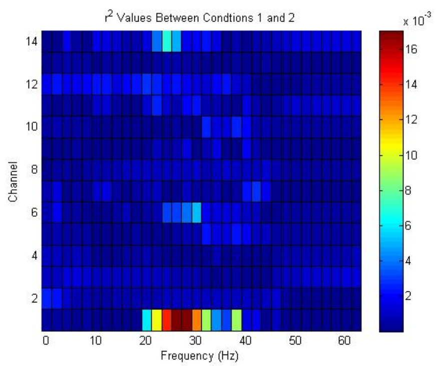
Experiment Results

-Experiment 1 (Cursor Task)

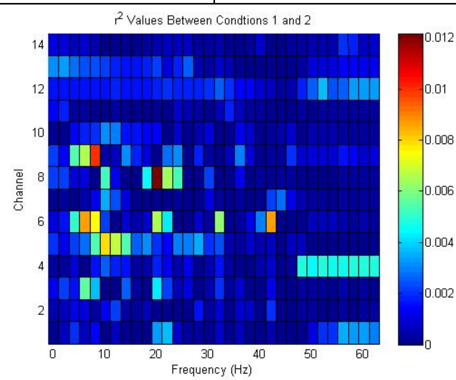
The Cursor Task performed for average of 100 trials for each specific motion. Since we used the linear classifier set up by Colleen, this classifier didn't find the specific signals that we wanted in general. The R^2 values are low that we can't use it for real-time EEG data collection.

Experiments 1 (Cursor Task) //Average of 100 Trials

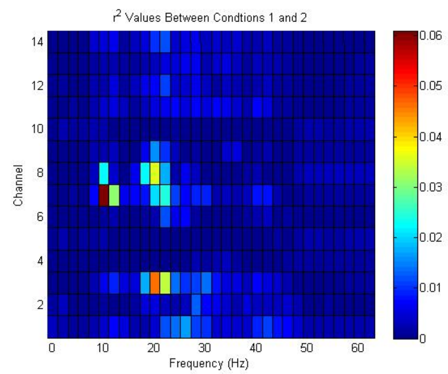
Movement	Highest Signal on Channel (#)	Magnitude of the Highest Signal(r^2 Value)	at Frequency (Hz)	Other Notable Signals on Channel (#)
Shoulder Rotation (DoHyun)	3	6.3*10^-3	26-28	5,10,14
Shoulder Rotation (Tom)	7	.06	10-12	-
Ankle Tapping (DoHyun)	14	9.6*10^-3	22-24	7
Ankle Tapping (Tom)	8	.012	20-22	9
Wrist Twisting (DoHyun)	1	16*10^-3	24-30	-
Wrist Twisting (Tom)	1	.12	20-24	3



DoHyun Kim Wrist Twisting



Tom Ankle Tapping



Tom Shoulder Rotation

-Experiment 2 (LR StimPresentation)

In these experiments, we found several interesting EEG signals properties. From the EEG data of different types of the Bicep Curling, we set up the hypothesis that constant holding action will generate higher R^2 values than repetitive actions. The Wrist Twisting Experiment shows the possible symmetrical EEG signal generations in Brain. Also Active Force generation seems to generate higher EEG R^2 values (might be caused by pain and fatigued muscle afferent neural signals). These series of experimental data shows higher R^2 values for left side movements in general. Since Tom and I are both right handed, we set up the hypothesis that motions for undeveloped side of brain or muscles will generate higher EEG data R^2 values.

Experiments 2 (LR StimPresentation) Data A

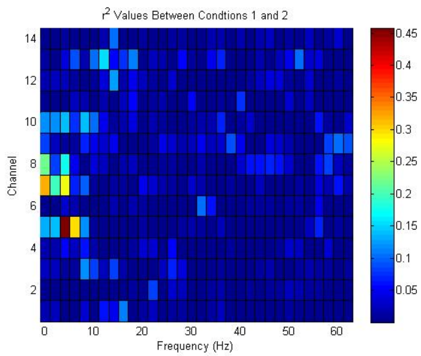
Movement	Left vs. Pause			Right vs. Pause			Left vs. Right		
	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)
Finger (DoHyun)	14	.22	26-28	14	.25	18-20	5	.15	34-36
Finger (Tom)	12	.3	22-24	12	.33	22-24	12	.1	62-64
Bicep Curling Twice	5	.26	4-6	2	.24	8-10	9	.12	46-48
Bicep Curling Once	14	.21	28-30	14	.22	30-32	13	.1	20-22
Bicep Curling Up	5	.45	4-6	5	.31	4-6	7	.13	0-2

Tongue (Tom)	Twisting			Rolling back		
	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)
	9	.22	20-22	5	.35	0-2

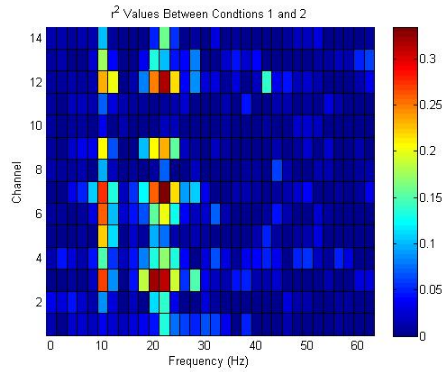
Experiments 2 (LR StimPresentation) Data B

Movement	Left vs. Pause			Right vs. Pause			Left vs. Right		
	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)
Bicep Lifting Up	5	.17	6-8	5	.2	6-8	13	.14	28-30
Fist Squeezing Firmly	9	.33	26-28	10	.3	8-10	3	.12	44-46
Fist Squeezing Softly	8	.16	34-36	14	.16	28-30	8	.09	18-20
Wrist Twisting and Hold (** Symmetry)	7	.26	26-28	10	.25	34-36	10	.21	46-48

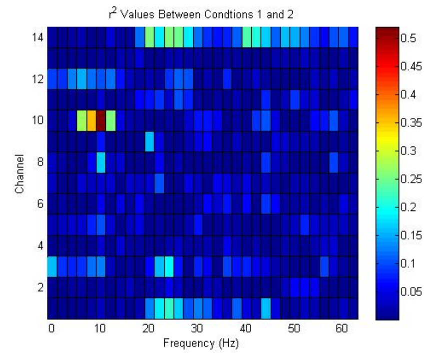
Wrist Rotation Open Hand	14	.31	20-22	14	.16	18-20	5	.19	28-30
Wrist Rotation with Fist	10	.51	10-12	10	.22	10-12	10	.24	10-12



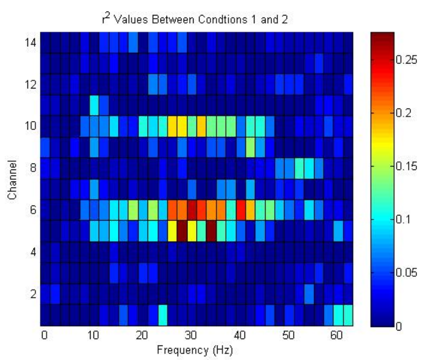
DoHyun Kim Bicep Curling Up (Left)

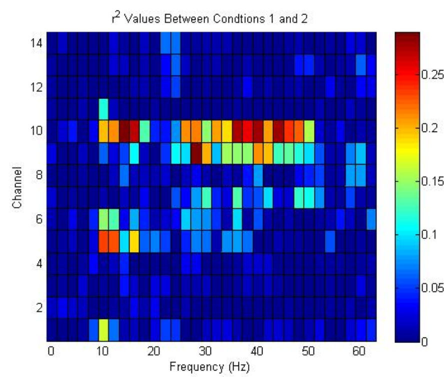


Tom Finger Connection (Right)

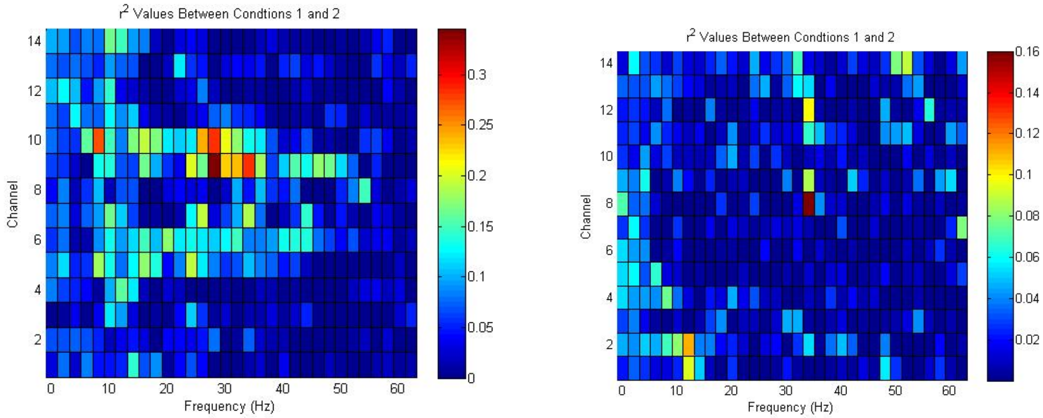


DoHyun Kim Wrist Twist + Fist Squeezing (Left)





DoHyun Kim Wrist Twisting (Left Hand vs. Right Hand) showing symmetrical EEG composition



DoHyun Kim Fist Squeezing Firmly (Active Force) vs. Softly (Passive Force)

-Experiment 3 (Constant Action vs. Repetitive Action)

Unlike the hypothesis we set up from the result of Experiment 2, results of experimental 3 demonstrate that repetitive actions generate higher EEG R^2 Values. The higher R^2 Values for constant actions in experiment 2 might come from the strong active force generation during constant actions. Experiment 3 shows that repetitive actions generates higher R^2 Values in general.

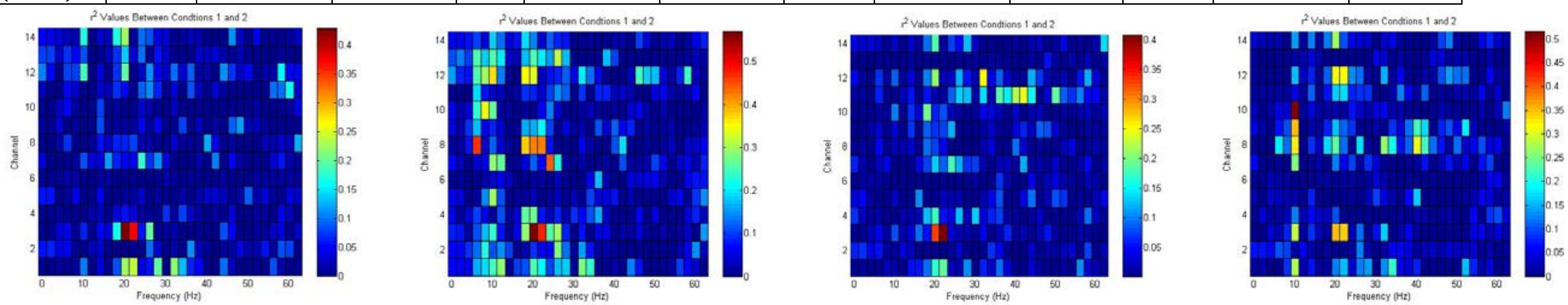
Experiment 3 (LR StimPresentation) Data A (Constant Action vs. Repetitive Action)

Movement	Constant Action			Repetitive Action			Constant vs. Repetitive		
	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)
Connecting Left Hand Fingers (Tom)	3	.41	20-22	3	.43	20-22	12	.11	20-22
Connecting Left Hand Fingers (DHK)	2	.24	8-10	2	.35	2-4	1	.11	56-58

Experiment 3 (LR StimPresentation) Data B (Constant Action vs. Repetitive Action)

Movement	Constant Action(Left)			Repetitive Action (Left)			Constant Action (Right)			Repetitive Action (Right)		
	Channel	Magnitude (r^2	Frequency	Chan	Magnitude (r^2	Frequency	Channel	Magnitude (r^2	Frequency	Channel	Magnitude (r^2	Frequency

	(#)	Value)	(Hz)	nel (#)	Value)	(Hz)	(#)	Value)	(Hz)	(#)	Value)	(Hz)
Wrist Twisting (DHK)	6	.26	26-28	2	.37	24-26	10	.35	58-60	3	.35	24-26
Wrist Twisting (Tom)	3	.4	22-24	10	. 5	10-12	3	.4	20-22	3	.53	20-22



Tom Wrist Twisting (Constant Action Left, Repetitive Action Left, Constant Action Right, and Repetitive Action Right)

-Experiment 4 (Few Large Muscles vs. Many Small Muscles)

Since our body movements are collective movements of several muscles, it's hard to find movement that is only generated by a single muscle.

Experiment 4 (LR StimPresentation) (Few Large Muscles Involved Movement)

Movement	Left vs. Pause			Right vs. Pause			Left vs. Right		
	Channe l (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)
Legs Lifting Up (Tom)	5	.27	0-2	10	.27	14-16	11	.16	18-20

-Experiment 5 (Imaginary Action vs. Actual Action)

Experiment 5 (Imaginary Action vs. Actual Action) prove that the imaginary action generated EEG signal can be distinguished by itself since its R^2 Values are around 0.15 – 0.25 at low frequencies in all channels. However it's slightly smaller than conventional standard EEG signal in real-time (it requires R^2 Values over 0.3). Also, compare to EEG signals generated by action motor units (actual actions), it's very small that we can't use both imaginary EEG signals and actual action generated EEG signals at same time.

Experiment 5 (LR StimPresentation) Data A (Imaginary Action vs. Actual Action)

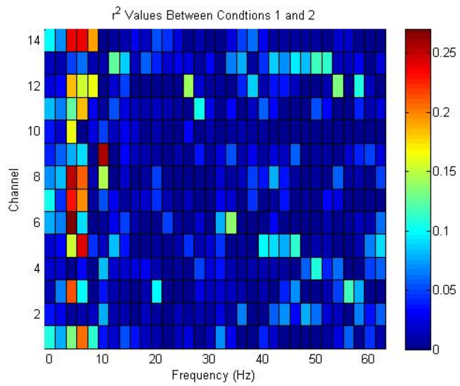
Movement	Actual Action			Imaginary Action			Actual vs. Imaginary		
	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)
Bicep Curling (Tom)	3	.21	20-22	6	.26	6-8	0	.35	10-12
Bicep Curling (DHK)	12	.2	4-6	6	.16	6-8	14	.21	Over 60
Fist Squeezing (DHK)	4	.16	6-8	3	.15	22-24	5	.19	8-10
Fist Squeezing (Tom)	14	.24	24-26	9	.15	4-6	12	.11	20-22

Experiment 5 (LR StimPresentation) Data B (Imaginary Ball 2D Control)

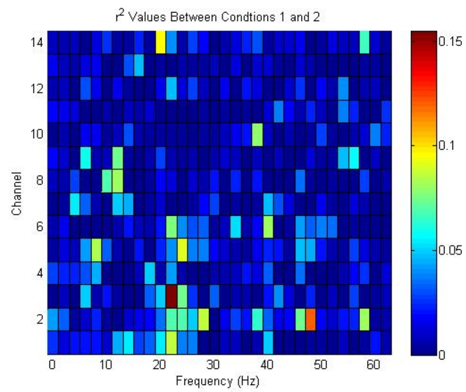
Imaginary Direction	Left			Right			Up			Down		
	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)
DHK	8	.19	16-18	5	.23	34-36	5	.15	28-30	6	.2	8-10

Experiment 5 (LR StimPresentation) Data C (Visual Stimulated Imaginary EEG)

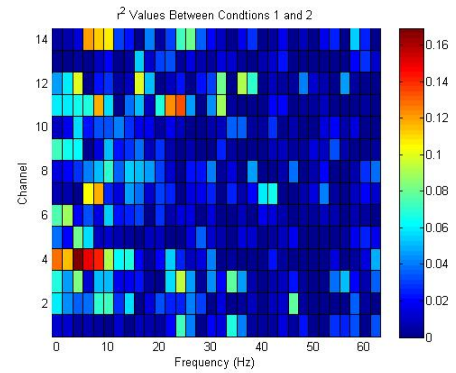
Movement	Image of a Balloon Floating in Sky			Image of a Balloon Stuck on Ground			Sky vs. Ground		
	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)
DHK	9	.27	18-20	8	.23	18-20	14	.31	26-28



Tom Imaginary Bicep Curling



DoHyun Kim Imaginary Fist Squeezing



DoHyun Kim Actual Fist Squeezing

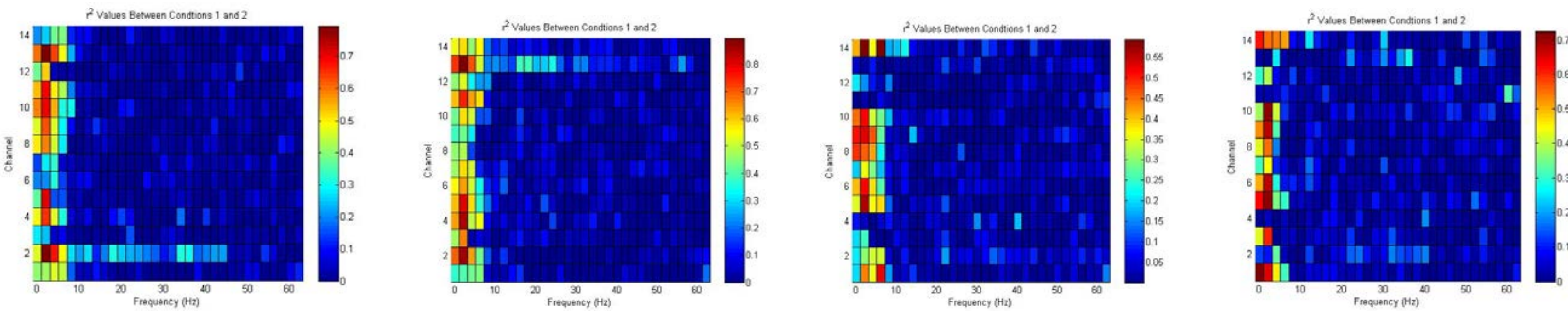
-Experiment 6 (Eye Movements// it's more like EMG artifacts)

Even though eye movements are not truly EEG signals (they are EMG signal artifacts), both slow eye movements and saccade generate high EEG R^2 Values. Interestingly, Saccade Movements are almost pure composed with 2-4 Hz (extremely low frequencies) while slow eye movements are composed with over 6 Hz (low frequencies). We have possibilities of using it for 2D control if we can clear up the noisy part in low frequencies.

Experiment 6 (LR StimPresentation) (Eye Movements)

Imaginary Direction	Left			Right			Up			Down		
	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)
Slow Eye Movement (DHK)	14	.36	26-28	13	.45	14-16	6	.37	38-40	7	.41	26-28
Saccade Movement (DHK)	14	.7	2-4	11	.83	2-4	14	.45	0-2	9	.51	2-4
Slow Eye Movement (Tom)	2	.51	6-8	13	.8	8-10	1	.45	6-8	14	.45	26-28

Saccade Movement (Tom)	2	.78	2-4	14	.84	2-4	14	.57	2-4	10	.71	2-4



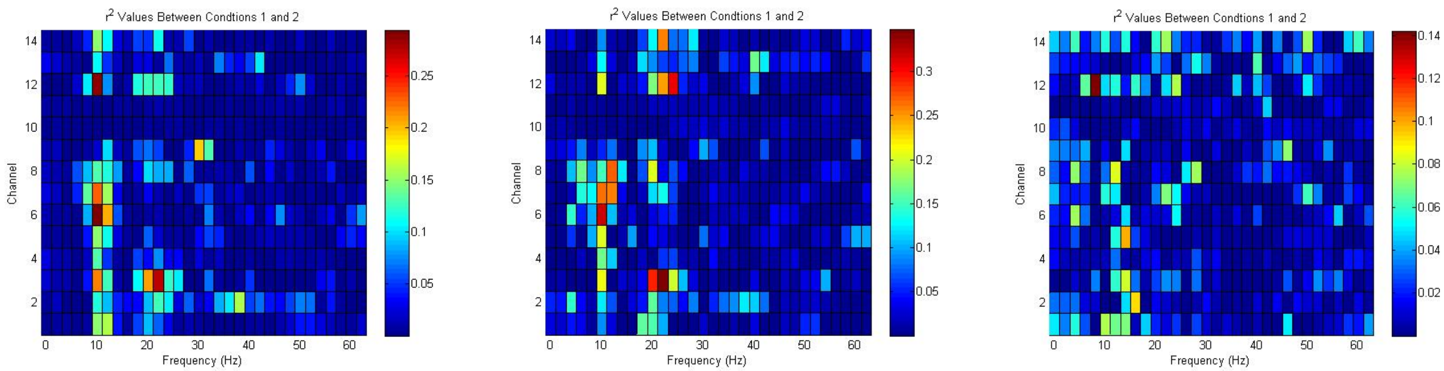
Tom Saccade Movement (toward left, right, up, and down)

-Experiment 7 (Trained Muscle Movement vs. Untrained Muscle Movement)

As we expected from the result in Experiment 2, the results of Experiment 7 show that untrained Muscle movement (and also less developed side of brain) generate EEG data of higher R^2 Values. We interpret this result that the untrained movement requires more concentration in both muscle movement and cognitive process in brain, resulting higher R^2 Values.

Experiment 7 (LR StimPresentation) (Trained vs. Untrained Muscle Movement)

Movement	Left vs. Pause			Right vs. Pause			Left vs. Right		
	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)	Channel (#)	Magnitude (r^2 Value)	Frequency (Hz)
Hand Writing (DHK)	1	.31	26-28	12	.19	22-24	12	.09	28-30
Hand Writing (Tom)	3	.33	22-24	3	.26	22-24	12	.14	8-10



Tom Hand Writing (Left Hand, Right Hand, Comparing Left Hand and Right Hand)

-Experiment 8 (Directional Movements) – reference:
http://digital.wustl.edu/e/etd/pdf/Anderson_wustl_0252D_10074.pdf

Professor Moran's ECoG experiment indicates that brain signal has directional properties that ECoG signal's amplitude can be graphed as a form of cosine waves. Even though Professor Moran's idea didn't apply for EEG data, some EEG signals in specific channel and frequencies follow his idea that R^2 Values have some trend of cosine graph.

Experiment 8 (LR StimPresentation) (Directional Movements)

	Left	Left-Up	Up	Right-Up	Right
DHK (Channel # 12 Frequency 46-48 Hz)	.21	.14	.26	.26	.18
DHK (Channel # 11 Frequency 0-2 Hz)	.05	.15	.25	.30	.23
Tom (Channel # 5 Frequency 10-12)	.28	.4	.43	.41	.24

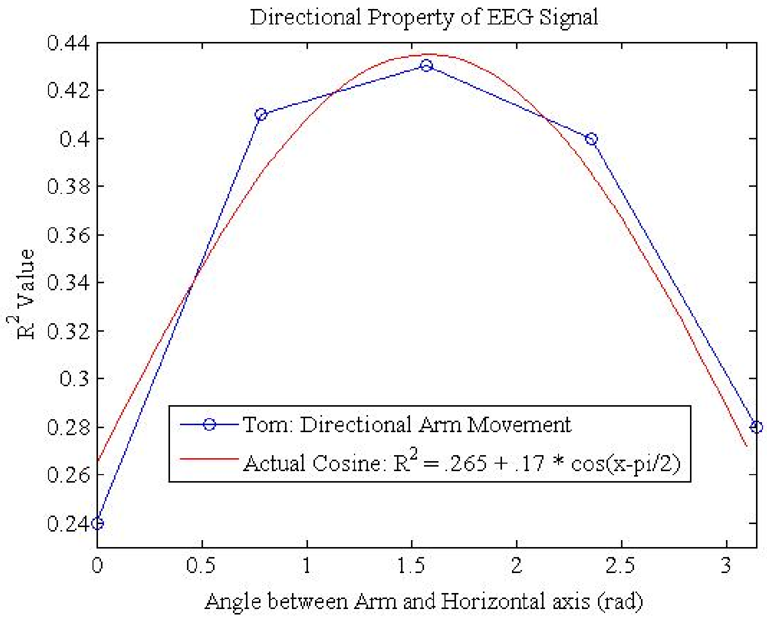


Figure: Tom Channel #5 Frequency 10-12Hz