Grant Title: Visual Body Illusions for Treatment of Osteoarthritis Pain

Award Holders: Dr Catherine Preston (University of York), Dr Daniel Baker (University of York), Dr Kirsten McKenzie (University of Lincoln).

PhD Student: Kirralise Hansford

Grant Duration: 01/10/21 – 30/09/2024 (36 months)

Report: This report describes progress over the period 12/05/23 – 13/05/24.

Abstract: Osteoarthritis is a leading cause of pain and disability in the UK, particularly in those over 50, and an ageing population means that the social and financial cost of osteoarthritis is increasing. Recent studies report that patients find current treatments unsatisfactory and that they often have severe side-effects, or even make clinical outcomes worse. Therefore, the need for an effective, drug-free treatment is imperative. Although osteoarthritis is characterised by damage to joint cartilage, there is growing evidence that arthritic pain is exacerbated by abnormalities in the brain's representation of the affected joint. Our previous studies have already shown dramatic pain relief and increased feelings of joint flexibility from body illusions that change the perceived size of arthritic joints. However, currently the methodology for delivering these analgesic illusions is expensive and cumbersome. A possible solution to this is through the development of body illusions relying on vision only, removing the need for expensive technology. Recent research suggests that immersive multisensory experiences, such as virtual or augmented reality, are not essential for delivering body illusions; changes to the perception of our bodies can be induced using non-immersive visual-only manipulations. However, it is currently unclear whether visual-only illusions have the same analgesic potential as fully immersive multisensory illusions. This question is important as visual-only illusions could allow for these methods to be widely accessible to patients via mobile phone applications. Therefore, this project will examine the therapeutic potential of visual body illusions for pain management in osteoarthritis. To achieve this, we will compare brain responses along with subjective changes in bodily perception and pain intensity between visual-only and multisensory illusions. Additionally, we will investigate the potential cumulative effect of experiencing visual illusions on arthritic pain, delivered using a mobile phone application.

Project aims: This project aims to further investigate the analgesic effects of multisensory body illusions in relation to neural mechanisms and feasibility for developing accessible illusion-based treatments via a mobile phone application. Specifically, we wish to establish a neural signature of illusion-based analgesia using EEG comparing highly immersive illusion induction to an alternative unimodal (visual) method as would be most suitable for a mobile phone app. We will aim to examine potential cumulative effects of experiencing visual illusions on levels of osteoarthritis pain to determine feasibility of such methods for long term management.

Progress so far: Despite initial COVID related delays in year one, the second year of the project was very productive which has continued into the third year with two thesis chapters now published in peer reviewed journals, a third submitted and under review and a fourth chapter submitted as a stage two registered report (with in principle acceptance). We have deviated from slightly the initial project due to delays with the registered report process. This delayed data acquisition for experiment two substantially and has ended up meaning that we separated the original experiment into two separate experiments one with health controls (submitted as a registered report) and one with chronic pain patients (data collection still ongoing). However, with our updated timeline we will complete data collection for this at the end of June and as all analysis pipelines are in place (identical to the completed experiment) this experiment will be completed in advance the end of the PhD funding. We also experience delays for the final longitudinal experiment using the app. This is due to technical issues with app development (it has been greatly improved since the original prototype). However, the app is now completed such that we anticipate commencing this final experiment in early June, which will allow us to complete data collection and write up within the PhD. We have already started early recruitment for this experiment so that we can begin as soon as the app is available. The delays for studies 2 and 3 allowed us to complete two additional studies, allowing Ms Hansford to contribute more to the experimental design. These two studies have been completed, with one published and the second under review (see details below). Ms Hansford continues to impress at her Thesis Advisory Panel meetings (held every six months with additional faculty from the department) due to her work ethic, productivity and engagement in open science practices.

Experiment one:

- The Experiment has been published in *Neuropsychologia.* This experiment outlined neural underpinnings of the finger stretching illusion. Associating multisensory integration with increased Gamma oscillations, which were absent in visual only illusions. We also demonstrated that a significant subset of participants did experience a strong stretching illusion with only visual input, and that this was associated with a distinct pattern of neural activity. The different types of illusions therefore have different neural signatures in the brain, which may help us understand more about how these illusions reduce pain in chronic pain patients.

Experiment two:

- This experiment has been split into two experiments. Experiment 2a conducted on healthy participants (N= 46) was accepted for stage one of a registered report (PCI group) and has now been submitted for stage two. Here we wanted to understand the effect of resizing illusions on the somatosensory cortex using somatosensory steady state evoked potentials (SSSEP) in EEG. Our results demonstrate small reductions in SSSEPs in the illusion conditions which do not relate to the subjective experience of the illusion. These brain changes may represent somatic sharpening which is theorised to be a potential mechanism underlying illusion-based analgesia.

- Experiment 2b, which is a replication of Experiment 2a conducted on chronic pain participants is still ongoing (currently N=10 of 30) with introduction and methods section already written and analysis codes in place (identical to experiment 2a).

Experiment three:

- Due to issues with the app development this experiment will commence in June 2024.

Additional Experiments

- The first additional experiment examines the impact of auditory stimuli on illusion strength, finding that a rising pitch tone enhances subjective experience of the illusion in the for visual only but not multisensory illusions. We did not find an effect of the rising pitch tone however on performance-based (reaching) tasks. The auditory stimulus is being implemented in the mobile phone app as this illusion is visual only. This experiment has been published in *Experimental Brain Research*.

- The second additional study examined facilitators and barriers for engaging in chronic pain research and involved focus groups (total N= 29) and on online survey (N=103). The main barriers identified were a distrust of the level of anonymity and confidentiality within research or having a distrust of medical or research professionals and lack of logistical practicality when taking part in research, including inaccessible physical locations, limited travel options or times to take part, having personal or technological impracticalities, which inhibit one's ability to take part in research. Facilitators to taking part in research were: Improved Accessibility, Positive Impact of Participation, Detailed and Accessible Information, Motivation, and Safe Space. We have since implemented these facilitators in our in-person EEG experiment (Experiment 2b) and are collecting data on participant experience as a result. This paper is currently under review at the European Journal of Pain.

Dissemination:

To gain impact for our project as well as facilitating networking and presenting experience for Ms Hansford, the work has been presented at several national and international conferences this year:

1. Oral presentation at the York Postgraduate Research Day, York, June 2023
2. Poster presentation at the Body Representation Network Conference, Majorca, September 2023.
3. Oral presentation at the North East Body Psychology meeting, York, September 2024
4. Poster presentation at the Experimental Psychology Society conference York, June 2024 (forthcoming).

Professional Development:

Outside the core project Ms Hansford has engaged with many other activities and training to help develop her skills and further her career.

1. Attendance of the Oxford Berlin Open Research School
2. Continued involvement in the *ReproduceMe* project, for which PhD students are trained to make research papers computationally replicable (using *R markdown*) and has resulted in an addition publication for Ms Hansford.
3. Continued graduate teaching duties (e.g., marking, leading tutorials) in the Psychology Department.

Awards:

1. Travel scholarship for the Oxford Berlin Open Research School (£200)
2. e-ReproNIM Fellowship (open research training) (€1000)
3. Nominated for a York Graduate teaching award

Publications and pre-preints:

Hansford, K. J., Baker, D. H., McKenzie, K. J., & Preston, C. E. (2023). Distinct neural signatures of multimodal resizing illusions. *Neuropsychologia*, *187*, 108622.

Hansford, K. J., Baker, D. H., McKenzie, K. J., & Preston, C. E. (2024). Multisensory processing and proprioceptive plasticity during resizing illusions. *Experimental Brain Research*, *242*(2), 451-462.

Hansford, K., McKenzie, K., Crossland, A., Baker, D. H., & Preston, C. (2024). Understanding Barriers and Facilitators to Non-Pharmaceutical Chronic Pain Research Engagement. *PsyArXiv*, https://doi.org/10.31234/osf.io/ymf3v

Hansford, K. J., Baker, D. H., McKenzie, K. J., & Preston, C. E. J. (2023). Somatosensory Response Changes During Illusory Finger Stretching. *In principle acceptance of Version 7 by Peer Community in Registered Reports.*

*Baker, D., Berg, M., Hansford, K., Quinn, B., Segala, F. G., & English, E. (2024). ReproduceMe: lessons from a pilot project on computational reproducibility. *Meta-Psychology*, In Press

*Open research project, separate to that directly involving the PhD