EEG Algorithm Descriptions

October 18, 2016

NeuroSky
Brain-Computer Interface Technologies

The NeuroSky® product families consist of hardware and software components for simple integration of this biosensor technology into consumer and industrial end-applications. All products are designed and manufactured to meet consumer thresholds for quality, pricing, and feature sets. NeuroSky sets itself apart by providing building block component solutions that offer friendly synergies with related and complementary technological solutions.

Contents

INTRODUCTION

NeuroSky offers a variety of EEG algorithms that work with **TGAM** - NeuroSky's brainwave sensor ASIC module. Such EEG algorithms perform signal processing and machine learning to decode a user's mental states based on their brainwaves in realtime. These algorithms can be adapted to run on different platforms relatively easily, from embedded systems, mobile devices, and computers. For the availability of an algorithm SDK for a specific platform, such as embedded, iOS, android, PC or Mac, please contact your regional FAE or Sales Representative.

In this document we provide background information about each of the algorithms – what they measure, why they can be useful, and how they should be used.

AVAILABLE ALGORITHMS

Attention (Att)

Attention calculates and reports how focused or single-minded the user is at the moment. It indicates the intensity of mental "focus" or "attention" by outputting a value from **0-100** each second. The more the user is focusing, the higher the algorithm output value.

Tips for driving attention: - Stare at an external object and focus.

Meditation (Med)

Meditation calculates and reports how calm and clear-minded the user is at the moment. It indicates the level of mental "calmness" or "relaxation" by outputting a value from **0-100** each second. The more the user's mind is relaxed, the higher the algorithm output value.

Tips for driving meditation: - Close your eyes, relax and empty your mind, deep breathes and slowly exhale.

BandPower (BP)

BandPower calculates and reports the power spectrum density of the user's brainwaves, as five frequency bands: Delta Band (<4 Hz), Theta Band (4~8 Hz), Alpha Band (8~13 Hz), Beta Band (13~30 Hz), and Gamma Band (>30 Hz). Each band is reported in **"dB"**, and all five band values are reported each second.

Eye Blink Detection and Strength (Blink)

Detects and reports eye blink events, and their strength. Events and strength are reported as a positive integer (> 0). The stronger the eye blink, the larger the eye blink strength value.

Appreciation (AP)

Appreciation calculates and reports the moment-to-moment **level of enjoyment or appreciation** of a user towards an external stimulus, e.g. video, music, etc, based on the user's brainwaves. Appreciation is reported as an enjoyment level from 1-4, corresponding to the table below. The algorithm can be configured to output an enjoyment level every 1, 2, 3, 4 or 5 seconds.

Definition of Appreciation algorithm index

Appreciation Index	Subject's appreciation/enjoyment level
1	Not at all
2	Low
3	Medium
4	High

eTensity (eTen)

eTensity calculates and reports the moment-to-moment **intensity of a user's emotions** towards an external stimulus, e.g. video, music, etc. eTensity is reported as an intensity level from 1-4, corresponding to the table below. The algorithm can be configured to output an eTensity level every 1, 2, 3, 4 or 5 seconds.

Definition of eTensity algorithm index

eTensity Index	Intensity level of user's emotion
1	Low
2	Medium-Low
3	Medium-High
4	High

Emotional Spectrum

The following diagram illustrates the Emotional Spectrum commonly studied in the field of psychology. It gives an approximate idea of how eTensity and YinYang could potentially be applied towards Emotional Spectrum. *Depending on the application*, eTensity and YinYang could potentially be used together to identify the Emotional Spectrum of the user. For example, it is well-established that YinYang 1 (Pleasant emotion) with eTensity 4 (High eTensity level) indicates that a user is "Excited" on an Emotional Spectrum. Other combinations could possibly be determined, based on the actual application/stimulus that the user is subjected to. (IMPORTANT: The applicability of this mapping must be carefully re-considered for each actual specific end-user application, since the exact definitions of the terms used to described emotions in psychology may not map exactly to the emotion concepts specific to each application!)

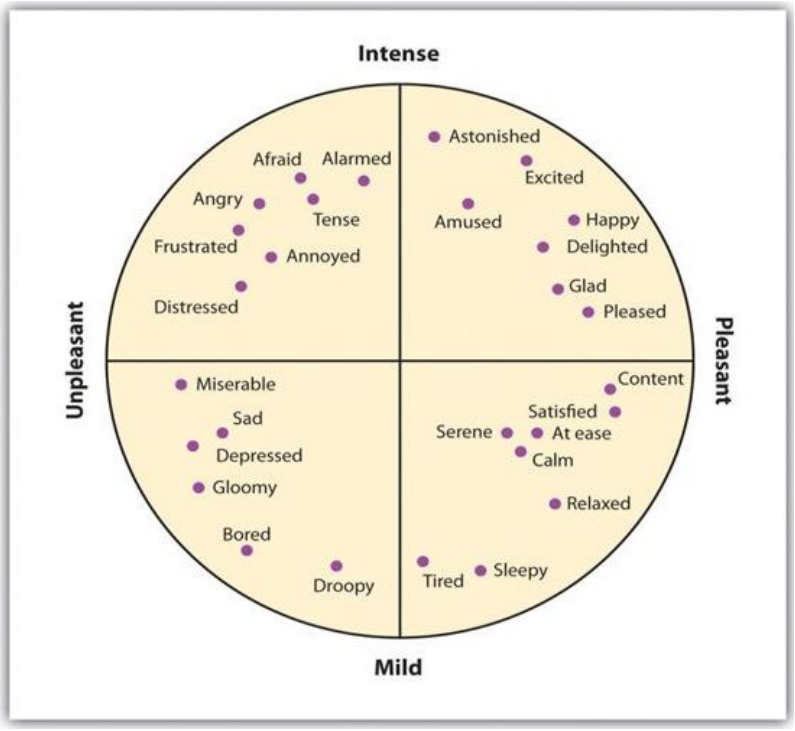

Figure 2.1:

YinYang (YY)

YinYang approximates and reports the moment-to-moment **emotional response** of a user towards an external stimulus, e.g. video, music, etc. YinYang is reported as -1, 0, or 1, representing an approximate category of **unpleasant, neutral, or pleasant**, corresponding to the table below. The algorithm can be configured to output YinYang indices every 5 or 10 seconds.

Definition of YinYang algorithm index

YinYang Index	Types of the Perceived Emotions
-1	Unpleasant emotion
0	Neutral emotion
1	Pleasant emotion

Emotional Spectrum

The following diagram illustrates the Emotional Spectrum commonly studied in the field of psychology. It gives an approximate idea of how eTensity and YinYang could potentially be applied towards Emotional Spectrum. *Depending on the application*, eTensity and YinYang could potentially be used together to identify the Emotional Spectrum of the user. For example, it is well-established that YinYang 1 (Pleasant emotion) with eTensity 4 (High eTensity level) indicates that a user is "Excited" on an Emotional Spectrum. Other combinations could possibly be determined, based on the actual

application/stimulus that the user is subjected to. (IMPORTANT: The applicability of this mapping must be carefully re-considered for each actual specific end-user application, since the exact definitions of the terms used to described emotions in psychology may not map exactly to the emotion concepts specific to each application!)

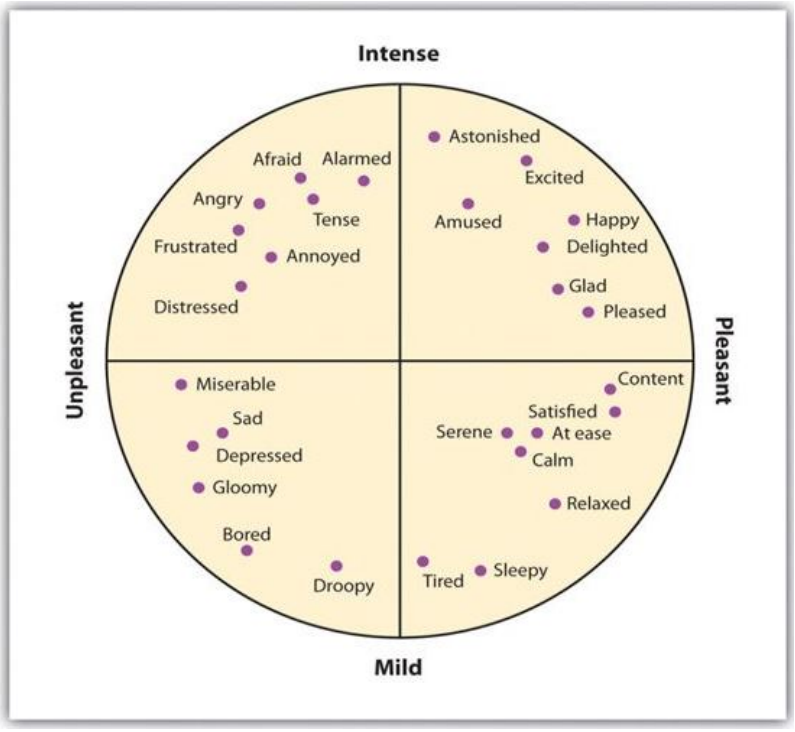

Figure 2.2:

Mental Effort (ME)

Mental Effort calculates and reports the moment-to-moment **mental workload** experienced by a user during a task. The harder the user's brain is working at the time (ostensibly on the task), the higher the Mental Effort value.

Definition and range of Mental Effort algorithm index

The Mental Effort algorithm outputs the following indexes at a configurable output rate of every 1, 2, 3, 4, or 5 seconds:

Output	Definition	Output range
Absolute Mental Effort Index (Abs ME)	Absolute Mental Effort index of subject at a particular moment	100 to -100
Differential Mental Effort Index (Diff ME)	Change of ME from last measured moment	100 to -100
Maximum and Minimum Value of Abs ME	Range of Absolute Mental Effort Index for current trial from	100 to -100

Definition and range of Mental Effort Secondary algorithm index

The Mental Effort secondary algorithm outputs the following indexes at a configured output rate between 30 seconds and 36000 seconds (10 hours) with a step of 1 second (i.e. 30s, 31s, 32s, …, 36000s)

Output	Definition	Output range
Total Mental Effort (Total ME)	Sum of Mental Effort during a certain period	720,000 to -720,000
Mental Effort Rate (ME Rate)	Rate of Mental Effort during a certain period	100 to -100
Changing Rate	Rate of Mental Effort change during a certain period	200 to -200

Familiarity (F)

Familiarity calculates and reports the moment-to-moment **learning progress** experienced by a user while practicing a new skill. It gives an indication of the "Learning Curve" during the skill acquisition process.

Definition and range of Familiarity algorithm index

The Familiarity algorithm outputs the following indexes at a configurable output rate of every 1, 2, 3, 4, or 5 seconds:

Output	Definition	Output range
Absolute Familiarity Index (Abs F)	Absolute Familiarity Index of subject at a particular moment	100 to -100
Differential Familiarity Index (Diff F)	Change of F from last measured moment	100 to -100
Maximum and Minimum Value of Abs F	Range of Absolute Familiarity Index for current trial from	100 to -100

Definition and range of Familiarity Secondary algorithm index

The Familiarity secondary algorithm outputs the following indexes at a configurable output rate between 30 seconds and 36000 seconds (10 hours) with a step of 1 second (i.e. 30s, 31s, 32s, …, 36000s)

Output	Definition	Output range
Progress Level	Progress within a certain period	1 - Very poor; 2 - Poor; 3 - Flat; 4 - Good; 5 - Great
Familiarity Degree (F Degree)	Overall measurement of the obtained Abs F within a certain period	100 to -100

Alertness (AL)

Alertness calculates and reports the moment-to-moment level of **alertness or vigilance** of a user. High Alertness values indicate the user is in a state of focus, while low values represent a relaxing state of mind.

Definition and range of Alertness algorithm value

The Alertness algorithm outputs values ranging from -1 to 1 at a configurable output interval of 1, 2, 3, 4 or 5 seconds.

Output	Definition	Output range
alertness value	level of alertness at the measured moment	-1 to 1

Definition and range of Alertness validity

The Alertness validity algorithm reports if there is a valid increase of user alertness level within a certain measurement period. Users could set their desirable threshold for alertness detection as light, medium or high and a measurement window from 30 seconds to 36000 seconds (10 hours) (step of 1 second, i.e. 30s, 31s, 32s, … , etc).

Output	Definition	Output range
BCQ valid	validity of alertness increase within certain measurement period	0 or 1

Creativity (CR)

Creativity calculates and reports the moment-to-moment level of **activity underlying creative cognition** of a user. High Creativity values indicate stronger brainwave activities promoting innovative

and creative thinking.

Definition and range of Creativity algorithm value

The Creativity algorithm outputs values ranging from -1 to 1 at a configurable output interval of 1, 2, 3, 4 or 5 seconds.

Output	Definition	Output range
creativity value	level of creativity at the measured moment	-1 to 1

Definition and range of Creativity validity

The Creativity validity algorithm reports if there is a valid increase of user creativity activity within a certain measurement period. Users could set their desirable threshold for creativity detection as light, medium or high and a measurement window from 30 seconds to 36000 seconds (10 hours) (step of 1 second, i.e. 30s, 31s, 32s, … , etc).

Output	Definition	Output range
BCQ valid	validity of creativity increase within certain measurement period	0 or 1

Cognitive Preparedness (CP)

Creativity calculates and reports the moment-to-moment **capacity of a user's brain for optimal cognitive performance** on a relatively complex task. In other words, it represents the brain's capacity for higher level cognitive functions.

Definition and range of Cognitive Preparedness algorithm value

The Cognitive Preparedness algorithm outputs values ranging from -1 to 1 at a configurable output interval of 1, 2, 3, 4 or 5 seconds.

Output	Definition	Output range
cognitive preparedness value	level of cognitive preparedness at the measured moment	-1 to 1

Definition and range of Cognitive Preparedness validity

The Cognitive Preparedness algorithm reports if there is a valid increase of user cognitive preparedness level within a certain measurement period. Users could set their desirable threshold for cognitive preparedness detection as light, medium or high and a measurement window from 30 seconds to 36000 seconds (10 hours) (step of 1 second, i.e. 30s, 31s, 32s, … , etc).

Output	Definition	Output range
BCQ valid	validity of cognitive preparedness increase within certain measurement period	0 or 1