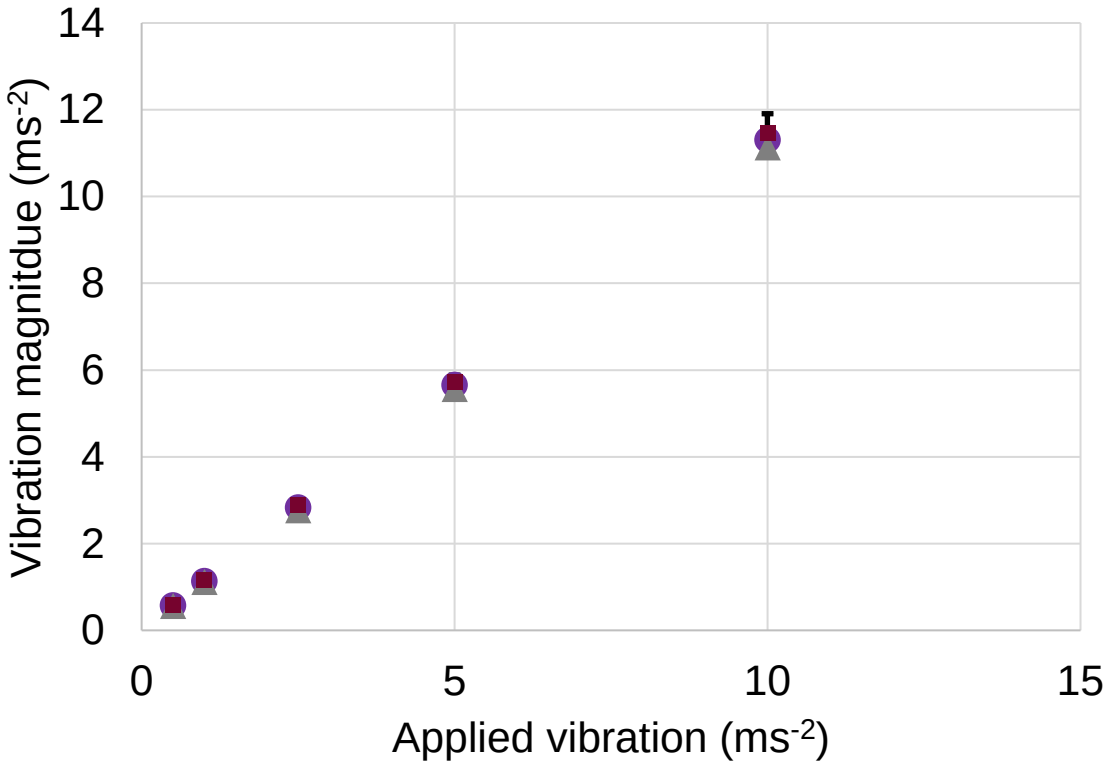


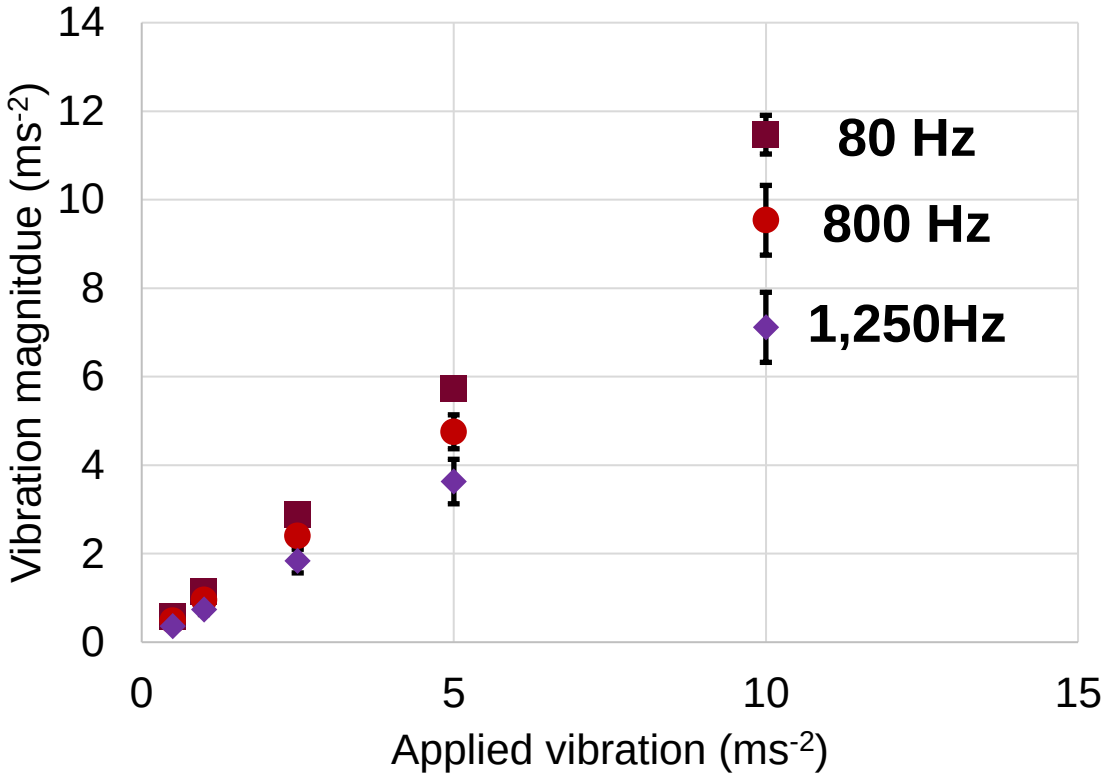


NTU

Rahemtulla, Z., Hughes-Riley, T., Dias, T. Vibration-sensing electronic yarns for the monitoring of hand transmitted vibrations. Sensors. **2021**, *21(8)*, 2780.

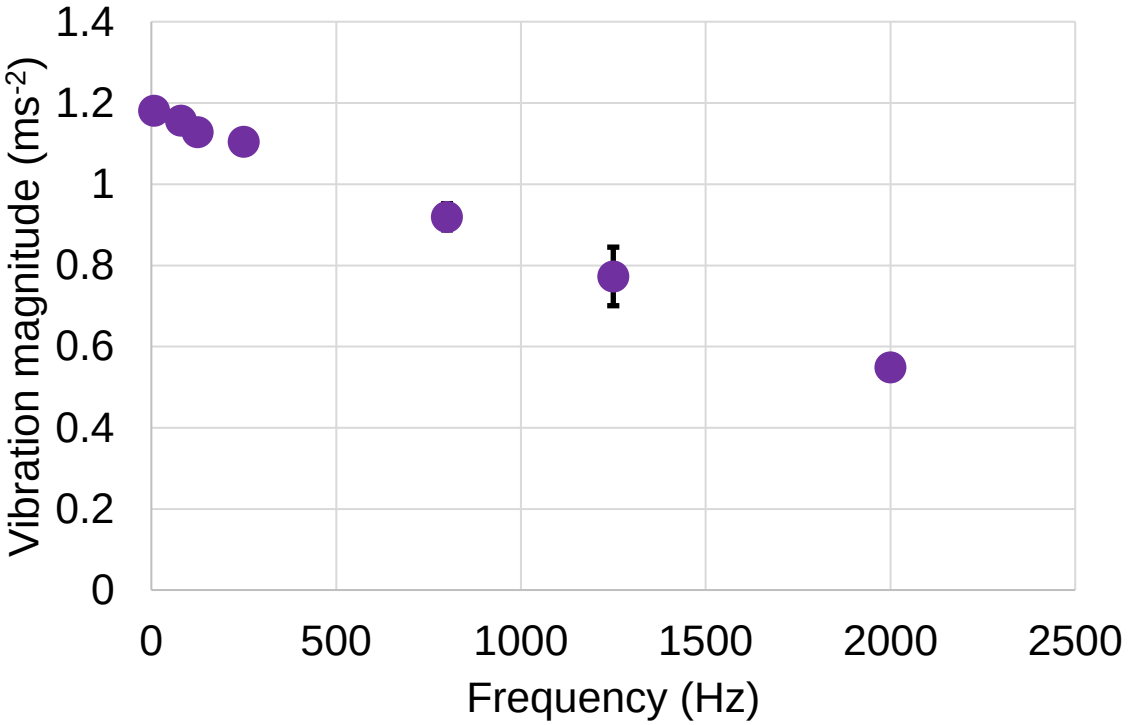
Amplitude response

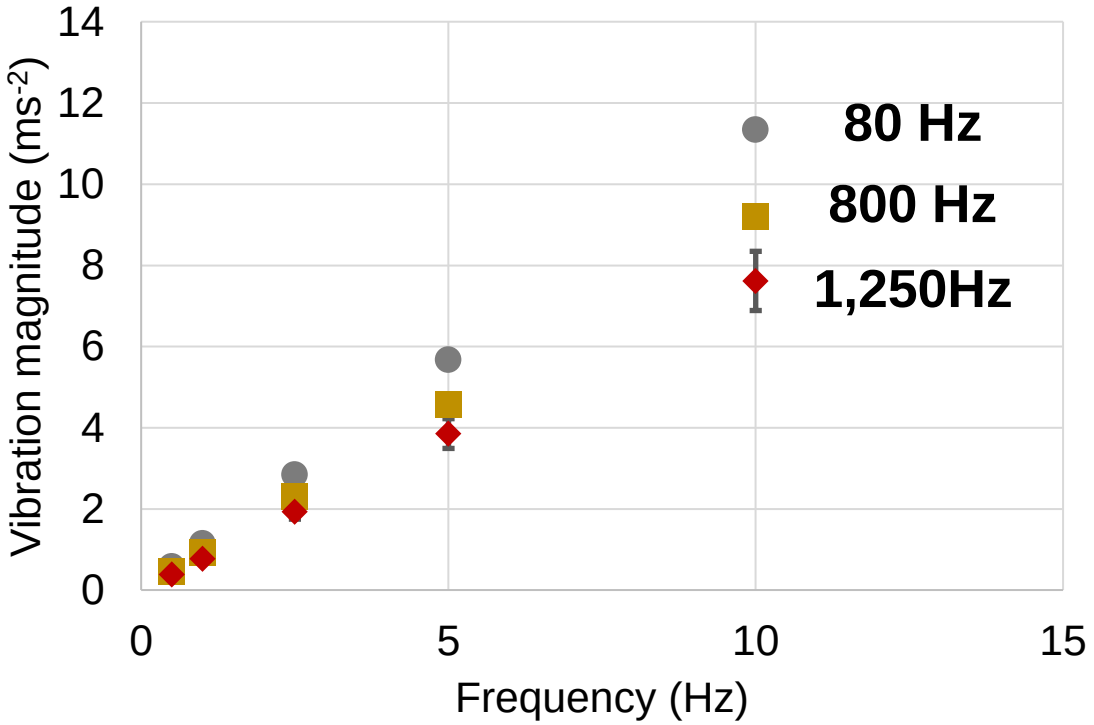




Rahemtulla, Z., Hughes-Riley, T., Dias, T. Vibration-sensing electronic yarns for the monitoring of hand transmitted vibrations. Sensors. **2021**, *21(8)*, 2780.

Fabric embedded E-yarn





NTU

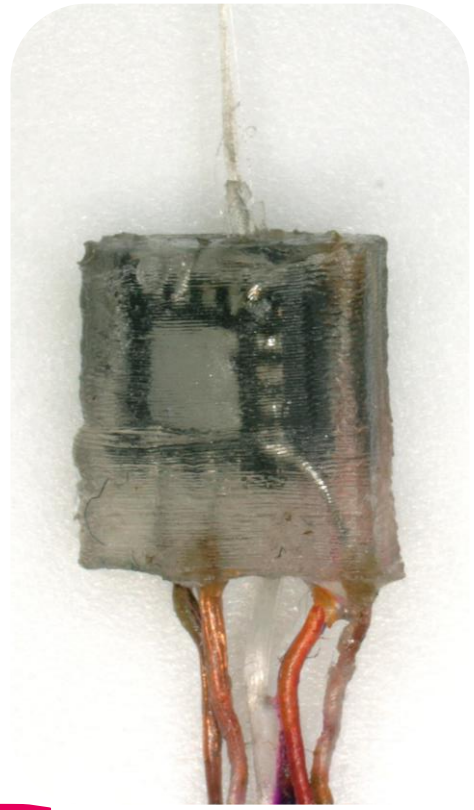
Rahemtulla, Z., Hughes-Riley, T., Dias, T. Vibration-sensing electronic yarns for the monitoring of hand transmitted vibrations. Sensors. **2021**, *21(8)*, 2780.

Vibration sensing glove

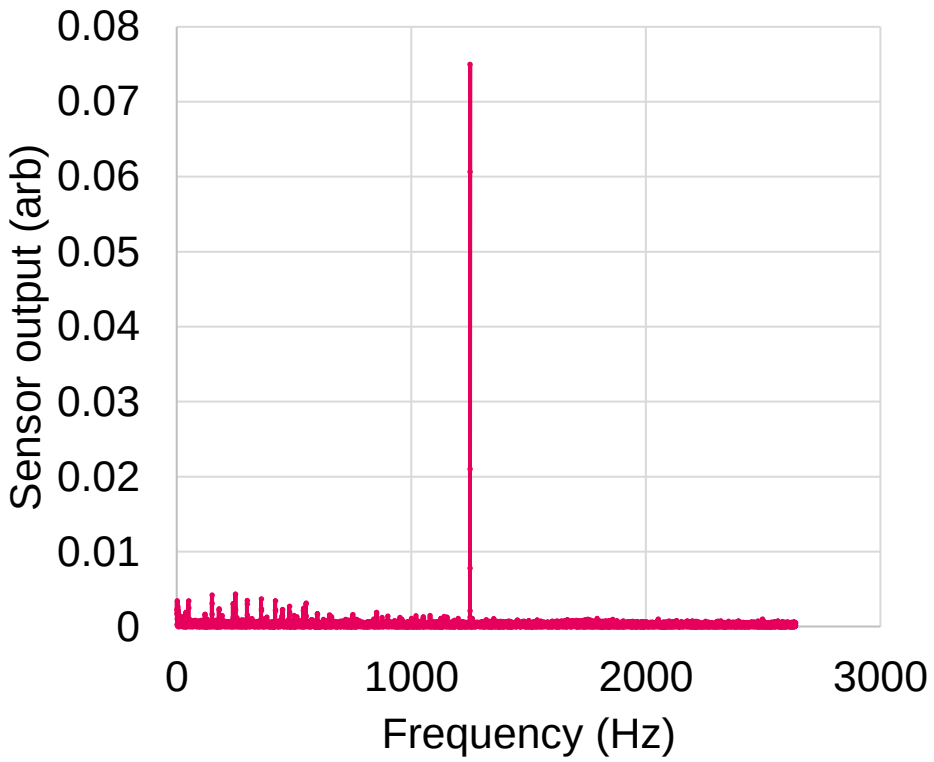
Rahemtulla, Z., Hughes-Riley, T., Dias, T. Vibration-sensing electronic yarns for the monitoring of hand transmitted vibrations. Sensors. **2021**, *21(8)*, 2780.

Refined vibration sensing E-yarn design

Encapsulated



Final E-yarn

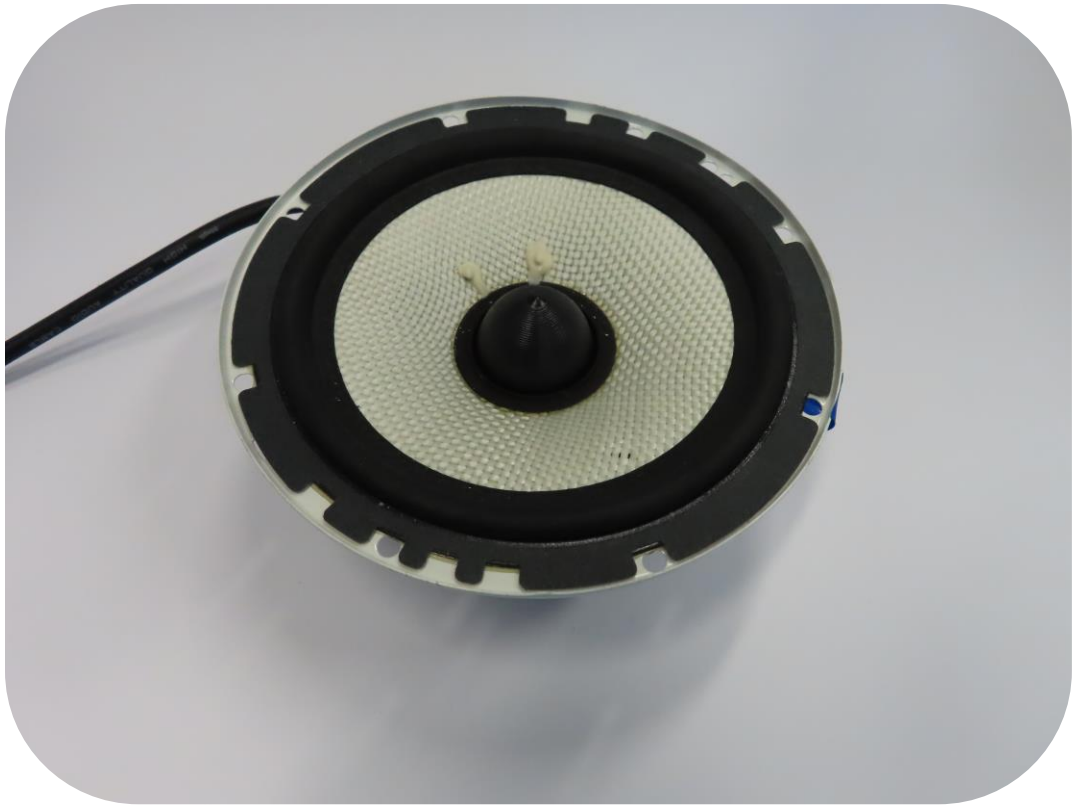


New vibration sensing glove

New vibration sensing glove

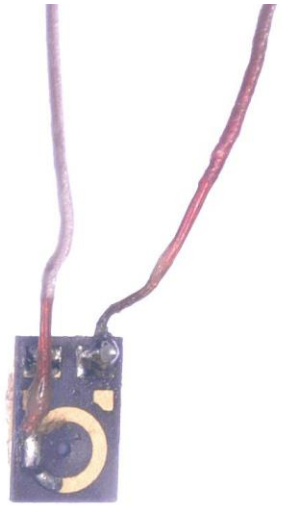
Noise induced hearing loss

- Noise exposure can lead to a variety of disorders including noise-induced hearing loss and tinnitus.
- These injuries can result from overexposure over time or a single acoustic trauma.
- Injury is dependent on the frequency, amplitude, and duration of the sound exposure.



Acoustic sensing electronic yarns

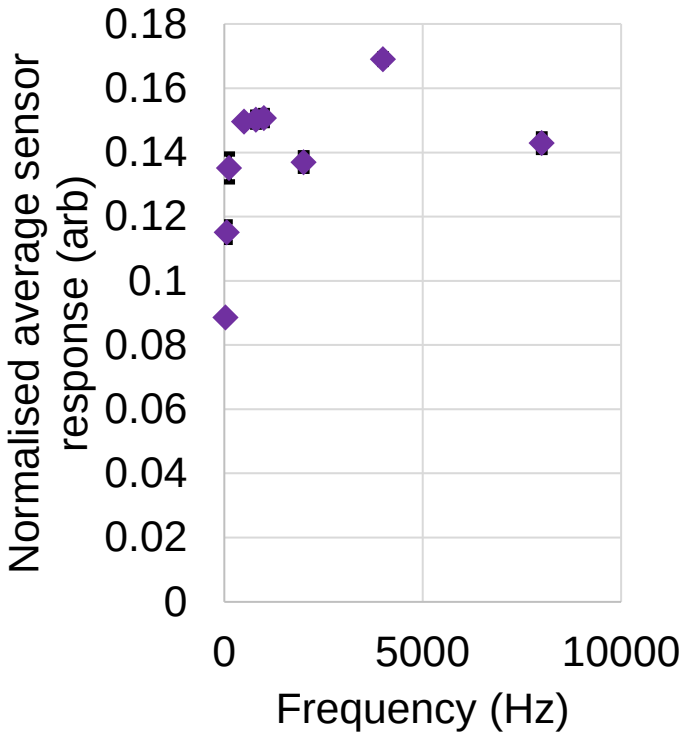
Soldered

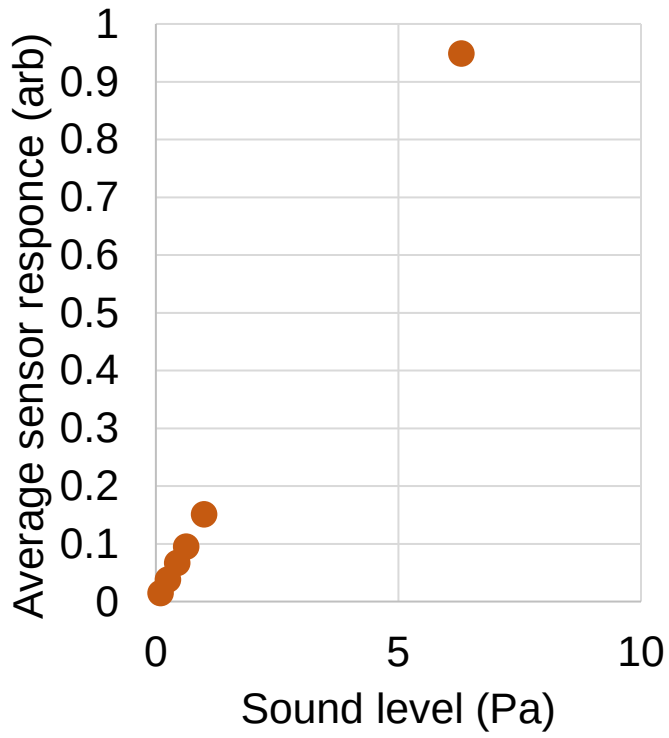


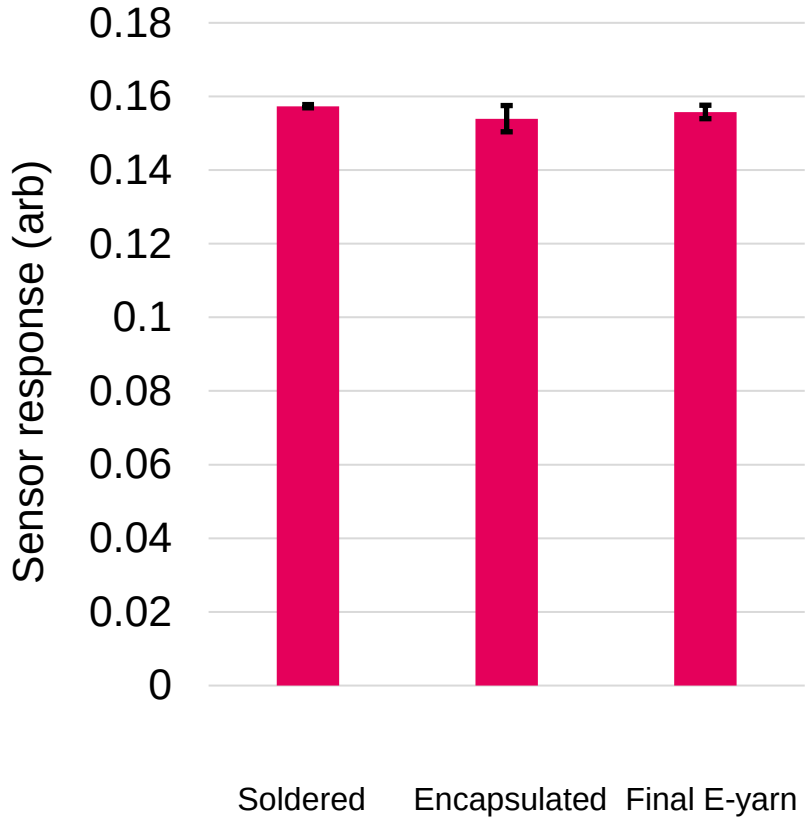
Encapsulated

Final E-yarn

Acoustic sensing electronic yarns characterisation







Acoustic sensing garments

Acoustic sensing helmet cover

Acoustic sensing hat

Hughes-Riley, T., Dias, T. Developing an Acoustic Sensing Yarn for Health Surveillance in a Military Setting. Sensors. **2018**, *18(5)*, 1590.

Summary

- Discussed the issues related to hand transmitted vibration and how this is currently monitored.
- Described the development of a vibration sensing yarn and glove.
- Detailed an acoustic sensing textile for the monitoring of noise exposure.

Acknowledgements

- This research was funded by the Engineering and Physical Sciences Research Council (EPSRC) grant EP/T001313/1, entitled ‘Production engineering research for the manufacture of novel electronically functional yarns (E-yarn) for multifunctional smart textiles’.
- Early work on the vibration sensing E-yarn received funding from the Nottingham Trent University Health and Wellbeing Proof of Concept Fund for providing funding towards this research.
- The original acoustic sensing E-yarn research was funded via the Defence & Security Accelerator Open Call for Innovation, via the Defence Science & Technology Laboratory (under contract number DSTLX1000114952).
- The authors would like to thank Dr Arash Shahidi, Dr Richard Arm, and Parvin Ebrahimi for their contributions to this work.

NTU