SUMMARY

[0008] One objective of this disclosure is to provide systems, devices, methods, and kits for monitoring physiologic and/or physical signals from a subject. Another objective is to provide systems and methods for assessing the autonomic nervous system (ANS), and/or neuroendocrine system of a subject for the purposes of patient selection for a treatment, treatment feedback, treatment outcome prediction, and treatment follow-up. Yet another objective is to provide emotional, visual, and/or autonomic feedback of a subject immersed in a virtual and/or augmented reality environment.

[0009] The above objectives are wholly or partially met by devices, systems, and methods according to the appended claims in accordance with the present disclosure. Features and aspects are set forth in the appended claims, in the following description, and in the annexed drawings in accordance with the present disclosure.

[0010] Disclosed is a method for assessing sympathetic and/or parasympathetic neural activity in an eye of a subject including: taking a plurality of images of the eye over a period of time; identifying and tracking a position of one or more features of an iris of the eye across the images to generate one or more trajectories thereof; and analyzing the trajectories to generate one or more metrics relating to sympathetic and/or parasympathetic neural activity in the eye.

[0010a] In one aspect, there is provided a method for assessing at least one of sympathetic and parasympathetic neural activity in an eye of a subject, the method comprising: taking a plurality of images of the eye over a period of time utilizing one or more back-facing image sensors of a head-mounted display; identifying and tracking a position of a plurality of features of an iris of the eye across the images to generate one or more trajectories thereof; analyzing two or more of the trajectories to determine a relative movement between two or more features of the iris of the eye; utilizing the determined relative movement between the two or more features to generate one or more metrics relating to at least one of sympathetic and parasympathetic neural activity in the eye.

[0010b] In another aspect, there is provided a system for assessing at least one of sympathetic and parasympathetic neural activity in an eye of a subject, the system comprising: a head-mounted display comprising one or more back-facing image sensors; and at least one processing device coupled to the one or more back-facing image sensors; the at least one processing device being configured: to utilize the one or more back-facing image sensors of to take a plurality of images of the eye over a period of time; to identify and track a position of a plurality of features of an iris of the eye across the images to generate one or more trajectories thereof; to analyze two or more of the trajectories to determine a relative movement between two or more features of the iris of the eye; and to utilize the determined relative movement between the two or more features to generate one or more metrics relating to at least one of sympathetic and parasympathetic neural activity in the eye.

[0011] In aspects, the features of the iris may include one or more of a ciliary zone, a pupil, a sphincter muscle/pupillary zone, a crypt, a peripheral crypt, a contraction furrow, a mole, a region of alternative/distinct color, a color distorted region, a region of contrast, an identifiable region, a diameter, boundary, centroid, area, distortion, a combination thereof, or the like.

[0012] In aspects, the position of one or more of the features may be calculated relative to a reference point in the images (e.g. a center of the pupil of the eye, a contrast point in the eye, a fiduciary light field marking on the eye, a region of a sclera, to a boundary of the pupil, etc.).

[0013] In aspects, the trajectory may include a radial movement and/or a rotational movement about the reference point. Such movement of interest may include high speed

presenting an image to, asking a question to, and/or playing music for the subject, or the like.

[0021] In aspects, the stress test may include providing a tactile input to one or more sites on the subject, stimulating, blocking, ablating, and/or treating one or more of a neural structure, a receptor, a nerve, a ganglion, a renal nerve, a renal receptor, a carotid sinus, a carotid body, a baroreceptor, a vagus nerve receptor, a skin surface, and/or an erogenous zone of the subject, a combination thereof, or the like.

[0022] In aspects, the stress test may include applying an electromagnetic field to, injecting a current into, applying pressure to, applying stroking to, or applying a change in barometric pressure surrounding the subject, or the like.

[0023] In aspects, the stress test may include having the subject sleep, cry, speak, laugh, lie down, jump, walk, run, change posture, exercise, perform a breath holding exercise, climb stairs, have sex, fight, play a game, relax, or the like.

[0024] In aspects, the method may include treating a target site within the patient, the metric related to a subject response to the treatment. Some non-limiting examples of treatments include one or more of performing an ablation, a neuromodulation, implantation of a neuromodulation device, a focused energy delivery, a radio frequency ablation, a microwave ablation, a high intensity focused ultrasound (HIFU) delivery, a cryoablation, a chemical ablation, a radiosurgical treatment, an optical ablation, an infrared ablation, a laser ablation, an MR guided HIFU treatment, or the like.

[0025] In aspects, the method may include administering a subsequent treatment and/or stress test to the target site, the metric during and/or after the subsequent treatment and/or stress test indicative of a state of completion of the treatment of the target site.

[0026] Disclosed is a method for assessing sympathetic and/or parasympathetic neural activity in a first eye and/or a second eye of a subject including: administering one of a muscarinic receptor agonist or an anticholinergic agent to the first eye; administering one of an alpha adrenergic agent or a sympathomimetic agent to the second eye; and tracking a position of one or more features of the first eye to generate a first metric relating to the sympathetic neural activity and tracking a position of one or

more features of the second eye to generate a second metric relating to the parasympathetic neural activity.

[0027] In aspects, one or more of the features may include one or more of a ciliary zone, a pupil, a sphincter muscle/pupillary zone, a crypt, a peripheral crypt, a contraction furrow, a mole, a region of alternative/distinct color, a color distorted region, a region of contrast, an identifiable region, a diameter, boundary, centroid, area, distortion, combination thereof, or the like.

[0028] In aspects the method may include comparing the first metric to the second metric to determine a differential change in the sympathetic neural activity and the parasympathetic neural activity.

[0029] Disclosed is a system for monitoring one or more physiologic, autonomic neural, and/or electrophysiological signals from a subject, including: a head mounted display sized for placement onto a head of the subject including a visual input device and a back-facing imaging sensor; the visual input device arranged within a field of view of the subject when the head mounted display is coupled thereto, the visual input device configured to display an output image for the subject; the back-facing imaging sensor arranged with a field of view covering one or more facial features of the subject when the head mounted display is coupled thereto, the back-facing imaging sensor configured to generate one or more feedback images the subject; and a processor electrically and/or wirelessly coupled to the visual input device and the back-facing imaging sensor, the processor configured to deliver the output images, accept the feedback images, and analyze the images to determine one or more of the physiologic, autonomic neural, and/or electrophysiological signals.

[0030] In aspects, the head mounted display may include a facial interfacing member in accordance with the present disclosure (e.g. herein referred to as a shroud), the shroud arranged so as to isolate one or more eyes of the subject from a surrounding environment, when the head mounted display is coupled to the head of the subject.

[0031] In aspects, the shroud may include one or more sensors and/or electrodes, the sensors and/or electrodes arranged along the shroud so as to bias against one or more skin

a perfusion sensor, a sweat analyte sensor, a galvanic skin response sensor, an interfacial pressure sensor, a flow sensor, a stretch sensor, a microphone, or the like.

[0043] In aspects, one or more of the physiologic sensors may be arranged for placement onto the perineal region, the perianal region, the pubic region, the inner thigh region, the posterior knee region, the neck, the ear, the ocular region, the breast, the axilla, the elbow, the wrist, the palm, the foot, the lips, and/or an erogenous zone of the subject.

[0044] In aspects, the system may include a stimulating device selected from an electrical stimulator, a thermoregulating device, a heating coil, a thermoelectric device, a Peltier device, a tactile stimulating component, a vibratory stimulating element, a combination thereof, or the like arranged so as to interface with the skin of the subject when coupled thereto.

[0045] In aspects, the system may include a treatment system for treating a target site within the subject, the treatment system including one or more of an ablation system, a neuromodulation device, a neuromodulation implant, an ablation catheter, a focused energy delivery device, a radio frequency ablation system or catheter, a microwave ablation system or catheter, an ultrasound energy delivery system, a high intensity focused ultrasound (HIFU) delivery system or catheter, a cryoablation system or catheter, a chemical ablation system or catheter, a radiosurgical system, an optical ablation system, an infrared ablation system, a laser ablation system, an MR guided HIFU system, or the like.

[0046] In aspects, the system may include a vascular substance delivery device, configured so as to administer a substance to an artery, a vein, an arteriole, and/or a venule of the subject.

[0047] In aspects, the processor may be included in or coupled to a host device, the host device integrated into a bedside alarm clock, housed in an accessory, within a purse, a backpack, a wallet, is or is included in a mobile computing device, a smartphone, a tablet computer, a pager, a laptop, a local router, a data recorder, a network hub, a server, a secondary mobile computing device, a repeater, or a combination thereof.

[0048] Disclosed is use of a system in accordance with the present disclosure to confirm completion of, follow up on, confirm partial completion of,

monitor a patient response to, or patient selection in connection with, a denervation procedure, a renal denervation procedure, ablation of a renal nerve, ablation of renal artery, and/or ablation of an accessory renal artery.

[0049] Disclosed is use of a system in accordance with the present disclosure to enhance a gaming experience of, assess an emotional state of, perform a lie detection test on, enhance a virtual shopping experience of, reduce a stress state of, or enhance a virtual interaction between a user and a subject.

[0050] Disclosed is use of a system in accordance with the present disclosure to perform an electroretinogram, an electroencephalogram, and/or an electrooculogram on a subject.

[0051] Disclosed is a method for assessing an autonomic nervous system of a subject, including: monitoring neural activity in an ocular feature of the subject to obtain one or more neural activity signals; performing a stress test on the subject; and analyzing the signals obtained before, during, and/or after the stress test to generate a metric, diagnostic, report, and/or additional signals therefrom relating to the autonomic nervous system of the subject.

[0052] In aspects, the stress test may include administration of a chemical, a drug, medicament, a hormone, an enzyme, a diuretic, a solution, electrolytes, a peptide, steroid, saline, a hypotonic solution, a hypertonic solution, a combination thereof, or the like to the subject. In aspects, the administration may be topical, systemic, intravenous, intra-arterial, intra-parenchymal, sub-dermal delivery, transdermal delivery, rectal, via vaginal suppositories, via urethral suppositories, via nasal suppositories, via rectal suppositories, inhaled, a combination thereof, or the like.

[0053] In aspects, the stress test may include delivery of energy to, stimulation of, electrical stimulation of, presenting an audio field to, application of thermal stress to, presenting a light field to, presenting an image to, asking a question to, or playing music for, the subject.

[0054] In aspects, the stress test may include providing a tactile input to one or more sites on the subject. In aspects, the stress test may include stimulating one or more of a

carotid sinus, a carotid body, a baroreceptor, a vagus nerve receptor, or an erogenous zone of the subject.

[0055] In aspects, the stress test may include applying an electromagnetic field to, injecting a current into, applying pressure to, applying stroking to, or applying a change in barometric pressure surrounding the subject (e.g. such as to the skin of the subject, to an internal stimulation site, etc.).

[0056] In aspects, the stress test may include having the subject sleep, cry, laugh, lie down, jump, walk, run, change posture, exercise, perform a breath holding exercise, climb stairs, or the like.

[0057] In aspects, one or more stimulation and/or monitoring sites may be coupled to the perineal region, the perianal region, the pubic region, the inner thigh region, the posterior knee region, the neck, the ear, the ocular region, the breast, the axilla, the elbow, the wrist, the palm, the foot, the lips, and/or an erogenous zone of the subject.

[0058] One or more of the steps of a method in accordance with the present disclosure may be performed at least in part by a system in accordance with the present disclosure.

[0059] Disclosed is a system for performing a neuromodulation and/or ablation procedure on a target site within a subject including: a treatment system for delivering energy or a chemical to the target site; a head mounted display including a back-facing imaging sensor configured to measure one or more electrophysiological signals, neural traffic signals, and/or physiologic parameters from the head of the subject so as to produce one or more activity signals; and a processor included in or coupled to the head mounted display, the processor configured to receive the activity signal(s), and/or one or more signals generated therefrom, the processor including an algorithm, the algorithm configured to analyze the activity signal(s) to determine the effect of the treatment system on the target site.

[0060] In aspects, the system may include one or more additional monitoring devices, the algorithm configured to compare activity signal(s) generated by the plurality of monitoring devices and the head mounted display against each other to determine the effect of the treatment system on the target site.

[0061] In aspects, the treatment system may include one or more of an ablation system, a neuromodulation device, a neuromodulation implant, an ablation catheter, a focused energy delivery device, a radio frequency ablation system or catheter, a microwave ablation system or catheter, an ultrasound energy delivery system, a high intensity focused ultrasound (HIFU) delivery system or catheter, a cryoablation system or catheter, a chemical ablation system or catheter, a radiosurgical system, an optical ablation system, an infrared ablation system, a laser ablation system, an MR guided HIFU system, or the like.

[0062] In aspects, the algorithm may be configured to indicate when only a partial neuromodulation and/or ablation procedure has been performed on a target site, and/or when a complete procedure has been performed on the target site.

[0063] In aspects, the system may include a stimulating device selected from an electrical stimulator, a thermoregulating device, a heating coil, a thermoelectric device, a Peltier device, a tactile stimulating component, a vibratory stimulating element, or a combination thereof, the stimulating device configured to stimulate the subject at one or more stimulation sites, the algorithm configured to compensate for the stimulation in the analysis. In aspects, one or more of the stimulating devices may be embedded in the treatment system. In aspects, the treatment system may be configured to deliver a stimulating energy or chemical agent to the target site, and/or one or more stimulatory sites within the subject (e.g. such as a HIFU stimulation of a neural structure in order to assess the function thereof, perform a stress test thereupon, assess treatment thereof, etc.).

[0064] Disclosed is a method for assessing and/or selecting a subject for a renal denervation procedure, including monitoring blood pressure of the subject to obtain one or more physiologic signals, performing a stress test on the subject, and analyzing the physiologic signal(s) obtained before, during, and/or after the stress test to generate a metric, diagnostic, report, and/or additional signals therefrom relating to the autonomic nervous system of the subject, the metric, diagnostic, report, and/or additional signal relating to the suitability of the subject for a renal denervation procedure.

[0065] In aspects, the stress test includes administration of a chemical, an adrenoceptor agonist/antagonist, a drug, medicament, a hormone, an enzyme, a diuretic, a solution,

WHAT IS CLAIMED IS:

1. A method for assessing at least one of sympathetic and parasympathetic neural activity in an eye of a subject, the method comprising:

taking a plurality of images of the eye over a period of time utilizing one or more back-facing image sensors of a head-mounted display;

identifying and tracking a position of a plurality of features of an iris of the eye across the images to generate one or more trajectories thereof;

analyzing two or more of the trajectories to determine a relative movement between two or more features of the iris of the eye;

utilizing the determined relative movement between the two or more features to generate one or more metrics relating to at least one of sympathetic and parasympathetic neural activity in the eye.

2. The method in accordance with claim 1, wherein the plurality of features of the iris comprise two or more of a ciliary zone, a pupil, a sphincter muscle/pupillary zone, a crypt, a peripheral crypt, a contraction furrow, a mole, a region of alternative/distinct color, a color distorted region, a region of contrast, an identifiable region, a diameter, boundary, centroid, area, and distortion.

3. The method in accordance with claim 1, wherein the position of one or more of the plurality of features is calculated relative to a reference point in the plurality of images, the reference point being substantially the center of a pupil of the eye.

4. The method in accordance with claim 3, wherein the two or more trajectories comprise at least one of a radial movement and a rotational movement about the reference point.

5. The method in accordance with claim 1, further comprising altering a light field near to one or more of the plurality of features in one or more of the plurality of images, wherein altering the light field occurs over an optical spectrum visible in the images but without substantially impacting a light reflex of the eye.

6. The method in accordance with claim 1, further comprising generating a corrected movement of at least a given one of the two or more features by converting movement of the given feature utilizing a solid mechanic model of movement of the iris to correct for a series mechanical interconnection of sphincter and dilator muscles coupled to each other and substantially anchored to the eye at the edge of the iris.

7. The method in accordance with claim 6, wherein the edge of the iris comprises an interface between the iris and the sclera.

8. The method in accordance with claim 1, wherein utilizing the determined relative movement between the two or more features comprises independently determining sphincter muscle related movement and dilator muscle related movement.

9. The method of claim 8, further comprising:

utilizing determined relative movement between the two or more features located in a vicinity of the pupil to identify the sphincter muscle related movement; and

utilizing determined relative movement between the two or more features located in a vicinity of an edge of the iris to identify the dilator muscle movement.

10. The method in accordance with claim 9, further comprising utilizing the identified sphincter muscle related movement to generate one or more metrics related to parasympathetic nervous system (PNS) outflow to the eye and utilizing the identified dilator muscle movement to generate one or more metrics related to sympathetic nervous system (SNS) outflow to the eye.

11. A system for assessing at least one of sympathetic and parasympathetic neural activity in an eye of a subject, the system comprising:

a head-mounted display comprising one or more back-facing image sensors; and

at least one processing device coupled to the one or more back-facing image sensors;

the at least one processing device being configured:

to utilize the one or more back-facing image sensors of to take a plurality of images of the eye over a period of time;

to identify and track a position of a plurality of features of an iris of the eye across the images to generate one or more trajectories thereof;

to analyze two or more of the trajectories to determine a relative movement between two or more features of the iris of the eye; and

to utilize the determined relative movement between the two or more features to generate one or more metrics relating to at least one of sympathetic and parasympathetic neural activity in the eye.

12. The system in accordance with claim 11, wherein the plurality of features of the iris comprise two or more of a ciliary zone, a pupil, a sphincter muscle/pupillary zone, a crypt, a peripheral crypt, a contraction furrow, a mole, a region of alternative/distinct color, a color distorted region, a region of contrast, an identifiable region, a diameter, boundary, centroid, area, and distortion.

13. The system in accordance with claim 11, wherein the position of one or more of the plurality of features is calculated relative to a reference point in the plurality of images, the reference point being substantially the center of a pupil of the eye.

14. The system in accordance with claim 13, wherein the two or more trajectories comprise at least one of a radial movement and a rotational movement about the reference point.

15. The system in accordance with claim 11, wherein the head-mounted display further comprises at least one visual input device, and wherein the at least one processing device is further configured to utilize the at least one visual input device to alter a light field near to one or more of the plurality of features in one or more of the plurality of images, wherein altering the light field occurs over an optical spectrum visible in the images but without substantially impacting a light reflex of the eye.

16. The system in accordance with claim 11, wherein the at least one processing device is further configured to generate a corrected movement of at least a given one of the two or more features by converting movement of the given feature utilizing a solid mechanic model of movement of the iris to correct for a series mechanical interconnection of sphincter and dilator muscles coupled to each other and substantially anchored to the eye at the edge of the iris.

17. The system in accordance with claim 16, wherein the edge of the iris comprises an interface between the iris and the sclera.

18. The system in accordance with claim 11, wherein utilizing the determined relative movement between the two or more features comprises independently determining sphincter muscle related movement and dilator muscle related movement.

19. The system in accordance with claim 18, wherein the at least one processing device is further configured:

to utilize determined relative movement between the two or more features located in a vicinity of the pupil to identify the sphincter muscle related movement; and

to utilize determined relative movement between the two or more features located in a vicinity of an edge of the iris to identify the dilator muscle movement.

20. The system in accordance with claim 19, wherein the at least one processing device is further configured to utilize the identified sphincter muscle related movement to generate one or more metrics related to parasympathetic nervous system (PNS) outflow to the eye and to utilize the identified dilator muscle movement to generate one or more metrics related to sympathetic nervous system (SNS) outflow to the eye.