H2020-MSCA-ITN-2019

Innovative Training Networks (ITN)

INTUITIVE

INnovative Network for Training in ToUch InteracTIVE Interfaces

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Deliverable number	**D2.3**
Title	First prototype of tactile transducer for use in rodents
Workpackage	2
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Deliverable Lead Beneficiary	Actronika
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Nature	Report

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Dissemination Level

PU	Public	**X**
CO	Confidential, only for members of the consortium (including the Commission Services)	

Executive Summary	This deliverable describes a tactile transducer able to support chronic electrophysiological recordings of the somatosensory system in rodents.

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1 Objective

Deliverable D2.3 concerns the design and realisation of a tactile transducer for use with rodents. The transducer should meet the overall requirement of a sufficiently flat frequency response and repeatable performance needed for performing well-controlled chronic electrophysiolocal neural recordings over extended periods of time. Other objectives included the provision of an interchangeable interface that could, for example, be made of a transparent material to enable the viewing and the imaging of the contact surface between a rodent's paw and the active surface.

Interaction with the INTUITIVE partner Neural Basis of Sensorimotor Control laboratory at Lund University arrived at the following specifications.

1. Overall dimensions as described by Fig. 1.
2. Bandwidth from 50 Hz to 500 Hz.
3. Displacements up to 100 µm.
4. Low level of vibrations transmission to the table on which the device is to be mounted.
5. Ability to support significant normal load, viz. 1.0 N, without significant loss of performance.

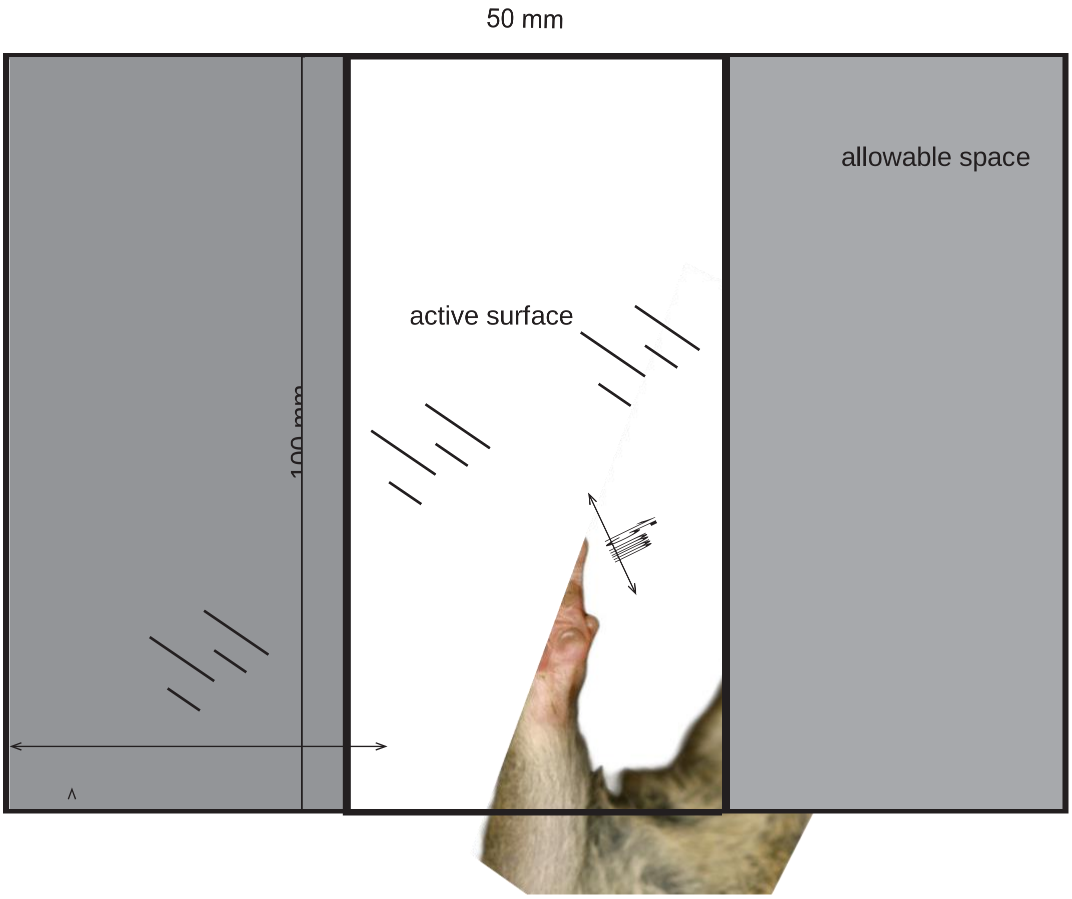

Figure 1: Overall dimensions of tactile stimulator.

2 Method

The design called for a four leaf-spring suspension which is known to be able to provide for guidance with controlled elasticity along one axial direction, say x, and to be stiff in the other two directions. The stiffness of such suspension can be tuned by adjusting the length, A, the thickness, B, and the width, C, of the leafs.

Two alternatives for the architecture of such suspension are shown in schematic form in Fig. 2. From beam theory, if E is the elastic modulus of the material, for small displacements the stiffness is, $K_x = 4E(CB^3/A^3)$ and $K_y = 4E(CB/A)$, which means that if, $A \gg B$, the suspension can be much stiffer along x than along y since $K_y/K_x = (A/B)^2$.

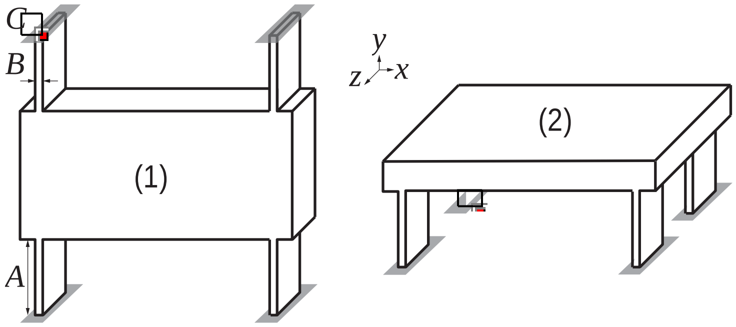

Figure 2: Two alternatives for a four-leaf suspension.

Alternative (1) has the property that the suspension stiffens when displacements become larger. In the present application, it is not a problem since the targeted displacements are small. It may even be viewed as an advantage by preventing excessive displacements. Alternative (2) does not have this property and has the disadvantage that axial displacements are coupled with out-of-plane displacements. Alternative (1) was therefore selected for implementation.

Actronika's patented modular actuators, see [1], were ideally suited to serve as prime-movers. Because of their high aspect ratio they could conveniently be placed to minimise out-of-plane efforts. Figure 3 shows their principle of operation. One module is a Halbach magnet array which, in this case, creates three regions of quasi-uniform magnetic field regions. The other module is a set of two counter-oriented flat coils. Actuation is effected by arranging the coils to interfere with the magnet in order to create a mutual force of Laplace between the two modules.

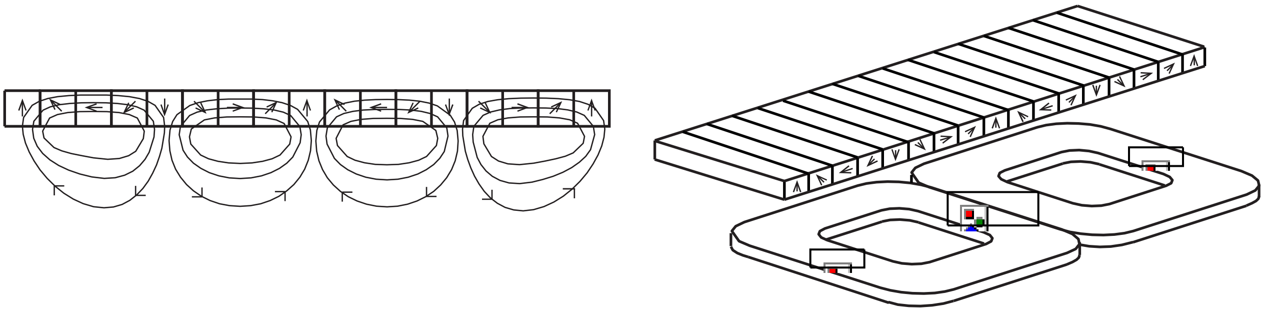

Figure 3: Actronika's patented modular actuator architecture. Left: Halbach magnet array creating three high-concentration magnetic field regions. Magnet array interacting with coil array.

It was found that the most convenient arrangement was to attach the magnet array to the active surface. This way there is no need to route the actuator wires to any moving parts. In addition owing the the high output of these actuators, there is little need to minimise the inertia of the active surface which carries the additional advantage of lowering the system's natural frequency.

3 Realisation

The realisation, see Fig. 4, is completely modular and can be easily reconfigured as any need may arise. The active surface is presently made of Polmethyl methacrylate (PMMA), also known under the trade names of Plexiglas, Perspex, Lucite, etc. For example, the active surface easily be extended on one side to accommodate experimental constraints and/or different preparations.

Connecting parts are 3D printed and reinforced with fastener inserts. In any future revision they could be machined or moulded.

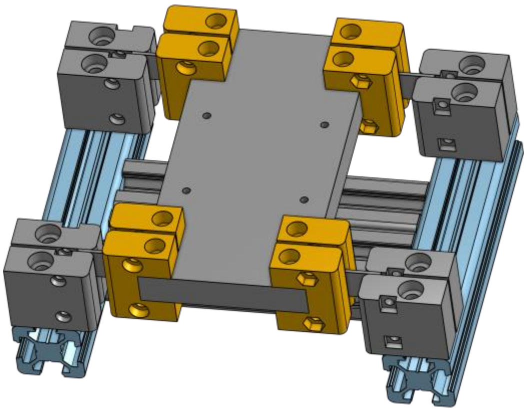

Figure 4: Modular realisation of the tactile transducer.

Figure 5 shows the two high-aspect ratio actuator modules. Figure 6 shows the assembled tactile transducer that was realised and delivered to Lund University, Neural Basis of Sensorimotor Control laboratory in March 2021.

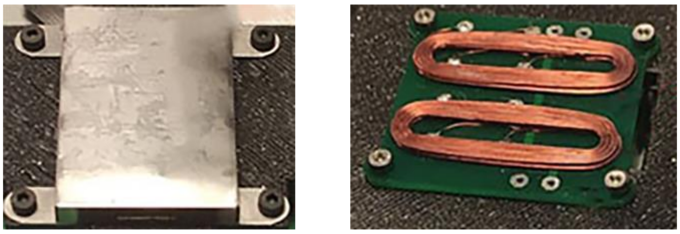

Figure 5: Actuator modular realisation.

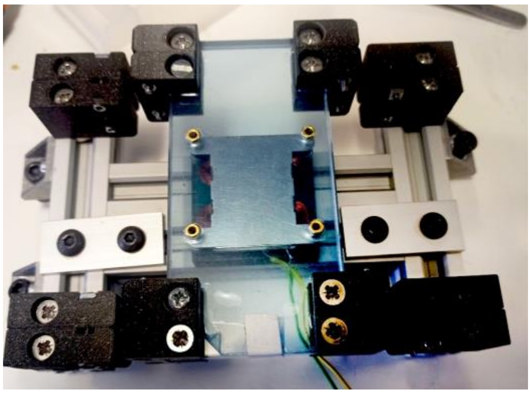

Figure 6: Modular realisation of the tactile transducer.

4 Results

Figure 7 reports the system’s acceleration response to sinusoidal inputs. The response is thus within specifications.

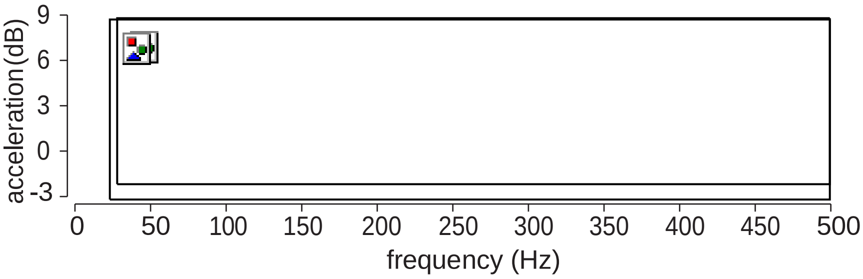

Figure 7: Transducer response.

The modular design makes this transducer a useful laboratory instrument able to support electrophysiolocal neural recordings experiments with rodents.

5 Commisionning

The apparatus was delivered at the partner’s facility, the Neural Basis of Sensorimotor Control Laboratory of the Department of Experimental Medical Science at Lund University. Commissioning included the development of appropriate drive electronics and methods for synchronisation and time stamping with neural recordings.

6 Preliminary Data

Figure 10 shows examples of evoked individual neurone esponses to brief stimuli localised in time. The data demonstrate the important neuronal coding principle of diversity. Here the response of two neurones to three different stimuli where the first two differ by only subtle differences. It may be observed that neurone 1 encodes the time of occurence of the stimulation while being relatively insensitive to its temporal properties. In contrast neurone 2 exhibits a sustained response not localised in time but is highly sensitive to its temporal properties.

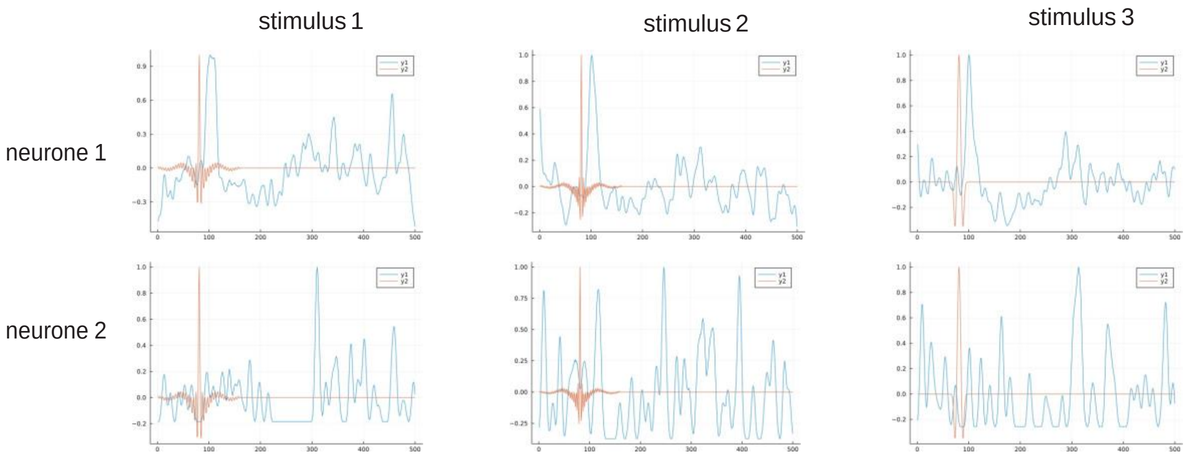

Figure 10: Neuronal diversity.

Figure 11 shows how identification performance increases with the number of neurones as a result of the application of the diversity principle. An ensemble of 40 neurones is sufficient to represent this this particular stimulus space made of brief temporal tactile events.

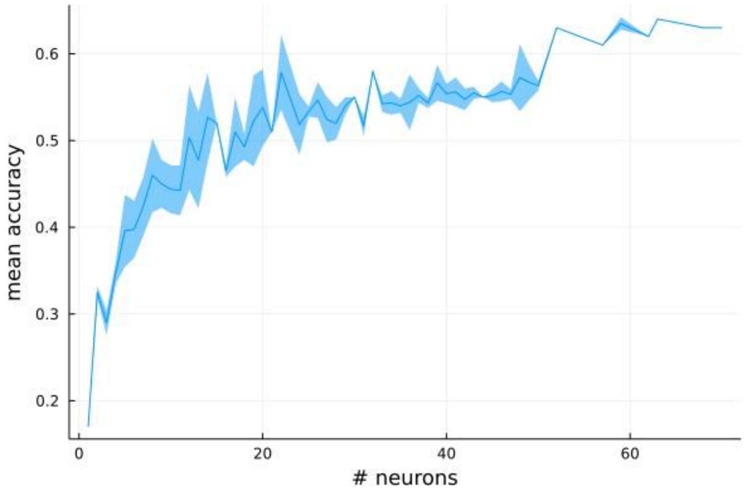

Figure 11: Neuronal convergence.

References

[1] V. Hayward, P. Comot, and R. Pijewski. Vibrotactile actuator. Patent, WO-2019008021-A1, 2019. 4