

# Brainfingers

Andrew Junker, PhD.  
Brain Actuated Technologies, Inc.

Special Needs Computers  
1-844-724-4922 | 1-905-641-4922  
sales@specialneedscomputers.ca

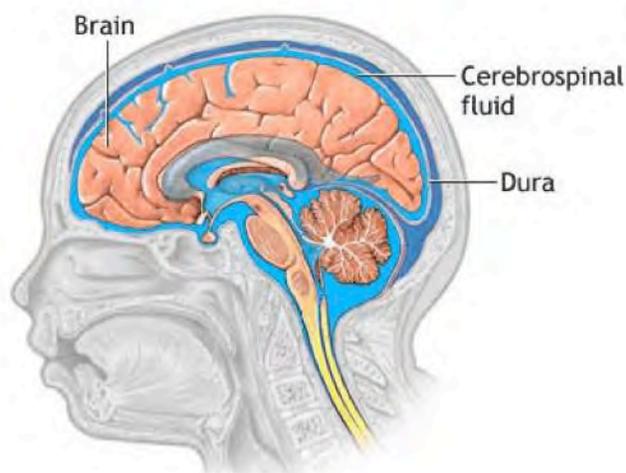
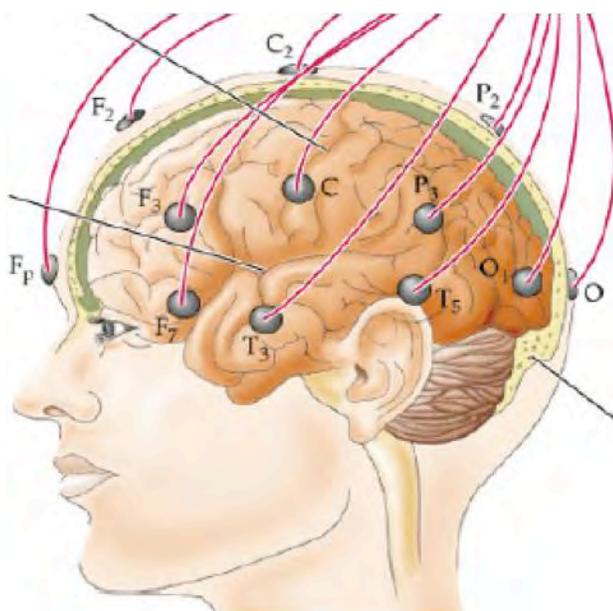
The following is an explanation of the brainfingers technology and how it can be used to create brain-body signals for monitoring and computer control.

## Measurements From The Surface of The Forehead -----

The brainfingers headband positions six electrodes over the forehead. The electrodes touch the surface of the skin, making an electrical connection.



Below the electrode-skin connection is the scalp, forehead muscles, skull and a container filled with cerebrospinal fluid in which floats the brain. All are electrically conductive. An electrical signal from brain neural impulse activity travels through the conductive layers to the surface of the skin.



Likewise an electrical signal from forehead muscle tensing/relaxing and eye glancing will be present at the surface of the skin. This electrical signal will combine with the electrical signal of the brain.



Measuring voltage from eye glancing is often referred to as electrooculography (EOG), measuring muscle activity as electromyography (EMG), and measuring brain activity as electroencephalography (EEG).

Useful EOG information is found in the frequency range [0.5 Hz to 15 Hz]. Useful EEG information is found in the range [0.5 Hz to 50 Hz]. EEG information is further classified as Theta ranging from [0.5 Hz to 7.5 Hz], Alpha ranging from [7.5 Hz to 12 Hz], and Beta ranging from [12 Hz to 50 Hz]. Useful EMG information is reported to range from [20 Hz to 500 Hz]. The forehead signal will contain an overlap of EOG with EEG and an overlap of EMG with EEG.

**The Headband Electrical Signal** -----

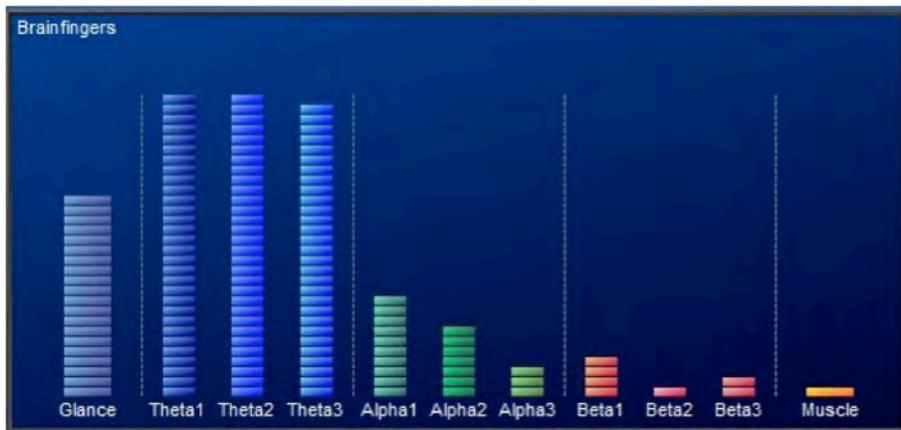
The six-electrode headband produces one signal. To process this signal the AC line noise is first filtered out. The remaining signal is divided in two. The part of the signal below 50 Hz is transformed into one Glance signal, three Theta signals, three Alpha signals, and three Beta signals. The part of the signal above 60 Hz is transformed into one signal called Muscle. The names for these eleven signals are chosen based upon their frequency transformed characteristics, which are listed in the table below.

<i>Signal</i>	<i>Center Frequency</i>	<i>Signal Width</i>
Glance	5.50 Hz	8.00 Hz
Theta 1	1.95 Hz	1.25 Hz
Theta 2	3.55 Hz	1.25 Hz
Theta 3	5.20 Hz	1.25 Hz
Alpha 1	7.75 Hz	2.50 Hz
Alpha 2	9.50 Hz	2.50 Hz
Alpha 3	11.25 Hz	2.50 Hz
Beta 1	16.50 Hz	2.50 Hz
Beta 2	20.75 Hz	2.50 Hz
Beta 3	25.00 Hz	2.50 Hz
Muscle	250 Hz	1925 Hz

The brainfingers software presents a real time display of the eleven signals. Insights into the responsiveness of these signals can be gained from observing this display while wearing the headband. Presented next are five screen images taken while I performed selected brain-body actions. I used "Screen Hunter" to capture the desired images.

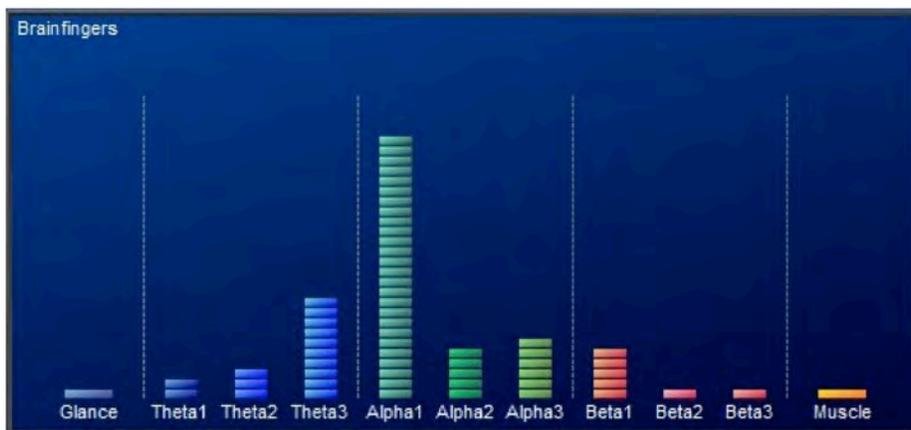
### 1. Glancing Left and Right

I moved my eyes to the left and to the right, back and forth. When the image demonstrated a dramatic difference between Glance and Muscle, I pressed the screen capture key.



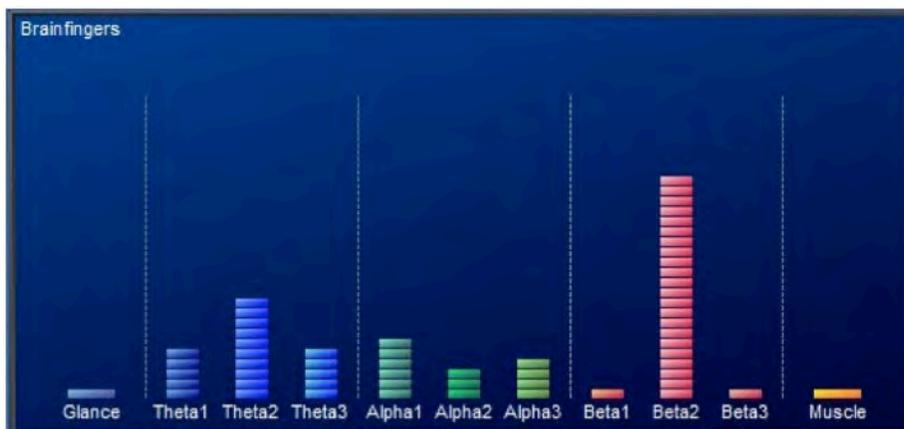
### 2. Relaxing

I sat in a relaxed position, relaxed my body and eyes and focused inward on the soles of my feet. I pressed the screen capture key when the image demonstrated strong activity in Alpha and minimal activity elsewhere.



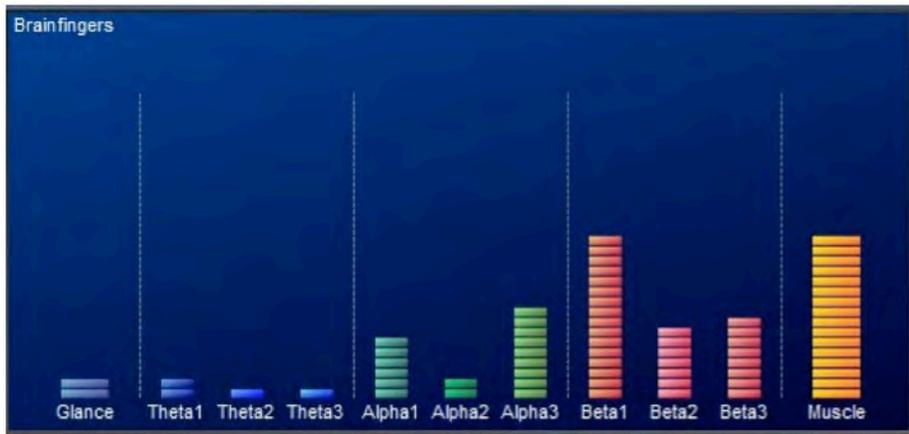
### 3. Mental Pushing

I first relaxed and then from inside my head I mentally pushed up. When Beta exhibited the desired strong signal activity I pressed the screen capture key.



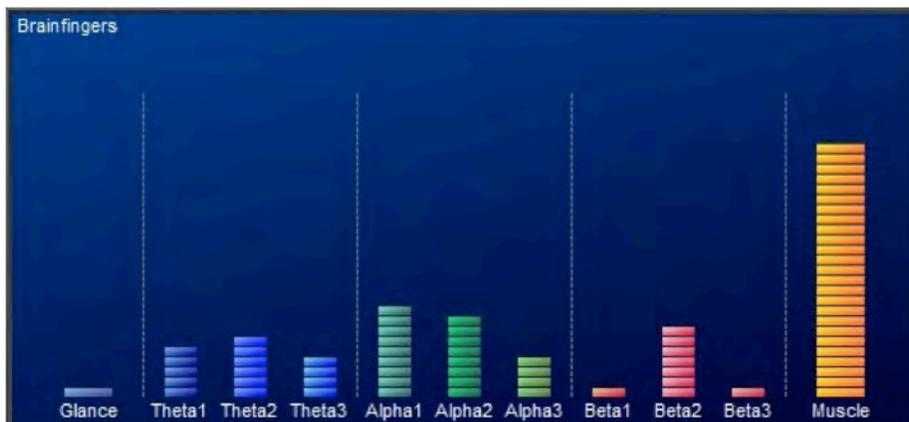
#### 4. Forehead Muscle Tensing -----

I started in a relaxed position and increased tension in my forehead to get the desired level of Muscle activity and then pressed the screen capture key.



#### 5. Jaw Muscle Tensing -----

I relaxed and then slowly tightened my jaw while keeping my eyes and forehead muscles relaxed. When the Muscle signal reached a high level I pressed the screen capture key.



#### Summary Comments About The Five Displays -----

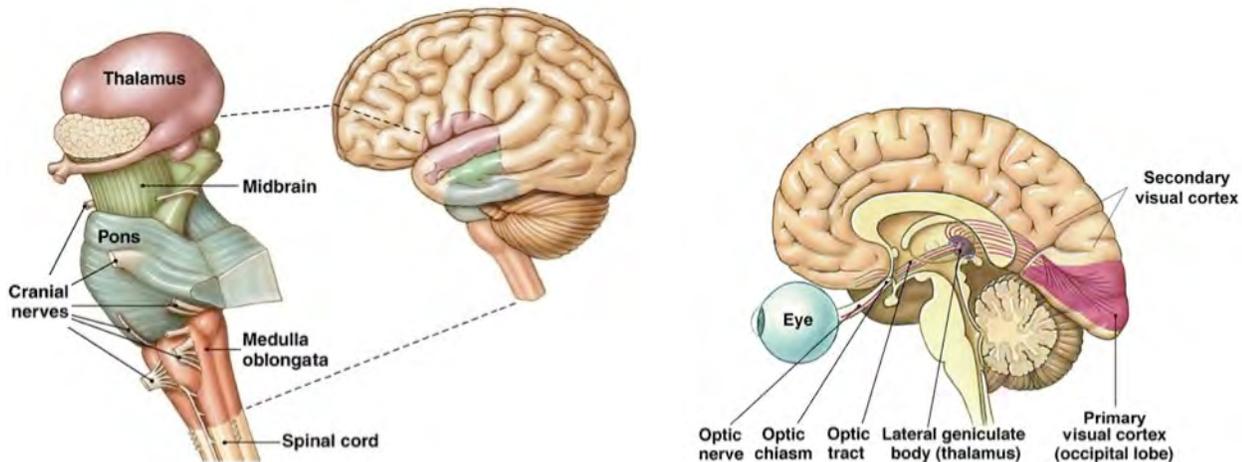
Eye movements left and right will cause a strong response in Theta and cause Glance and Alpha to go up. Relaxing will cause Alpha to go up. Tensing whether actual or imagined will cause Beta and Muscle to go up. Glance overlaps with Theta and Alpha. Muscle overlaps with Beta and Alpha.

#### Information about Alpha and Beta from the Internet -----

It is relatively easy to embrace the idea that moving our eyes and tensing our muscles will cause increases in the Muscle and Glance signals. But what causes Alpha and Beta to increase and decrease? To answer this question so as to make more efficient use of the Alpha and Beta signals I turned to the Internet to find what others report about alpha and beta brainwaves. The paragraphs and pictures that follow present what I consider some interesting findings.

## Alpha and the Thalamus

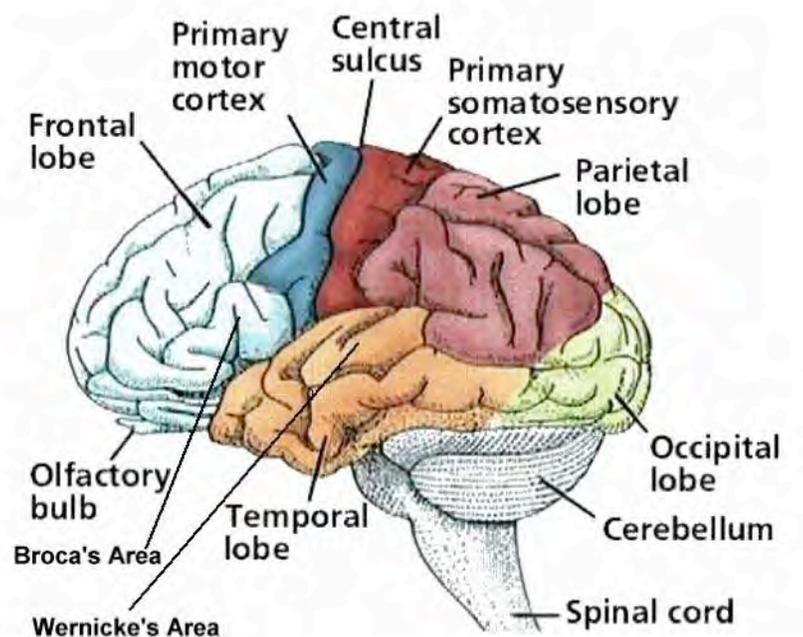
It is hypothesized that the source of alpha is from synchronous and coherent (in phase/constructive) electrical activity of thalamic pacemaker cells with the cortex. The thalamus lies within the center of our head and sits on top of the brain stem. Besides being involved in alpha signal generation, the thalamus is the primary relay of the three senses; vision, touch and hearing. The thalamus is sometimes referred to as the brain within the brain. The thalamus is intimately positioned and connected to the cortex.



Resulting alpha signal activity is present in the occipital and frontal lobes of the cortex. The occipital lobe is mostly occupied with analysis of visual input. It is reported that frontal lobes are associated with regulation of emotions, creativity, memory and dreams.

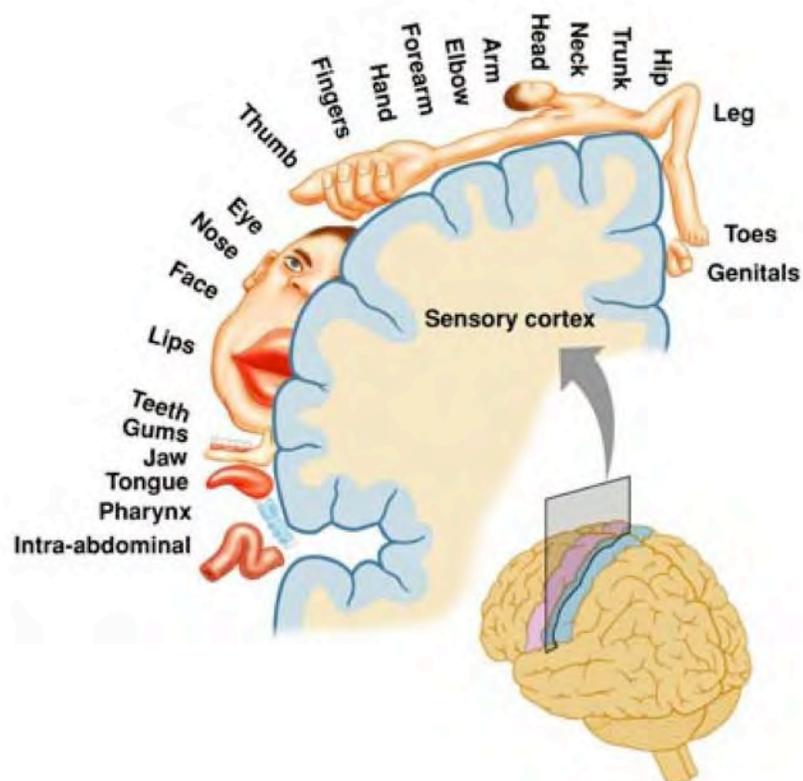
## Alpha and Motor Cortex

Alpha signal activity is also found in the area of the motor cortex. In the literature this signal is often referred to as mu waves. It is reported that this alpha signal is most prominent when one is relaxed and decreases as tension increases from a motor action or visualization of a motor action. This alpha signal is reported to appear as bursts of alpha waves.



## Alpha and Sensory Cortex

This image shows mapping of our body sense to the Sensory cortex. Focusing on one's hands or feet in a relaxed way is reported to result in an increase in alpha brainwaves over the sensory cortex. The sensory cortex forms an arch from one temporal lobe to the other along with the motor cortex. This suggests that an intimate mixing of sensory and motor cortex signals will be present at the surface of the head.



## Beta and Motor Cortex

It is believed by many that beta brain waves are confined mostly to the pre-motor cortex and the motor cortex. Research findings suggest that the pre-motor cortex plans movements that are then "coded" in the motor cortex and relayed to motor neurons in the spinal cord. It is reported that bursts of beta activity are associated with a strengthening of sensory feedback in static motor control and reduced when there is release. Beta activity is increased when movement has to be resisted or voluntarily suppressed. From this we may conclude that beta is associated with tension.

## Why Alpha Resonance

If one searches on Google "Why Alpha Resonance?" an interesting correlation between the resonance of the earth-ionosphere and alpha is presented. This resonance is called the Schumann Resonance and is at the frequency 7.8 Hz. This frequency value is the same as a low frequency alpha brainwave.

## Integration -----

The eleven signals are the result of neural impulse activity from eye glancing, brain and muscle activity.

Eye glancing will cause Glance as well as Theta and Alpha to increase. Tensing will cause Beta to increase as well as Muscle.

Results from the five screens suggest glancing left and right will cause Glance, Theta and Alpha signals to go up. Tensing whether actual or imagined will cause Beta and Muscle to go up. As we increase tension in our body and brain, Alpha will decrease and Beta may show an observable increase.

The thalamus is a relay station for vision, sensing and hearing and is reported to be the pacemaker for alpha resonance. We might therefore conclude that we can affect the thalamic alpha pacemakers by relaxing our eyes and relaxing our body. There exists an intimate connection between the thalamus and the sensory cortex and motor cortex. We might further conclude that focusing on specific parts of our body in a relaxed way may contribute to an increase in alpha brainwaves, and focusing on specific parts of our body with tension may contribute to a reduction in alpha brainwaves and an increase in beta brainwaves. This suggests pathways for consciousness hacking\*.

The observation that the earth-ionosphere resonance frequency is at the same value as a low frequency alpha brainwave is curious. As indicated in the table of frequency values on page 2, the Alpha 1 signal is centered at 7.75 Hz with a signal width of 2.5 Hz so it will show signal energy at 7.8 Hz. Further if you look more closely at Screen 2 "Relaxing" on page 3, it is the Alpha 1 signal that has the largest signal strength. I have noticed a trend with brainfingers and relaxing, I find that Alpha 1 increases more easily than Alpha 2 and Alpha 3 when I relax and direct my relaxed attention to that part of my body that is in contact with the floor or the chair I am sitting in.

\* **Consciousness Hacking**: Using and making new tools for self-exploration, in order to positively change the way we think, feel, and live. It's an inside out perspective on how technology can serve us by changing our relationship to both the world and ourselves.

## Brainfingers Brain-Body Mixer -----

To use the eleven signals for control and monitoring we created a signal mixer. The mixer is modeled after functionality of a sound mixer. The mixer includes a monitor of the eleven signals, a mixing board for combining the eleven signals into a desired mix and a display of the resulting mix that can be used as a computer controller or can be used to monitor brainfingering behavior.

The following images are presented to illustrate how the Brain-Body Mixer can be configured to create controls and monitoring signals.

## Muscle Switch

The following image of the Mixer screen shows the creation of a muscle switch. The mixing board allows for negative to positive addition of signal [-100% to 100%]. The mixing board was set to allow 33% of the Muscle signal to pass through to the output. All the other signals were set to 0%.

For the screen image I created a quick jaw muscle contraction and release when the yellow trace of the output signal approached the 3.0-second mark. The yellow trace mirrored back the pulse that occurred. As the yellow trace came back down to the zero line I pressed the screen capture key.

The screenshot displays the software interface for creating a muscle switch. It is divided into several sections:

- Monitor View Core Brainfingers:** A bar chart showing signal levels for various brainfingers: Glance, Theta1, Theta2, Theta3, Alpha1, Alpha2, Alpha3, Beta1, Beta2, Beta3, and Muscle. The Muscle signal is the most prominent.
- Monitor Adjust:** Controls for the monitor view, including Shift (0.00), Magnify (1.0), and Smooth (0.20).
- Mixer Core Bfs to Output Signal C Muscle:** A mixing board where each signal's contribution is set. Glance, Theta1, Theta2, Theta3, Alpha1, Alpha2, Alpha3, Beta1, Beta2, and Beta3 are all set to 0. The Muscle signal is set to 33.
- Output Adjust:** Controls for the output signal, including Shift (0.00), Magnify (1.0), and Smooth (0.03).
- Graph:** A plot titled "C SW 1: C Muscle" showing a pulse in the output signal at approximately 3.0 seconds. The graph includes a "Trigger Line" and "Fast Switch Detection" (checked).

Text on the right side of the interface reads: "Use Output Adjust to shift, magnify, and smooth Output Signal." and "Fix False Clicks".

## Beta – Alpha Switch

The following image of the Mixer screen shows the creation of a Beta - Alpha mixture for switch control. The mixing board was set to allow a positive contribution from Beta to pass through to the output and a negative contribution of Alpha to pass through to the output. The addition of negative Alpha counteracts unconsciously generated Beta making it easier to keep the yellow trace of the output signal at zero.

To create the screen image I mentally tensed to create beta bursts while keeping facial muscle tension to a minimum. The yellow trace mirrored back the pulse that occurred. When the yellow signal trace came down I pressed the screen capture key.

The screenshot displays the software interface for creating a Beta-Alpha mixture. It is divided into several sections:

- Monitor View Core Brainfingers:** A bar chart showing the relative levels of various brainfingers: Glance, Theta1, Theta2, Theta3, Alpha1, Alpha2, Alpha3, Beta1, Beta2, Beta3, and Muscle. Beta1 and Beta2 are the most prominent.
- Monitor Adjust:** Controls for Shift (0.00), Magnify (1.0), and Smooth (0.20). Includes 'Up', 'Down', 'More', and 'Less' buttons.
- Mixer Core Bfs to Output Signal:** A mixing board for 'C Beta-Alpha'. It features sliders for Glance (0), Theta1 (0), Theta2 (0), Theta3 (0), Alpha1 (-100), Alpha2 (-100), Alpha3 (0), Beta1 (50), Beta2 (71), Beta3 (0), and Muscle (0). Each slider has '+' and '-' buttons.
- Output Adjust:** Controls for Shift (0.00), Magnify (1.0), and Smooth (0.03). Includes 'Up', 'Down', 'More', and 'Less' buttons.
- Graph:** A plot titled 'C Sw 2: C Beta-Alpha Mode: Single' showing a yellow signal trace over a 5-second period. A horizontal dashed line represents the 'Trigger Line' at approximately 2.5. A checkbox for 'Fast Switch Detection' is checked.
- Text and Buttons:** A note says 'Use Output Adjust to shift, magnify, and smooth Output Signal.' A button labeled 'Fix False Clicks' is also present.

**Vertical Cursor Control** -----

The mixer provides capabilities for creating joystick controls as well as switch controls. The following image of the Mixer screen shows the creation of a vertical joystick control. The output is displayed as a vertical slide bar with two trigger zones Z1 and Z2. The user controls the height of the slide. In the image the slide is in Zone 2. The mixer is setup to use 40% of Muscle to control the vertical joystick slide position.

To create the screen image I tensed my jaw enough to bring the slide above the Z2 trigger and pressed the screen capture key.

**Monitor** *View Core Brainfingers* Apply Cancel

Brainfingers

Glance Theta1 Theta2 Theta3 Alpha1 Alpha2 Alpha3 Beta1 Beta2 Beta3 Muscle

**Monitor Adjust**

Shift 0.00 Magnify 1.0 Smooth 0.80

Up More More

Down Less Less

Defaults

**Mixer** *Core Bfs to Output Signal* **C Muscle** Zero Mixer

Glance 0 Theta1 0 Theta2 0 Theta3 0 Alpha1 0 Alpha2 0 Alpha3 0 Beta1 0 Beta2 0 Beta3 0 Muscle 40

+ + + + + + + + + + +

- - - - - - - - - - -

**Output Adjust**

Shift 0.00 Magnify 1.0 Smooth 0.80

Up More More

Down Less Less

Defaults

Use Output Adjust to shift, magnify, and smooth Output Signal.

**C Muscle**

1.0 0.8 0.6 0.4 0.2

Z2

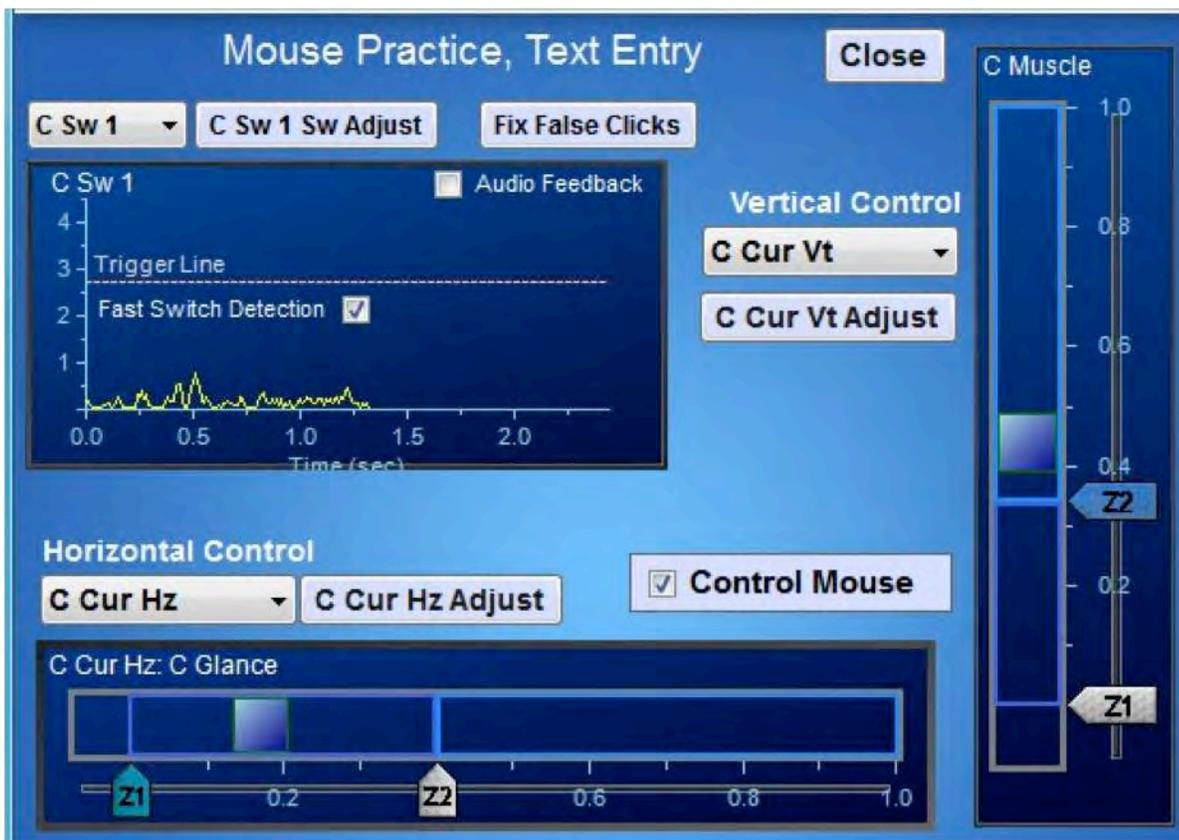
Z1

Z2: 34%  
Z1: 0%

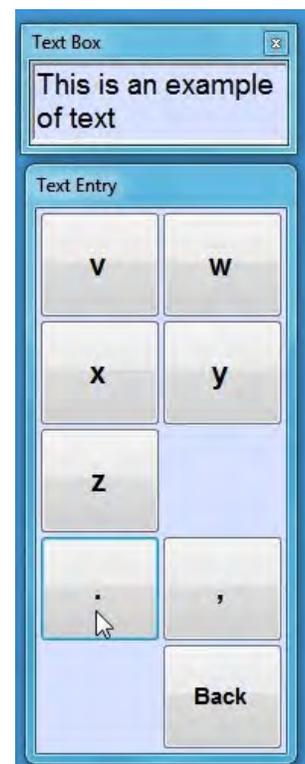
## Mouse Control

---

Mouse control with brainfingers involves coordinating control of a switch for mouse clicks with vertical and horizontal joysticks for cursor movement.



A simple direct selection keyboard is also provided for practicing text entry through mouse movement and mouse click selection. I took a screen capture of these two displays as I was about to select and type a "." at the end of the sentence "This is an example of text". Note that the cursor is pointing to the text entry key "."



**Relax Control**

To demonstrate the monitoring capability of brainfingers I created a Relax control. The mixer was set to pass through positive values of Alpha signals and negative values of all the other signals. The resulting output is displayed on a meter that ranges [0 to 100]. When the output is 0 or less the meter points to 0, when the output reaches or exceeds the meter maximum range of 100 the meter points to 100.

To create the screen image I relaxed and when the meter reached the 100 mark I pressed the screen capture key.

The screenshot displays the Brainfingers software interface with the following components:

- Monitor View Core Brainfingers:** A bar chart showing the amplitude of various brainfingers. The values are approximately: Glance (-10), Theta1 (-20), Theta2 (-20), Theta3 (-10), Alpha1 (100), Alpha2 (100), Alpha3 (100), Beta1 (-10), Beta2 (-20), Beta3 (-30), and Muscle (-100).
- Monitor Adjust:** Controls for Shift (0.00), Magnify (1.0), and Smooth (0.80). A question mark icon is present to the right.
- Mixer Core Bfs to Output Signal Relax:** A row of sliders for each brainfinger. The values are: Glance (-100), Theta1 (-30), Theta2 (-20), Theta3 (-10), Alpha1 (100), Alpha2 (100), Alpha3 (100), Beta1 (-10), Beta2 (-20), Beta3 (-30), and Muscle (-100).
- Output Adjust:** Controls for Shift (0.00), Magnify (1.0), and Smooth (0.80).
- Joystick Top Meter:** A semi-circular scale from 0 to 100. The needle is at 100. The text 'C Bf 1 Relax' is displayed in the center, with 'Less' and 'More' at the bottom.

Use Output Adjust to shift, magnify, and smooth Output Signal.

### Focus Control

To further demonstrate the monitoring capability of brainfingers I created a Focus control. In creating this control I based the design on the premise that Beta would increase and Alpha would decrease as a result of focusing. I wanted to capture the Beta without Muscle. The mixer was set to pass through positive values of Beta, and negative values of Alpha and negative values of Muscle.

To create the screen image I relaxed. Then as I remained mindful of the Alpha signals in the Monitor I focused internally and when the meter reached the 100 mark I pressed the screen capture key.

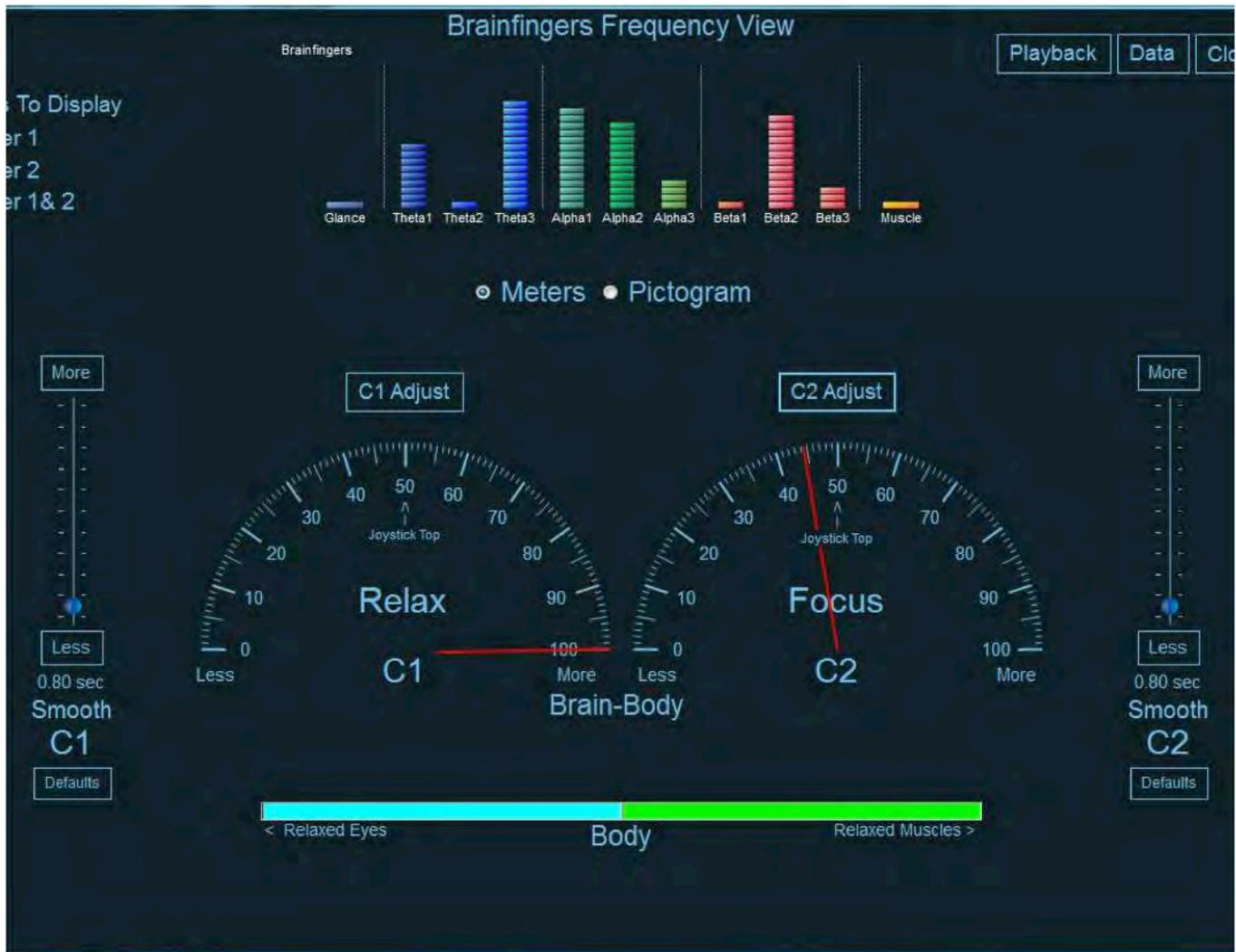
The screenshot displays the Brainfingers software interface with the following components:

- Monitor View Core Brainfingers:** A bar chart showing signal levels for various brainfingers: Glance, Theta1, Theta2, Theta3, Alpha1, Alpha2, Alpha3, Beta1, Beta2, Beta3, and Muscle. Beta1 and Beta2 show the highest positive values.
- Monitor Adjust:** A control panel with three sliders: Shift (0.00), Magnify (1.0), and Smooth (0.80). Each slider has 'Up/More' and 'Down/Less' buttons.
- Mixer Core Bfs to Output Signal:** A row of sliders for each brainfinger. The current values are: Glance (0), Theta1 (0), Theta2 (0), Theta3 (0), Alpha1 (-10), Alpha2 (-20), Alpha3 (-20), Beta1 (100), Beta2 (100), Beta3 (0), and Muscle (-100).
- Focus:** A central control panel with a 'Zero Mixer' button and a 'Focus' meter.
- Output Adjust:** A control panel with three sliders: Shift (0.00), Magnify (1.0), and Smooth (0.80), identical to the Monitor Adjust panel.
- Focus Meter:** A semi-circular gauge labeled 'C Bf 2' with a 'Focus' needle pointing to 100. The scale ranges from 0 (Less) to 100 (More).
- Instructions:** Text on the right side reads: 'Use Output Adjust to shift, magnify, and smooth Output Signal.'

## Relax and Focus as an Awareness Monitor

The Relax and Focus meters were incorporated into a window I created for awareness practice. A screen image of this window is presented below. In this window I included the monitor portion of the Mixer that shows the eleven signals. This is labeled “Brainfingers Frequency View.” I also added a horizontal display, called “Body” that expands leftward the more the user relaxes their Glance signal and expands rightward the more the use relaxes their Muscle signal. In the middle I included the Relax and Focus meters and labeled them “Brain-Body”. Two “Smooth” time adjustments are provided for changing the amount of weighting placed on past signal history. Shorter smoothing times allow the more responsive alpha and beta bursts to stand out in the signals.

To create the screen image I first relaxed my facial muscles and eyes to get the Body display to expand. I continued relaxing and received confirmation of this from the Relax meter. Once the meter reached 100, I focused internally to drive the Focus meter towards the 100 mark while keeping the Relax meter at 100. When the Focus meter reached the highest level I could attain, while keeping the Relax meter at 100, I pressed the screen capture key.



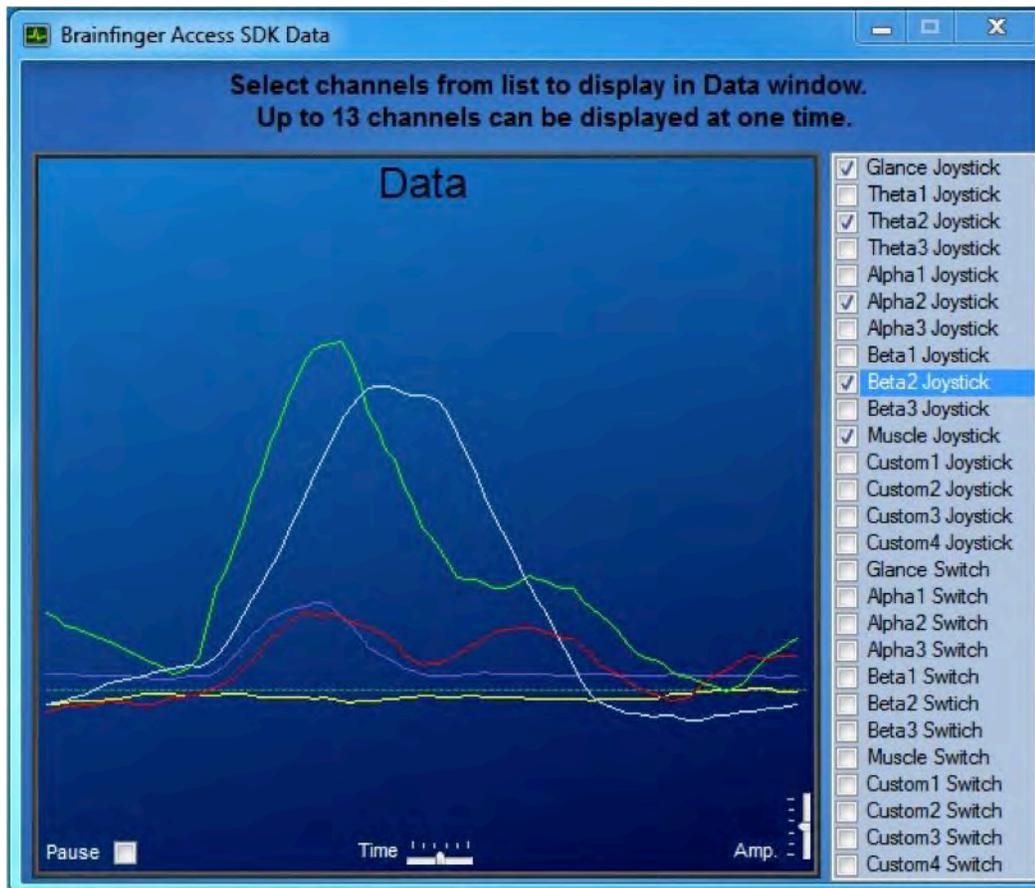
## In Closing

The forehead is a desirable location from which to obtain brain-body information. The electrical signal present is rich with information of eye glancing, facial muscle and brain tensing/relaxing. Transforming this signal into useful information is challenging. On the one hand a system must be able to accommodate the strong dominance of eye glancing and muscle tensing. On the other hand the system must accommodate the subtler tensing/relaxing information of the brain. The brainfingers system does this and the brain-body mixer provides a user-friendly interface to craft the extracted information into useful control and monitor signals.

I have been in human behavior research for many years. Creating and configuring a measurement system to test a hypothesis is often the most time consuming part of doing research. Brainfingers can be easily reconfigured thus alleviating this problem.

I created all signal responses for this paper with a brainfingers system. Likewise, you can experience your brain-body connection and construct controls for yourself and others with a brainfingers system.

Brainfingers is a software developer's kit (SDK), a tool to create controls for individuals with disabilities and a tool for researchers and developers exploring human brain-body function. Memory sharing (client-server) software is incorporated into brainfingers. The image below is an example C# project available to illustrate memory sharing of switch and joystick values.



For further information please call or write.

Andrew Junker, phone (937) 767-2674, email: [andrew@brainfingers.com](mailto:andrew@brainfingers.com)