
CHRONIC PAIN
NEUROTECHNOLOGY
NETWORK+
Annual Report 2024

Contents

Summary

The Chronic Pain Neurotechnology Network+ (CPNN+) was launched in October 2022 to establish a UK network focused on responsible innovation. It was funded by the EPSRC for a period of three years. Our primary aim is to build capacity for the development of novel technologies to treat the chronic pain across the spectrum of patients and chronic pain subtypes. We aim to provide infrastructure support for a diverse and inclusive community of UK researchers, especially early career researchers, seeding new ideas and collaborations, and gaining visibility for this area of research across the broader UK and global landscape.

Scientifically, our emphasis is understanding how to put together current and future available technologies to build working therapeutic systems that can transform the management of chronic pain. The network includes feasibility studies that aim to lay the groundwork for future substantive research programs.

This annual report reflects back on our second year. In terms of capacity building, we've now fully established our lecture course, which has seen fantastic numbers of participants and had excellent feedback. We've held our second practical workshop, focused on non-invasive stimulation, in Exeter; also with great feedback. We've launched a number of PPI projects through our funding scheme. Our mentorship network has been supporting a diverse group of early career researchers. We've set up new PPI panels and have embarking on a major artistic project to explore the lived reality of chronic pain.

In terms of scientific work, our feasibility projects are all underway and progressing according to plan. These have led to new collaborations and follow-on funding, and this new funding has now far exceeded the initial award. The team is also working on a comprehensive overview of the field as our key legacy publication. Finally, our vision of where we will go after the end of the funding period is taking shape, in terms of the foundations we have built, continuation of the networks established, and through the next generation of early career researchers we have supported.

Chronic Pain Lecture Course

The lecture course ran from October 2023 until July 2024, and continues as a stand-alone course. The final list of lectures is as follows:

Basic science 17.10.23 – 07.11.23

- Introduction to the pain system
- Brain mechanisms: descending control and pharmacology – What the brain tells the spinal cord
- Brain mechanisms: motivation and learning
- Brain mechanisms: sensory processing

Core Technologies 14.11.23 – 19.03.24

- Foundations and applications of transcranial direct current stimulation (tDCS) in pain research
- Brain monitoring: An introduction to EEG technology
- Neurofeedback
- Virtual Reality: A Novel Immersive Technology in the Study and Management of Chronic Pain
- EEG biomarkers and applications of machine learning
- Non-invasive brain stimulation II
- Deep brain and spinal cord stimulation to treat chronic pain
- Transcutaneous Electrical Nerve Stimulation for the Relief of Pain
- Non-invasive brain stimulation with ultrasound III
- Developing fMRI-based biomarkers of pain: Promises and challenges
- Model Based CBT
- Emerging Neuromodulation Modalities
- Embodied Technology: To be (biomimetic) or not to be?
- Collecting pain and other symptoms in daily life- intensive longitudinal methods
- Manufacturing Electrodes for Neurostimulation
- Functional electrical stimulation (FES) & Motor Rehabilitation

Clinical Translation 23.04.24 – 11.06.24

- Chronic pain mechanisms – from models to patients

- Potential of game platforms as a tool for monitoring motor performance, pain and fatigue
- Precision rehabilitation and pain
- Physiologic control systems for the treatment of chronic pain
- Closed-loop DBS for Movement Disorders
- Patient and clinician opinions regarding the use of technology to support healthcare delivery – can it help technology development?
- Spinal injury
- Clinical Device Trials in Chronic Pain: the EPIONE trial

The course is now available as a stand-alone course, as all lectures are now online and accessible, and we have a steady stream of new enrolments.

Number of people signed-up: **512**

Number of people currently completing: **394**

Number of people who have completed the entire course: **35**

Those that complete the course and pass all the assessment quizzes receive the CPD-accredited certificate:


CHRONIC PAIN NEUROTECHNOLOGY NETWORK+
Responsible research and innovation

CERTIFICATE
OF
CONTINUING PROFESSIONAL DEVELOPMENT

The CPD Certification Service certifies that

Name will automatically be inserted here

the above named has participated in the following CPD activity

Chronic Pain Neurotechnology Network online course

CPD Provider Organisation

CPNN+

An initiative to increase standards of CPD provision to professionals in relevant market sectors.

Date of CPD Activity:

Number of CPD hours/credits: 21

CPD CERTIFIED

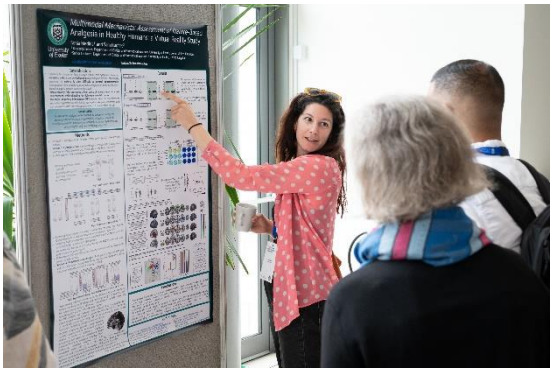
Feedback (35 responses)

- Did you find this course was easy to fit within your schedule? 34/35 said yes
- Was the Canvas platform easy to use? 35/35 said yes
- Were you satisfied with the scientific content of the course? 35/35 said yes
- Were you satisfied with the format of the course? 35/35 said yes
- Did your progress through the course make sense? 35/35 said yes
- In general, would you say that you were satisfied by the overall quality of the course? 32/35 said agree or strongly agree
- Do you feel more positively about pain/technology having now completed the course? 33/35 said agree or strongly agree
- Having completed the course, has it changed your perspective on pain and/or technology? 32/35 said agree or strongly agree
- Has the course changed your knowledge, practice and/or teaching? 33/35 said agree or strongly agree
- Would you say that the quizzes were useful to you? 30/35 said agree or strongly agree

Exeter Neurotechnology and Pain Workshop (July 2024)

The CPNN+ Neurotechnology & Pain Workshop, hosted at the University of Exeter, offered a platform for knowledge-sharing and collaboration with networking opportunities throughout. This two-day event featured a varied agenda, including keynote talks, interactive workshops, poster sessions, and social/networking events, which collectively fostered engagement among early-career researchers, established experts, and industry partners.

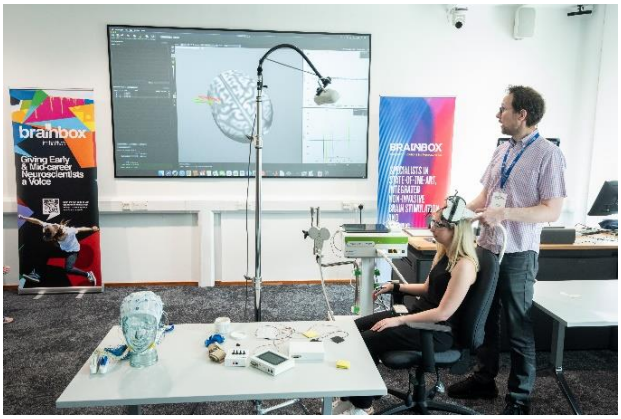
The structured program facilitated networking throughout. Morning sessions included a keynote address by Professors Thomas Graven-Nielsen from Aalborg University, Denmark. Lunchtime poster sessions encouraged informal networking as participants presented their latest research.



Poster prize winners included Danielle Hewitt for her study on pain anticipation using VR, Sonia Medina for work on nature-based analgesia, and Bhushan Thakkar for research into corticomotor excitability in neuropathic pain.

In the evening, we organised a dinner at Reed Hall which offered a relaxed setting for networking. This event enabled participants to deepen connections established during the day, discuss collaborative opportunities, and share experiences in a more informal environment. These moments were pivotal in building a sense of community among attendees and laying the groundwork for future interdisciplinary projects.

The interactive workshops, such as hands-on TMS and TUS sessions supported by BrainBox and Prof Elsa Fouragnan from the University of Plymouth, further facilitated networking by allowing participants to work closely in small groups. These practical sessions encouraged peer learning and created an environment conducive to collaboration on future projects.



Feedback

All scores were rated out of 10 (10 – excellent - 1 poor). Please see the average score provided below for each question asked. How would you rate:	
1. The overall scope of the morning talk topics covered	8.8
2. The overall quality of the morning talks	8.9
3. The scope of material covered in the afternoon practical sessions (if attended)	8.7
4. The quality of the afternoon practical sessions	8.8
5. The standard of the accommodation (if staying)	8.4
6. The quality of the meeting venue	9.4
7. The quality of the workshop dinner (if attended)	9.4
8. How did you find the overall workshop organisation?	9.6
9. Do you feel you had a good chance to meet and network with colleagues?	9.6
10. Please let us know the best things about the workshop	Variety of topics, relaxed atmosphere, networking
11. Please let us know anything you think could be improved	Providing handouts of slide presentations (if speakers allow them). Maybe a few more talks from ECRs on ongoing research studies.
12. Can you give an overall evaluation for the workshop as a whole?	9.3

Feasibility Studies

Impact of tonic pain on the modulation of the nociceptive withdrawal reflex (NWR) through the gait cycle in healthy individuals (University of Cardiff and Exeter).

Figure 1Treadmill training success at the University of Hertfordshire

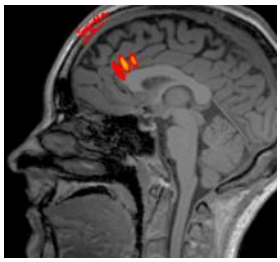
Dr Jo Reeves was recruited to the post doc position in July and shortly afterwards completing training at the University of Hertfordshire to become a certified operator of the MOTEK GRAIL system, which includes the treadmill which is integral to the project. We have received ethical approval for the study: Impact of tonic pain on the modulation of the nociceptive withdrawal reflex (NWR) through the gait cycle in healthy individuals. The original plan was to mimic tonic pain through a cold gel stimulus. However, during piloting with different consistencies of gel mixtures we found the pain disappeared after the hand is removed from the gel and as it would not be suitable for the hand to be in the gel while walking, pain would not be present during walking trials. We are now trialling a cold therapy glove that is cooled in the freezer as an alternative, as this can be worn during walking. Preliminary testing would indicate the pain from the glove lasts around 10 minutes. We have piloted eliciting the NWR with electrical stimulation in sitting and have developed an analysis programme to determine in post processing if the z-score threshold from the literature has been reached. We are now exploring some technical solutions to be able to achieve this in real time, to then be able to apply the correct level of stimulation in walking. We aim to design and implement methods to evaluate NWR threshold by the end of December 2024 and establish the feasibility of quantifying the modulation of the nociceptive withdrawal reflex throughout the gait cycle, and the effect of tonic pain on this modulation by the end of January 2025. We aim to conduct the study including administrative tasks associated with the research project by March 2025.

Mapping the brain circuit of pain modulation with transcranial ultrasound stimulation (TUS) (University of Exeter)

This study is being conducted at the Brain research and Imaging Centre (BRIC) at the University of Plymouth by Dr Sophie Clarke, Samuel Mugglestone, Dr Sam Hughes and Dr Elsa Fouragnan. It aims to investigate the effects of neuromodulation by transcranial ultrasound (TUS) on pain

processing in healthy human participants. The TUS (or sham stimulation) is applied to the dorsal anterior cingulate cortex (dACC) during a tonic cold pain stimulus, followed by functional magnetic resonance (fMRI) during the same cold pain stimulus to investigate the effects of the stimulation on pain responses. Data collection is ongoing and is planned to be completed in January 2025 after which full analysis will be completed.

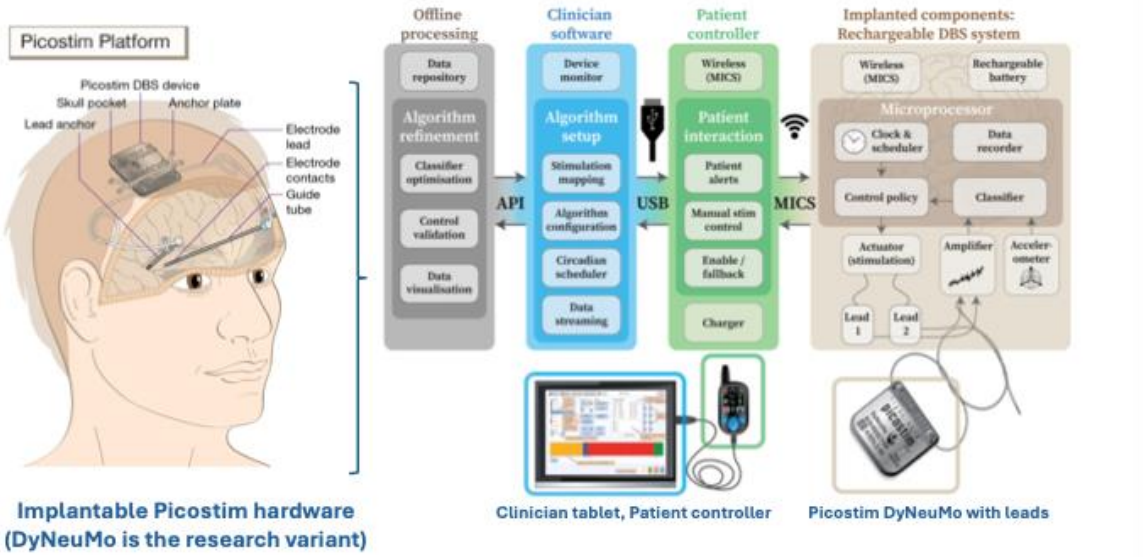
Data collected includes cuff-pressure algometry measures of pain thresholds, conditioned pain modulation (CPM) and temporal summation of pain (TSP) measures both pre-TUS and post-TUS, as well as participant reported pain ratings for the cold stimulus at three timepoints. Neuroimaging data collected includes fMRI blocks both at rest and during a cold stimulus, as well as magnetic resonance spectroscopy (MRS) data also during a cold stimulus. Data analysis will focus on comparing responses following the real TUS compared to sham TUS to elucidate the neuromodulatory effects of TUS on pain processing. We will explore changes in functional connectivity between the dACC target region and other brain regions involved in pain responses.



Integrated systems for intracranial recordings, neurofeedback and virtual reality (University of Oxford, University of Glasgow).

The aim of this study is to design and integrate a novel virtual reality game for neurofeedback with intracranial recordings from patients with chronic pain. This requires the development of neurofeedback algorithms using biomarkers for chronic pain, as well as a co-designed neurofeedback game that can be integrated with signal processing from both invasive (local field potentials from deep brain stimulation) and non-invasive (EEG) recordings.

Dr. Tory Marks received an OH-BRC Pain Pump Priming (P3) award, which allowed us to gather initial feedback from people with lived experience on their perceptions of neurofeedback and the feasibility of virtual reality games, as well as on specific study designs and the comprehensiveness of study documents.



Work carried out by an undergraduate summer intern, Anyu Shan, resulted in the development of a novel virtual-reality based neurofeedback game whereby the goal is to control one's physiological signal of interest to make flowers grow (Figure 1). Anyu was able to develop a prototype that is suitable for integration with any physiological signal (EEG, LFP, EMG etc.) and adjusts the growth rate of the flower based on a modifiable algorithm threshold. This algorithm filters the input signal and calibrates the threshold for flower growth based on the patient's resting data.

Figure 1. Snapshots of the virtual reality world for new neurofeedback game. Patients resting state signals are first calibrated to determine the threshold at which the flower will begin to start or stop growing. Patients will then try to control their brain signals to make the flowers grow.

In our second phase of co-design, Dr. Marks and Dr. Crockett have received further funding to gain user feedback on the game itself and the feasibility of the study protocol from hands-on visits from patients with chronic pain. The next phase of development will be to use neurophysiological recordings from chronic pain patients to identify the appropriate algorithms and thresholds for effective game control. This will allow the intracranial signals streamed into the game to be interpretable for the patients as they seek to gain control over the brain signals that may be causing their pain.

Neurofeedback for Nociplastic Pain in Rheumatoid Arthritis: A Pilot Study (University of Glasgow)

Prof. Aleksandra Vuckovic

Study aim: To evaluate the effectiveness of 10 sessions of neurofeedback (NF) on nociplastic pain in people with Rheumatoid Arthritis (RA).

Background: Rheumatoid arthritis pain is considered to have inflammatory origin, yet pain commonly persists after complete alleviation of inflammation. The residual pain could be fibromyalgia, a type of nociplastic pain. Literature shows fibromyalgia can be treated by neurofeedback (NF), a non-invasive method that is based on the voluntary modulation of brain activity. This pilot study tests the effect of NF on nociplastic pain in rheumatoid arthritis and investigates its effects on comorbidities such as fatigue and sleep disturbance.

Methods: The intervention consists of 10 sessions of NF, across approximately 5 weeks. Pain is measured by the American College of Rheumatology Fibromyalgia (ACR-FM) Scale before and after the intervention, by a 10-point visual analogue scale (VAS), before and after each session, and at a follow-up assessment one month after the last intervention session. Participants rate from 0 to 10 their pain, fatigue, depression and sleep disruption in a diary throughout the study. We consider the intervention to be effective if pain reduction on the pain VAS, diary and ACR-FM occurs concurrently with voluntarily modulation of brain activity.

Progress: To date, 23 participants were approached, six met the inclusion criteria and agreed to take part, five were recruited; of these, two completed the study and three are under treatment. All three participants who completed more than 50% of the intervention sessions modulated brain activity as required, in at least two sessions. Two reported pain reduction from 8 to 5, and from 7 to 4, respectively, in the post-NF pain VAS, and in the diary. One patient's reported fatigue decreased from 8 to 5 throughout the study. At follow-up, one of two participants reported lower pain levels compared to pre-study, although this was not reflected in the pain rating. One participant did not report any change in pain, fatigue, sleep disruption or depression.

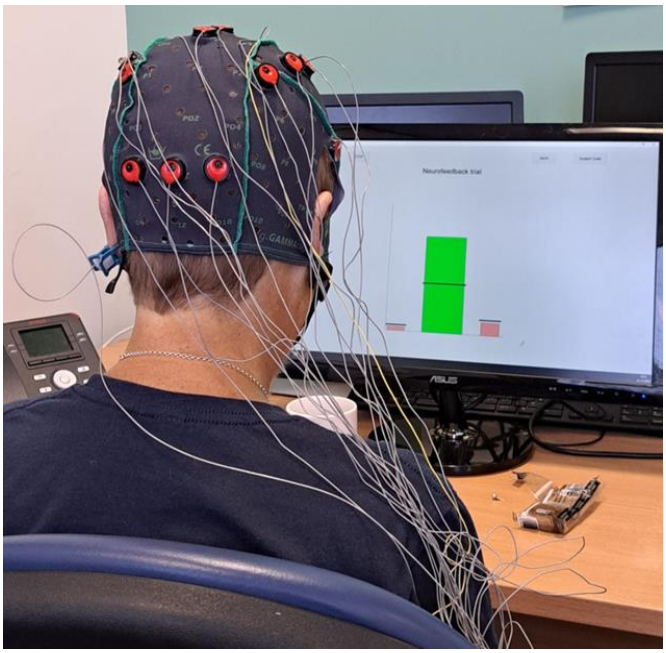


Figure 2 One participant attempting voluntary modulation of brain activity (neurofeedback). The central bar on the computer screen is green when the participant's brain activity over the sensorimotor cortex is above their resting state level.

NeuroMotion: Precision rehabilitation for people living with post-stroke pain.

The NeuroMotion project focuses on developing an advanced digital health platform that aims to manage pain for stroke survivors through real-time assessment and personalised interventions. Pain is a common and debilitating issue among stroke survivors, often stemming from both musculoskeletal and or central origins. Accurate pain management is essential for promoting rehabilitation, yet current methods often lack the precision and adaptability required for this complex patient group.

NeuroMotion leverages state-of-the-art motion capture technology combined with AI-driven analysis to monitor pain and movement continuously. This enables the platform to provide personalised exercise interventions specifically designed to alleviate pain and enhance mobility in stroke survivors. While exercise and improved movement quality are crucial for pain relief, movement itself can sometimes exacerbate pain, the game platform aims to identify in real time the optimal balance where therapeutic exercises are most effective without causing additional discomfort. The core innovation of the platform lies in its ability to detect subtle variations in movement and pain response, allowing for targeted pain management that adapts to each patient's needs, delivered through engaging and accessible games with standardised processes that are cost-effective and highly scalable.

The project encompasses two primary work packages: co-development of the gamified pain relief program, a validation study to assess the platform's effectiveness,. This comprehensive approach ensures that the system is tailored to meet the unique challenges of stroke survivors, ultimately improving their rehabilitation outcomes and quality of life.

Figure 3 Prof. Helen Dawes with a participant

Figure 4 VR lab

Mentorship Network

This year we launched our national mentorship network, adopting a model developed by the R4N Network+. We disseminated an offer through the network to ECRs, and all co-I's engaged in offering mentorship, which was allocated through a matching process. Overall, we have been mentoring 10 ECRs (female: x) over the year, and feedback from all co-Is was that this was felt to be a helpful and valuable process. In November we also sought simple feedback from the mentees:

Value 3 responses received so far – all 'definitely agree'

Changed decisions – 3 responses received so far – 'definitely agree', 'definitely agree' & 'neutral'

Hopefully some comments too.- 3 responses received so far

'I really enjoyed my mentorship sessions and would like them to continue beyond a one-year period, if possible. They were extremely useful for me.'

'I had already decided on the 'big' career decisions before starting the mentorship, but the sessions with the mentor helped me think about career-related decisions from a different perspective'.

'A great opportunity to engage in discussions about research topics and career plans with experts'.

Public and patient involvement and engagement

Last year we funded 4 PPI studies, which are now underway. They are:

Mr. Alexander Smith (University of Plymouth).
'Nature-based Analgesia and Chronic Low-Back Pain: A Role for Immersive Virtual Reality?'

Dr. George Tackley & Co-PI: Dr David McGonigle, Cardiff University.
'Exploring the Use of Immersive Virtual Reality (IVR) for the Treatment of Chronic Back Pain (CBP) – Patient perspectives and expectations'.

Dr. Janet Bultitude & co-applicant Ms. Caitlin Naylor, PhD Student, University of Bath.
'Patient-informed development of a personalized virtual reality intervention for body representation distortion and chronic pain'.

Dr. Jordan Tsigarides - University of East Anglia (UEA).
'Creation of a National Co-Development Hub for Therapeutic Digital Health Interventions in Chronic Pain'.

CPNN+ awards four successful applicants - CPNN+

We have also developed our own PPI activates across the various centres, including through working with the Oxford and Exeter BRCs. For example, at Oxford we have now established a PPI panel (6 members with various forms of chronic pain) to provide broad reaching insight and oversight into new projects.

Living with Pain: an ongoing partnership with artist Marysa Dowling.

Background to project

Chronic pain is a dominant manifestation of many chronic medical conditions, and also often occurs without any obvious external cause - as a condition in its own right. Pain resides purely within the subjective experience of the sufferer, it cannot be easily observed or objectively verified by others. Rather, it is a private, self-intimating experience with the potential to cause great disability and suffering. Pain remains poorly understood within neuroscience, and much of our understanding of pain in humans comes from experimental contexts with brief pain stimuli. But these don't capture the persistent, ongoing background pain that chronic pain patients feel. This persistent pain is very different from the sort of pain that we readily associate with an external event, but instead seems to reflect an internal signal that tells us our body is damaged or injured. This pain can have a negative impact on many aspects of thought and emotion – abolishing one's motivation and desires, causing physical and mental exhaustion, and removing the ability to enjoy life. We want to understand this persistent pain, and how it influences people's lives, better. We want to understand how pain shapes the environment they live in; to 'see' how pain affects their home; their daily decisions; how they interact with their friends, family and community. We want to better understand what people do when their pain is bad, and how they continue with their lives in the context of unremitting pain with often little hope of recovery in the near term. We think this is critical both to help shape new neuroscience questions and research, and also to help people with chronic pain to communicate their experience and realise a means of expressing it. By its very nature, however, chronic pain is hard for others to comprehend. Conventional approaches such as an interview across the clinic desk or PPIE panel still struggle to capture the lived reality of chronic pain. We therefore aim to explore a more in- depth approach, partnering with an artist to work with a small group of patients to explore ways of capturing their experience in a way that can be communicated to others through art.

Objectives of our 'Living with Pain' project

- To commission a joint artwork/report, to explore how persistent pain impacts different people and how they interact with their physical and social environment.

- To create a collaborative artwork between chronic pain patients and an artist (Marysa Dowling) that explores how persistent pain impacts sufferers and how they interact with their physical and social environment. This PPIE project will not only provide art that will give valuable insight into the suffering caused by chronic pain but will also provide the researchers with valuable information to help shape our research questions by incorporating lived experience.

Nature of Work

We (researchers) will identify clinical pathways which provide good access to patients across a diversity of different types of pain, and demographics. We will consider common elements of pain across different causes (e.g. spinal injury, neuropathy, burns, musculoskeletal, cancer, headache, etc), and work closely with a small number of people from different racial/ethnic and also socioeconomic backgrounds.

In the first stage, we worked with around a dozen patients from our various clinics, with an initial discussion process involving remote one-on-one calls (e.g. over Microsoft (MS) Teams) to gather insight and develop core foci of interest. This created a short list of specific topics for exploration within this, and included looking through some images, previous research, sensory information and carrying out some small activities as an introductory session.

In the second stage, we have worked more intensively with a small number individuals for an in-person engagement exercise, in which the artist (Marysa Dowling) has been spending several days visiting individuals, following their daily lives, talking, using creative photography techniques and sound recordings, alongside undertaking various other creative exercises designed to help them express their individual lived reality of pain.

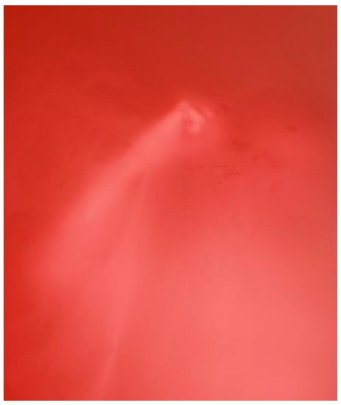
The creative outcomes will be used to support further research. These will include;

• To facilitate creative safe spaces where patients (participants) can playfully explore and express their lived experiences of pain.

• Using photographic processes (both analogue and digital) alongside text reflection, Marysa will develop ideas for expressing patients' lived experience of persistent pain which covers the physical, emotional, domestic, economic and social consequences and impact on their lives. These ideas will be further developed during the collaboration process with each participant.

• To map and record with simple photographically based materials and technologies, additionally simple writing and sound recordings.





Much of this material is now collected, and the next stage is preparing this for creative dissemination.

Events and Meetings

11th Interdisciplinary World Congress on Low Back and Pelvic Girdle Pain in Melbourne, Australia. Nov 2023

Colleagues (past and present) from Cardiff University, Noudy Eleryan (PhD student), Dr Liba Sheeran and Dr Akushla Rathnayake (former PhD student at Cardiff, now based at the University of Hertfordshire) recently attended the above event to present their work.

Noudy Eleryan – The effect of self-management interventions on musculoskeletal disorders in musicians: A scoping review.

Dr Akushla Rathnayake: Normalisation process theory (NPT) analysis of user experience of BACK-to-FITTM – A novel digital intervention to promote exercise self-management and physical activity in people with low back pain.

Dr Liba Sheeran: Assessment of spinal and pelvic kinematics using inertial measurement units in people with persistent low back pain. Co-production of BACK-on-LINETM, a work-based digital self-management of low back pain, for implementation and scaleup the rail industry. Phenotyping low back pain from video capture using computer vision and machine learning.

International Spinal Cord Society Tour Nov 2023

Delegates of the 62nd annual meeting of the International Spinal Cord Society (ISCoS) held in Edinburgh, visited the Queen Elizabeth National Spinal Injuries Unit and the Scottish Centre for Innovation for Spinal Cord Injury in a pre-conference visit on 1st October 2023. Around 40 delegates from research centres all around the world and patient representatives of the ISCoS society had a chance to see how neurorehabilitation research has been embedded into clinics, in this UK unique setting. Dr Aleksandra Vuckovic alongside her PhD students Ioana Susnoschi Luca, Shamsul Arefin, Emily Nicol and Research Associate Dr Rab Nawaz demonstrated the ongoing research with cutting edge neurotechnology, including systems for neuromodulatory treatment of spasticity, long-term home-based brain monitoring in people with chronic pain and spinal cord stimulation for rehabilitation of arm and hand function. A hospital tour and a welcome speech by the Director of the Spinal Unit Dr Mariel Purcell were also included in the visit.

Verity XR Feb 2024

VerityXR is excited to share news of our partnership with the esteemed University of Oxford. During a recent visit to the Institute of Biomedical Engineering, University of Oxford, our leadership team engaged in productive workshops with Prof. Ben Seymour, Professor of Clinical Neuroscience, and his team. Together, we explored potential research projects aimed at deepening our understanding of pain and its effects on individuals. We extend our sincere gratitude to Prof. Ben Seymour and his team for their gracious hospitality. We are looking forward to joining forces with them on innovative and impactful research initiatives in the field of pain neuroscience.

Oxford Health BRC Pain Conference March 2024

This two-day hybrid conference included expert presentations and conversations about cutting-edge pain research and discussions on how the latest insights could be applied in clinical practice. The Oxford team hosted a very successful conference at Lady Margaret Hall. The meeting was organised by the NIHR Oxford Health Biomedical Research Centre (BRC), in collaboration with several other of the national BRC's and CPNN+. This brought together researchers and patients to discuss the latest progress on the development of new therapies for chronic pain.

Virtual Reality in Healthcare – Cardiff April 2024

One of our Co-Applicant's (Val Sparkes) organised a recent in-person 'Virtual Reality in Healthcare' event held at Cardiff University on 17th April 2024.

With 35 attendees, the above event was held on Wednesday 17th April 2024, and covered a morning on virtual reality in Healthcare at the University of Cardiff. Our Co-Applicant (Valerie Sparkes) opened the event and also presented on 'Multimodal approaches used in Virtual Reality for LBP – How do we know what works?'. The event also included speakers; Juan Hernandez Vega presenting on the 'Human-robot interaction, and collaboration via multimodal immersive interfaces' & Soumya Barathi presenting on 'Exergaming' (Exercise controlled gaming). Mohammed Alghamdi from

Cardiff's School of Healthcare Sciences (pictured), presented on 'Why use immersive virtual reality for chronic pain?', along with a closing workshop held by Mohammad Al Amri (School of Healthcare Sciences). Programme as follows:

Virtual reality In Healthcare. Venue Sparc Building, Cardiff University Maindy Road Cardiff

Programme 17th April 2024

- 9.00-9.30 Coffee and tea and pastries and fruit
- 9.30 Opening Valerie Sparkes
- HIVE -introduction Digital & Teaching Innovation Unit, School of Medicine, Cardiff University.
- 9.45-10.15 Juan Hernandez Vega, Human-robot interaction, and collaboration via multimodal immersive interfaces. School of Computer Science and Informatics
- 10.15-10.45 Mohammad Alghamdi, -Why use immersive virtual reality for chronic pain. School of Healthcare Sciences.
- Short break
- 11.00 -11.30 Soumya Barathi, Exergaming (Exercise controlled gaming). School of Computer Science and Informatics
- 11.30 -12.00 Valerie Sparkes, Multimodal approaches used in Virtual Reality for LBP- How do we know what works?
- 12.00 -12.30 Workshop Mohammad Al Amri School of Healthcare Sciences
- Lunch & tea and coffee and networking 12.30 onwards.

APDP annual conference June 2024

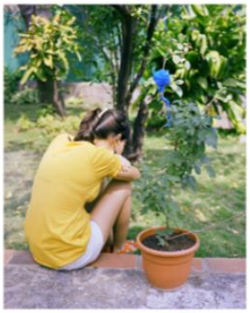
We presented an update of the network at the annual APDP conference in Nottingham, on 7th June 2024.

Capacity building

- Series of practical workshops
  - Virtual reality (Dec 2022)
  - Brain stimulation (July 2024)
  - Neurofeedback (summer 2025)
- Online neurotechnology course
  - 28 lectures, free, fully CPD accredited
- UK Mentorship network

Engagement

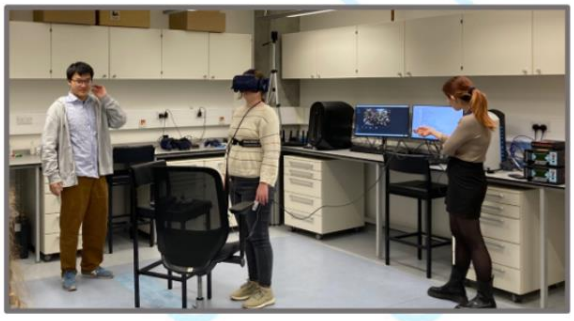
- Community-based creative PPIE with a dedicated artist.
- PPIE funding competition (over £20,000 funded so far)
- Working with public, people with lived experience, policy makers
- Building a researcher network across the UK



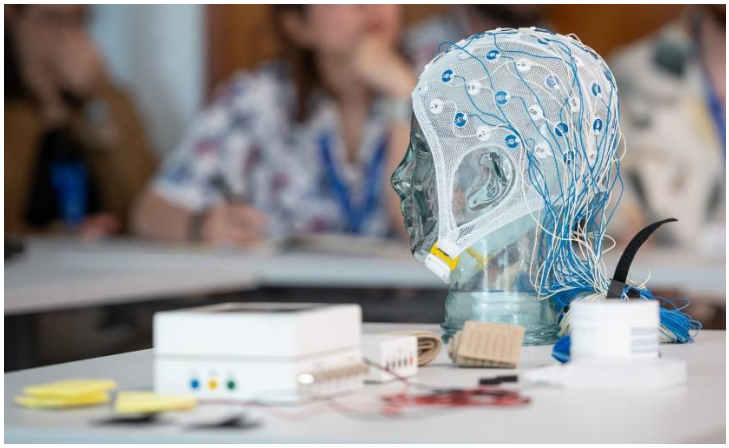
3

Driving new research

- A substantive overview of pain neurotechnology (2025)
- Series of collaborative feasibility studies focusing on technology integration
- Working with industry partners



Exeter Workshop July 2024



[Neurotechnology & Pain workshop - CPNN+]

National Eisteddfod, Wales. August 2024

The 2024 National Eisteddfod took place at Ynysangharad Park, Pontypridd, Rhonda Cynon Taf in Wales. One of our network co-applicants (Valerie Sparkes, pictured) had a great day hosting a stand for young people related to pain and the brain. The young people wore an eye mask and ear defenders whilst we gently brushed their forearm with a small brush from a selection of different brushes, and then they drew a picture or wrote words to describe what they felt the sensation was like and then we hung the pictures up. Some of the words they used to describe the sensations were 'slippery', 'odd', 'soft', 'fluffy' and 'paint brush with dry pain on it'. We also had models of the brain that could be taken apart and re-assembled, and we had a word game with Welsh and English words, such as 'Thalamus'-'Thalamws', 'Insular' – 'ynysol', 'Pain Matrix' – 'Matrics Poen'. Val was helped by Welsh speaker Osian Williams, an undergraduate from Cardiff University. The event was attended by over 400 visitors on Thursday 8th August 2024 at the Cardiff University marquee.

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD
CHRONIC PAIN NEUROTECHNOLOGY NETWORK+
Y Rhwydwaith Niwrodechnoleg Poen *Gronig*

Matrics Poen	Pain Matrix
Prif Gortecs Somatosynhwyraidd Yn gyfrifol am wahaniaethu synhwyraidd. Mae'n penderfynu o ble mae signalau poen yn tarddu.	**Primary Somatosensory Cortex** Responsible for sensory discrimination, determining where pain signals originate.
Cortecs Somatosynhwyraidd Eilaidd Yn gysylltiedig â gwahaniaethu difrifoldeb poen.	**Secondary Somatosensory Cortex** Associated with pain intensity discrimination.
Cortecs Cylchrwyog Blaen Yn ymwneud ag agweddau emosiynol a gwybyddol ar brosesu poen.	**Anterior Cingulate Cortex** Involved in emotional and cognitive aspects of pain processing.
Cortecs Ynysol Yn chwarae rhan yng nghanfyddiad synhwyraidd ac emosiynol o boen.	**Insular Cortex** Plays a role in both sensory and affective perception of pain.
Cortecs rhagflaenol Yn gysylltiedig â throsi poen a gwerthuso poen yn wybyddol	**Prefrontal cortex** Linked to pain modulation and cognitive evaluation of pain
Mae **Thalamws** yn gweithredu fel safle cyfnewid i signalau poen o fadruddyn y cefn i'r cortecs	**Thalamus** acts as a relay station for pain signals from spinal cord to cortex

Working with other the Network+s

We continue to have an active and positive working relationship with the other network. Examples of this include working Neuromod+, which co-funded a project led by Else Fouragnan and Sam Hughes looking at. We are also supporting a Neuromod+ project on neurotechnology ethics (led by Dr Sarah Chan). We have been engaging with CloseNIT, including on a Glasgow led project on "Improving Neurofeedback Efficacy with Brain-Responsive Music" with Andrew

Jackson from the University of Newcastle, total value £93,322.66. The project has been running since August 2024.

Similarly a project at Oxford led by Dr Wako Yoshida explores the use of neurofeedback to understand social observational learning, in a project that also engaged with the R4N network in terms of gathering the voice of people with autism. R4N have been close partners in other domains, including partnerships on mentoring and delivering lectures. Overall, we have enjoyed being part of the broader network+ community, at both research and administrative levels, and interactions with these have been universally positive

Follow on Funding

A number of our feasibility projects and related activities have led to or supported new funding, including:

Dr Sonia Medina University of Exeter NIHR Biomedical Research Centre Translational Research Fellowship. **'Mind the Gap: Steps towards precision rehabilitation in chronic pain'**. £80,000.

Sam Hughes & Elsa Fouragnan (University of Exeter, Plymouth). **Multi-site and state-dependent effects of Transcranial Ultrasound Stimulation on brain function and cognition**. £1,223,819.81. Jan 1st 2024 (4 years)

Sam Hughes. Neuromod+ **"Leveraging Multisite Transcranial Ultrasound Stimulation of the Anterior Cingulate Cortex for Endogenous Pain Modulation".** £80,000.

Aleksandra Vuckovic. EPSRC / CloseNIT "**Improving Neurofeedback Efficacy with Brain-Responsive Music"** with Andrew Jackson from the University of Newcastle, total value £93,322.66. The project has been running since August 2024.

Aleksandra Vuckovic. EPSRC Impact Acceleration Account "**Testing Neurofeedback Treatment of Neuropathic Pain in Singapore Clinical Setting"** in collaboration with Sengkang Hospital, Singapore and the Singapore Institute of Technology. £ 41,974

Ben Seymour, Wako Yoshida, Apostolos Tsiachristas, Nick Chater. ARIA **"Quantifying preferences for interventional neurotechnologies: a novel, co-designed, market-based evaluation tool"** £384,521. 1st Jan 2025-31st Dec 2026.

Looking ahead

Looking ahead to the next and final year, we will continue many of our activities. We will continue to enrol new participants into our lecture course, and will likely offer certificates for completion of the individual modules (of which there are 3), to make the course more manageable and appeal to a broader audience. We will continue our mentorship network.

Next, we are launching a **travel bursaries award (late November),** again aiming to support ECRs to attend and present at conferences, or undertake other career development activities.

Scientifically, one of our major anticipated outputs is a major p**eer-reviewed review of the field i.e. neurotechnology for chronic pain**. This aims to provide a single, authoritative and comprehensive overview of the state and potential of neurotechnology, intending to cement this as a priority area of research.

We are also developing our strategy for after the end of the funding period. In particular, we are further integrating some of our core networking and capacity building activities through engagement with the NIHR Biomedical Research Centres (BRC)s at Oxford and Exeter, and the NIHR Translational research Collaborations (TRC)s, such as a Musculoskeletal TRC.

Forthcoming workshops:

University of Glasgow. July 2025

We are continuing our successful model of combining talk-based ad hands-on practical workshop experience, and fully funding a competitively selected cohort of ECRs to take part. The focus on the workshop will be neurofeedback, and will take place in Glasgow.

A two day workshop, dedicated to neurofeedback and its applications for treatment of chronic pain, will take place at the Advanced Research Centre (ARC) at the University of Glasgow, comprising of morning talks and afternoon workshops and poster exhibitions. First-day workshop will provide hands on experience of EEG neurofeedback system design, in combination with virtual reality for more advanced level. Second-day workshop will offer tutorials in fMRI and NIRS neurofeedback with demonstrations. Companies such as g.tec Medical Engineering Austria, Neuroconcise UK and Brain Innovation will take part. We will cover a two day accommodation for about 40 participants. The workshop organisation will be supported by the Centre for Neurotechnology, University of Glasgow

University of Glasgow Advanced Research Centre

EFIC: Lyon, 26th April 2025,

‘How can we design integrated pain neurotechnologies: theory, innovation and design’.

Workshop description: There has been considerable progress in the development of new technologies to treat chronic pain, with examples spanning neurostimulation, neuromodulation, virtual reality, neurofeedback and digital technologies. Technology-based therapeutics have an appeal afforded by the potential of controllable, side-effect minimal, and mechanism-targeted treatments. Despite this, current evidence of efficacy on individual technologies is limited. Arguably, the most effective approach is likely to involve combining different technologies alongside each other. to allow more multifaceted and comprehensive targeting of pain mechanisms. However, this presents a number of technical and clinical challenges. This workshop addresses these challenges to consider the design, development and translation of integrated technologies. We discuss the current state-of-the-art for pain technology. We ask whether theoretical models of chronic pain are sufficient to support innovation and effective target identification. Next, we consider the software, hardware, and systems engineering challenges related to device and system integration, considering also the role of patients in the design process. We then review these factors for a detailed example: transcranial ultrasound used in combination with virtual reality-based movement therapy. And lastly we consider how such technologies might fit into the clinical pain management and neurorehabilitation landscape, noting also ethical issues and clinical trial design.

Objectives: Provide a high-level, multidisciplinary overview of integrated technologies for pain. Explore the extent to which innovation can be based on known mechanisms of pain pathogenesis. Understand how patients can contribute to the technology design process, and consider inclusivity. Consider ethical aspects that advanced and complex technologies present to pain management.