Development of a vibrotactile stimulation system for cognitive rehabilitation

Master Thesis

In partial fulfillment of the requirements for the degree

"Master of Science in Engineering"

Study program:

Mechatronics & Smart Technologies

Management Center Innsbruck

Supervisor:

Prof. Yeongmi Kim, PhD

Author:

Lukas Sieß

52010293

Declaration in Lieu of Oath

„I hereby declare, under oath, that this master thesis has been my independent work and has not been aided with any prohibited means. I declare, to the best of my knowledge and belief, that all passages taken from published and unpublished sources or docments have been reproduced whether as original, slightlychanged or in thought, have been mentioned as such at the corresponding placesof the thesis, by citation, where the extend of the original quotes is indicated.“

Place, Date

Signature

Kurzfassung

Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text ...

Schlagwörter: Schlagwort 1, Schlagwort 2, Schlagwort 3, Schlagwort 4, Schlagwort 5

Abstract

Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text Text ...

Keywords: Keyword 1, Keyword 2, Keyword 3, Keyword 4, Keyword 5

Contents

1 Introduction

1.1 Motivation and Problem Statement

[1], [2]

[3]

[4], [5], [6]

1.2 Objectives of the Thesis

Erl"autern Sie an dieser Stelle *genau* was ihre Aufgabe ist. Gegebenfalls grenzen Sie auch die Teile aus, welche nicht im Umfang der Arbeit liegen. Dies kann Ihnen gegen Ende ihrer Arbeit bei der Argumentation helfen.

1.3 Structure of the Thesis

Geben Sie in diesem Abschnitt eine grobe Vorausschau auf den Aufbau der Arbeit. Die Arbeit k"onnte empirisch motiviert sein und mit der Auswertung eines Experimentes beginnen oder theoreitsch und somit logischerweise mit einem Theoriekapitel beginnen.

Etst

2 Theoretical Background

2.1 Cognitive Rehabilitation: Concepts, Methods, and Target Groups

Multidisziplinäre Ansätze [3]

EEG-Biomarker wie der Brain Symmetry Index (BSI) und der Laterality Coefficient (LC) erlauben eine objektive Bewertung des funktionellen Zustands des Gehirns. Die EEG-Analyse ermöglicht eine individualisierte Rehabilitationssteuerung, indem sie Veränderungen in der Hirnaktivität erfasst – insbesondere im Zusammenhang mit Motor Imagery, einer etablierten kognitiven Rehabilitationsmethode. Die Zielgruppe der Studie sind Schlaganfallpatienten, die oft sowohl motorische als auch kognitive Beeinträchtigungen aufweisen.

[7]

Table 2.1 ergleich verschiedener Studien zur taktilen niederfrequenten Vibration in der Demenzbehandlung

2.2 Vibrotactile Stimulation: Principles and Therapeutic Applications

[7]

[8, 9, 10, 11, 12, 13, 14, 15, 16]

2.3 Actuation Technologies for Haptic Feedbacks

40 Hz & Gamma Frequenzen, [17] [4] [5] [6] zeigen neurobiologische Wirkung

2.4 Voice Coil Actuators for Vibrotactile Stimulation

EEG & Wearables [18] [19] [20] [21] über EEG-Tech, BCI, und mobile Erfassung

2.5 Overview of Existing Vibrotactile Stimulation Systems

3 Analysis of the Current VCA-Based System

3.1 Overview of the Current VCA System

This section provides an overview of the existing Voice Coil Actuator (VCA)-based setup. The System consists of seven main parts.

- Spring frame (Minimizing the loss of vertical motion transmitted to the node)
- Magnet Housing (fixed Magnetic field is always formed)
- Bobbin Coil (Magnetic field is formed only when current flows)
- Node (Transmitting vertical motion directly to the human body as sound and vibration)
- Node screw (fixes the node to the bobbin coil)
- Rubber frame (Suppresses vibration from the body from being transmitted to the outside world)
- Connection PCB (Take the analog signal from the AMP and apply it to the bobbin coil)

3.2 Dynamic Behavior: Frequency Measurement

3.2.1 Objective

3.2.2 Measurement Setup

3.2.3 Results & Interpretation

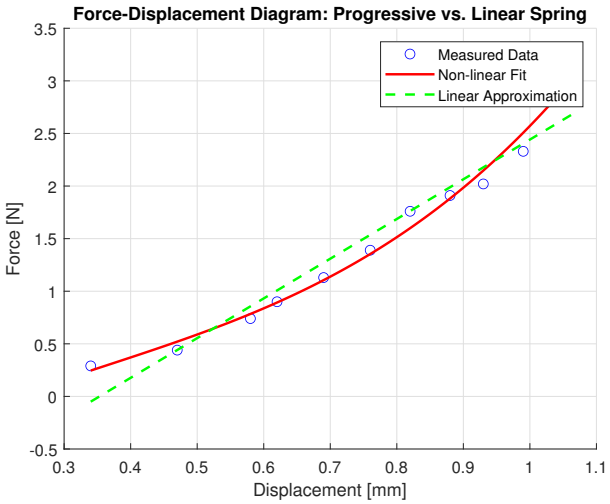

Figure 3.1 SpringTest

3.3 Limitations and Identified Challenges

4 Modify

5 Evaluation

6 Conclusion

Bibliography

[1] Alzheimer's Disease International, "Dementia statistics," 2024, accessed: 2025-04-22. [Online]. Available: https://www.alzint.org/about/dementia-facts-figures/dementia-statistics/

[2] World Health Organization, "Dementia – fact sheet," 2024, accessed: 2025-04-22. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/dementia

[3] C. Zucchella, E. Sinforiani, S. Tamburin, A. Federico, E. Mantovani, S. Bernini, R. Casale, and M. Bartolo, "The Multidisciplinary Approach to Alzheimer's Disease and Dementia. A Narrative Review of Non-Pharmacological Treatment," *Frontiers in neurology*, vol. 9, p. 1058, 2018.

[4] A. J. Mably and L. L. Colgin, "Gamma oscillations in cognitive disorders," *Current opinion in neurobiology*, vol. 52, pp. 182–187, 2018.

[5] H. F. Iaccarino, A. C. Singer, A. J. Martorell, A. Rudenko, F. Gao, T. Z. Gillingham, H. Mathys, J. Seo, O. Kritskiy, F. Abdurrob, C. Adaikkan, R. G. Canter, R. Rueda, E. N. Brown, E. S. Boyden, and L.-H. Tsai, "Gamma frequency entrainment attenuates amyloid load and modifies microglia," *Nature*, vol. 540, no. 7632, pp. 230–235, 2016.

[6] A. J. Martorell, A. L. Paulson, H.-J. Suk, F. Abdurrob, G. T. Drummond, W. Guan, J. Z. Young, D. N.-W. Kim, O. Kritskiy, S. J. Barker, V. Mangena, S. M. Prince, E. N. Brown, K. Chung, E. S. Boyden, A. C. Singer, and L.-H. Tsai, "Multi-sensory Gamma Stimulation Ameliorates Alzheimer's-Associated Pathology and Improves Cognition," *Cell*, vol. 177, no. 2, pp. 256–271.e22, 2019.

[7] E. A. Campbell, J. Kantor, L. Kantorová, Z. Svobodová, and T. Wosch, "Tactile Low Frequency Vibration in Dementia Management: A Scoping Review," *Frontiers in psychology*, vol. 13, p. 854794, 2022.

[8] A. Clements-Cortes, H. Ahonen, M. Evans, M. Freedman, and L. Bartel, "Short-Term Effects of Rhythmic Sensory Stimulation in Alzheimer's Disease: An Exploratory Pilot Study," *Journal of Alzheimer's disease : JAD*, vol. 52, no. 2, pp. 651–660, 2016.

[9] M. Heesterbeek, E. A. van der Zee, and M. J. G. van Heuvelen, "Feasibility of Three Novel Forms of Passive Exercise in a Multisensory Environment in Vulnerable Institutionalized Older Adults with Dementia," *Journal of Alzheimer's disease : JAD*, vol. 70, no. 3, pp. 681–690, 2019.

[10] F. M. H. Lam, L. R. Liao, T. C. Y. Kwok, and M. Y. C. Pang, “Effects of adding whole-body vibration to routine day activity program on physical functioning in elderly with mild or moderate dementia: a randomized controlled trial,” *International journal of geriatric psychiatry*, vol. 33, no. 1, pp. 21–30, 2018.

[11] A. A. Clair and B. Bernstein, “The Preference for Vibrotactile Versus Auditory Stimuli in Severely Regressed Persons with Dementia of the Alzheimer’s Type Compared to Those with Dementia due to Alcohol Abuse,” *Music Therapy Perspectives*, vol. 11, no. 1, pp. 24–27, 1993.

[12] K.-H. Kim and H.-B. Lee, “The effects of whole body vibration exercise intervention on electroencephalogram activation and cognitive function in women with senile dementia,” *Journal of exercise rehabilitation*, vol. 14, no. 4, pp. 586–591, 2018.

[13] A. Clements-Cortes, L. Bartel, H. Ahonen, M. Freedman, M. Evans, and D. Tang-Wai, “Can Rhythmic Sensory Stimulation Decrease Cognitive Decline in Alzheimer’s Disease?: A Clinical Case Study,” *Music and Medicine*, vol. 9, no. 3, p. 174, 2017.

[14] C. Mercado and E. Mercado, “A Program Using Environmental Manipulation, Music Therapy Activities, and the Somatron(C) Vibroacoustic Chair To Reduce Agitation Behaviors of Nursing Home Residents with Psychiatric Disorders,” *Music Therapy Perspectives*, vol. 24, no. 1, pp. 30–38, 2006.

[15] A. Clements-Cortes, L. Bartel, H. Ahonen, and M. Freedman, “The Potential of Rhythmic Sensory Stimulation Treatments for Persons with Alzheimer’s Disease,” *Music and Medicine*, vol. 9, no. 3, p. 167, 2017.

[16] A. Clements-Cortes and L. Bartel, “Long-Term Multi-Sensory Gamma Stimulation of Dementia Patients: A Case Series Report,” *International journal of environmental research and public health*, vol. 19, no. 23, 2022.

[17] Y. K. Reiko Tutida, “Low-Frequency, Whole Body Vibration Induced Neurite Outgrowth by Pc12m3 Cells with Impaired Nerve Growth Factor-Induced Neurite Outgrowth,” *Journal of Novel Physiotherapies*, vol. 05, no. 01, 2014.

[18] C. Guger, G. Krausz, B. Z. Allison, and G. Edlinger, “Comparison of dry and gel based electrodes for p300 brain-computer interfaces,” *Frontiers in neuroscience*, vol. 6, p. 60, 2012.

[19] C. Guger, R. Spataro, B. Z. Allison, A. Heilinger, R. Ortner, W. Cho, and V. La Bella, “Complete Locked-in and Locked-in Patients: Command Following Assessment and Communication with Vibro-Tactile P300 and Motor Imagery Brain-Computer Interface Tools,” *Frontiers in neuroscience*, vol. 11, p. 251, 2017.

[20] M. Sebastián-Romagosa, E. Udina, R. Ortner, J. Dinarès-Ferran, W. Cho, N. Murovec, C. Matencio-Peralba, S. Sieghartsleitner, B. Z. Allison, and C. Guger, “EEG Biomarkers Related With the Functional State of Stroke Patients,” *Frontiers in neuroscience*, vol. 14, p. 582, 2020.

[21] R. Xu, R. Spataro, B. Z. Allison, and C. Guger, “Brain-Computer Interfaces in Acute and Subacute Disorders of Consciousness,” *Journal of clinical neurophysiology : official publication of the American Electroencephalographic Society*, vol. 39, no. 1, pp. 32–39, 2022.

List of Figures

List of Tables