Analyzing Brainwave Signals for Real Insights

Prabhavathi Matta & Vaidyanath Venkitasubramanian

Project Advisor: Prof. John Chung

Master's Final Project

School of Information, University of California- Berkeley

May, 2014

Acknowledgements

We would like to thank our advisor, Prof. John Chuang, for his insight and guidance on this project. We would also like to thank all the I School peeps for their support and enthusiasm towards this project.

Special thanks to Sohpie Barness, Deb Linton, Ankita Bhosle, Divya Anand, Divya Karthikeyan, Max Gutman, Peter Swigert, Ray Larson, Seema Hari, Noriko Misra, Anthony Suen, Faith Hutchison, Luis Aguilar, Lisa Jervis, Haroon Rasheed, Ashwin Chandak, Victor Starostenko, Jenton Lee, Kate Rushton, Ashley DeSouza, Shaun Giudici, Sarah Van Wart, Derek Kan, Kelli Martin, Madalyn Friedrich, Raymon Sutedjo, Kiki Qi Liu, Sandra Yeun Helsley for their participation and patience in our hour long NeuroClick experimental study.

Table of Contents

1. Introduction

1.1. Why?

Advances in EEG (electro-encephalogram) biosensor technologies over the past few years have opened up brainwave research and application development at an unprecedented level. Brainwave data collection traditionally used expensive research equipment, but similar data can now be collected using consumer-grade sensors built into simple headsets, such as Neurosky devices, and many more.

The increased interest in Brain Computer Interfaces as a topic of research and the availability of consumer-grade sensors means that there is an increased potential for the use of such technology in fields that conventionally make use of other techniques such as gaming, marketing and user research. Even though there has been some usage of such technology in some areas, there has not been too many software platforms that enable a seamless pipeline for data collection, analysis and visualization for other purposes.

1.2 What?

Our project, **NeuroClick,** aims to explore the relationship between brainwave signals and "interest" that users develop to various external stimuli. Does an interesting photo pique our attention more than a usual photo? Does an attention catching video actually induce a significant brainwave signal? Can the brain wave signal analysis allow us to predict what goes viral on social media?

Apart from judging cute cat photos, this technology could also find applications in design, advertising, marketing, A/B testing and various other fields, which might benefit from the knowledge of user attention/interest.

1.3 How?

In pursuit of our goal, we designed and developed a platform consisting of various tools to interface with the Neurosky device and performed semi automated experiments with users and archive data anonymously. We also perform data analysis on the gathered data to find interesting insights on user responses to various stimuli (text, images and videos)

In our research, the proposed human subject experiment are run on various volunteered subjects whose brain wave signals are collected when they are presented various stimuli like text, pictures, videos. We analyzed the data using standard correlation techniques to see whether there is any correlation between features of brainwave signals and stimuli presented to the human subjects.

We recruited 30 participants from different gender, ethnicity, and age groups. This number is based on the level of statistical significance we wished to attain for our analysis, as well as to account for the possibility that some participants may fail to complete the single session requirement for the study.

2. Background Research

2.1. The Technology

The device to collect brainwave is a headset with a built-in non-invasive EEG sensor manufactured by Neurosky. It is a consumer-grade EEG sensor that has a direct connection to a dry electrode and operates on a single channel (as opposed to a wet sensor operating on multiple channels that is commonly available). It has a sampling rate of 512 Hz and can collect signals within the frequency range from 3-100 Hz and operates at a voltage of 2.97 ~3.63V. It is connected to a laptop through bluetooth and streams packets that contain various information that includes the raw spectrum sampled at 512Hz, information about the quality of the signal and other such information.

Fig. 1. Neurosky MindWave headset

2.2. The Terminology

Electroencephalography (EEG) is the recording of electrical activity along the scalp. EEG measures voltage fluctuations resulting from ionic current flows within the neurons of the brain. The EEG signal is represented by the presence of rhythmic activity that is divided into preset bands based on the frequency. Scientifically the activity within a certain frequency band has been observed to have some biological significance.

Name	Frequency Band	Indicates
Delta	<4	slow-wave sleep, continuous attention tasks
Theta	4 -7	drowsiness, idling
Alpha	8 - 15	relaxed
Beta	16-31	active thinking, high alert
Gamma	32 +	familiarity
Mu	8 – 12	rest-state motor neurons

Table 1. EEG frequency bands (Data from Wikipedia)

Of these frequency bands, the neurosky hardware provided information about alpha, beta, gamma, delta and theta bands.

3. Implementation

3.1. Experimental Design

3.1.1. Stimulus Selection

We chose stimuli that are diverse (text, pic, video) and evoke different responses from the users. Along with the stimulus type, we also wanted to experiment with the time-duration of the stimulus and see how it affects participants' response. We selected stimuli from various social media on the internet like youtube, twitter, vine, book reviews, etc. Each of these stimuli have specific properties associated with them such as the duration, how many people liked it/favorited it, highlighted it based on which we decided the measure of popularity of the stimulus. In the end, these are the set of representative stimuli that are chosen for the experimental study:

(i) tweets, pictures and vines from twitter,

(ii) text snippets from amazon book reviews,

(iii) videos from youtube.

Sample of the meta-data along with other stimulus details are given in the fig below:

Tag	Meta	data-time	data-transperiod	url	Likes	views	Dislikes	Revines
vid1	P	7	2	<iframe class="vine-embed" src="https://vine.co/v/htbr9vhq5HB/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	35.9k			28.8k
vid2	P	70	2	<iframe width="560" height="315" src="//www.youtube.com/embed/w4lnVx2BAYk&start=0&end=70" frameborder="0" allowfullscreen></iframe>	50498	7611819	2100	
vid3	P	56	2	<iframe width="560" height="315" src="//www.youtube.com/embed/_OBlgSz8sSM" frameborde	1202489	677930244	185924	
vid4	NP	8	2	<iframe class="vine-embed" src="https://vine.co/v/MbMm9ltnTjF/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	0			0
vid5	NP	7	2	<iframe class="vine-embed" src="https://vine.co/v/hpeAW7W2MbJ/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	2			0
vid6	P	6	2	<iframe class="vine-embed" src="https://vine.co/v/MzqJb9Kei3E/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	22.9k			25.1k
vid7	NP	111	2	<iframe width="560" height="315" src="//www.youtube.com/embed/ilrJVpsa3k0" frameborder='	23	1897	18	
vid8	P	6	2	<iframe class="vine-embed" src="https://vine.co/v/MWd03dtgbBb/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	129.4			69.4k
vid9	NP	151	2	<iframe width="420" height="315" src="//www.youtube.com/embed/HhEjpl6L6Qc" frameborder	10	5419	1	
vid10	P	6	2	<iframe class="vine-embed" src="https://vine.co/v/hlUaFxUKqm6/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	35.8			41.1
vid11	NP	6	2	<iframe class="vine-embed" src="https://vine.co/v/MmPh0PTxjvz/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	143			102
vid12	P	4	2	<iframe class="vine-embed" src="https://vine.co/v/MzwlgwptbaZ/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	9635			8357
vid13	P	103	2	<iframe width="560" height="315" src="//www.youtube.com/embed/Hwt2Jt6mxpE" frameborde	9			
vid14	P	6	2	<iframe class="vine-embed" src="https://vine.co/v/MAeD2DK6W9X/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	79.3k			93.4k
vid15	P	68	2	<iframe width="560" height="315" src="//www.youtube.com/embed/eN6c8aHBIbU" frameborder="0" allowfullscreen></iframe>	1945	675896	363	
				<iframe class="vine-embed" src="https://vine.co/v/MmMXrrFZI20/embed/simple?audio=1"				

Fig 2. Meta data information

Text:

For text, we chose Amazon Kindle book reviews as our source and shortlisted around 40 text snippets from various books based on number of words in the text and the popularity of the snippet as indicated by the highlight count. We went through a lot of iterations before ending up with a final list of 40 text snippets to choose a representative sample for popular and non-popular text. We also calculated an estimate of the time that would be required by an average user to read the text. This was primarily based on the number of words in the text.

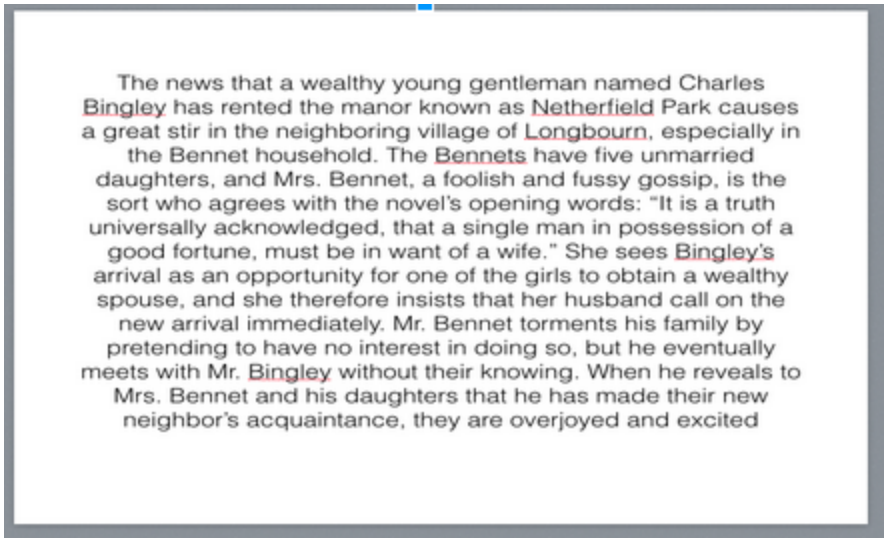


Fig 3. Sample Long Text

Images

Images were selected mainly from twitter and meta-data such as favourites and retweets associated with the tweet formed the basis of our categorization into popular and non-popular.

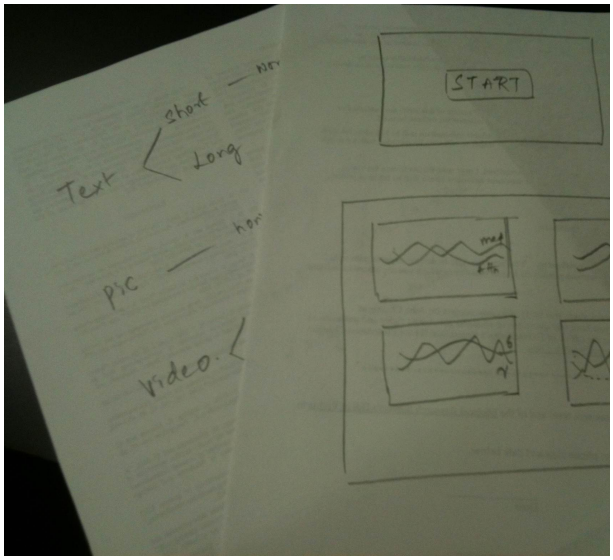
Fig 4. Sample Image Stimuli

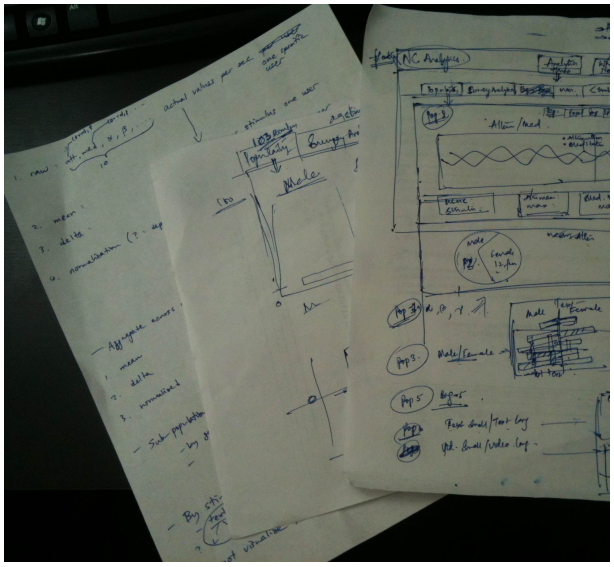
Video

Various youtube videos and vines are chosen for variety in length of time-duration and availability of rich meta-data in terms of likes, views, downvotes, retweets, favourites, etc. For short video stimulus type, vines of about 4-6 sec and for long video stimulus type, 1-3 min youtube videos were selected.

3.1.2. Initial Prototype

During the initial prototype, we combined Neuroview, a proprietary software of Neurosky Co. and Keynote presentation, to collect brainwave signals in response to the stimuli presented in the keynote.





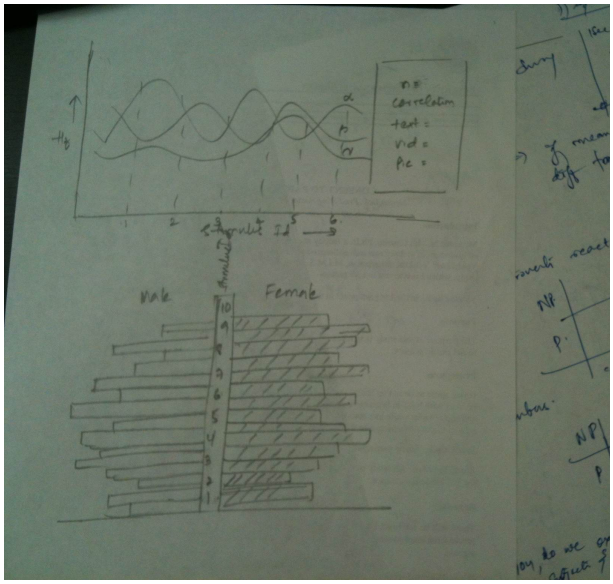


Fig. 7. Initial Prototype for dashboard

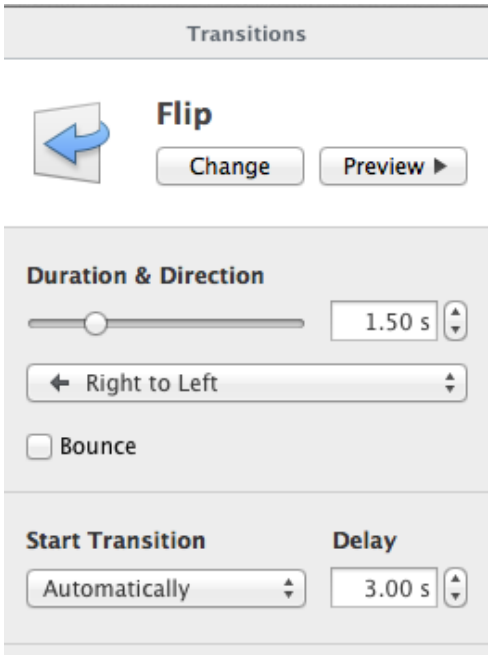


Fig. 8 Initial Prototype configuring time

We also configured appropriate transition times between the stimulus to help with easy control of brain wave signal analysis from one stimulus to another and to avoid overlap of brain wave response of one stimulus into the next stimulus.

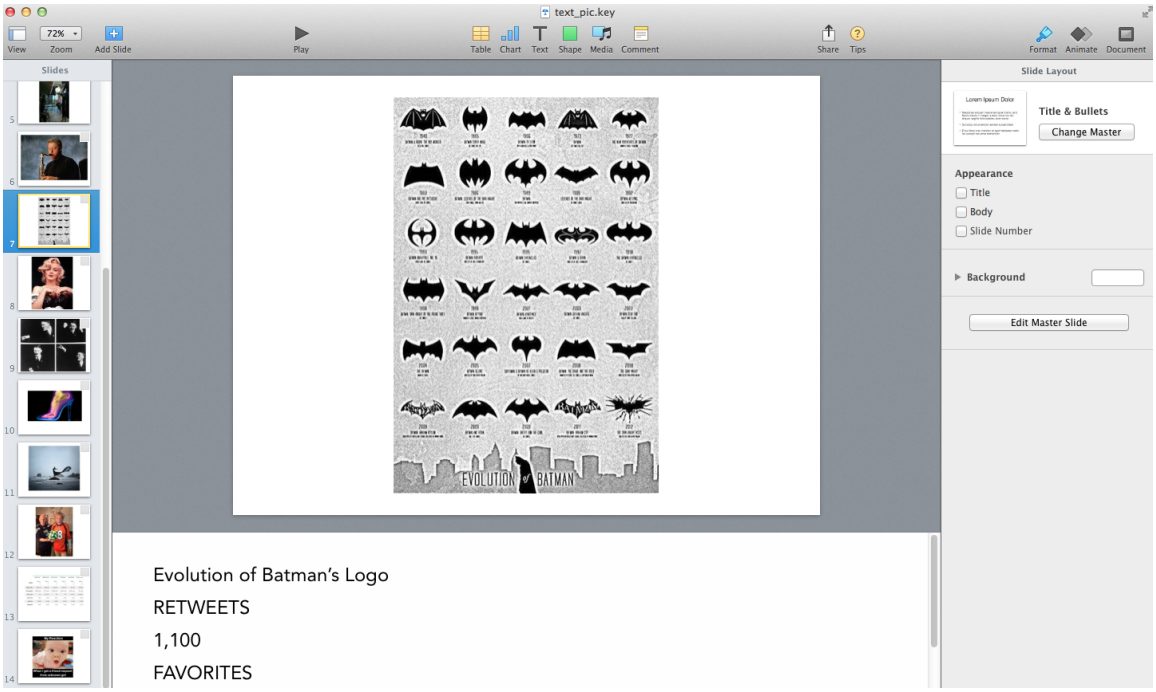


Fig. 9. Initial Prototype for experiment framework

Though we could collect stream of brain wave signals for the duration of the experiment, there was difficulty in synchronization of both the applications and get exact time snapshots of the signals. Since the signal stream data is collected every sec, it caused errors during analysis.

3.2. Data Collection

3.2.1. System Architecture

The system was designed to be a fully integrated seamless pipeline that can be configured to load the various stimuli for the experiment and configure the duration for which each stimulus has to be displayed, record the EEG signals during the experiment and save the data for processing later. The data that was stored was not associated to any user by any kind of personally identifiable information. Each user's data was saved with a system generated number.

Software Used:

Python, Flask
Light blue (Bluetooth library for python)
Gevent
Socket IO
HTML, CSS3, JavaScript, JQuery
Numpy, Scipy
HighCharts, D3.js

There were two important points that we had to focus on with the implementation of the system. One was the component that would be visible to the end user who is the subject of the experiment. This was really important because the whole process had to be automated so that the user can remain undisturbed during the course of the experiment. We created a system that was built using HTML, CSS3 and JavaScript that allows the person conducting the experiment to decide what stimuli needs to be inserted and then configure various settings such as the duration for which the stimulus should appear on screen, the time required for transition from one stimulus to the other etc.

The second important part of the system was the one that was used for monitoring of the brainwave signals as the experiment progressed. This was necessary in order to make sure that the device was well connected at all times and that the quality of signal was good. For this we integrated this systemm to a backend that interfaced with the neurosky headset via bluetooth and streamed the relevant information that included the different signals such as alpha, beta, delta waves at regular intervals(each second).

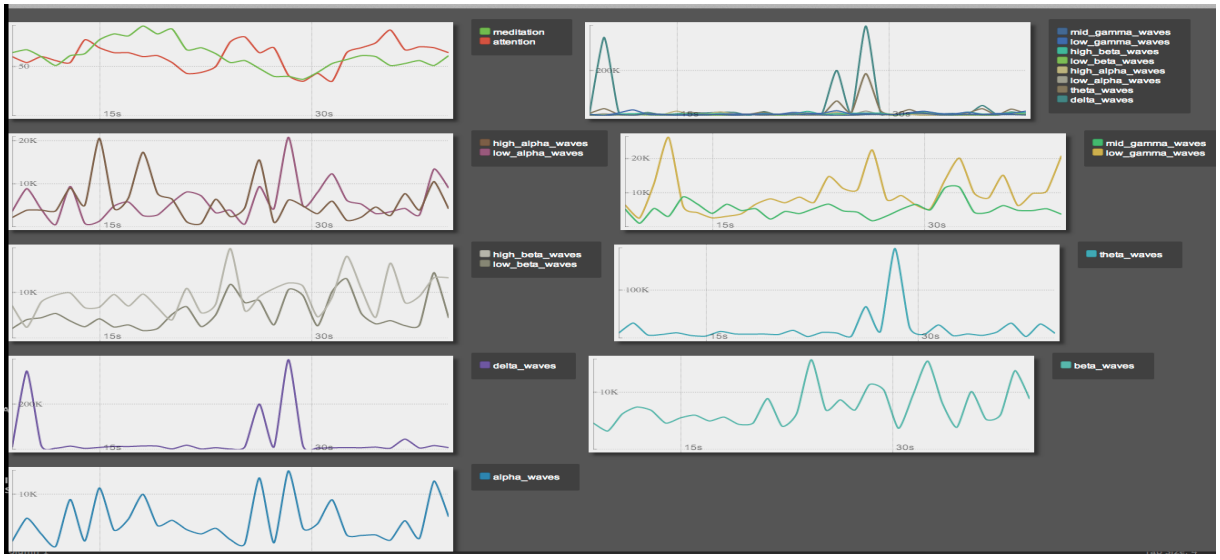


Fig 10. Real time monitor during the experiment.

For the backend, the most important component was to interact with the hardware to collect the streaming data via bluetooth. The system was designed in such a way that we would be able to monitor the real time streaming data and also synchronize the time stamps for data analysis. This was done in two steps - the first was to establish a connection with the bluetooth device (neurosky headset) and then streaming this data to the frontend at regular intervals so that this could be monitored in real time. The second was to save this data - which included information about the signal quality, the raw spectrum, the amplitude at various frequency bands etc. All of these information were saved for later use with the time stamp. We also saved the information about the stimulus such as the timestamp at which each stimulus showed up on screen, the transition times and other information as well. This information was necessary in order to identify the data specific to a particular stimulus.

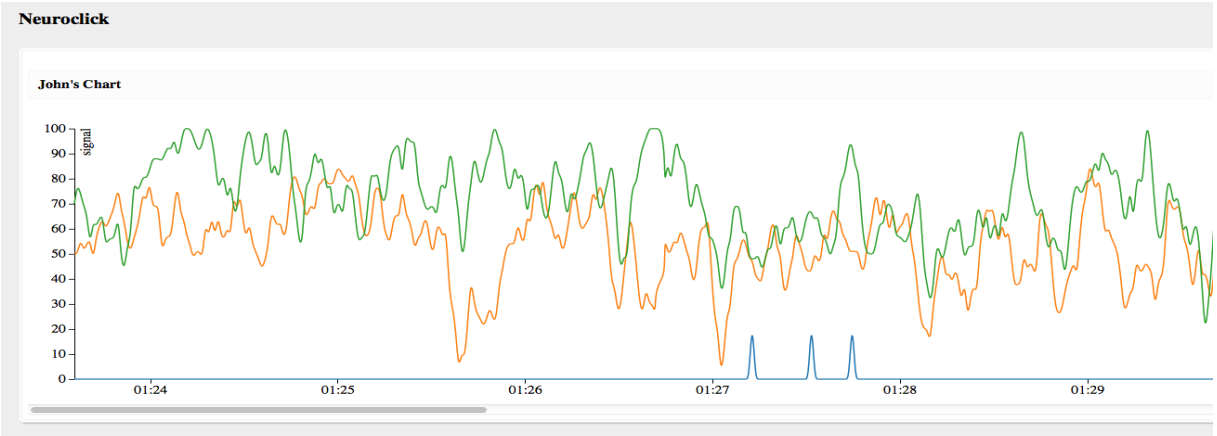


Fig. 11. Time series graph of user data after experiment for analysis

3.2.3. Procedure

Each participant will first be briefed on the objective of the study and the procedure of the session. Then, the participant will be instructed to put on the commercially available headset with built-in non-invasive EEG sensors. The experimenter will help adjust the headset to ensure that it is worn properly. Then, the participant will be asked to watch a series of stimuli like text, pictures and videos taken from social media. EEG data will be recorded in real-time on the researcher's computer while the stimuli are being presented to the participant. An anonymous questionnaire on the participant's evaluation of the level of involvement or enjoyment of the various stimuli will be taken. The metadata collected will include time and date of session, tasks performed, participant ID (not identifiable). No personally identifiable data will be collected.

Each of the project personnel will be responsible for conducting the study procedures. The procedures will take place at a quiet location on or near the UCB campus and at a time that is of mutual convenience to the participant and researcher. The session will last approximately 1 hour.

Fig. 12. Experimental study in progress

3.4. Data Processing

3.4.1. Data Cleaning

The data saved during the experiment could not be used directly for the analysis since there was a lot of noise associated with the raw data.So the second part of our system had to deal with this before we could perform any kind of analysis on the collected data. Since the data that was recorded included data during the transition of slides in addition to the actual data that was collected when the stimulus was being shown, we had to do some kind of slicing of the data to only include the relevant data for analysis.

3.4.3. Data Formatting

Time Synchronization

Since all of the data that we had were recorded with different time stamps, the first step of data preprocessing that we had to do was to reorganize the data so that it would be possible to isolate the timestamps that were associated with a particular stimuli among all users. This was required so that we could use this information for all of our statistical analysis and models.

MetaData Information

Since most of our analysis was centered on using the meta data of the stimuli and the users, such as the gender of the user and the popularity of the stimulus, the category of the stimulus (short, long etc.) we had to build a data structure that would enable us to access all of this information with ease. This was especially important since we required to use this information quite frequently with each iteration of analysis.

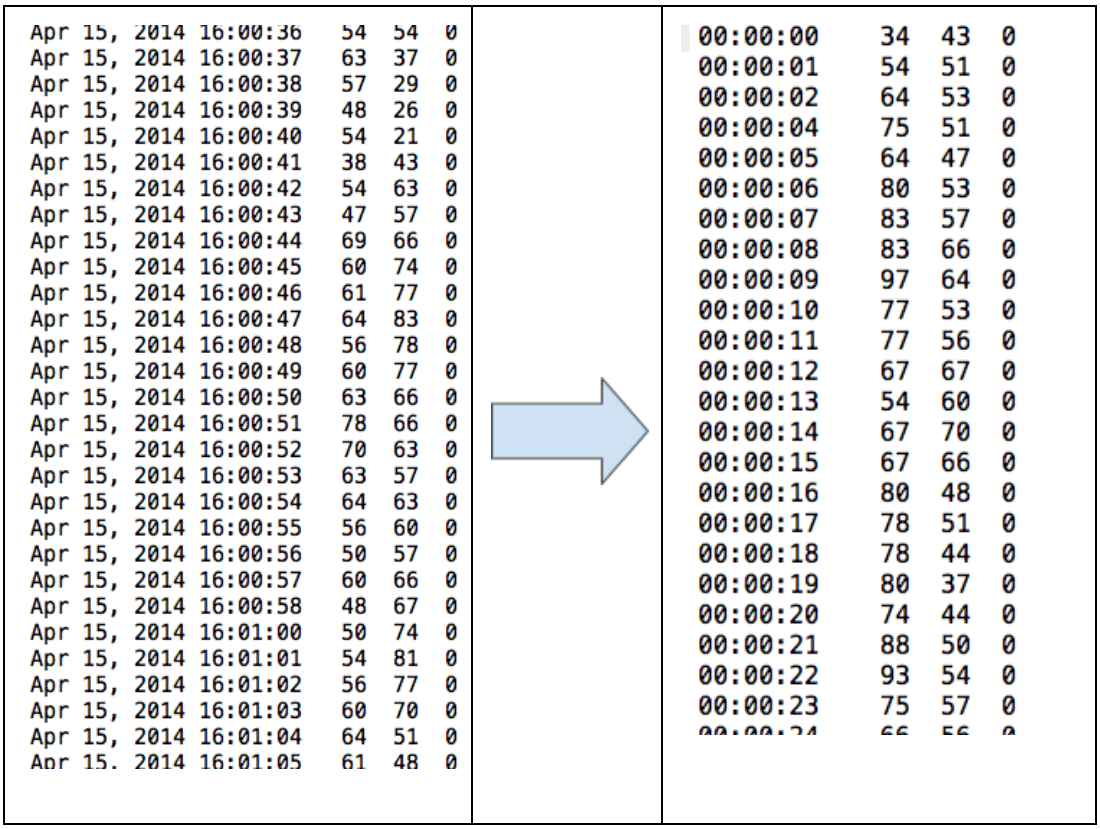


Fig. 13. Formatted data from raw data

3.5 Data Analysis

3.5.1. Frequency Data Analysis

We started with the most basic analysis - how different users responded to each of the stimulus that were presented to them. We chose two metrics - attention and meditation to look at how the user's response was to various stimuli.

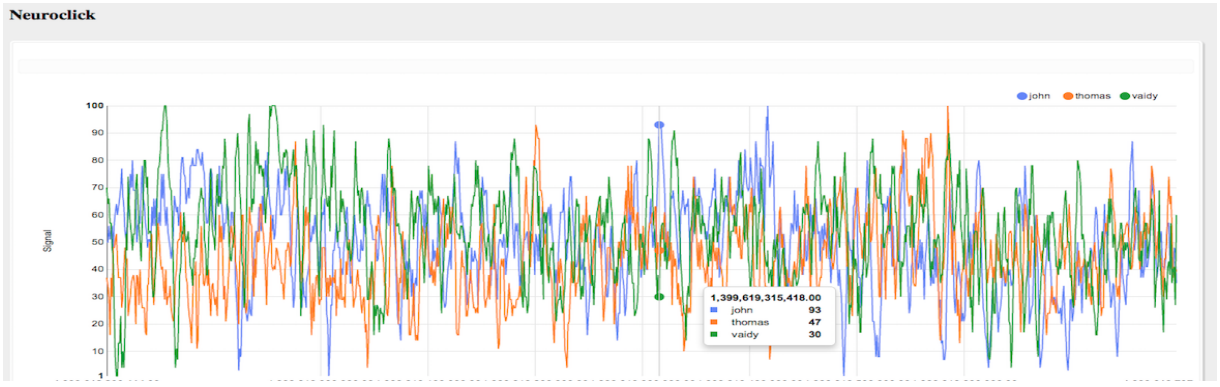


Fig. 14. Frequency data analysis

It was quite interesting to start the analysis this way and notice patterns in the responses.We noticed that the average attention of all users was relatively higher in the beginning and that there was a gradual decrease in the attention level with time.

3.5.2. Stimulus Type Analysis

We also analyzed the data to see if the effect remained the same even for specific portions of certain stimuli. We also analyzed how users reacted to certain stimuli that we hypothesized would evoke a strong response in the user.

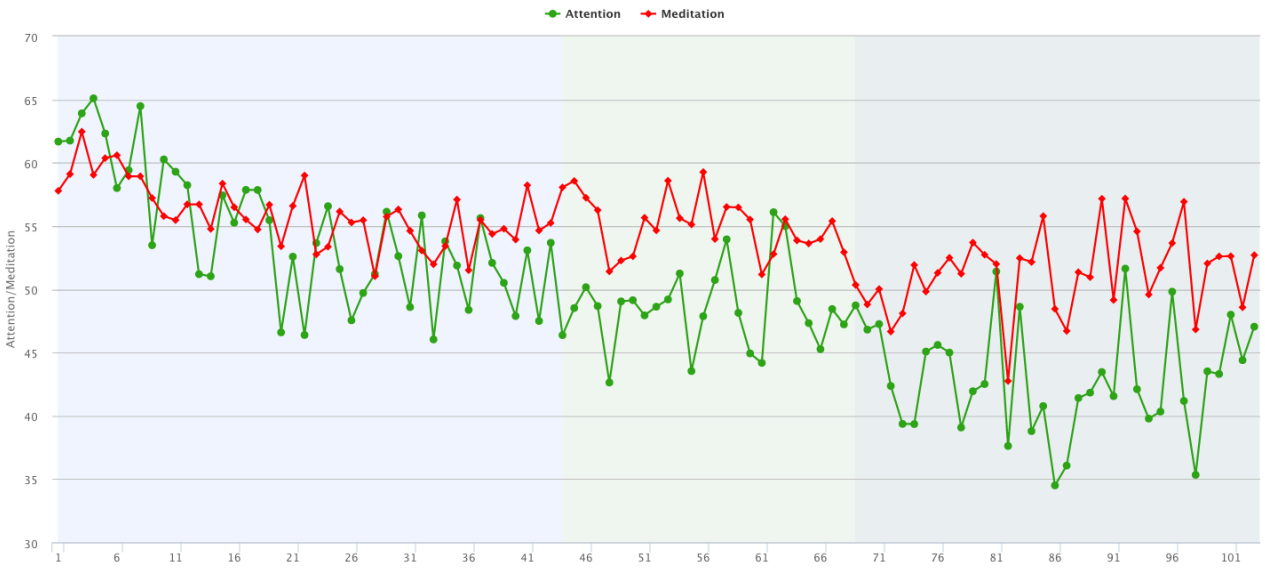


Fig. 15. Stimulus Type data analysis

3.5.3. Time Slice/Blink Effect Analysis

Further, we wanted to see if there is any significant impact on the response in the first few seconds when a stimulus is presented to the user. For this, we computed values that reflect the user's reaction to specific time slices for each stimuli. We observed that the users stopped paying attention (relatively) to a stimulus as the experiment progressed. We could see a dip of almost 50%in the attention level of users from the beginning to the end of the experiment.

We also repeated this analysis through various iterations over different time slices and by looking at the longest sequences of spikes/decrease in activity for a particular sequence. This was with the hypothesis that all users have a similar response to a specific slice of a specific stimuli.

3.5.4. Survey Feedback Data Analysis

We also carried out the above analysis with the data that we collected from the post-experiment surveys that served as a ground truth for us in terms of assessing the interest of the user. With the initial analysis, we took the meta-data of the selected stimuli (popular/not popular) as the label for our statistical models. But towards the later stages of analysis, we looked at these results to determine if the stimuli is popular or not popular (specific to a user).

*********** AVERAGE DATA **********

Combined correlation of all 29 users and all 29 survey stimuli
Attention

Stimulus type: VID_LONG Corr: -0.0919113000543 p_val: 0.326457894604

Stimulus type: IMAGE Corr: 0.0716296230827 p_val: 0.0847868172133

Stimulus type: VID_SHORT Corr: 0.0427330374628 p_val: 0.609803852792

Combined correlation of all 29 users and all 29 survey stimuli
Meditation

Stimulus type: VID_LONG Corr: 0.0848279461388 p_val: 0.365272616127

Stimulus type: IMAGE Corr: 0.0177091528522 p_val: 0.670394839017

Stimulus type: VID_SHORT Corr: 0.0617905220655 p_val: 0.460318522462

***************BLINK DATA ********************

Combined correlation of all 29 users and all 29 survey stimuli
Attention

Stimulus type: VID_LONG Corr: -0.136980973553 p_val: 0.142573633532

Stimulus type: IMAGE Corr: 0.0780988625422 p_val: 0.0601511797546

Stimulus type: VID_SHORT Corr: 0.0449157208661 p_val: 0.59164993473

Combined correlation of all 29 users and all 29 survey stimuli
Meditation

Stimulus type: VID_LONG Corr: 0.0217437117229 p_val: 0.816787993974

Stimulus type: IMAGE Corr: 0.0271734291736 p_val: 0.513671409084

Stimulus type: VID_SHORT Corr: 0.0832717427047 p_val: 0.319358700574

3.5.5. Gender Analysis

We also ended up getting some really interesting insights on how the responses were different among the male and the female sections of the population. Our participants' sample has almost equal split in male and female population.

Observations from Average Signal Data

- attention level was higher among the female population than the male population for text , whereas it is vice-versa for videos.

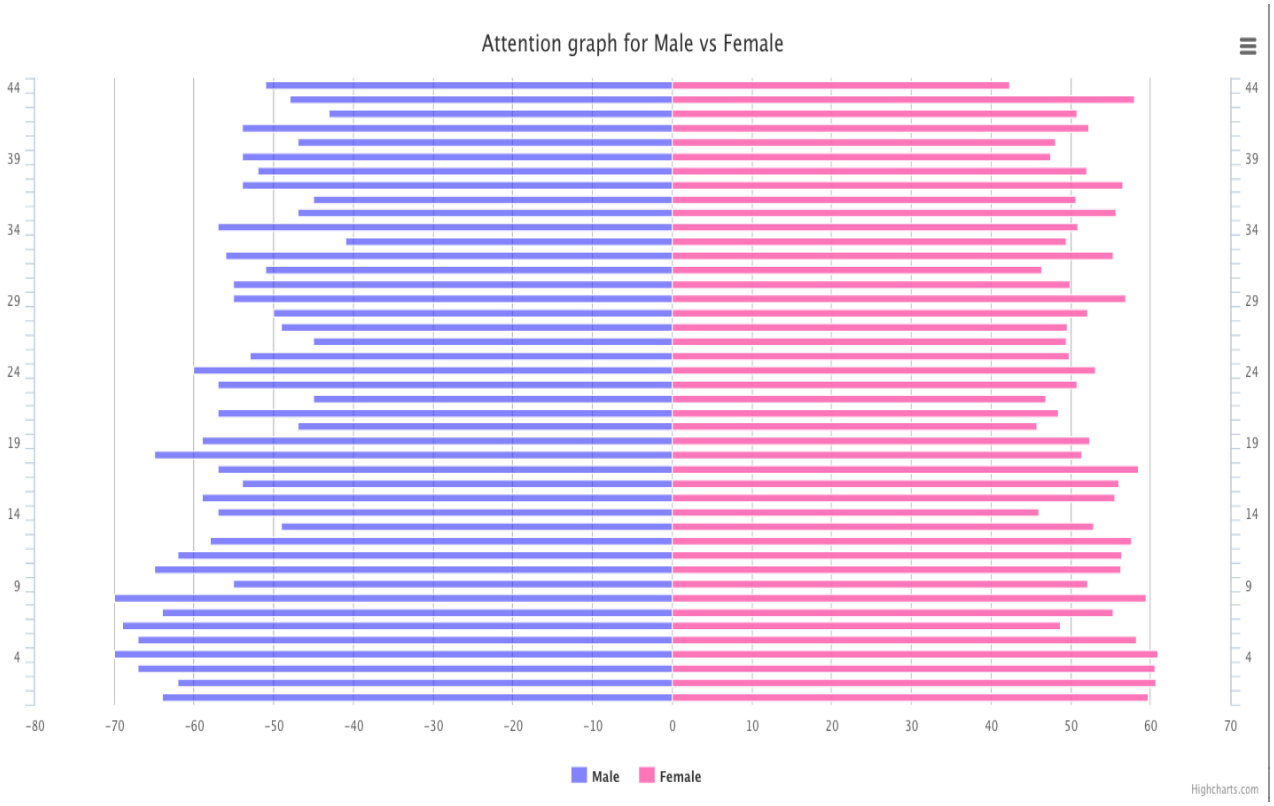
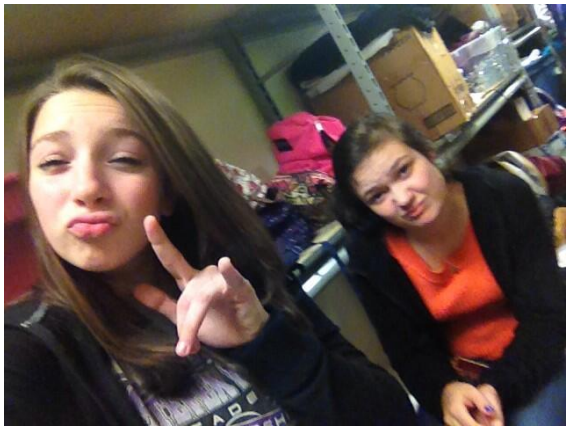


Fig. 16. Gender data analysis

Most Liked by Women and the stimulus that evoked the least attention in men

Evoked highest attention among Men and relatively lower attention from women



Less than average attention for this image from Women, while there was a significantly high attention from men

Observations from Time Slice/Blink Effect Data

- attention level for the first few seconds in each stimulus was fairly higher among the male population than the female population, which was quite interesting.

-there was no visible difference in the attention levels between male and female population for videos.

- for most images, men and women and diametrically opposite responses in terms of attention.

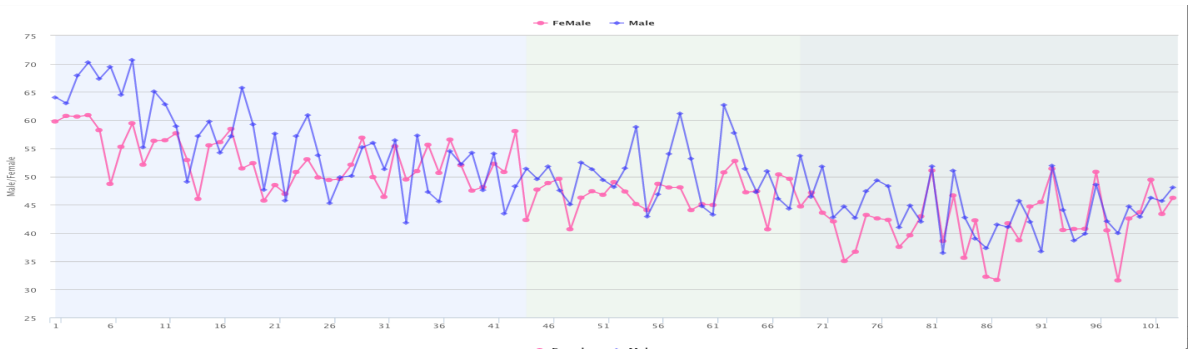


Fig. 17. Gender data analysis

4. Future Work

Being in the nascent stages of research, this technology has lots of avenues in terms of research. There were a lot of decisions that we had to make with respect to the experiment due to the want of time, but as a full fledged research a lot of variations could be done with the experiments, both in terms of the stimuli that are chosen for the experiment as well as the variations with the experimental setup.

There were a few information that we had collected during the post-experiment survey that gives an indication of the behavior of the users in group settings and it would be interesting to look at the various kinds of analysis that we can run with that information - how does the brain wave response differ among introverts and extroverts, for instance.

Appendices

Appendix A: Stimulus Metadata

Tag	Meta	data-time	data-transperiod	url	Likes	views	Dislikes	Revines
vid1	P	7	2	<iframe class="vine-embed" src="https://vine.co/v/htbr9vhq5HB/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	35.9k			28.8k
vid2	P	70	2	<iframe width="560" height="315" src="//www.youtube.com/embed/w4lnVx2BAYk&start=0&end=70" frameborder="0" allowfullscreen></iframe>	50498	7611819	2100	
vid3	P	56	2	<iframe width="560" height="315" src="//www.youtube.com/embed/_OBlgSz8sSM" frameborde	1202489	677930244	185924	
vid4	NP	8	2	<iframe class="vine-embed" src="https://vine.co/v/MbMm9ltnTjF/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	0			0
vid5	NP	7	2	<iframe class="vine-embed" src="https://vine.co/v/hpeAW7W2MbJ/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	2			0
vid6	P	6	2	<iframe class="vine-embed" src="https://vine.co/v/MzqJb9Kei3E/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	22.9k			25.1k
vid7	NP	111	2	<iframe width="560" height="315" src="//www.youtube.com/embed/ilrJVpsa3k0" frameborder='	23	1897	18	
vid8	P	6	2	<iframe class="vine-embed" src="https://vine.co/v/MWd03dtgbBb/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	129.4			69.4k
vid9	NP	151	2	<iframe width="420" height="315" src="//www.youtube.com/embed/HhEjpI6L6Qc" frameborder	10	5419	1	
vid10	P	6	2	<iframe class="vine-embed" src="https://vine.co/v/hlUaFxUKqm6/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	35.8			41.1
vid11	NP	6	2	<iframe class="vine-embed" src="https://vine.co/v/MmPh0PTxjvz/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	143			102
vid12	P	4	2	<iframe class="vine-embed" src="https://vine.co/v/MzwlgwptbaZ/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	9635			8357
vid13	P	103	2	<iframe width="560" height="315" src="//www.youtube.com/embed/Hwt2Jt6mxpE" frameborde	9			
vid14	P	6	2	<iframe class="vine-embed" src="https://vine.co/v/MAeD2DK6W9X/embed/simple?audio=1" width="600" height="600" frameborder="0"></iframe><script async src="//platform.vine.co/static/scripts/embed.js" charset="utf-8"></script>	79.3k			93.4k
vid15	P	68	2	<iframe width="560" height="315" src="//www.youtube.com/embed/eN6c8aHBIbU" frameborder="0" allowfullscreen></iframe>	1945	675896	363	
				<iframe class="vine-embed" src="https://vine.co/v/MmMXrrFZI20/embed/simple?audio=1"				

Stimulus Id	Stimulus Time	P/NP	Stimulus Type	Stimulus SubType
1	25	1	text0	Long
2	7	1	baseline1	baseline
3	21	1	text1	Long
4	27	1	text2	Long
5	37	-1	text3	Long
6	26	1	text4	Long
7	11	-1	text5	Short
8	40	-1	text6	Long
9	9	-1	text7	Short
10	13	-1	text8	Long
11	27	-1	text9	Long
12	52	-1	text10	Long
13	4	1	text11	Short
14	9	-1	text12	Short
15	22	1	text13	Long
16	13	-1	text14	Long
17	15	-1	text15	Long
18	6	-1	text16	Short
19	9	-1	text17	Short
20	7	1	text18	Short
21	6	1	text19	Short
22	10	-1	text20	Short
23	7	1	baseline2	baseline
24	36	1	text21	Long
25	5	1	text22	Short
26	6	-1	text23	Short
27	4	1	text24	Short

Appendix B: Sample SurveyA Questions

Q.No	Image1	Image2
Q1	pic4	pic1
Q2	pic2	pic9
Q3	pic25	pic7
Q4	pic15	pic10
Q5	pic23	pic22
Q6	pic8	pic19
Q7	pic24	pic17
Q8	pic11	pic20
Q9	pic5	pic3
Q10	pic12	pic16

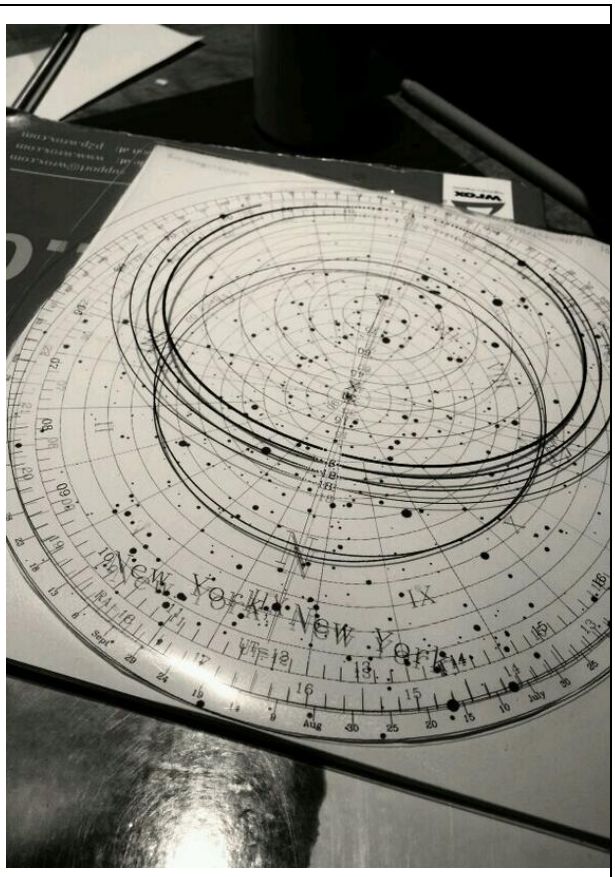
Gender* Required

- **F**
- **M**

Please take a few minutes to fill this survey. This would help us with getting to know your preferences about some of the images and videos that you watched during the experiment.

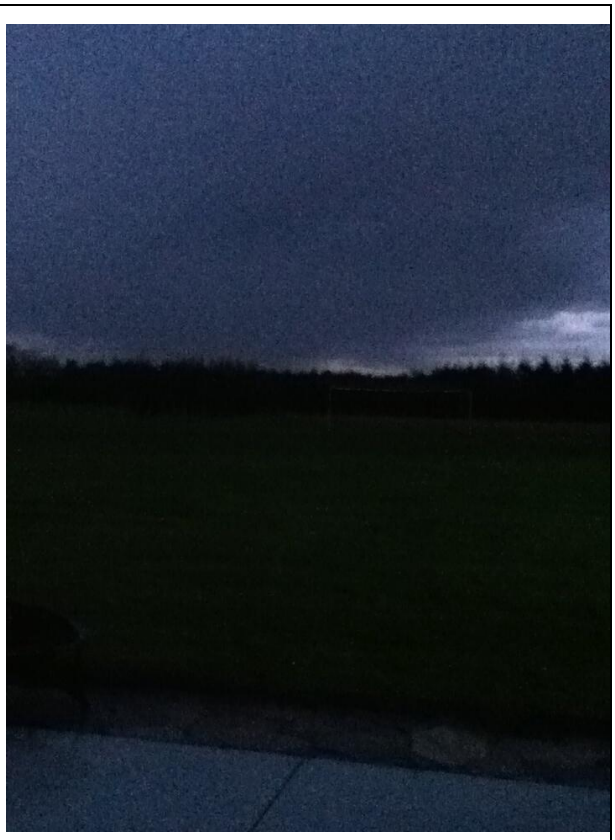
Which of the two pictures caught your attention?* Required

- **pic1**
- **pic2**
- **Both**
- **I dont remember seeing these images**

Which of the two pictures caught your attention?* Required

- **pic1**
- **pic2**
- **Both**
- **I dont remember seeing these images**

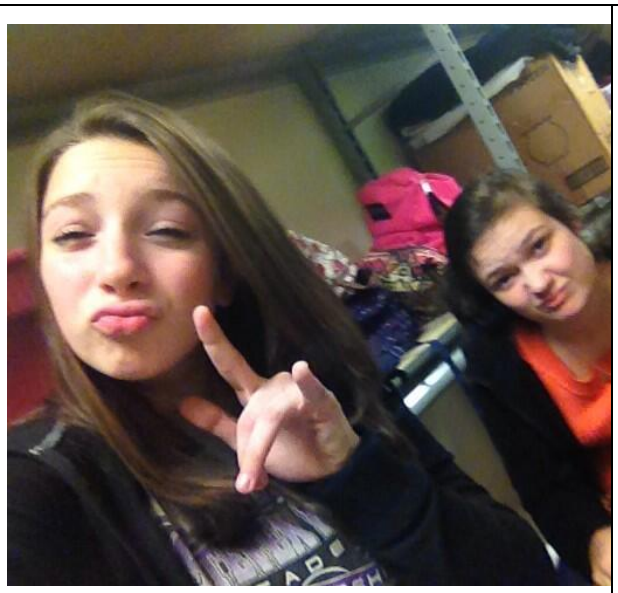
	

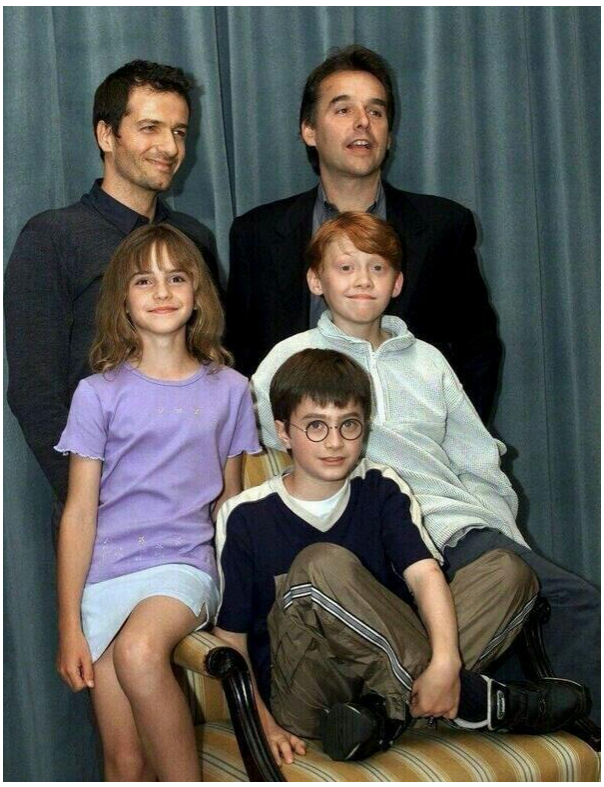
Which of the two pictures caught your attention?* Required

- **pic1**
- **pic2**
- **Both**
- **I dont remember seeing these images**

Which of the two pictures caught your attention?* Required

- **pic1**
- **pic2**
- **Both**
- **I dont remember seeing these images**





Rate these videos from a scale of 1(Lowest) to 5(Highest) based on how much detail you remember each of these. Please choose NA if you do not remember watching the video* Required

	1	2	3	4	5	NA
Arnold Crushing objects with a tank						
Psychology experiment for persuasion						
Horticulture video of a guy explaining how to divide iris						

Appendix C: SurveyB Questions

Enter User ID*

In the table below, for each statement 1-50 mark how much you agree with on the scale 1-5, where 1=disagree, 2=slightly disagree, 3=neutral, 4=slightly agree and 5=agree

	1	2	3	4	5
1. Am the life of the party.					
2. Feel little concern for others.					
3. Am always prepared.					
4. Get stressed out easily.					
5. Have a rich vocabulary.					
6. Don't talk a lot.					
7. Am interested in people.					
8. Leave my belongings around.					
9. Am relaxed most of the time.					
10. Have difficulty understanding abstract ideas.					

Continue to next page

In the table below, for each statement 1-50 mark how much you agree with on the scale 1-5, where 1=disagree, 2=slightly disagree, 3=neutral, 4=slightly agree and 5=agree

	1	2	3	4	5
11. Feel comfortable around people.					
12. Insult people.					
13. Pay attention to details.					
14. Worry about things.					
15. Have a vivid imagination.					
16. Keep in the background.					
17. Sympathize with others' feelings.					
18. Make a mess of things.					
19. Seldom feel blue.					
20. Am not interested in abstract ideas.					

Continue to next page

In the table below, for each statement 1-50 mark how much you agree with on the scale 1-5, where 1=disagree, 2=slightly disagree, 3=neutral, 4=slightly agree and 5=agree

	1	2	3	4	5
21. Start conversations.					

22. Am not interested in other people's problems.	
23. Get chores done right away.	
24. Am easily disturbed.	
25. Have excellent ideas.	
26. Have little to say.	
27. Have a soft heart.	
28. Often forget to put things back in their proper place.	
29. Get upset easily.	
30. Do not have a good imagination.	

Continue to next page

In the table below, for each statement 1-50 mark how much you agree with on the scale 1-5, where 1=disagree, 2=slightly disagree, 3=neutral, 4=slightly agree and 5=agree

	1	2	3	4	5
31. Talk to a lot of different people at parties.					

32. Am not really interested in others.	
33. Like order.	
34. Change my mood a lot.	
35. Am quick to understand things.	
36. Don't like to draw attention to myself.	
37. Take time out for others.	
38. Shirk my duties.	
39. Have frequent mood swings.	
40. Use difficult words.	

Continue to next page

In the table below, for each statement 1-50 mark how much you agree with on the scale 1-5, where 1=disagree, 2=slightly disagree, 3=neutral, 4=slightly agree and 5=agree

	1	**2**	**3**	**4**	**5**
41. Don't mind being the center of attention.					
42. Feel others' emotions.					

43. Follow a schedule.	
44. Get irritated easily.	
45. Spend time reflecting on things.	
46. Am quiet around strangers.	
47. Make people feel at ease.	
48. Am exacting in my work.	
49. Often feel blue.	
50. Am full of ideas.	

References:

- J. Chuang, H. Nguyen, C. Wang, B. Johnson. 2013, “I Think, Therefore I Am: Usability and Security of Authentication Using Brainwaves” , Workshop on Usable Security (USEC13), April 2013.
- Mak, J.N.; Chan, R.H.M.; Wong, S.W.H., "Evaluation of mental workload in visual-motor task: Spectral analysis of single-channel frontal EEG," Industrial Electronics Society, IECON 2013 - 39th Annual Conference of the IEEE , vol., no., pp.8426,8430, 10-13 Nov. 2013
- Mak, J.N, et.al .;”Spectral modulation of frontal EEG activities during motor skill acquisition: task familiarity monitoring using single-channel EEG.”, EEE Eng Med Biol Soc. 2013;
- Neurosky headset, http://neurosky.com/
- Big Five Personality Test, ipip.ori.org. http://personality-testing.info/print/big-five-personality-test.pdf