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(54) **BRUXISM TRACKING AND REDUCTION DEVICE AND METHODS**

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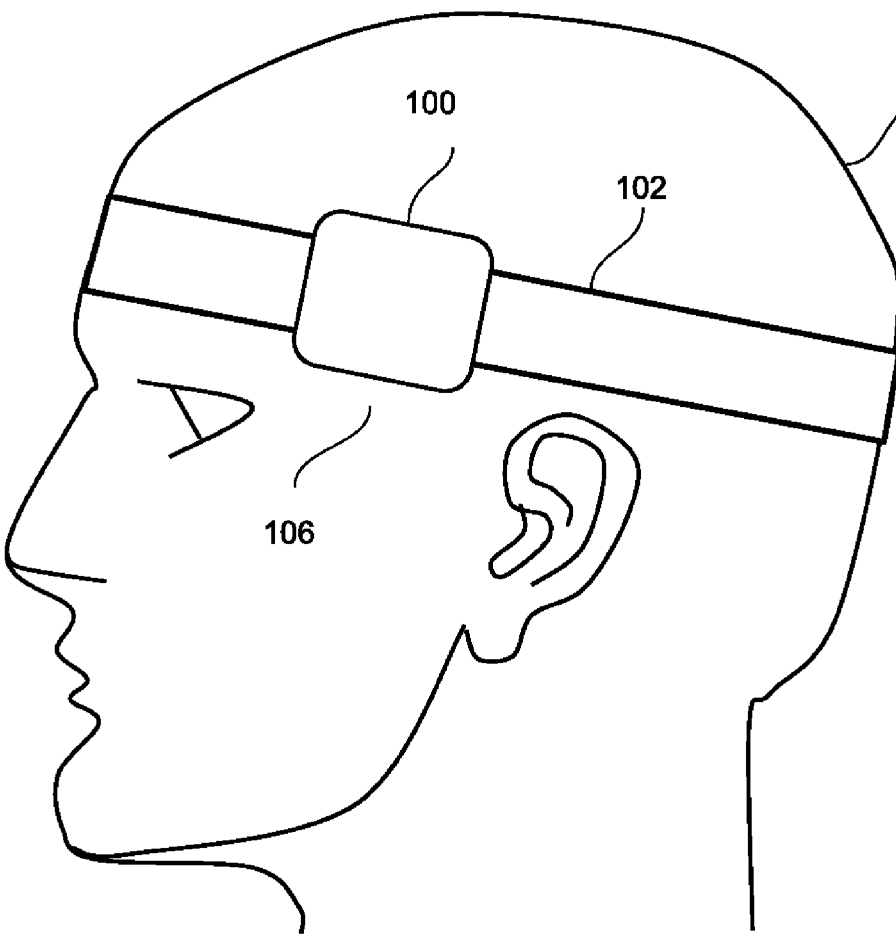
(57) **ABSTRACT**

A device and method for tracking and reducing bruxism and related conditions. In one embodiment using an optical muscle activity sensor and a prediction based biofeedback method for reducing bruxism. The device can also be used to track bruxism by the user or a health professional. One embodiment is worn as a headband and positioned over the temporalis muscle with biofeedback provided directly to the temporalis muscle.



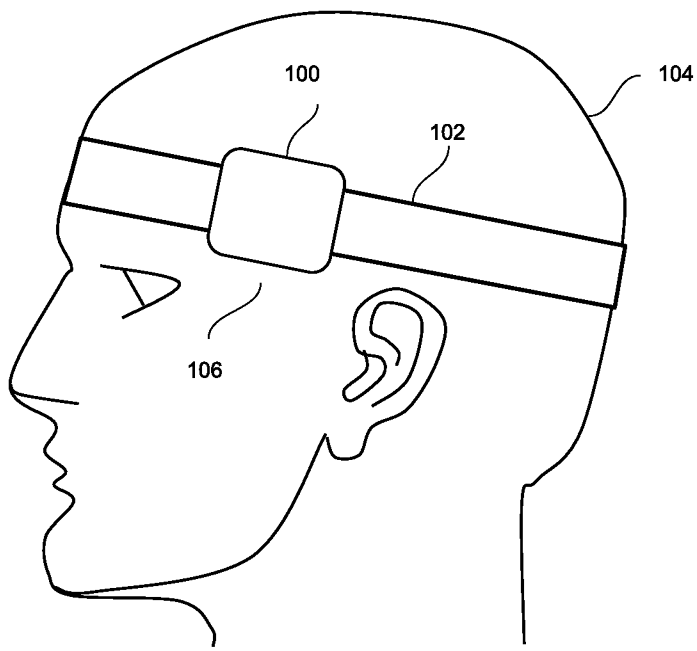


Fig. 1

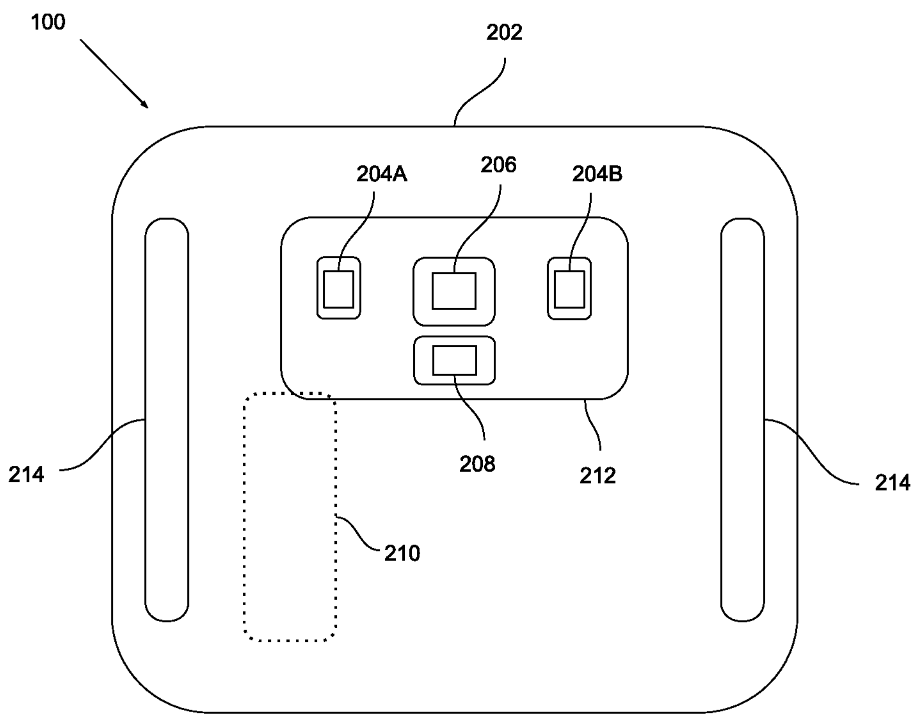


Fig. 2

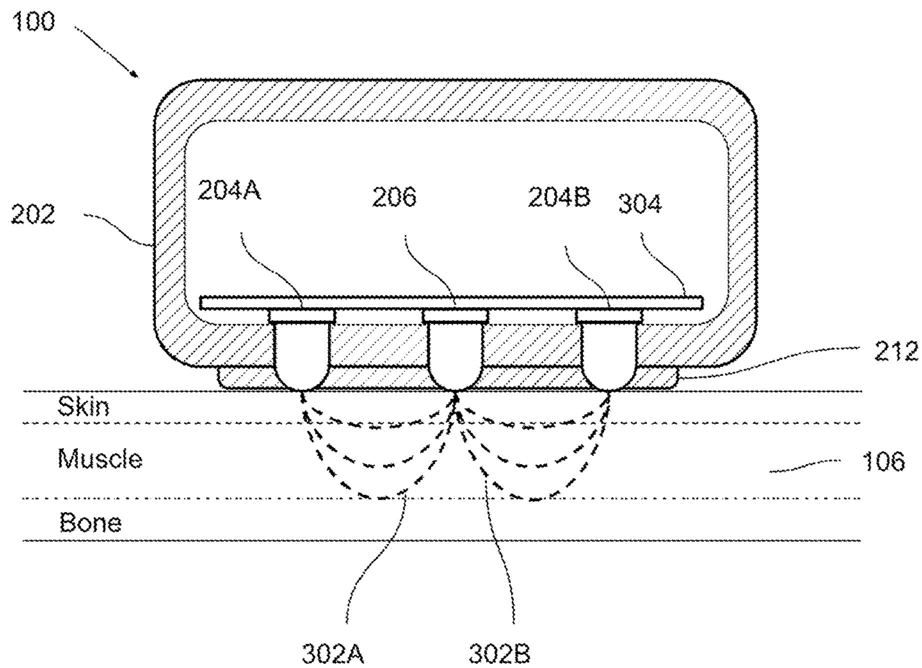


Fig. 3

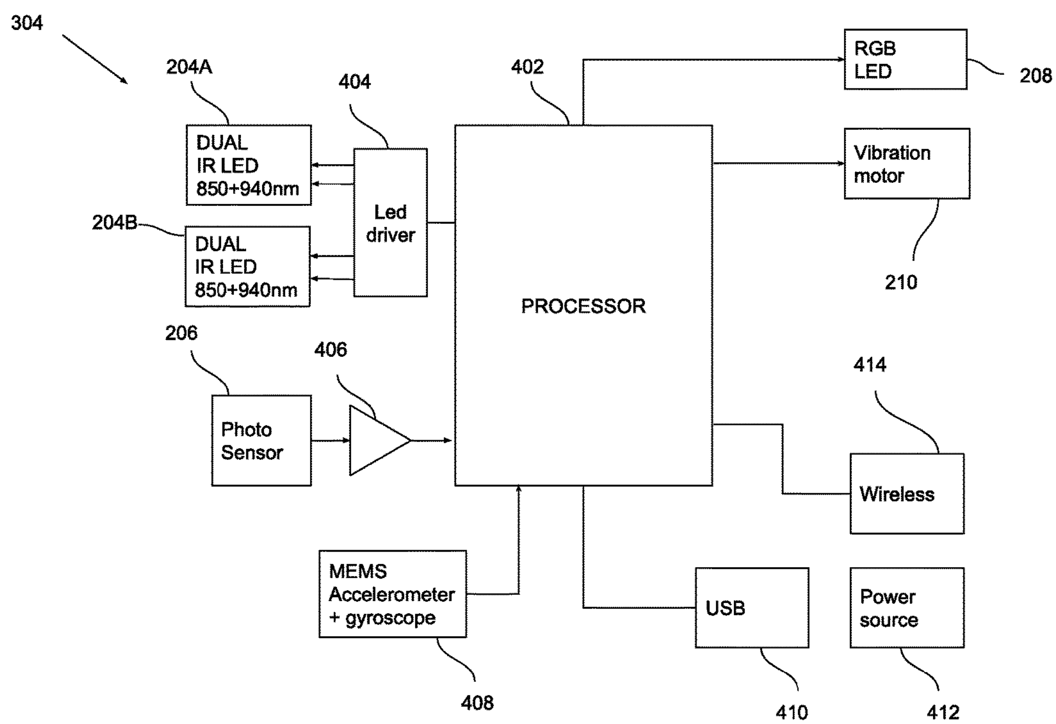

304
204A
DUAL
IR LED
850+940nm
204B
DUAL
IR LED
850+940nm
404
Led
driver
402
PROCESSOR
RGB
LED
208
Vibration
motor
210
206
Photo
Sensor
406
414
Wireless
MEMS
Accelerometer
+ gyroscope
408
USB
410
Power
source
412

Fig. 4

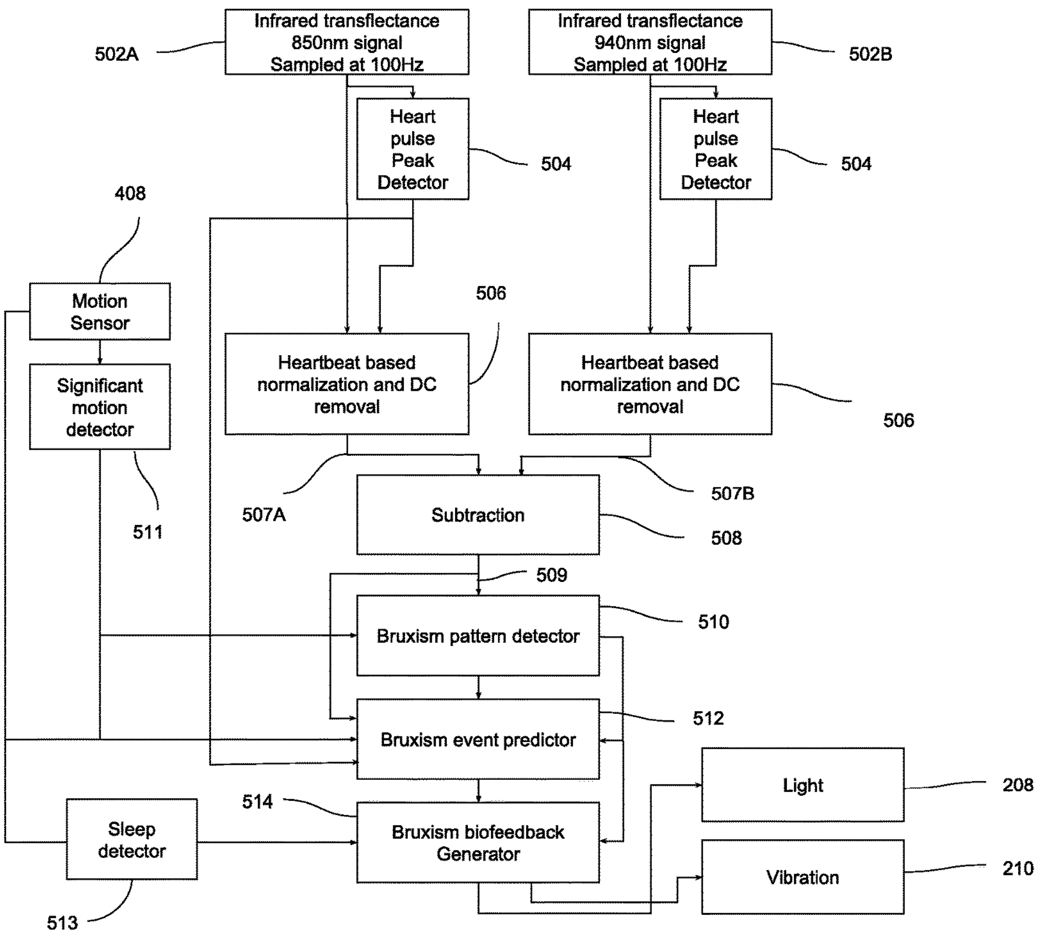

Infrared transflectance
850nm signal
Sampled at 100Hz
502A
Infrared transflectance
940nm signal
Sampled at 100Hz
502B
Heart
pulse
Peak
Detector
504
Heart
pulse
Peak
Detector
504
408
Motion
Sensor
Significant
motion
detector
511
506
Heartbeat based
normalization and DC
removal
Heartbeat based
normalization and DC
removal
506
507A
507B
Subtraction
508
509
Bruxism pattern detector
510
Bruxism event predictor
512
Light
208
514
Sleep
detector
Bruxism biofeedback
Generator
Vibration
210
513

Fig. 5

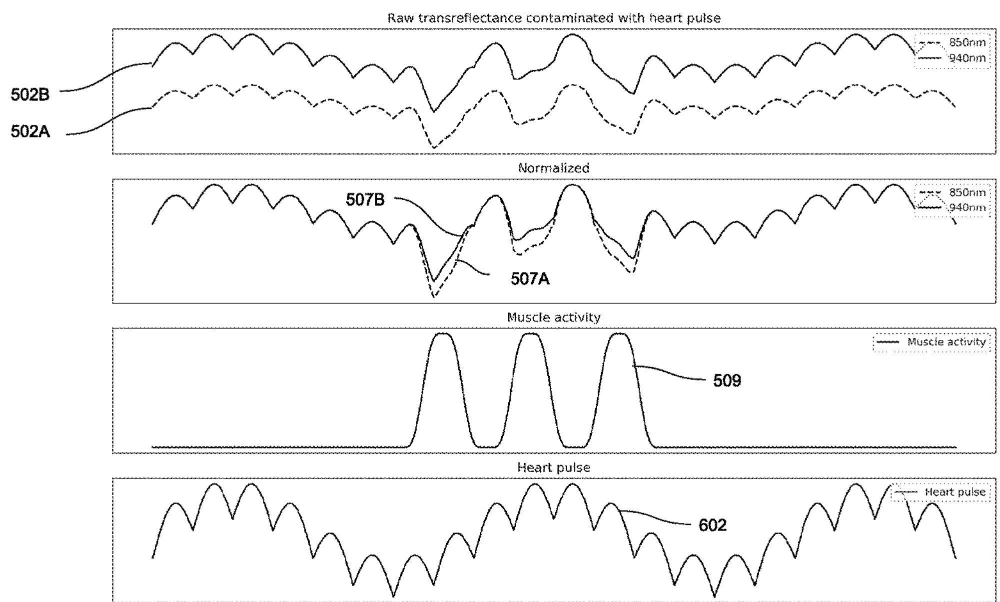

Raw transreflectance contaminated with heart pulse
850nm
940nm
502B
502A
Normalized
850nm
940nm
507B
507A
Muscle activity
Muscle activity
509
Heart pulse
Heart pulse
602

Fig. 6

BRUXISM TRACKING AND REDUCTION DEVICE AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/48,250, filed on Apr. 6, 2018, the entire disclosure of which is incorporated by reference herein.

TECHNICAL FIELD

[0002] The present invention related to biofeedback devices and muscle sensors, and more particularly an apparatus and method of tracking and reducing bruxism and related conditions.

BACKGROUND OF THE INVENTION

Field of the Invention

[0003] Teeth Grinding (bruxism) and clenching are a serious problem for a large percentage of the population. Causing teeth wear, cracks in teeth, tooth mobility, and headaches. The most common solution is to protect the teeth with a dental mouth guard. Which only protects from tooth damage, but does not alleviate headaches or prevent tooth mobility.

[0004] Some believe that lifestyle interventions can help with the problem. Things like alcohol and tobacco consumption, stress and anxiety are believed to be correlated with the problem. Without the means of a tracking the problem it's hard to know what intervention works and which does not.

[0005] Biofeedback is a promising method of bruxism reduction if properly implemented.

Description of Prior Art

[0006] The most common way to monitor mastication muscle activity is using Electromyography (EMG). For example in device presented by Lee Weinstein et al in U.S. Pat. No. 5,270,466B1. The problem with using EMG to measure muscle activity is that it requires an electrical contact with the skin on top of the muscle. Electrical contact with the skin frequently caused adverse reactions like rashes and burns, this is particularly problematic since the device is worn for prolonged periods of time. Every night during sleep which on average 8 hours continuously.

[0007] EMG has other problems like the fact that EMG electrode contacts deteriorate over time and some devices even use single-use electrodes which is expensive if you use the device every night.

[0008] EMG electrodes also have a minimum size to provide good electrical contact with the skin, which makes miniaturization harder and thus makes the EMG based devices more uncomfortable to wear.

[0009] Different methods of biofeedback have been proposed in the past. Like electrical stimulation in patent US20120271190A1 which require electrical contact with the skin, this has similar problems as EMG. U.S. Pat. No. 6,270,466B1 proposes the use of an acoustic transducer which can disturb a partner sleeping in the same bed.

[0010] The other problem with previously mentioned biofeedback system is that they wait for the muscle activity to happen before applying stimulation. Which is too late since the force on the teeth was already exerted.

SUMMARY OF THE EMBODIMENTS

[0011] One embodiment of the bruxism tracking and reduction device includes an optical muscle sensor first presented in this patent application and a visual and a vibratory stimulation device to provide bruxism reduction through biofeedback. A novel bruxism event prediction is used to predict and inhibit the bruxism event before it happens.

[0012] The device can be used for to reduce and treat bruxism as well as for tracking bruxism by the user or a health professional. The device is small and comfortable to wear.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. **1** shows the user wearing the first embodiment.

[0014] FIG. **2** shows the first embodiment from the bottom size that touched the skin while wearing.

[0015] FIG. **3** shows positions of the light sources and photodetectors over a muscle.

[0016] FIG. **4** shows a block diagram of the PCB assembly

[0017] FIG. **5** shows the algorithm flow diagram.

[0018] FIG. **6** shows characteristic waveforms during a bruxism event

DRAWINGS—LIST OF REFERENCE NUMERALS

[0019] **100** Device Assembly—bruxism tracking and reduction device

[0020] **102** Elastic band

[0021] **104** User

[0022] **106** Temporalis muscle

[0023] **202** Device enclosure

[0024] **204**A/B Dual wavelength infrared light source

[0025] **206** Photosensor

[0026] **208** Visual stimulation light source

[0027] **210** Vibration motor

[0028] **212** Sensor cluster

[0029] **214** mounting slots

[0030] **302**A/B Transflectance through the muscle

[0031] **304** PCB Assembly

[0032] **402** Processor

[0033] **404** LED Driver

[0034] **406** Transimpedance amplifier

[0035] **408** Motion sensor

[0036] **410** USB connection

[0037] **412** Power source

[0038] **414** Wireless module

[0039] **502**A/B Sampled transflectance signal

[0040] **504** heart pulse peak detector

[0041] **506** heartbeat based normalization and DC removal

[0042] **507**A/B Aligned transflectance signals

[0043] **508** Subtraction

[0044] **509** Muscle activity

[0045] **510** Bruxism pattern detector

[0046] **511** Significant motion detector

[0047] **512** Bruxism event predictor

[0048] **513** Sleep detector

[0049] **514** Bruxism biofeedback generator

[0050] **602** Heart pulse

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Detailed Description—First Embodiment

[0051] FIG. **1** shows the user wearing one embodiment of the bruxism tracking and reduction device assembly **100**. In this embodiment, the device assembly **100** is affixed to the user **104** using an elastic band **102** in a way that the devices sensors cluster **212** is positioned over the temporalis muscle **106**. The sensor cluster **212** is tightly coupled to the skin in a way that it prevents accidental movement while wearing.

[0052] FIG. **2** shows the device assembly **100** from the bottom side which is touching the skin. The enclosure **202** is made out of opaque material that does not pass through light. The sensor cluster **212** is slightly raised over the overall enclosure **202** to provide better contact with the skin and prevent outside light from reaching the sensors. There is a photosensor **206** in the center of the sensor cluster **212**, the photosensor **206** can be a photodiode, a CMOS camera or other means for measuring light intensity. On the sides of the photosensor **206**, there are dual wavelength infrared light sources **204**A/B that emit light at wavelengths 850 nm and 940 nm or other wavelengths that provide a different path through the muscle tissue depending on the wavelength. The light sources **204** are spaced approximately 1 cm from the photosensor **206**. This provides good transflectance **302**A/B through the temporalis muscle **106**.

[0053] Visual stimulation light source **208** is an RGB LED diode in one embodiment. It's positioned in the sensor cluster **212** to provide good contact with the skin and prevent the light escaping. The stimulation light source **208** stimulates the optic nerve of the user **104** through the skull. Other embodiments are possible where the stimulation light source is position in front of the user's eyes or light source that is external to the device can be used.

[0054] The device assembly **100** is attached to the elastic band **102** through mounting slits **214**.

[0055] Haptic or vibrational stimulation is provided through a vibration motor **210** which could be an eccentric mass vibration motor, a linear actuator, a piezo or other means of generation vibration.

[0056] FIG. **4** shows the overview of the components on the PCB assembly **304**. The main part is a processor **402** which in one embodiment is a low power microcontroller which includes memory, ADC and DAC converters etc. For example, STM32L443 manufactured by ST Microelectronics. The led driver **404** is connected to the light sources **204**A/B and allows the processor **402** to control the current through the light sources **204** individually. The photosensor **206** is connected the processor **402** through a transimpedance amplifier **406** which converts electrical current to voltage. Other embodiments might a monolith solution which includes all sensor components in one part.

[0057] A motion sensor **408**, which could be a MEMS sensor unit that includes an accelerometer and a gyroscope is also connected the processor **402**.

[0058] The PCB assembly also has a power source **412**, a USB connection **410** an a wireless module **414**.

Operation—First Embodiment

[0059] The first embodiment measures a plurality of biological signals like muscle activity, heart pulse, and motion and provides bruxism activity information to the users and reduces bruxism using a biofeedback method.

[0060] The novel optical muscle sensor works by measuring thickness changes of the temporalis muscle **106** caused by muscle contractions. It measures transflectance **302**A/B through the muscle at two different wavelengths and compares them. The transflectance through skin and muscle is affected by blood pressure changes caused by heart pulse and muscle contractions. The ratio of the contribution to the transflectance change depends on the wavelength. Thus if we measure it at different wavelengths we can algorithmically determine the contribution of each.

[0061] The transflectance **302**A/B is sampled at regular interval for example at 100 Hz providing the signal samples **502**A/B on FIG. **5** and FIG. **6**. FIG. **6** show the typical signal waveforms during a bruxism event. The signals **502** have different gains and DC offsets and need to be aligned before they can be used. The aligned transflectance signals **507**A/B can be then be subtracted to get the muscle activity signal **509**. Other embodiments could use Independent Component Analysis or similar methods to extract the muscle activity **509** and the heart pulse signal **602**.

[0062] One way to extract the muscle activity **509** and detect and predict bruxism events is presented in FIG. **5**. The transflectance signals **502**A/B are first passed through a heart pulse peak detector **504** which extract peaks and valleys of the pulse using methods also used in pulse oximetry devices. This provides the gains for heartbeat based normalization and DC removal **506** which is effectively aligning the signals **502**A/B into **507**A/B. The difference between the signal is then calculated using subtraction **508** which gives the muscle activity signal **509**.

[0063] This gives the base for the novel optical muscle sensor. Using light sources **204**A/B and photosensor **206** and producing a muscle activity signal **509** using the method presented in part of the FIG. **5**.

[0064] The samples from the motion sensor **408** are first passed to significant motion detector **511** which senses user's **104** movement that might contaminate the transflectance **302**A/B signals.

[0065] The muscle activity **509** is then passed to a bruxism pattern detector **510** together with the motion data from significant motion detector **511**. The bruxism pattern detector **510** in one of the embodiments is a recurrent neural network trained on labeled bruxism event data from this or a similar device.

[0066] The other novel innovation is a bruxism event predictor **512** which predicts the bruxism event before it happens, based on the data from all the available sensors. The motion sensor **408**, the heart pulse from the heart pulse peak detector **504** and previous data from the bruxisms pattern detector **510**. The bruxism event predictor **512** is a recurrent neural network trained on labeled bruxism events collected for this or similar device.

[0067] The biofeedback method of bruxism reduction uses visual and/or vibrational means of stimulation. The bruxism biofeedback generator **514** generates a stimulation when a start of a bruxism event is detected by the detector **510** or when a bruxism event is predicted by the bruxism event predictor **512**. The signal from the actigraphy-based sleep detector **513** is used to inhibit the stimulation when the user **104** is not asleep. The bruxism biofeedback generator **514** adjusts and personalizes biofeedback parameters based on the effectiveness of preceding biofeedback stimulations. A plurality of biofeedback strategies can be set over the wireless or USB connection.

[0068] A combination of a vibration motor **210** and a visual stimulation light source **208** is used so that the bruxism biofeedback generator can assess the effectiveness of biofeedback-based on the result from the bruxism pattern detector **510** and personalizes the biofeedback to the user. The vibration generated by the vibration motor **210** is chosen from the range of approximately 15 Hz and 250 Hz and positioned in a way that it stimulates the temporalis muscle **106** and the tendons connecting the temporalis muscle to the jaw. This vibration signals the brain to open the jaw subconsciously. The duration of the stimulation is typically 0.5 to 2 seconds.

[0069] Another method of stimulation like sound, heat, direct transcranial current stimulation or other brain stimulation methods could also be used.

[0070] The device **100** has a USB connection **410** and/or a wireless module **414** to transfer the bruxism event and biofeedback data to an external system like a mobile phone where the effectiveness can be evaluated by the user **104** or others like a trained sleep or dental professional.

[0071] Thus this embodiment presents several novel and important advantages over the existing methods and devices.

[0072] The optical-based muscle sensor is more reliable and comfortable to use compared to EMG based sensor since it does not require direct contact with the skin.

[0073] The biofeedback method uses the bruxism event prediction which can predict a bruxism event before it starts and inhibits it before it happens.

[0074] The visual stimulation light source **208** is positioned in a way that it stimulates the optic nerve through the skull. Thus the light does not disturb a partner sleeping in the same bed.

[0075] The vibration motor **210** stimulates the temporalis muscle **106** and it's tendons directly to signal the subconscious brain to open the jaw without waking up the user. While the previous methods used vibration as a means to alert or wake up the user when bruxism was detected.

[0076] Although the description above contains many specifics these should not be construed as limiting the scope the embodiments but merely providing an illustration of some possible embodiments.

[0077] For example, in another embodiment, the device may be positioned over a different mastication muscle like the masseter muscle. Instead of the elastic band, the device can be secured to the user using different means, like using an adhesive. Instead of an optical muscle sensor, an acoustic or vibratory muscle sensor could be used to measure muscle contraction. The optical muscle sensor could use a different method to extract the muscle signal, for example, principal component analysis, independent component analysis, or a least squares minimizer. The bruxism event detector and predictor can be implemented in ways other than using a recurrent neural network, it could use other types of neural networks or be handcrafted code based on the feature of the bruxism event.

[0078] The presented embodiment has two multi-wavelength light sources for redundancy. But other combinations of light sources and photosensors are possible providing one or more transflectance measurements across two or more wavelengths.

[0079] The bruxism event predictor **512** could also use a plurality of other biological signals like breathing rate, brain activity from a near-infrared spectroscopy based brain sensor or an EEG sensor, blood oxygenation etc.

What is claimed is:

1. A method for tracking and reducing bruxism, the method comprising:

measuring a mastication muscle activity;

measuring a plurality of biological signals;

generating a prediction of a bruxism event based on preceding data samples of said biological signals, and preceding data samples of said mastication muscle activity;

generating a stimulation based on said bruxism event prediction, said mastication muscle activity;

whereby said bruxism is reduced.

2. A method for tracking and reducing bruxism from claim **1**, wherein said stimulation is visual.

3. A method for tracking and reducing bruxism from claim **1**, wherein said stimulation is a vibration.

4. A method for tracking and reducing bruxism from claim **1**, wherein said prediction of the bruxism event is generated by a neural network.

5. A method for tracking and reducing bruxism from claim **1**, further comprising:

adjusting said stimulation based on the effectiveness of preceding stimulations.

6. A method for tracking and reducing bruxism from claim **1**, further comprising:

adjusting said stimulation based on the effectiveness of preceding stimulations of other users.

7. A Bruxism reduction device, comprising:

a mastication muscle activity sensor;

a processor;

a means for measuring a plurality of biological signals;

a means for stimulation;

wherein said processor implements a bruxism event prediction algorithm that uses said biological signals, and said mastication muscle activity to generate a bruxism event prediction, before said bruxism event happens;

said processor implements a bruxism reduction algorithm that uses said bruxism event prediction, said mastication muscle activity to stimulate the user using said means for stimulation;

whereby bruxism is reduced.

8. A Bruxism reduction device from claim **7** wherein said bruxism event prediction algorithm is a neural network.

9. A Bruxism reduction device from claim **7** wherein said bruxism reduction algorithm has a means for adjusting parameters of said means for stimulation based on the effectiveness of prior stimulations.

10. A Bruxism reduction device from claim **7** wherein said means for stimulation is a vibration generation device.

11. A Bruxism reduction device from claim **7** wherein said means for stimulation is a means for generating sound.

12. A Bruxism reduction device from claim **7** wherein said means for stimulation is a light source.

13. A Bruxism reduction device from claim **7** wherein said means for stimulation is a light source device positioned on a user in a way that said light stimulates an optic nerve through users skull.

14. A Bruxism reduction device from claim **7** wherein said bruxism device is securely attached to a user using an elastic band.

15. A muscle activity sensor, comprising:

a one or more light sources;

a one or more photosensors;

a processor;

wherein said processor is connected to said light sources and said photodetectors and said light sources and said photodetectors are positioned in a way that a transflectance through said muscle can be measured at two or more different wavelengths;

said processor uses a means for calculating muscle position changes from changes in said transflectance at different wavelengths;

whereby said muscle activity is measured.

16. A muscle activity sensor from claim **15** wherein said light sources emit infrared light.

17. A muscle activity sensor from claim **15** wherein said light sources emit infrared light at wavelengths 850 nm and 940 nm.

18. A muscle activity sensor from claim **15** wherein said means to calculate muscle position changes is a neural network.

19. A muscle activity sensor from claim **15** wherein said means for calculating muscle position changes is an algorithm that uses said transflectance preceding said muscle activity to align and subtract said transflectances.

20. A muscle activity sensor from claim **15** wherein said means for calculating muscle position changes is an algorithm that uses Independent Component Analysis.

* * * * *