Technische Universität München
Department of Electrical Engineering and Information Technology
Bio-Inspired Information Processing

Master's Thesis

Investigation of Cortical Responses to Modulated Noise Stimuli Using fNIRS

Pei-Yi Lin

Date of Submission:
August 19, 2022

Supervisors:
Prof. Dr.-Ing. Werner Hemmert
Dr. Ali Saeedi
M.Sc. Carmen Marie Castañeda González

Abstract

Write your abstract here or use \input{} command.

Acknowledgments

Thanks people!

Contents

Chapter 1

Motivation

This research is aimed for better understanding of the brain activities when the subjects are exposed to different audio stimuli with the help of fNIRS measurement.

In the field of neuro-imaging, although fMRI is widely used and provides excellent (spatial) resolution, it still has many limitations, especially when it comes to hearing research. First of all, MRI rooms are noisy, which makes it difficult to control the audio stimulation desired due to inevitable environmental noises. In addition, fMRI scans are done in a magnetic field. It has not yet been proved that pregnant women and infants can be safely exposed to an external magnetic field in the MRI room. For people with hearing disabilities, more specifically cochlear implant patients, going into a MRI room would not be ideal, either. Although there are already cochlear implants that can be worn to a magnetic field, it is still generally not suggested to wear a piece of metal in a MRI room.

fNIRS, short for functional near-infrared spectroscopy. With fNIRS, we can measure brain activity by using near-infrared light to estimate cortical hemodynamic activity which occur in response to neural activity. It is non-invasive and risk-free. The fNIRS device is portable and works silently. With the cap secured on the head, it is also more resilient to motion artifacts. All these makes it ideal for hearing researches. However, it is not yet commonly used in clinical diagnostics due to the lack of understanding of the expected brain activities measured with fNIRS. Therefore, in this research, we'd like to perform some fNIRS measurement and analyse the fNRIS data under different experiment conditions.

If fNIRS can provide more meaningful data and be more commonly used in early clinical diagnosis, we may find hearing abnormality of patients earlier. This is especially important for infants or children. As language development happens in the early stages of one's life, the sooner we find the hearing abnormality and fix it, the better. After a child turns 8, it is practically not possible for him to understand human speech even with perfect hearing. I personally find hearing research a meaningful topic. For one, speech is the primary and direct way of human communication. We express ourselves and perceive other people's opinion via speech. For the other, music has always been an important part of my life for me personally. Without the ability to hear and listen, neither speech nor music will be possible to be perceived. Therefore, I want to help other people with hearing disabilities get better diagnosis and treatment. fNIRS is of great potential to help solve the issue.

Chapter 2

Introduction

Chapter 3

Related Work

Chapter 4

Methods

4.1 Study Participants

We measured 8 normal hearing people. Participant 8 was given silent stimuli as a comparison. The detailed information about the subjects are listed in the table.

Participant	Gender	Handedness	Race	Hair color	Age
1 chang	F	right-handed	east asian	dark	22 yr
2 gleb	M	right-handed	caucasian	blond	18
3 jonas	M	left-handed	caucasian	brunet	21
4 lin	F	right-handed	east asian	dark	21
5 lukas	M	right-handed	caucasian	blond	26
6 shelia	F	right-handed	southeast asian	dark	22
7 liao.	M	right-handed	east asian	dark	22
8 lukas	M	right-handed	caucasian	blond	22

Table 4.1: Study Participants.

4.2 Probe Design

The probes were first designed in AtlasViewer [pic] [Aasted et al., 2015]. I tried to replicate the probe design as close as possible to the research from Weder et al. However, several modifications need to be made due to device limitations.

First of all, the paper only provided a rough 2D-sketch of their probe design. [see pic] The channels were not described in detail. Though there are different ways to define the channels, we believe it shouldn't matter as long as the mid-points of the channel correspond to that of the previous research.

Due to device limitations, we only measured one side of the brain. According to previous research [Frost et al., 1999] , language processing has been predominantly associated to cortical activity in the left hemisphere. As a result, we've decided to focus on the left hemisphere.

The fNIRS device we use also has limited number of sources and detectors. If we'd like to keep the original design, we'd need 9 sources and 9 detectors. However, the device we are using has only 10 sources and 8 detectors. Hence, we shifted one channel around T7 a little bit to the left, so that one less detector is needed.

4.3 Acoustic Stimulation during fNIRS Experiment

Auditory stimuli were delivered binaurally via audio metric headphone. Stimuli consisted of 20-s chunks of the ICRA noise [Dreschler et al., 2001].

To begin with, ICRA noise was developed to be used as background noise in clinical tests of hearing aids and possibly for measruing characteristics of non-linear instruments. The signals are based on live English speech from the EUROM database (Chan, 1995) in which a female speaker is explaining about the system of arithmetical notation. The speech signals were sampled with a sampling rate of 44.1 kHz. By composing the speech signals with well defined spectral and temporal characteristic, the modified signals have long-term spectrums but are completely unintelligible. We chose to use ICRA noise as stimuli based on several reasons. For one, ICRA noise is broadband amplitude-modulated signal. By selecting a broadband stimulus, broad cortical auditory areas and be activated more strongly compared with simple static stimulus. The bandwidth of auditory stimuli is positively correlated with the mean percentage signal change and spread of cortical activation [Hall et al., 2001]. Previous fMRI study also manifested that more complex auditory stimuli elicit greater response in most parts of the auditory cortes [Belin et al., 2002].

4.4 fNIRS Setup

4.5 Data preprocession

Data preprocessing and analysis was executed in MATLAB (Mathworks, USA) and the Homer3 toolbox. The following steps were executed.

First, the hemodynamic response was extracted with the Homer3 toolbox. Raw data were converted into optical densitoes. Motion artifacts were removed by using wavelet transformation of the data. The Homer3 toolbox bandpass filter (0.01 and 0.5 Hz) reduced drift, broadband noise, heartbeat, and respiration artifacts. Concentration if oxygenated and deoxygenated hemogloblin were estimated by applying the modified Beer-Lambert Law. It is important that the noise due to motion artifacts, drift, broadband noise, heartbeat, and respiration artifacts need to be processed before the concentration was estimated, according to the previous research [Huppert et al., 2009].

Later on, the extracerrebral component in long channels was reduced by using measurements from the short channels as follows: the first principal components from the two short channels were estimated.

Chapter 5

Results

Chapter 6

Discussion

Chapter 7

Future prospectives

List of Figures

List of Tables

Bibliography

[Aasted et al., 2015] Aasted, C. M., Yücel, M. A., Cooper, R. J., Dubb, J., Tsuzuki, D., Becerra, L., Petkov, M. P., Borsook, D., Dan, I., and Boas, D. A. (2015). Anatomical guidance for functional near-infrared spectroscopy: AtlasViewer tutorial. *Neurophotonics*, 2(2):020801.

[Belin et al., 2002] Belin, P., Zatorre, R., and Ahad, P. (2002). Human temporal-lobe response to vocal sounds. *Brain research. Cognitive brain research*, 13:17–26.

[Dreschler et al., 2001] Dreschler, W., Herschuure, H., Ludvigsen, C., and Westermann, S. (2001). Icra noises: Artificial noise signals with speech-like spectral and temporal properties for hearing aid assessment. *Audiology*, 40:148–157.

[Frost et al., 1999] Frost, J. A., Binder, J. R., Springer, J. A., Hammeke, T. A., Bellgowan, P. S., Rao, S. M., and Cox, R. W. (1999). Language processing is strongly left lateralized in both sexes. evidence from functional MRI. *Brain*, 122 (Pt 2):199–208.

[Hall et al., 2001] Hall, D., Haggard, M., Summerfield, A., Akeroyd, M., Palmer, A., and Bowtell, R. (2001). Functional magnetic resonance imaging measurements of sound-level encoding in the absence of background scanner noise. *The Journal of the Acoustical Society of America*, 109:1559–70.

[Huppert et al., 2009] Huppert, T. J., Diamond, S. G., Franceschini, M. A., and Boas, D. A. (2009). Homer: a review of time-series analysis methods for near-infrared spectroscopy of the brain. *Appl. Opt.*, 48(10):D280–D298.

Erklärung der Selbstständigkeit

Hiermit versichere ich, die vorliegende Arbeit selbstständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt sowie die Zitate deutlich kenntlich gemacht zu haben.

....

Ort, Datum Pei-Yi Lin