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**WEARABLE HABIT CESSATION SENSOR AND FEEDBACK DEVICE**

**BACKGROUND**

**Field of the Invention**

The present invention is directed to a combination of sensors and feedback mechanisms worn on the body for treatment of unconscious and unwanted behaviors. Of such behaviors, this invention particularly aids in the treatment of trichotillomania (hair pulling disorder), excoriation (skin picking disorder), nail biting and thumb sucking. Those who engage in these behaviors are often not aware that they are engaging in them. Studies have shown that if people are alerted when they are unconsciously engaging or about to engage in unwanted behaviors of this sort then they do not engage in the unwanted behavior. Studies have shown that a wearable device or devices which can provide this service can lead to the long term, continual and independent cessation of the behavior.

Trichotillomania, also called hair-pulling disorder, is a mental disorder that involves recurrent, irresistible urges to pull out hair from the scalp, eyebrows or other areas of the body, despite efforts to stop. Hair pulling from the scalp often leaves patchy bald spots, which causes significant distress and can interfere with social or work functioning. People with trichotillomania may go to great lengths to disguise the loss of hair. For some affected people, trichotillomania may be mild and generally manageable. For others, the compulsive urge to pull hair is overwhelming or unconscious. Some treatment options have helped many people reduce or entirely stop their hair pulling.

Excoriation disorder, also known as skin picking disorder, is defined as repetitive and compulsive picking of skin which results in tissue damage. Episodes of skin picking are often preceded or accompanied by tension, anxiety, or stress. The region most commonly picked is the face. Most patients with excoriation disorder report having a primary area of the body that they focus their picking on. Complications arising from excoriation disorder include: infection at the site of picking, tissue damage, and septicemia. Damage from picking can be so severe as to require skin grafting.

Thumb-sucking is normal in babies and young children. In some cases, thumb-sucking after age 5 is in response to an emotional problem or other disorder, such as anxiety. Children who suck their thumbs often or with great intensity around age 4 or 5, or those who are still sucking their thumbs at age 6 or later, are at risk for dental or speech problems. Prolonged thumb-sucking may cause the teeth to become improperly aligned (malocclusion) or push the teeth outward.

CBT (Cognitive Behavioral Therapy) and ACT (Acceptance and Commitment Therapy) are both used to treat harmful hair pulling and skin picking behavior, but are not always effective. The present inventive device can be used in conjunction with talk therapies to increase the effectiveness of treatment. Talk therapies tends to focus on conscious thought processes. The present inventive device provides a therapeutic intervention during or before unconscious pulling of the hair or picking of the skin, a situation in which introspection and reflective decision making encouraged by CBT cannot apply. Hair pulling, skin picking, nail biting, thumb sucking and similar unwanted manipulation of the body can all take place unconsciously. Studies have shown that making individuals more aware that they are participating in these behaviors greatly decreases their propensity to engage in these behaviors in the future. Unhealthy thumb sucking has been treated with a blocking device worn on the hand which physically impedes thumb sucking, as well as the application of a bad tasting substance applied to the thumb to dissuade thumb sucking. Both of these treatments may be uncomfortable or even painful to a child. Both of these treatments may also be outside the bounds of culturally acceptable child care. The present invention does not cause discomfort because it only applies enough vibrotactile feedback to induce awareness of a behavior.

**DESCRIPTION OF THE RELATED ART**

There are devices in existence (such as HabitAware Liv™) which are worn around the wrist, use an accelerometer or other relative position sensor, detect gestures correlated to unwanted behaviors and provide vibrotactile feedback to the user making them aware of the gesture. These devices consist of the following components: a relative position sensor (accelerometer, gyroscope, magnetometer etc.), a processing unit (microcontroller or System on Chip such as ARM Cortex family), and a radio transceiver such a Bluetooth and a vibration motor. This is the same combination and configuration of hardware components contained in activity trackers such as the FitBit™. The HabitAware Liv™ device essentially consists of the same mechanical and electrical parts as a commonly available activity tracker, such as the FitBit™, configured to detect a gesture of the hand (such as raising of the hand to unconsciously pull hair) instead of the steps taken during running or walking and other common activities. Similar configurations of sensors, processing units and feedback mechanisms exist to monitor sleep, in fact the same device can sometimes be used to monitor walking and sleep. In many cases the device ‘syncs’ or connects to a software program on a computer or smartphone, often connected to an internet platform or online “cloud” platform.

The present inventive device differs from the HabitAware Liv™ and other prior devices by providing novel and inventive means to decrease false positive feedback which is feedback that is mistakenly provided by the prior device when the target gesture is not taking place. The present inventive device further decreases missed unwanted behavior events which warrant feedback, in which case feedback is not provided when it should be.

Prior devices make use of accelerometers and other relative position sensors. These sensors cannot “dead reckon” their position. Thus, the sensor may detect the angular position of the device relative to gravity but it cannot detect whether the device is above, below or to the side of the user’s head or any other object.

In one embodiment of the present device, the addition of a contactless thermometer allows the device to sense whether it is pointed at the body (the body having higher temperature than other objects) which enables the device’s data processing algorithm to tie the relative position data of the accelerometer to the absolute position of the device across from the body. This at least partially overcomes the “dead reckoning” problem associated with accelerometers, gyroscopes and magnetometers.

Additional embodiments of the present inventive device obtain information about the user’s emotive state using sensors to detect physiological characteristics correlated with emotive states such as detecting increased heart rate. These emotive states, for instance, stress, are indicative of the undesirable behavior which the present device is designed to detect. The emotive state information also serves to minimize false positive feedback and missed events which warrant feedback in a fashion which is superior to prior devices.

**SUMMARY**

The present inventive device is worn on the underside of the wrist or wrists and consists of an array of sensors which in combination with a data processing unit detect unwanted, unconscious behaviors involving placement of the hand or hands and provide feedback to the user making the user aware of the unwanted behavior.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIGURE 1 shows the present inventive device, separated into three functional blocks for illustrative purposes, mounted on a cross section of the user’s wrist. The user’s head and thermal radiation emanating from the head are also shown.

FIGURE 2 shows a sequence of events over time in which the inventive device is used to detect and indicate an undesirable behavior.

FIGURE 3 shows a conceptual outline of the discrete components which make up the present invention.

FIGURE 4 shows a specific embodiment of the inventive device wherein the device is contained in a loop mounted around the underside of a watchstrap, bracelet, or other strap worn around the wrist.

**DETAILED DESCRIPTION OF THE INVENTION**

Embodiments of the present inventive device comprise a set of sensors contained in or mounted on a unit (enclosure, attachment or similar container or base) held close to or against the wrist by means such as a strap or similar fastening, the sensors including at least the following:

1. An accelerometer, gyroscope, magnetometer or combination of the aforementioned sensors. These sensors serve to determine the angular position of the device relative to gravity and/or the acceleration of the device in a given direction. When the user makes an undesirable gesture related to an unwanted behavior such as pulling of hair, the angular position and/or movement of the hand will be consistent and predictable. By matching the angular position and/or movement of the device with the predictable angular position and/or movement of the hand during the undesirable gesture the device is able to detect the undesirable gesture and provide immediate feedback or relevant data to the user.
2. A contactless sensor located at the bottom of the wrist and pointed away from the wrist determining the distance, presence, or characteristics (such as pulse or respiration) of the user’s body. This sensor may be active, for example a proximity sensor which emits infrared radiation from an infrared producing light emitting diode (LED) and then detects the infrared radiation which may have bounced off the user’s body or other object using an infrared phototransistor. Or the contactless sensor may be passive, such as a pyrometer which measures the infrared energy emitted by the body or other source. Although the angular position of the device as detected by an accelerometer, gyroscope, magnetometer or combination thereof may be matched to an undesirable gesture, there will be many false positive matches because that angular position or movement signature used to detect the undesirable gesture will match other gestures. For example, if angular position and acceleration alone were used by the device, it might provide feedback to the user when they are reaching up to take a book off a shelf that is at head level. When the user reaches for the book, the bottom of the user’s wrist partially or entirely faces the book shelf. In contrast, if the user had been attempting to pull the user’s hair, the bottom of the wrist would be pointed towards the user’s body. By incorporating a pyrometer (contactless thermometer) into the bottom of the device facing away from the wrist, the device will, for example, detect that the wrist is pointed towards a room temperature (e.g. 70 degrees Fahrenheit) bookcase instead of the user’s body (which might be detected as 90 degrees Fahrenheit assuming minor obstruction by hair). Similarly, if a child were wearing the device with the intention of providing feedback when the child attempts to suck the child’s thumb, using a position/motion sensor alone might cause the device to provide false positive feedback when the child reaches up to clutch its chest. In this case the pyrometer can differentiate between different parts of the body, not merely the presence of the body in contrast to other objects. The temperature detected by the pyrometer when the child is actually sucking its thumb might be 95 degrees Fahrenheit, while the temperature detected when the child is clutching its chest might be 85 degrees because of the obstruction of clothing between the device and the body.

*Additional sensor(s) detecting emotive states*: In addition to the sensors described above, in one embodiment of the present invention there is a sensor or sensors immediately adjacent to the skin of the user’s wrist where the device makes contact with the wrist. This sensor or sensors detects physiological characteristics of the user which are associated with the unwanted behavior. For example, the user may engage in the unwanted behavior because the user is under stress. In this case, physiological characteristics of psychological stress such as a faster pulse will be detected by the device and contribute to determining when a gesture related to a negative gesture is likely to take place. In addition to detecting when a gesture related to negative habit is going to take place outright, the detection of physiological characteristics and various bioindicators may be used in combination with other sensors such as accelerometers and contactless thermometers to help in reducing false positives that might otherwise be generated if those sensors were used by themselves. Until recently, physiological characteristics such as pulse and respiration could only be determined by sensors in contact with a person’s skin. There are now contactless sensors which may be able to detect a person’s respiration and pulse from a distance. The use of biosensing device sensors in contact with the user’s skin will in one embodiment be replaced by corresponding contactless sensors mounted on the device and pointed towards the user’s body.

The present inventive device is located at the underside of the wrist for significant reasons:

1. Some embodiments of the inventive device contain a body contact sensor for detecting emotive states related to an unwanted behavior. The prominence of vasculature on the underside of the wrist as compared to the top of the wrist increases the efficacy of bio-sensing such as the detection of respiration, galvanic skin response, heart beat and other cardiovascular activity. All of these bio-indicators are correlated to the emotive states of the wearer.
2. The bottom of the wrist is pointed towards the body during gestures such as moving towards or placing the hand near the head, moving towards or placing the hand nearing the mouth, as well as moving or placing the hand near numerous other areas of the body. This means that the bottom of the wrist is uniquely suited to the use of contactless sensors such as distance sensors (infrared, laser etc.), pyrometers (contactless thermometers) and numerous other sensors that can detect the presence and/or proximity of the user’s body.
3. Placement of sensors and/or other parts of the device makes it more discrete. Many people with disorders such as trichlitomania, habits such thumb sucking and other habituated activity of the hands are intensely self-conscious about their condition. They may forgo or stop the use of a wearable habit cessation device because they do not want other people to see it. By placing the device beneath the wrist, the device is less visible and self-conscious individuals may feel more comfortable using it.

*Value of Collected Sensor Data:* Users may benefit from tracking the behavior they are trying to stop using data gathered by and stored in the present device. In one embodiment of the inventive device this data will be stored and provided to a health professional or other third party. This data can also be applied in companion software, such as a smartphone app, or installed on a computer.

*Wireless Communication:* In further embodiments of the invention, the device can communicate wirelessly with a computer, phone, router or other receiver/transceiver. This involves communication technologies such as Bluetooth, WiFi, or infrared PWM (Pulse Width Modulation). These embodiments involve interaction with an application or custom software that records and makes use of data gained from the device’s sensors and device sensor data processing.

In additional embodiments, the present inventive device connects by a cable to a computer, phone or other electronic device. This connection involves such communication protocols as USB (Universal Serial Bus), serial post communication, or a Local Area Network.

*Use as a general activity tracker:* In recent years a variety of devices worn on the wrist have become available for tracking user activity. These devices track such parameters as the number of steps taken during a day with the goal of helping users measure exercise such as running and walking. These devices share some characteristics with the inventive device presently described: they often contain a combination of accelerometer, microcontroller, vibration motor and Bluetooth communication radio. The present inventive device may act in a similar but superior manner. Additional sensors and specific sensor placement as described provide helpful data resulting in superior performance. Relative position sensors such as accelerometers are not able to “dead reckon” their position relative to another object. By using a contactless thermometer to detect that the present device is pointed to a part of the user’s body, the relative position data from the accelerometer or similar device can be combined with this additional data to gain a better understanding of how the position of the device reflects behaviors of the user such as running, walking and body posture. This holds true for monitoring sleep activity as well.

Further detailed description of the present invention is provided in Figure 1 which shows a cross section of the user’s hand with the inventive device worn on the underside of the wrist. For nonlimiting, illustrative purposes only, the shown device has been divided into three parts: a sensor or sensors facing and in contact with the user’s wrist (shown as reference character “a”), all components of the device which are not external sensors (reference character b), a contactless sensor or sensors to detect the presence and or distance of the device from the head, mouth or other significant body area (reference character c). A portion of the user’s head and an indication of infrared radiation emanating from the head are also illustrated. The components indicated by reference characters a, b and c are all contained in a single enclosure which is held against the wrist by a strap.

In one embodiment of the device, reference character c of Figure 1 is a contactless thermometer which passively receives infrared thermal radiation, converts that radiation into electricity, amplifies this electricity and uses the resulting signal to determine the temperature of the surface at which it is pointed. In the case of intervening in hair pulling, if the user reaches to pull their hair, the user’s wrist will necessarily be pointed in the direction of the body. This means that detecting that the wrist is pointed at the body by measuring the temperature of the body surface immediately opposite the inventive device is a necessary indicator that the behavior gesture to be detected (reaching for the hair) is occurring. If the only sensor in use were a relative position sensor such as an accelerometer, a false positive gesture detection might take place if the user reached above their head to reach a book on a book shelf. In this case however, the device’s contactless thermometer on the bottom of the wrist would be pointed towards the bookcase and indicate the ambient temperature. Thus, the contactless thermometer would screen out this false positive gesture detection.

In such embodiments of the invention, several models of thermopile based contactless thermometers are employed such as the Melexis MLX90614™ and the Texas Instruments TMP007™.

In another embodiment of the present device, reference character c of Figure 1 is an active infrared position sensor such as the Vishay VCNL4010™. In another embodiment of the device, reference character c is an active infrared integrated gesture detection sensor such as the Avago APDS-9960™.

In one embodiment of the device, reference character a of Figure 1 is a pulse oximetry based heart rate and heart rate variability sensor. This sensor functions by determining the blood oxygen levels, which is indicative of heart behavior, by detecting the body’s absorption of red and infrared light. In one embodiment of the device, reference character a is the Maxim Integrated MAX30100™.

In another embodiment of the device, reference character a of Figure 1 is entirely absent. In this embodiment there is no sensor in contact with the wrist and no attempt to detect the emotive state of the user. In this embodiment the only sensor in addition to relative position detection is the contactless thermometer or similar outward facing contactless thermometer as described by reference character c of Figure 1. A significant innovation in the present inventive device is the presence of reference character c and its enabling position on the bottom of the wrist.

The area of the device indicated by reference character b of Figure 1 contains the majority of the device components. Without limitation, this includes a battery, a battery charge/discharge regulator, a relative position sensor such as an accelerometer, a data processing unit such as a microcontroller of SoC (System on Chip) computer, a vibration motor, a vibration motor power driver, a wired data interface such as a USB port, a wireless data radio such as Bluetooth or WIFI. In one embodiment these components are mounted on a printed circuit board (PCP) inside an Acrylonitrile Butadiene Styrene (ABS) plastic enclosure. This enclosure contains ports for outside facing sensors such as the MAX30100™ and the MLX90614™.

Further detailed description of the present invention is provided in Figure 2 which shows the sequence of events over time which comprise the use of the present inventive device. Reference character “a” of Figure 2 describes the time just before the user engages or attempts to engage in the unwanted behavior. At this time the user will have physiological indications of stress or anxiety which precede the unwanted behavior. Reference character “b” of Figure 2 describes the period at which the user has just begun or is in the midst of executing the gesture related to unwanted behavior, such as moving the hand towards the hair to pull it. The angular position of the device - as measured on three axis’s (x, y, z) by a relative position sensor or combination of sensors such as accelerometer, gyroscope, or magnetometer will shift in a predictable and detectable fashion when this gesture is partially or fully executed. Reference character “c” describes the period at which the emotive state of the user changes from the user’s baseline to an anxious or aroused state which predictively precedes the unwanted behavior. At this point, physiological indicators such as heart rate which are correlated to the shift in emotive state will also change in a predictable and detectable fashion. This may occur before or in the midst of the unwanted behavior. Reference character “d” describes the period at which the device detects that the user is engaging or about to engage in the unwanted behavior by:

1) detecting that physical movement and position of the device matches a predictable movement or position associated with a gesture related to the unwanted behavior, for example the hand reaching to pull the hair;

2) the presence and position of the user’s body opposite the device as determined by a contactless sensor such as an infrared thermopile contactless thermometer; and

3) in one but not all embodiments, the emotive state of the user is determined by physiological indicators such as heart rate as indicated by a sensor in contact with the user’s body such as a pulse oximetry heart rate sensor.

When detecting a gesture, the device will in one embodiment match the x,y,x angular position of the device to the predicted x,y,z angular position associated with the gesture. In another embodiment the device will analyze the x,y,z angular position of the device over a period of time and over multiple sensor readings. Multiple sensor readings and their relationship over time will be used to detect a match to information of the same type specific to the gesture being detected. Reference character “e” of Figure 2 describes the period in which an unwanted behavior is about to, or is in the midst of taking place, as detected by the inventive device and in turn has triggered feedback from the device. Once the device has combined data from multiple sensors to provide a reliable and dependable indication that feedback should be provided, power is supplied to a small vibration motor. Vibrations are transmitted from this motor to the uniquely sensitive underside of the user’s wrist. These vibrations are strong enough to alert the user that the device has been activated. In one embodiment, the user must turn the vibration motor off using a switch on the device. In another embodiment the vibration motor will turn off when the sensors indicate that the user is not engaged or about to engage in a gesture associated with the unwanted behavior. Reference character “f” of Figure 2 describes the point after the device has provided feedback and the user has been made aware that the user is about to unconsciously engage in an unwanted behavior. Having the awareness necessary to do so, the user has chosen not to engage in the undesirable behavior. Over time this process will result in the cessation of the unwanted behavior even when the device is not being worn.

Even in the case of conscious behavior, there will be a benefit because the user is forced to contemplate the destructiveness of their behavior and the uncomfortable contradiction of engaging in the behavior despite wearing a device designed to prevent the behavior. Additionally, in one embodiment the vibrotactile feedback is severe enough to cause physical discomfort which inhibits the unwanted behavior even if the user consciously tries to engage in the behavior.

Further detailed description of the present invention is provided in Figure 3 which shows a conceptual outline of the inventive device components and their relation to one another. One embodiment of the device includes the following:

*Reference character a*: ARM Cortex™ M0 SoC (System on Chip) microcontroller embedded in a Nordic nRF51822™ integrated 2.4GHz Bluetooth transceiver.

*Reference character b*: InvenSense MPU-6050™ accelerometer.

*Reference character c*: Maxim Integrated MAX30100™ pulse oximetry sensor

*Reference character d*: Texas Instruments TMP007™ infrared thermopile contactless thermometer.

*Reference character e*: 3.3v coin vibration motor drawing 50mAh, diameter 10mm height 2mm.

*Reference character f*: Micro SD Card and interface circuit.

*Reference character g*: Nordic nRF51822™ integrated 2.4GHz Bluetooth transceiver and micro USB plug.

Sensors reference characters b-d of Figure 3 interface with reference character a using a two wire i2c bus. Reference character e is powered by a MOSFET transistor driver controlled by a digital i/o signal from the reference character a ARM M0 microcontroller. All the aforementioned components are powered by a 150mAh 3.7v lithium polymer rechargeable battery. Battery overcharge/undercharge components are also present in the device. The device battery can be recharged from the micro USB port power leads by way of a MAX1555 lithium polymer battery management integrated chip.

Another embodiment of the inventive device contains all the components and functions listed above with the exception that reference character c of Figure 3, the pulse oximetry sensor, will be entirely absent.

Further detailed description of the present invention is provided in Figure 4 which shows an embodiment of the inventive device with a highly creative and uniquely innovative design. Many people choose to wear watches, bracelets or other straps around their wrist. This impedes them from wearing an additional device around the wrist such as the present inventive device. By mounting the device in a loop worn around a watchband, bracelet or other strap worn around the wrist, then this conflict is resolved. In addition, some people, especially those suffering from anxiety which often coexists with compulsive behaviors, may be too self-conscious about the appearance of a device such as the Fitbit™ or HabitAware Liv™ to even consider its use. By hiding the inventive device in an inconspicuous loop under the wrist around a secondary, more aesthetically pleasing and socially acceptable device such as a watch, this destructive anxiety is avoided. The device is mounted inside a loop which can fit around a watchband, bracelet or other strap worn around the wrist. In one such embodiment this loop is silicone rubber and stretches around the target strap it surrounds in order to stay in place. In this embodiment, the device components are separated into two halves, some between the wrist and surrounded strap, the rest above the surrounded strap.

Reference characters a and f of Figure 4 represent the portion of the loop between the separate strap, such as a watchband, and the wrist. The vibrotactile feedback providing vibration motor (reference character e of Figure 3) is located here where vibrations are best felt by the user. The contact sensor, such as a Maxim Integrated MAX30100™ pulse oximetry sensor, is located here as well. Reference characters c and e of Figure 4 represent the portion of the loop covering the separate strap and facing away from the user. The contactless sensor, such as the Texas Instruments TMP007™ infrared thermopile contactless thermometer, will be located here where it can receive infrared radiation from objects opposite the device. A relative position sensor such as the InvenSense MPU-6050™ accelerometer, battery, microcontroller, data storage, wireless communication transceiver and battery charger are located in reference characters a and f of Figure 4 in one embodiment, in reference characters c and e in another embodiment and all possible individual component distribution combinations in additional embodiments.

**EXEMPLARY CLAIM**

An apparatus for treatment of unwanted behaviors comprising:

an enclosure releasably attached to a wrist of a person having an unwanted behavior;

a sensor in physical contact with the wrist, said sensor selected from the group consisting of accelerometer, gyroscope and magnetometer and located within the enclosure;

a contactless sensor for measuring body temperature, heart rate and/or blood oxygen level wherein the contactless sensor is located within the enclosure and oriented toward the person’s body without contact with the person’s body;

a data processing unit located within the enclosure;

a battery located within the enclosure;

a vibration motor located within the enclosure for providing biofeedback of the unwanted behavior.