Investigation of Optimal Stimulus Type for an Auditory Based Brain-Computer Interface

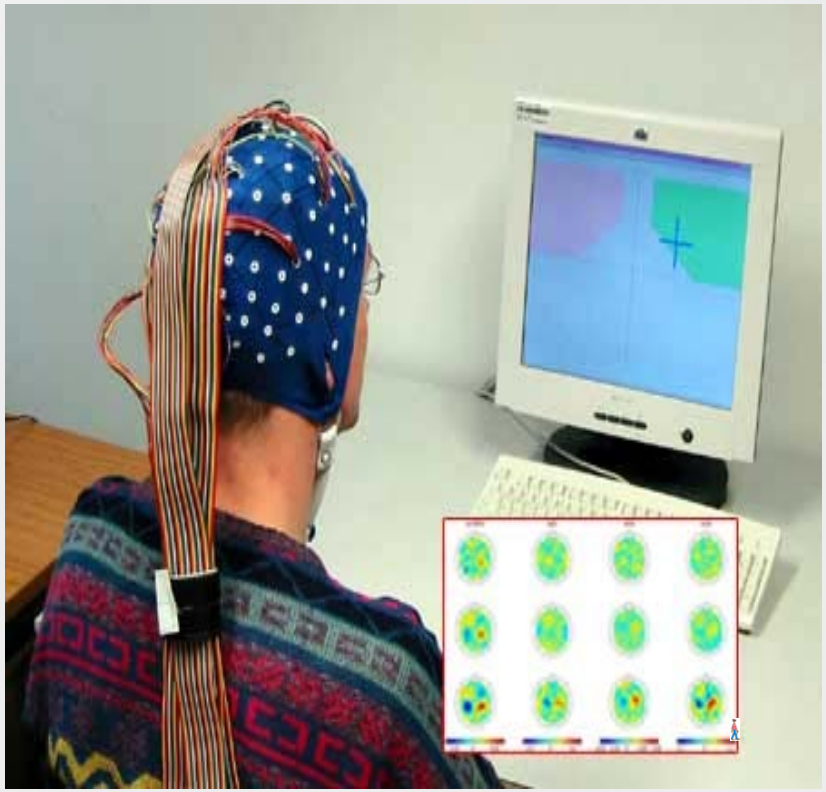
Stephan Kienzle
Briarcliff High School

Research Objectives

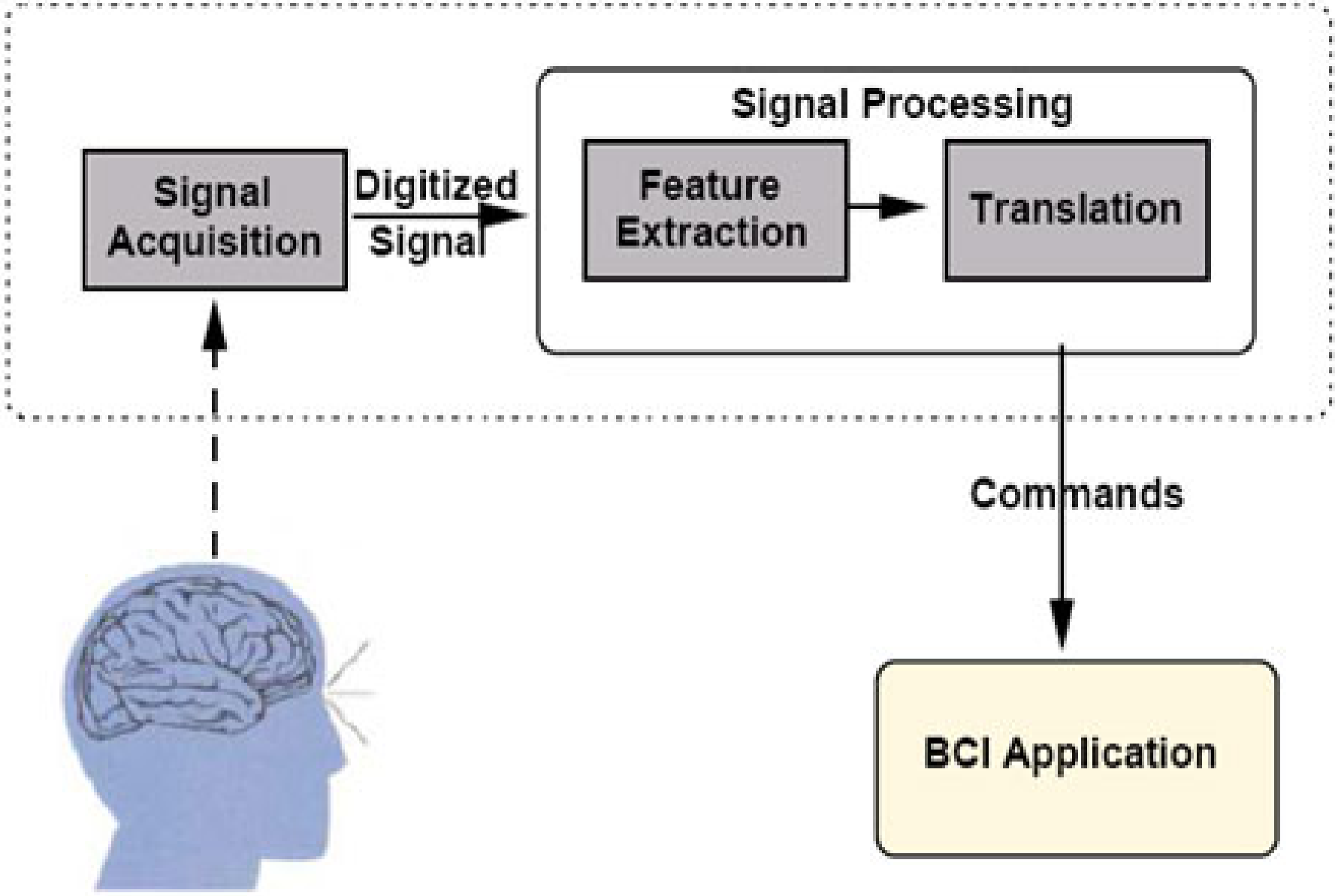
- To develop and auditory-based binary decision Brain-Computer Interface (BCI) system, with a focus on optimal stimulus type
- Designed to aid patients with severe ALS who are "locked-in" and cannot rely on muscular or ocular means of communication(Ohki et al. 1994)

Brain-Computer Interface

- BCI connects the brain and a computer system without the body's normal output pathways (Wolpaw et al. 2002)
- Electrodes used to collect neural signals analyzed by discrimination and mathematical algorithms



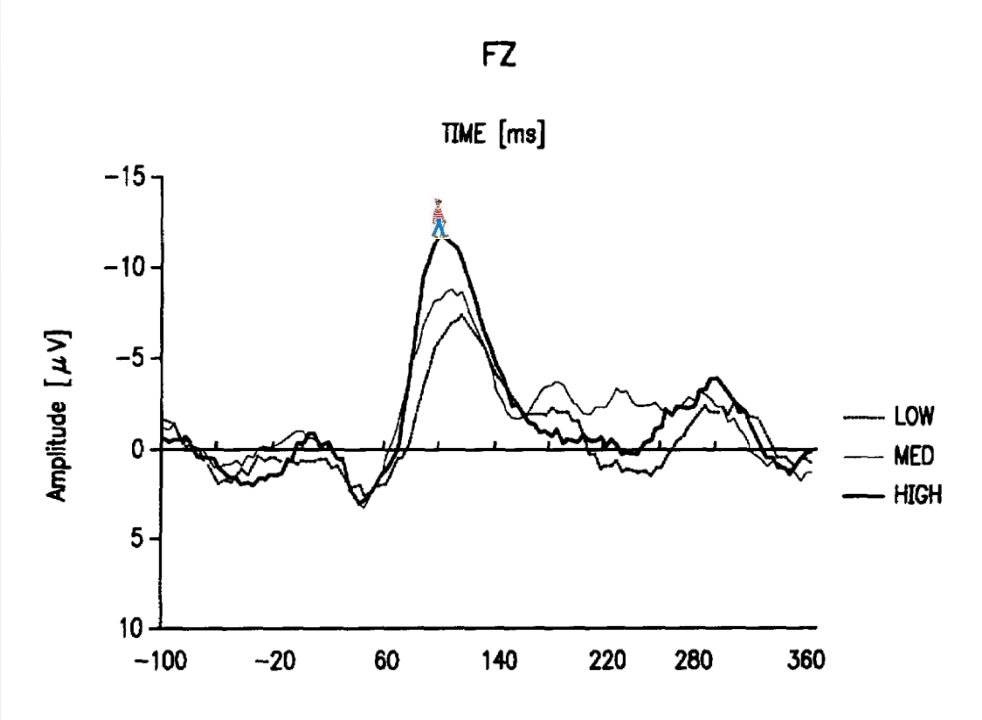
http://archive.eurescom.eu/message/messageDec2004/The_Berlin_Brain_Computer_Interface.asp



http://www.fidis.net/resources/deliverables/hightechid/d122-study-on-emerging-ami-technologies/doc/8/

Auditory Neural Response

- An attended stimulus results in a negative peak in EEG activity dispersed around the vertex of the brain approximately 100-200 ms after the stimulus (Hillyard et al. 1973)

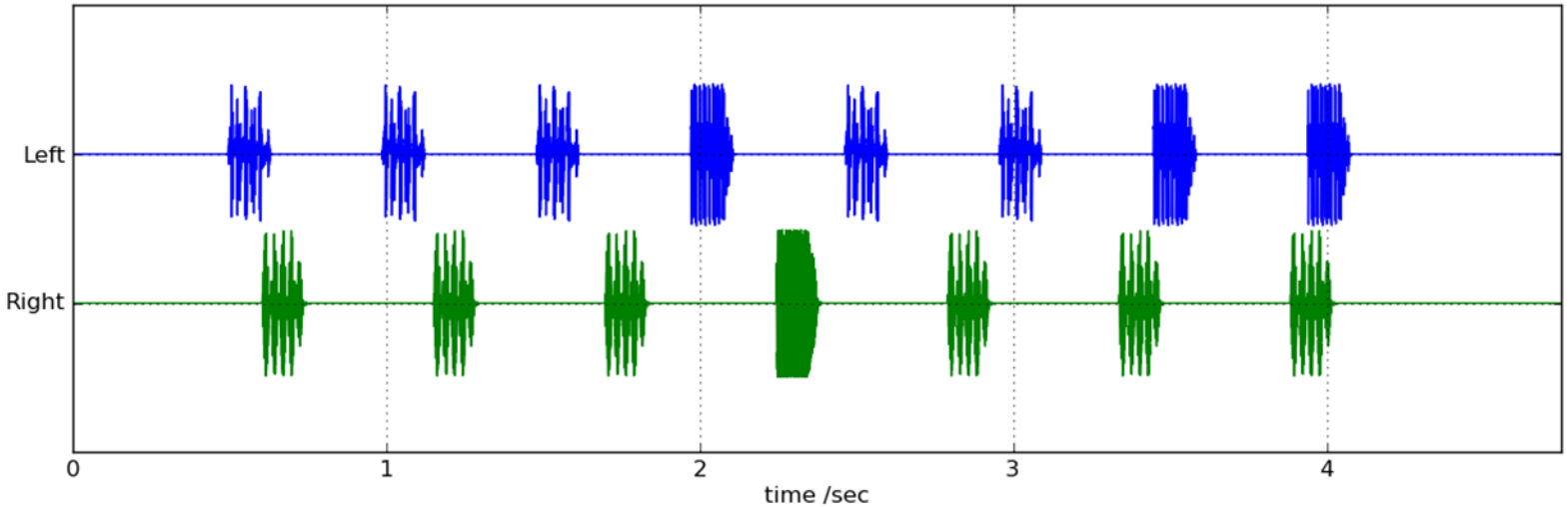


http://www.freepatentsonline.com/7081085.html

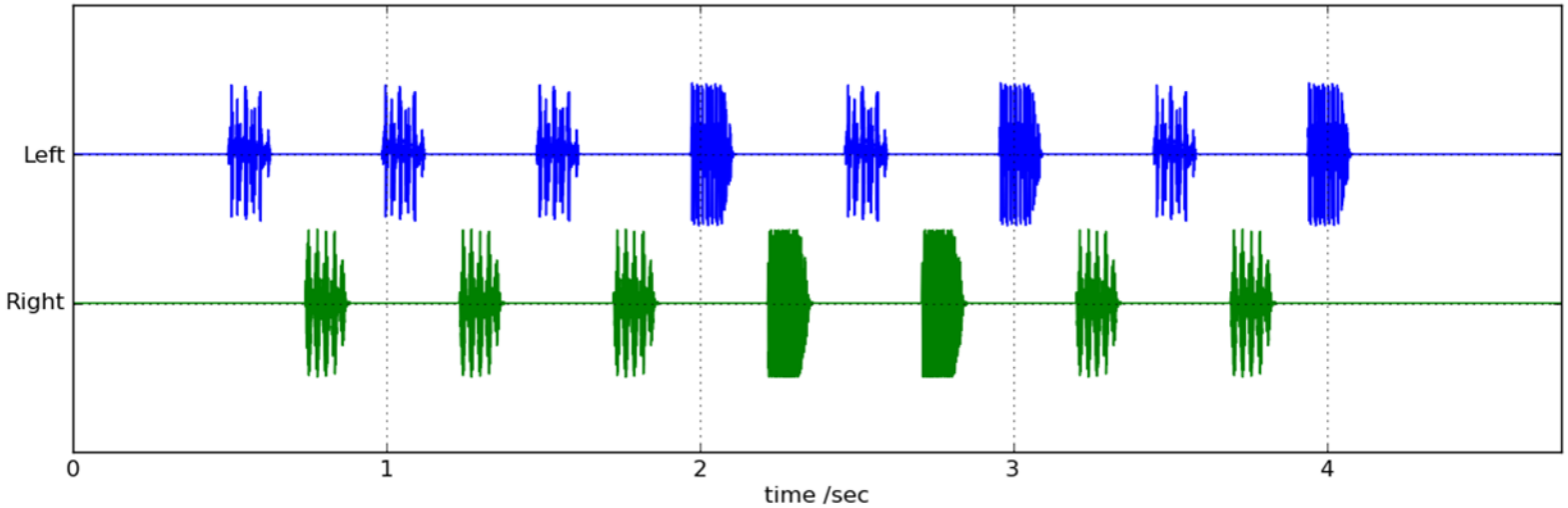
Auditory BCI

- Auditory BCI systems have been achieved with numerous selectable stimuli, however the systems did not function for all subjects (Klobassa et al. 2009) (Furdea et al. 2009)

- Other systems have been binary-decision, but proved applicable to all subjects and with greater accuracy(Hill et al. 2005) (Kanoh et al. 2010)



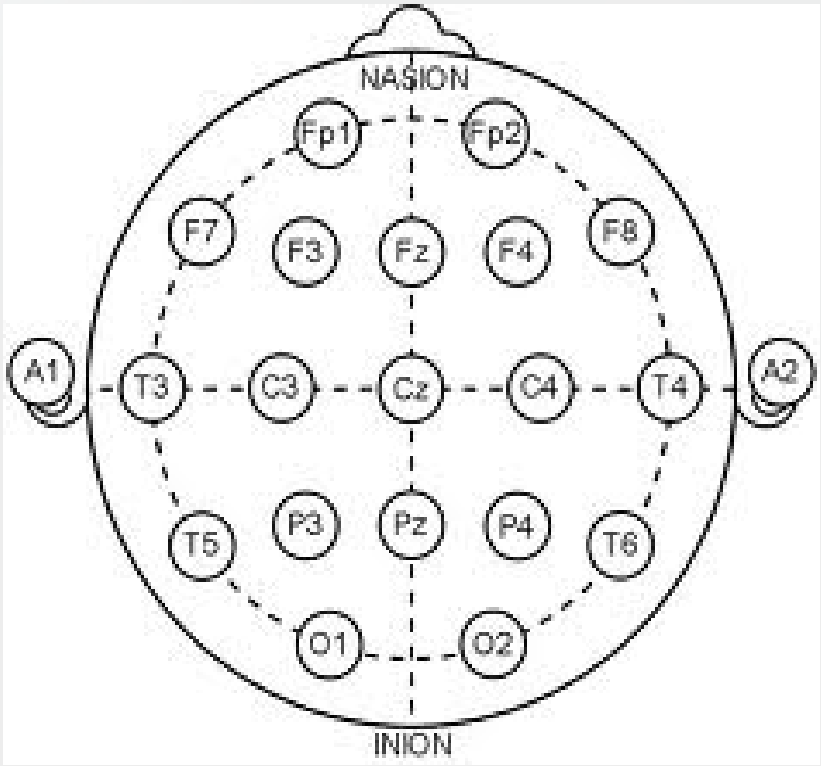
- Drifting interstimulus period proposed by Hill et al 2005
- Proven to be effective stimulus method in the 2005 and unpublished 2009-10 study



- Fixed interstimulus period proposed by Kanoh et al. 2008
- Limitations: stimuli not presented in binaural fashion, only offline analysis used

Methods

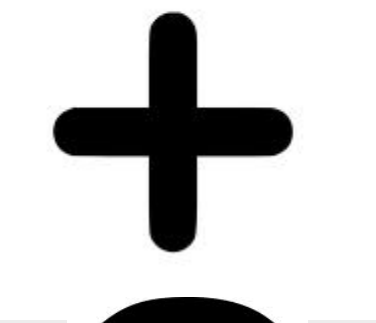
- Electroencephalography (EEG)
- 16 electrodes
- Stereo Headphones
- Logistic regression analysis
- MATLAB data analysis



http://en.wikipedia.org/wiki/File:21_electrodes_of_International_10-20_system_for_EEG.svg

Methods

- <u>One trial</u>: directional arrow, stimuli presented, subject response

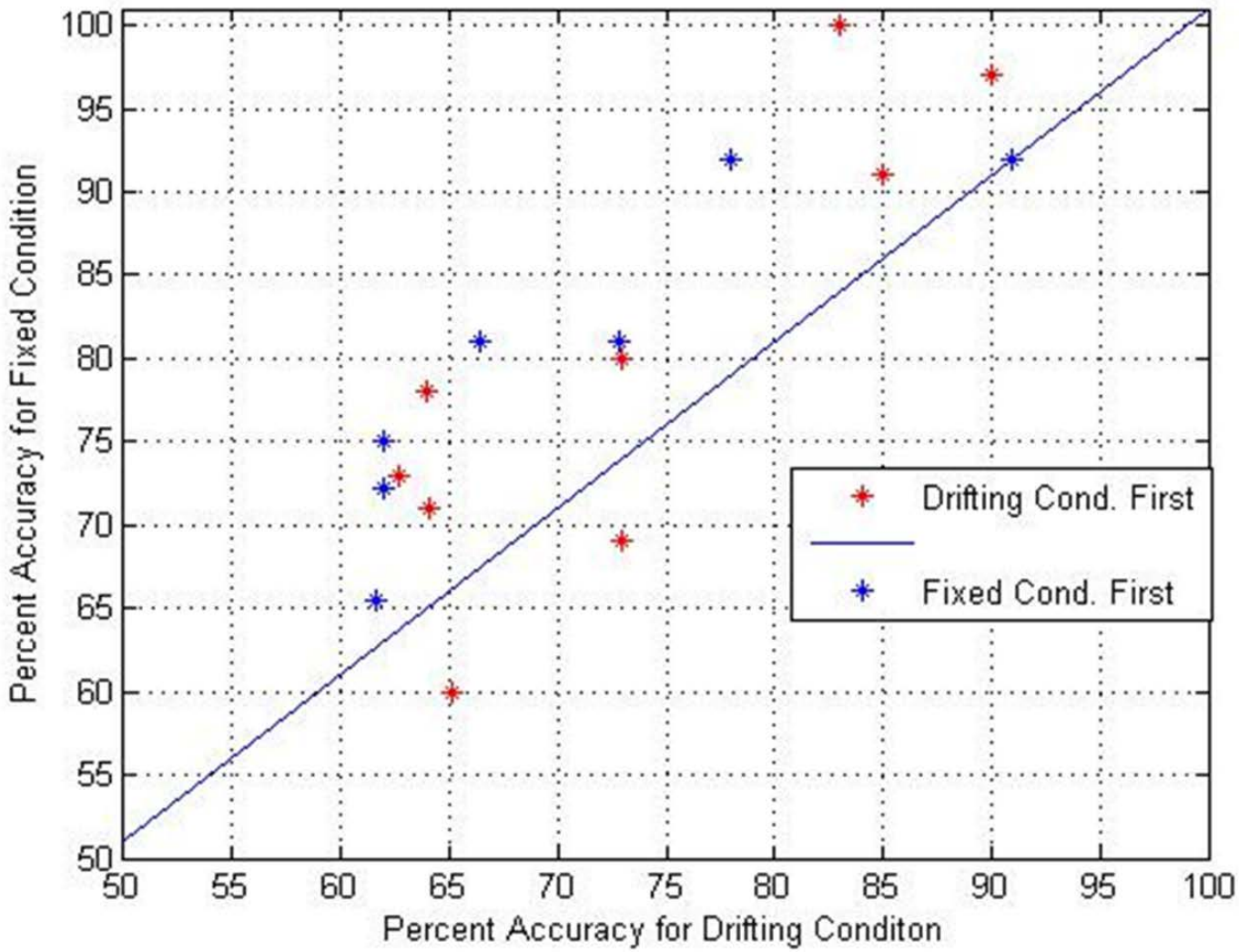


- 20 trials per run
- 12 runs per subject
- Alt. conditions every 3 runs
- 9 subjects given drifting cond. First
- 7 given fixed cond. first.

Methods

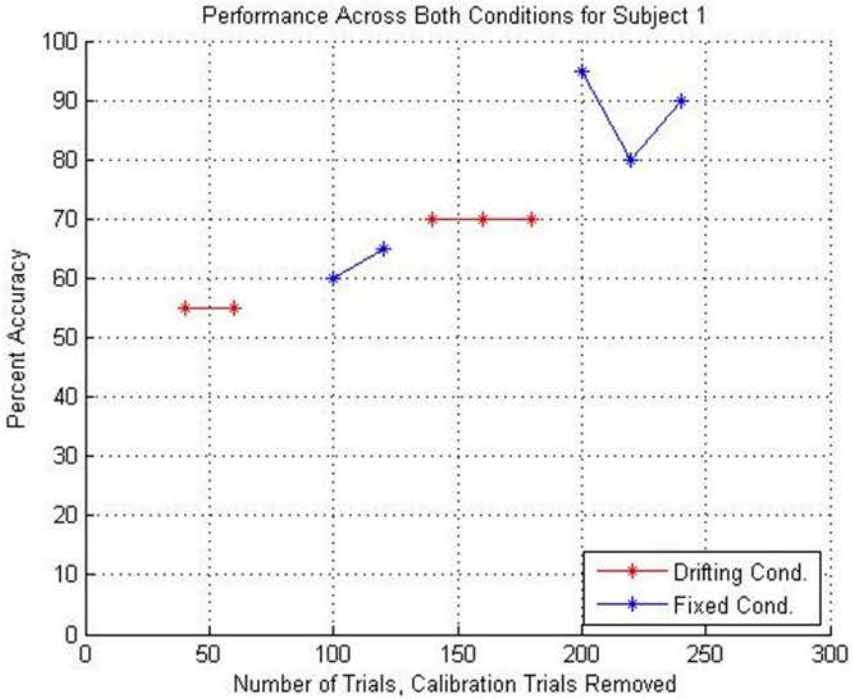
- Use classification software
- After each run data is input into MATLAB cumulative analysis and used for future classification
- Subject's first run in each condition not put through predictor

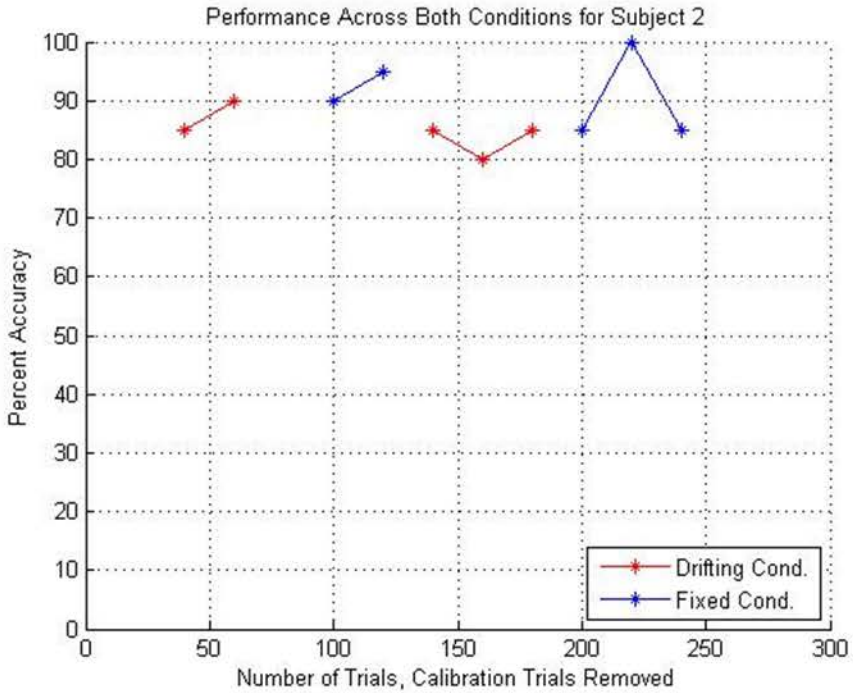
Subject Performance in Both Conditions

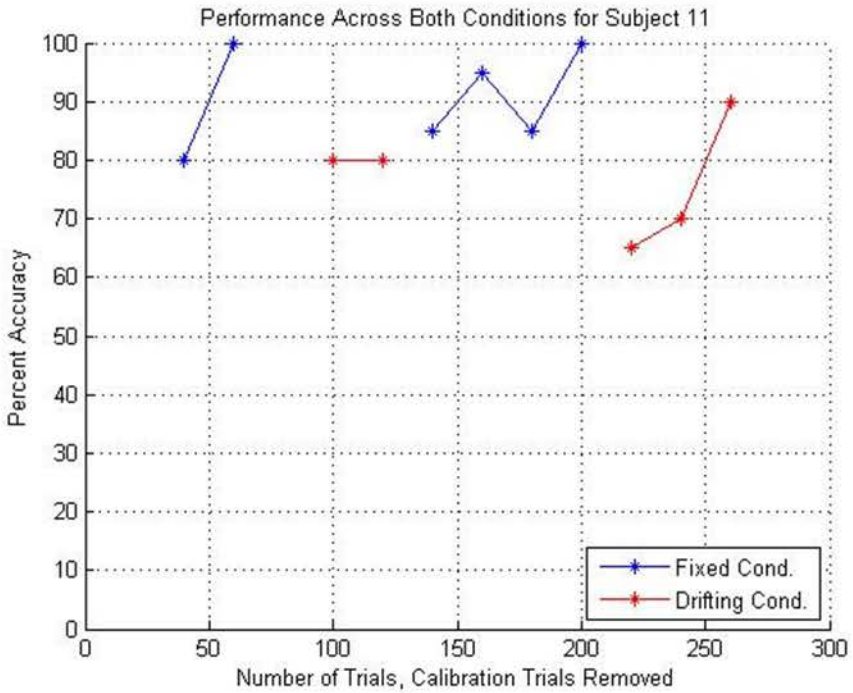


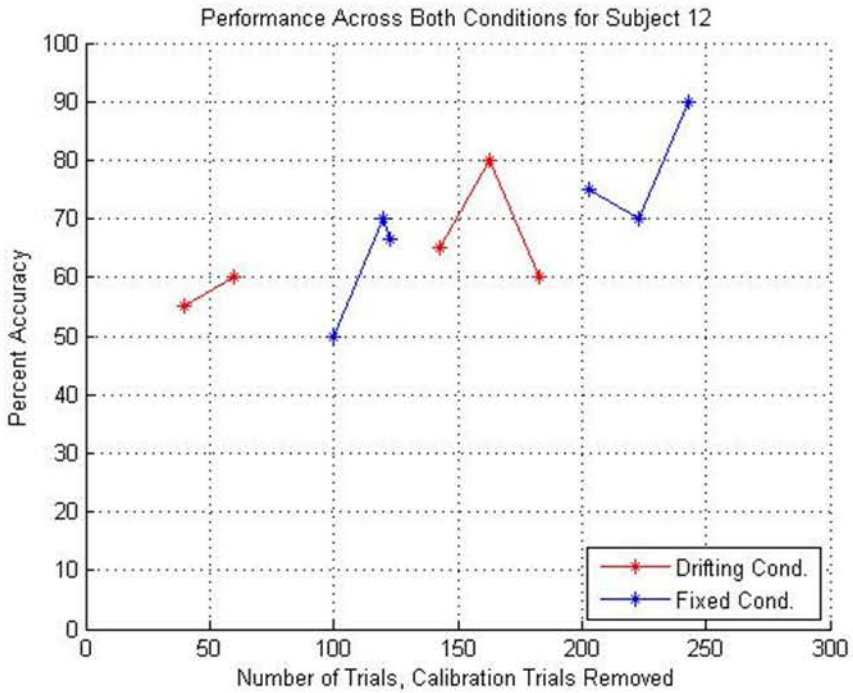
Statistical Analysis

- Wilcoxon Sign Rank test
- Used to detect a difference in the mean accuracies for the two conditions
- P-value of .0016


Performance Across Both Conditions for Subject 1
Percent Accuracy
Number of Trials, Calibration Trials Removed
Drifting Cond.
Fixed Cond.


Performance Across Both Conditions for Subject 2
Percent Accuracy
Number of Trials, Calibration Trials Removed
Drifting Cond.
Fixed Cond.


Performance Across Both Conditions for Subject 11
Percent Accuracy
Number of Trials, Calibration Trials Removed
Fixed Cond.
Drifting Cond.


Performance Across Both Conditions for Subject 12
Percent Accuracy
Number of Trials, Calibration Trials Removed
Drifting Cond.
Fixed Cond.

Statistical Analysis

- Wilcoxon Sign Rank test
- Used to detect difference in performance between first and last runs for Fixed Condition
- P-value of .0109

Results

- <u>Fixed-phase more accurate</u>
- Subject able to differentiate between the streams despite time lock and the computer classification is easier

- <u>Evidence of improvement</u>
- This may be due to computer's improved subject specific profile
- Longer-term data is needed to explore further learning

Conclusions

- Proof of function for auditory BCIs
- This time using only 16 channels
- Clearly stimuli time-locked to each other are more useful
- Increase in performance during initial sessions

References

- Wolpaw JR, Birbaumer N, McFarland DJ, Pfurtscheller G, Vaughan TM Brain-computer interfaces for communication and control. Clinical Neurophysiology 113: 767–791. 2002
- Birbaumer N, K¨ubler A, Ghanayim N, Hinterberger T, Perelmouter J, Kaiser J, Iversen I, Kotchoubey B, Neumann N, and Flor H. The Thought Translation Device (TTD) for Completely Paralyzed Patients. IEEE Transactions on Rehabilitation Engineering, 8(2):190–193, 2000.
- Riggs LA, Ratliff F, Cornsweet JC, and Cornsweet TN. The disappearance of steadily fixated visual test objects. Journal of the Optical Society of America, 43:495–501, 1953.
- Ohki M, Kanayama R, Nakamura T, Okuyama T, Kimura Y, Koike Y. Ocular abnormalities in amyotrophic lateral sclerosis. Acta Otolaryngol Suppl. 511:138–42. 1994
- Piccione F et al., P300-based brain computer interface: reliability and performance in healthy and paralysed participants, Clinical Neurophysiology 117 pp. 531–537 2004
- Schalk G, McFarland DJ, Hinterberger T, Birbaumer N and Wolpaw JR, BCI2000: development of a general purpose brain–computer interface (BCI) system. Social Neuroscience Abstract 27 p. 168. 2001
- Hill NJ, Lal TN, Bierig K, Birbaumer N, Schölkopf B. An Auditory Paradigm for Brain-Computer Interfaces. In: Saul L, Weiss Y, Bottou L, editors. Advanced Neural Information Processing Systems volume 17. : 569–76. 2005
- S.A. Hillyard, R.F. Hink, V.L. Schwent, and T.W. Picton. Electrical signs of selective attention in the human brain. Science, 182:177–180, 1973.
- Kanoh S, Ichiro Miyamoto K, Yoshinobu T A Brain-Computer Interface (BCI) System Based on Auditory Stream Segregation. In: Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE. NC MBE 642-645
- Klobassa DS, Vaughan TM, Brunner P, Schwartz NE, Wolpaw JR, et al.Toward a high-throughput auditory P300-based brain-computer interface. Clin Neurophysiology 120: 1252–1261. 2009
- Furdea A, Halder S, Krusienski DJ, Bross D, Nijboer F, et al. An auditory oddball (P300) spelling system for brain-computer interfaces. Psychophysiology 46: 617–625. 2009
- Kim DW, Hwang HJ, Lim JH, Lee YH, Jung KY, Im CH Classification of selective attention to auditory stimuli: Toward vision-free brain–computer interfacing. Journal of Neuroscience Methods Volume 197. 180-185 2011
- Schreuder M., Blankertz B., Tangermann M. A new auditory multi-class brain-computer interface paradigm: spatial hearing as an informative cue. PLoS ONE 5, edition 9813. 2010

Future Research

- Varied speed of stimuli
- Long-term research to analyze improvement
- Apply useful application to binary choices