

fMRI neurofeedback for pain: a proof-of-concept study

Maite van der Miesen¹; Sophie Raible²; Clara Pantel¹; Bert Joosten^{1,3}; Carine Vossen^{1,3}; Judith Eck²; Inge Timmers⁴; Judith Peters²; David Linden⁵

¹*Department of Anesthesiology and Pain Management, Mental Health and Neuroscience Research Institute, Maastricht University, Maastricht, The Netherlands*

²*Department of Cognitive Neuroscience, Maastricht University, Maastricht, The Netherlands*

³*Department of Anesthesiology and Pain Medicine, Maastricht University Medical Centre, Maastricht, The Netherlands*

⁴*Department of Medical and Clinical Psychology, Tilburg University, The Netherlands*

⁵*Department of Psychiatry and Neuropsychology; Mental Health and Neuroscience Research Institute, Maastricht University, Maastricht, The Netherlands*

Introduction

fMRI studies for acute pain have shown that neurofeedback may promote the ability to self-regulate activity in pain-related areas in healthy participants, although a clear link to pain reports is still absent (Patel et al., 2020). In a controlled proof-of-concept fMRI study, we aim to investigate neurofeedback for pain targeting the anterior mid-cingulate cortex (aMCC) using pain-related images. We use visual stimuli to prevent the habituation effects that would occur with the use of physical painful stimulation during neurofeedback training (van der Miesen et al., 2025). Our pilot results demonstrated that pain-related images lead to reliable activity in the aMCC that shows considerable overlap with electrical pain-related activity (van der Miesen et al., 2026). The current neurofeedback study investigates whether regulating the aMCC response during pain-related images is effective for regulating the response during painful physical stimulation.

Methods

20 healthy participants were invited for five sessions in a matched-controlled trial. During the first and last sessions, participants received painful electrical stimulation on the finger. A localizer run where the baseline activation during pain-related images is assessed is also performed. The intervention group (n = 10) participated in a neurofeedback training in the MRI scanner for the middle three sessions. During these neurofeedback sessions, participants viewed pain-related images and used mental strategies to down-regulate their brain activation in the aMCC using real-time feedback. The control group (n = 10) participated in a mock scanner training for the middle three sessions. During these sessions, participants similarly viewed pain-related images and used mental strategies to regulate their response, without receiving any feedback. During the fifth session, both groups applied their learned mental strategies to the painful stimulation to investigate the effect on their pain response. Pain reports of images and electrical stimulation (both groups, all sessions) as well as neuroimaging data were collected (all sessions for the intervention group, session 1 and 5 for the control group).

Results

Our results demonstrate a significant decrease in pain reports from the first to last session in the intervention group. Pain reports while viewing the images during the neurofeedback sessions did not

significantly decrease across sessions. Perceived regulation success also remained stable across the neurofeedback sessions. In line with these findings, we showed that brain activation in the aMCC during regulation did not significantly decrease across the neurofeedback sessions. Nevertheless, the activation during regulation is lower than during the localizer run which consisted of passive viewing. The control group data collection is currently being finalized. Results will indicate whether training mental strategies without receiving feedback will also result in a decrease in pain reports, or whether our decrease in pain can be attributed to the neurofeedback training, despite not seeing a direct change in activation across sessions.

Conclusions

This study aims to show the feasibility of down-regulating activity in the aMCC during pain-related images and its effect on pain. Our preliminary results indicate that there is no training effect shown in both the aMCC activation as well as the perceived pain and regulation success. However, a significant decrease in pain reports from first to last session is shown. Further analysis of the control group will demonstrate whether this effect can be attributed to a potential placebo effect. This study is the first study to use alternative stimuli for physical stimulation during neurofeedback training, limiting habituation effects and assessing the true neurofeedback effect. Our proof-of-concept study will be used to design larger controlled trials which aim to analyze effects of neurofeedback in treatment of chronic pain.

References

- Patel, K., Sutherland, H., Henshaw, J., Taylor, J. R., Brown, C. A., Casson, A. J., Trujillo-Barreton, N. J., Jones, A. K., & Sivan, M. (2020). Effects of neurofeedback in the management of chronic pain: A systematic review and meta-analysis of clinical trials. *European Journal of Pain*, 24(8), 1440-1457.
- van der Miesen, M. M., Vossen, C. J., Compère, V. N., Joosten, E. A., Linden, D. E., Peters, J. C., & Kaas, A. L. (2025). Individual differences in response to repeated painful stimulation: Habituation, sensitization, and placebo effects. *The Journal of Pain*, 105377.
- van der Miesen, M. M. (2026). *Tracking pain over time: individual differences in habituation and sensitization to pain*. Doctoral Thesis, Maastricht University.
<https://doi.org/10.26481/dis.20260409mm>