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(54) MODULE AND METHOD FOR DETERMINING VISUAL FATIGUE

(57) A visual fatigue determining module (10) configured to determine visual fatigue level of a user, the module comprising at least:
- a communication component (12) configured to receive from a visual fatigue determining device, visual behavior data indicative of the at least one visual behavior parameter of the user,
- a memory (14) configured to store computer executable instructions; and
- a processor (16) for executing the computer executable instructions, wherein the computer executable instructions comprises instructions for:
- processing the visual behavior data to generate visual fatigue information indicative of the visual fatigue level of the user.

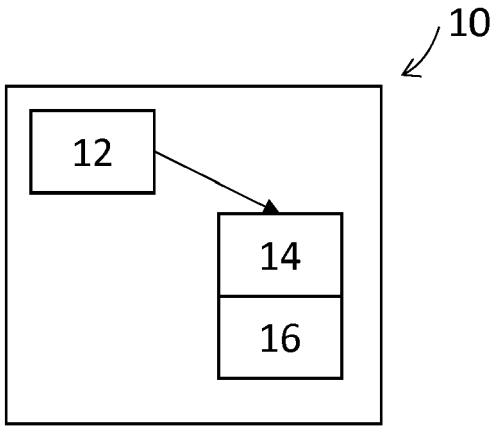

Figure 1

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Description

FIELD OF THE INVENTION

[0001] The invention relates to a vision fatigue monitoring module, a visual monitoring device comprising a vision fatigue monitoring module of the invention and a method for monitoring the visual fatigue of a user.

BACKGROUND OF THE INVENTION

[0002] Visual fatigue is a phenomenon difficult to measure. In particular it is difficult to have an easy-to-measure device to assess visual fatigue.

[0003] The problem is that up to now it is difficult to make an easy measurement of the visual fatigue, which could be used in all day life without requiring complex device and controlled environment, and which can give an accurate measurement of visual fatigue level that is dependent on the individual.

[0004] Furthermore, visual fatigue may help predict general fatigue of an individual and determining the level of fatigue of an individual may be useful in many situations.

[0005] For example, some activities require a great degree of concentration. It is useful to be able to provide to the user or a third party carrying out such activity an indication of the level of fatigue of the user. Indeed, it has been observed that a change in behavior upon carrying out an activity may lead to very different results in terms of achievement of the activity.

[0006] Typically, when a person is driving it can be very useful to analyze the fatigue level of the person so as to provide an alert when the determined fatigue level is greater than a threshold value and driving represents a risk.

[0007] Therefore, there is a need for a vision fatigue monitoring module for monitoring the visual fatigue of a user.

[0008] One object of the present invention is to provide such a module and method for monitoring the visual fatigue.

SUMMARY OF THE INVENTION

[0009] To this end, the invention proposes a vision fatigue monitoring module configured to monitor eye fatigue of a user, the module comprising at least:

- a communication unit configured to receive eye data indicative of the at least one parameter relating to the current visual behavior of the user,
- a memory configured to store computer executable instructions; and
- a processor for executing the computer executable instructions, wherein the computer executable instructions comprises instructions for:
- receiving eye data via the communication unit,
- monitoring the visual fatigue of the user based on the received eye data.

[0010] Advantageously, the vision fatigue monitoring module can be mounted on an existing optical equipment or head mounted device or communicate with a sensing device to monitor the visual fatigue of the user.

[0011] According to further embodiments which can be considered alone or in combination:

- the communication component is further configured to receive activity data indicative of the activity of the user and wherein both the visual behavior data and activity data are processed to generate visual fatigue information; and/or
- the processing of said visual behavior data is done by comparing said visual behavior data with a predetermined threshold value; and/or
- the predetermined threshold value is adapting based on the activity data;
  and/or
- the visual fatigue information is an alert information; and/or
- the communication component is further configured to receive subjective fatigue level data indicative of a subjective fatigue level provided by the user, and
- the computer executable instructions further comprise instructions for:

    - ◦ receiving the subjective fatigue level data,
    - ◦ receiving subjective visual behavior data indicative of the at least one visual behavior parameter the user in the subjective fatigue level,
    - ◦ adapting the processing of the visual behavior data based on the subjective fatigue level data and the subjective visual behavior data; and/or

- the instructions for processing the visual behavior data are arranged to generate visual fatigue information indicative of an anticipated visual fatigue level of the user; and/or
- the eye data comprise data relating to the pupil and/or vergence microfluctuation of the user and/or the near point of convergence of the user, and/or microfluctuations of eyemovements and/or accomodation microfluctuation; and/or

[0012] The invention further relates to a visual fatigue determining device, for example intended to be worn by a user, comprising at least one sensor configured to sense at least one visual behavior parameter indicative of the visual behavior of the user when wearing the visual fatigue determining device and a communication unit configured to communicate visual behavior data indicative of the sense visual behavior parameter to a visual fatigue determining module according to the invention.

[0013] According to further embodiments which can be considered alone or in combination

- the communication unit is further configured to receive from the visual fatigue determining module information indicative of the visual fatigue level of the user; and/or
- the visual fatigue determining device further comprises an output unit arranged to output a signal to the user based on the information indicative of the visual fatigue level of the user received from the visual fatigue determining module; and/or
- the visual fatigue determining device further comprises at least one activity input unit configured to collect activity information indicative of the activity of the user and the communication unit is further configured to communicate the activity information indicative to the visual fatigue determining module; and/or
- the visual fatigue device is a head mounted device; and/or
- the visual fatigue device is a smartphone; and/or
- the visual fatigue device is a touch pad; and/or
- the visual fatigue device is a computer/ laptop equipped with a webcam.

[0014] The invention also relates to a method of determining the visual fatigue level of a user, comprising:

- a visual behavior data receiving step during which visual behavior data indicative of the visual behavior of the user are received,
- a processing step during which the visual behavior data are processed to generate visual fatigue information indicative of the visual fatigue level of the user.

[0015] The method according to the invention may further comprise:

- an activity data providing step, during which activity data indicative of the activity of the user are provided, and

wherein during the processing step the visual fatigue information are generated based on the visual behavior data and the activity data.

[0016] The invention further relates to a method for improving a visual fatigue determining module according to the invention, comprising:

- a subjective fatigue level data providing step during which subjective fatigue level data indicative of a subjective fatigue level are provided, for example by the user of the visual fatigue determining module,
- a subjective visual behavior data receiving step during which subjective visual behavior data indicative of at least one visual behavior parameter of the user in the subjective fatigue level are provided,
- an adapting step during which the computer executable instructions for processing the visual behavior data are adapted based on the subjective fatigue level data and the subjective visual behavior data.

[0017] The invention further relates to a computer program product comprising one or more stored sequences of instructions that are accessible to a processor and which, when executed by the processor, causes the processor to carry out the steps of the method according to the invention.

[0018] The invention also relates to a computer-readable storage medium having a program recorded thereon; where the program makes the computer execute the method of the invention.

[0019] The invention further relates to a device comprising a processor adapted to store one or more sequence of instructions and to carry out at least one of the steps of the method according to the invention.

[0020] Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions utilizing terms such as "computing", "calculating", or the like, refer to the action and/or processes of a computer or computing system, or similar electronic computing device, that manipulate and/or transform

data represented as physical, such as electronic, quantities within the computing system's registers and/or memories into other data similarly represented as physical quantities within the computing system's memories, registers or other such information storage, transmission or display devices.

[0021] Embodiments of the present invention may include apparatuses for performing the operations herein. This apparatus may be specially constructed for the desired purposes, or it may comprise a general purpose computer or Digital Signal Processor ("DSP") selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs) electrically programmable read-only memories (EPROMs), electrically erasable and programmable read only memories (EEPROMs), magnetic or optical cards, or any other type of media suitable for storing electronic instructions, and capable of being coupled to a computer system bus.

[0022] The processes and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct a more specialized apparatus to perform the desired method.

[0023] The desired structure for a variety of these systems will appear from the description below. In addition, embodiments of the present invention are not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the inventions as described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Embodiments of the invention will now be described, by way of example only, and with reference to the following drawings in which:

- Figure 1 is a schematic representation of a visual fatigue determining module according to the invention;
- Figure 2 is a schematic representation of a visual fatigue determining device according to the invention;
- Figure 3 represents a network configuration of the visual fatigue determining device according to the invention;
- Figures 4 and 5 are illustrations of chart-flow of methods according to the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0025] Elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions of some of the elements in the figure may be exaggerated relative to other elements to help improve the understanding of the embodiments of the present invention.

[0026] The invention relates to a visual fatigue determining module configured to determine visual fatigue level of a user. As illustrated on figure 1, the visual fatigue determining module 10 comprises a communication component 12, an image memory 14 and a processor 16.

[0027] The communication component 12 is configured to receive visual behavior data, for example from a visual fatigue determining device as described in greater detail latter. The visual behavior data are indicative of at least one visual behavior parameter of the user.

[0028] The inventors have observed that among the different visual behavior parameter of the user visual behavior data relating to the pupil and/or vergence micro fluctuation and/or the near point of convergence, and/or microfluctuations of eyemovements and/or accomodation microfluctuation allow determining the visual fatigue with a great accuracy.

[0029] From the study that measured refraction and pupil with a power refractor before & after30 minutes of visual search task and processed using fast Fourier transformation in MATLAB to obtain accommodation and pupil microfluctuations (Low frequency component (LFC), high frequency component (HFC)) showed that, both microfluctuations of accommodation & pupil changes significantly after the task, particularly the low frequency component (LFC) Furthermore, capturing pupil may be relatively easy and quick and it can be done using a camera/ webcam.

[0030] Advantageously, using the microfluctation of pupil of the user as visual behavior parameter allows direct measurement, easy-to-measure (no optical alignment neither fixation point) and cheap (simple camera, preferably in infrared for dark eyes) device for assessing visual fatigue.

[0031] Similarly, microfluctuations of vergence and eye movement increased significantly after 30 minutes (in particular LFC) of performing the task.

[0032] The memory 14 is configured to store at least computer executable instructions. The memory 14 may also be configured to store at least part of the received visual behavior data.

[0033] The memory 14 may also store further user related data that may be used for determining the user visual fatigue.

[0034] The processor 16 is configured to execute the computer executable instructions stored in the memory 14. The computer executable instructions comprise instructions for processing the visual behavior data to generate visual fatigue

information indicative of the visual fatigue level of the user.

[0035] According to an embodiment of the invention, the visual fatigue information may include, but is not limited to, statistical information based at least on the visual behavior data processing. The processing can be, for example, a statistical analysis.

[0036] Statistics involves the collection, organization, analysis, interpretation, and/or presentation of measured/collected data. With advances in technology, more extensive and complex computing allows massive amounts of data to be collected, stored and/or processed. Further, methods for evaluating the data are numerous.

[0037] Statistical analysis can be employed to process and/or evaluate data received by the visual fatigue module of the invention. The two main types of statistics are descriptive and inferential statistics.

[0038] Descriptive statistics includes methods for organizing and summarizing collected data. These methods include, but are not limited to, graphs, tables, charts and measurements such as averages, percentiles, and measures of variation of the data. Data mining for pattern detection, machine learning and artificial intelligence methods, regression modeling and summary statistics can be employed in descriptive statistics.

[0039] Inferential statistics is based on methods for making conclusions about data collected based on the evaluation of a sample of the data. For example, predictions can be made regarding the entire set of data. An example prediction can relate to the likelihood that a level of visual fatigue is reached based on the visual behavior data collected. Recommendations can be made according to such predictions.

[0040] Statistical methods such as regression analysis can be employed to analyze data. Regression analysis includes techniques for analyzing different variables to determine the relationship between one or more dependent variables and independent variables. For example, the analysis can be employed to determine how the value of a dependent variable changes when a value of one independent variable changes while keeping the values of other independent variables constant. Regression analysis can be employed for prediction and overlaps with the field of machine learning (a branch of artificial intelligence that employs algorithms to identify patterns in data and/or make predictions based on evaluated data).

[0041] Different models can be employed in regression analysis to model the relationship between two variables. Linear regression is a type of regression analysis. Linear regression models the relationship between a dependent variable and an independent variable using linear predictor functions. Unknown model parameters are estimated from the data on which linear regression is performed. Interpolation methods can be employed to perform prediction based on values within the set of collected data used for model-fitting while extrapolation can be employed to perform prediction based on values outside the set of collected data.

[0042] In linear regression models, the conditional mean of an independent variable given the dependent variable value is typically an affine function. In some cases, the median, or some other quantile of the conditional distribution of the independent variable given the dependent variable is a linear function of the dependent variable.

[0043] Non-linear regression is a type of regression analysis in which observed information is modeled by a non-linear function. The non-linear function is a combination of the model parameters and depends on an independent variable.

[0044] According to a further embodiment of the invention, the processing of the visual behavior data is done by comparing said visual behavior data with at least one predetermined threshold value.

[0045] The processing of the visual behavior may further comprise comparing said visual behavior data with a set of threshold values allowing to predict or anticipate a level of visual fatigue of the user.

[0046] The visual fatigue information may be an alert information sent to the user or to a third party. The alert information may be of any type, such as visual alert as a message, an alert sound such as a specific sound, a haptic feedback such as a specific vibration. The alert information provides a feedback to the user or a third person on the determined visual fatigue level of the user.

[0047] The visual fatigue information may prompt the user that he may need anti-fatigue lenses and/or other general precautions like maintaining right posture, distance from computer, have a break or a pause, close his eyes for a given time etc.

[0048] Correspondence between the level of visual fatigue and the type of alert to be provided and to whom may be stored as a look-up table or a data base, for example in the memory of the visual fatigue determining module. Such correspondence may further be stored in a distant entity, such as a distant server, a smartphone, a touchpad, or a smart watch.

[0049] According to an embodiment of the invention, the communication component 12 is further configured to receive activity data indicative of the activity of the user. When generating visual fatigue information both the visual behavior data and activity data are processed. Indeed, the inventors have observed that the processing of the visual behavior is to be adjusted based on the activity of the user.

[0050] The activity data may identify directly an activity carried out by the user or may be data allowing determining such activity, for example an indication allowing determining the activity of the user from a data base and/or lookup table.

[0051] The person activity data may be provided directly by the user itself, for example by selecting an activity in a list of activities.

[0052] Furthermore, the person activity data may be determined based on analysis of data provided by sensors that measure the user's behavior or the environment of the wearer.

[0053] The activity data may identify the current activity of the user to adapt the processing of the visual behavior data. Indeed, the processing of the visual may be a different according to the activity of the user. For example if the user is reading or computing his visual fatigue may increase more quickly than if the user is walking in the street or in the forest.

[0054] The activity data may relate to the past activity of the user or the past so as, for example, to process more accurately the past visual behavior data.

[0055] The activity data may relate to a future activity. For example, the user may indicate that he is to carry out a specific activity and based on his current visual behavior, the module of the invention may generate information predicting a future visual fatigue level.

[0056] The activity that may be identified may be for example, but not limited to driving, sport, playing golf, playing tennis, practicing archery, reading, walking, paragliding, computing, etc...

[0057] When the processing of the visual behavior data is done using one or a set of predetermined threshold values, the value(s) of the predetermined threshold may be adapted based on the activity data.

[0058] So as to improve the accuracy of the module of the invention, such module may be arranged to allow for calibration. Such calibration may be an initial calibration carried out when the user first uses the module or may be performed regularly when the user is using the module, so as to improve the processing of the visual behavior data specifically to said user.

[0059] Typically, the communication component may be configured to receive subjective fatigue level data indicative of a subjective fatigue level provided, for example by the user. The subjective fatigue level data are indicative of the visual fatigue level experienced by the user.

[0060] Typically, the user rates his visual fatigue level using a scale. Scale examples may include a letter grade or a numerical value, such as 1-10, but can be any desired scale.

[0061] Together with the subjective fatigue level data, the communication unit receives subjective visual behavior data indicative of at least one visual behavior parameter the user in the subjective fatigue level.

[0062] The processing of the visual behavior data may be adapted based on the subjective fatigue level data and the subjective visual behavior data.

[0063] Advantageously, the processing of the visual behavior may be more and more accurate as the user provides subjective visual behavior level.

[0064] The visual fatigue determining module 10 may further provide information concerning the general fatigue condition of the user. Indeed, in some cases, it is possible to link the visual fatigue level of the user with his general fatigue condition.

[0065] As illustrated on figure 2, the invention further relates to a visual fatigue determining device 20 intended to be worn by a user. Typically, the visual fatigue determining device is a head mounted device comprising a spectacle frame that may comprise optical lenses 22. Other head mounted device may be used, in particular head mounted devices that do not comprise optical lenses.

[0066] According to an embodiment of the invention, the visual fatigue determining device 20 may comprise active optical lenses. The optical function of the active optical lenses may be controlled by an optical function controller (not shown).

[0067] For example, the visual fatigue determining device 20 can determine that that the eyes of the user are fatigue and alerts the user and/or control the active optical lenses to adapt the optical function to the visual fatigue level of the user.

[0068] The optical function may comprise dioptric function, light absorption, polarizing capability, reinforcement of contrast capacity, etc...

[0069] The dioptric function corresponds to the optical lens power (mean power, astigmatism etc...) as a function of the gaze direction.

[0070] The optical function of the head mounted device may comprise the dioptric function of at least one of the lenses that the head mounted device may comprise, a sun protection function for example by controlling a transmission parameter of the head mounted device or the polarization of a surface of at least one of the lenses that the head mounted device may comprise.

[0071] For example, the dioptric function may be adapted based on the visual fatigue level by adapting the addition in the near zone to relieve the user from the visual fatigue. The color or light absorption of the optical lenses may also be adapted based on the visual fatigue level of the user.

[0072] Advantageously, that optical function won't comprise the addition/ tint when it is not needed by the user and thus protecting eyes of the user from unnecessary symptoms of headache, dizziness etc.

[0073] The visual fatigue determining device 20 illustrated on figure 2, further comprises sensors 32 and a communication unit 38.

[0074] The sensors 32 are configured to sense at least one visual behavior parameter indicative of the visual behavior of the user when wearing the visual fatigue determining device.

[0075] For measuring pupil microfluctation, binocular or monocular tracking may be user. For example capturing both pupil and then considering worst eye provides good results, monocular tracking is enough for pupilla size monitoring.

[0076] Pupil diameter is measured by image processing. A normalization relative to inter-pupillary distance or distance between two nodal points of the face permit to compensate variation of distance between camera and eyes.

[0077] For example, when measuring the pupil size, if the distance between the camera and the pupil becomes shorter, the pupil size may appear bigger on the camera sensor even if the real size is the same. The inter-pupillary distance may also similarly appear bigger, so it is possible to use the parameter:

$$\text{DiamPupNor}=\text{DiamPupCam}/\text{DistPupCam},$$

with DiamPupNorm being the normalized pupil diameter, DiamPupCam being the pupil diam size seen by the camera (size in pixels) and DistPupCam being the interpupilary distance seen by the camera (in pixels).

[0078] If measuring the pupilla size variation, the distance variation can be compensated using the size of the IRIS that is constant.

[0079] Spectrum of pupil diameter variation over time may be calculated with Fourier transform. Energy in specific bandwidth are assessed (low is below 1Hz, medium is between 1Hz and 2.5 Hz). From the results low frequency is good enough to measure.

[0080] If pupil microfluctuations exceeds a particular threshold in one eye (low frequency component>0.002) or evolves during the day then this would imply that person is visually fatigue and may need anti-fatigue lenses. The duration for measurement may typically be between 10 and 20 seconds.

[0081] It is further possible to measure the rate (or microfluctuations) of vergence and eye movement

[0082] The vergence fluctuation calculation can be done based on the center of rotation of the eye, interpupillary distance and distance between the camera and the eyes.

[0083] The vergence fluctuation can be calculated using the variation of the papillary distance, for example using the following formula:

$$\Delta=\text{atan}[(\text{DistPup}-\text{DistPupMoy})/\text{CRE}]=\text{atan}(\Delta\text{DistPup}/\text{CRE})$$

[0084] With CRE being the radius of the eye and DistPup being the actual pupillary distance and DistPupMoy being the average (vs time) pupillary distance

Δ being the fluctuation of convergence over a period of time

[0085] The vergence fluctuation can further be determined based on the gaze values of right and left eyes.

[0086] For example, if (alphaR,betaR) and (alphaL,BetaL) are the gaze direction for R/L eye,

Δ can be calculated using the variation of BetaL, BetaR for example Δ=(BetaL+BetaR)* 1.75 (in prism diopters)

[0087] Eyemovement speed can be calculated based on the gaze values of x- and y-coordinates for each eye.

[0088] For example, if (alphaR,betaR) and (alphaL,BetaL) are the gaze direction for R/L eye,

Δ for Right eye can be calculated as [sqrt(alphaR2-alphaR1)^2 + (betaR2-betaR1)^2]/Time2-Time1; Δ being the fluctuation of eye movement.

[0089] Similar to pupil microfluctuations, spectrum of vergence and eye movement variation is calculated with Fourier transform.

[0090] Threshold for vergence - low frequency component >0.25 and threshold for eye movement - low frequency component >0.1. Considering low frequency component is good enough for vergence and eye movement microfluctuations.

[0091] The visual fatigue determining device 20 according to the invention may further sense visual behavior of the user based on the near point of convergence.

[0092] An object or target is positioned at set distances and the user is asked if it appears double or examiner or camera can pick if one of the eyes loses fixation.

[0093] A target is shown which is placed at a particular defined distance and move towards the user and the user fixates at the target tip and reports when the target splits into two or the camera in the tool can detect the deviation of the eye.

[0094] For example, it is possible to use image from the camera to determine the gaze direction of both eyes, using known techniques, for example using videooculography method. So it is possible to check if one of the eyes gaze direction do not go through the target.

[0095] It is also possible to determine the pupil position of both eyes using standard image processing, and detect the movement when the distance between pupils suddenly increase, that reveals a loss of convergence of the person.

[0096] It is also possible to use the camera to display on the tablet screen the position of both eyes, and let the user

detect by himself when one of the two eyes deviates.

[0097] Distance from the eyes to the target may be recorded by the camera, or as an alternative can be recorded via a position sensor associated to the target.

[0098] Typically, for a user over 20 year old :

a distance smaller than or equal to 6 cm corresponds to no Fatigue
a distance between 7 and 8 cm corresponds to a risk of being visually fatigue soon (moderate fatigue), needs preventive measures, for example prescribe small addition (Essilor Anti-fatigue or small addition lenses),
a distance greater than or equal to 9 cm correspond to a need of treatment for visual fatigue (Severe Fatigue).

[0099] For kids, teenagers and up to 20years of age, criteria can be slightly different:

a distance smaller than or equal to 5 cm corresponds to no Fatigue
a distance between 6 and 8 cm corresponds to a risk of being visually fatigue soon (moderate fatigue), needs preventive measures, for example prescribe small addition (Essilor Anti-fatigue or small addition lenses),
a distance greater than or equal to 9 cm correspond to a need of treatment for visual fatigue (Severe Fatigue).

[0100] The communication unit 38 is configured to communicate visual behavior data indicative of the sense visual behavior parameter to a visual fatigue determining module 10 according to the invention.

[0101] The communication unit 38 may further be configured to receive from the visual fatigue determining module 10 information indicative of the visual fatigue of the user.

[0102] As illustrated on figure 2, the visual fatigue determining device 20 may further comprise an output unit arranged to output a signal to the user based on the information indicative of the visual fatigue level of the user received from visual fatigue determining module 10.

[0103] Typically, the output unit may be a visual output unit configured to provide a visual signal to the user based on the information indicative of the visual fatigue level. Such visual signal output unit may be a simple led or a more complex display device allowing for example to display a text message to the user.

[0104] The output unit may be an audio output unit such as a speaker or an intraocular prosthesis outputting an audio message to the user.

[0105] The output unit may be configured to provide a haptic feedback to the user such as a specific vibration.

[0106] Although represented as part of the visual fatigue determining device 20, the output unit could be part of a distant entity connected to the visual fatigue determining device or module. For example the output unit may be part a personal digital assistants, an audio/video device, a mobile phone, a MPEG-1 Audio Layer 3 (MP3) player, a personal computer, a laptop, a tablet, a bluetooth headset, a watch, a wristband, etc...

[0107] Such distant entity may typically communicate with the visual fatigue determining device or module by wireless communication. The wireless communication can use different communication protocols such a Bluetooth, Zigbee, Wifi or others.

[0108] The visual fatigue determining device 20 may further comprise an activity input unit 18 configured to collect activity information indicative of the activity of the user. The activity information may be communicated to the visual fatigue determining module 10 by the communication unit 38.

[0109] The activity input unit 18 may comprise a sensor, such as a scene camera, adapted to determine information concerning the activity of the user.

[0110] The activity input unit 18 may further comprise input means, such as voice control, a keyboard virtual or not, or any device that allows the user to provide an indication of his activity. For example the user may select his activity in a list of activities. Advantageously, the user may provide information concerning his past activities and/or future activities.

[0111] If the device assessing fatigue is connected to a device currently used by the user as a Smartphone, or a personal computer, the activity may be automatically provided.

[0112] As indicated previously, the activity data may be used by the visual fatigue determining module 10 when generating the visual fatigue information.

[0113] In the example represented on figure 2, the visual fatigue determining module 10 is embedded in the visual fatigue determining device 20.

[0114] However, as represented on figure 3, the visual fatigue determining module 10 may be a distant entity communicating with the visual fatigue determining device 20.

[0115] The visual fatigue determining device 20 communicates with a distant entity that comprises a visual fatigue determining module 10 according to the invention. Communication can be done through different communication devices and protocols, like Bluetooth, Zigbee, WiFi or others.

[0116] Furthermore, the communication unit may be configured to communicate with the distant entity either to store the measured features in a memory MEM or to provide information indicative of the visual behavior of the user.

[0117] Typically, the distant entity comprises a communication module 12 configured to communicate at least with the communication unit 38 of the visual fatigue determining device 20, a memory 14, at least one processor 16 and program instructions stored on a non-transitory computer-readable medium and executable by the at least one processor to execute the steps of the method of the invention.

[0118] The distant entity can include different computing objects such as personal digital assistants, audio/video devices, mobile phones, MPEG-1 Audio Layer 3 (MP3) players, personal computers, laptops, tablets, bluetooth headset, watch, wristband, etc...

[0119] Each computing object and the head mounted device can communicate with one or more other by way of a communication network, either directly or indirectly. Even though illustrated as a single element in figure 3, network can include other computing objects and computing devices that provide services to the system of figure 3, and/or can represent multiple interconnected networks, which are not shown.

[0120] In a network environment in which the communications network/bus can be the Internet, the computing objects can be Web servers, file servers, media servers, etc. with which the client computing objects or devices communicate via any of a number of known protocols, such as the hypertext transfer protocol (HTTP).

[0121] According to an embodiment of the invention, the device can be in the form of a simple stick having graduations for distance measurement, one end of the stick is intended to be in contact with the chin of the person, and a target movable along the stick.

[0122] In this case, it is preferable that an operator look at the user so as to check if there is a loss of convergence (instead of asking the person if he/she experiment double vision) because of the possibility of suppression of one of the both eye image by the person.

[0123] According to an embodiment of the invention, the visual fatigue determining device may be a smartphone comprising the visual fatigue determining module.

[0124] The camera of the phone can be used to sense the distance corresponding to the near point of convergence and if the camera detects 6/8 cm it may display on the screen 'move back' that is, to start from further distance.

[0125] When the camera is at a distance greater than 9 cm, a 'correct distance' or 'proceed' may be displayed.

[0126] A target, for example a tower such as the Eiffel tower, may be displayed on the screen and the user looks at the tip of the tower and if tower appears single then click on button 'OK' on the screen and move to next closer distance and if target still appears single click on 'OK' and if double then click on 'double' tab.

[0127] A message may appear on the screen 'moderate fatigue' - needs preventive measures. If the user pushes 'double' tab for the distance of 9 cm then 'severe fatigue' is displayed which implies, need for visual fatigue treatment.

[0128] The camera of the smartphone or touch pad is be able to sense the distance in different ways:

[0129] For example, the camera can be a stereo camera that is able to sense the 3D scene, and so determine the distance of the imaged environment,

[0130] Furthermore, the camera is a standard camera, and known dimension of an imaged object (the head size of the person, or the pupil distance of the person) is provided, so that it is possible to scale the image.

[0131] Other means can be provided such as time of flight sensor or triangulation.

[0132] Another way for visual fatigue assessment may be instead of having the user push the button, is to have the camera arranged to sense when one of the eyes deviates more than the specified convergence range. Depending on the distance from eye to the camera, the user's visual fatigue level is either no fatigue, moderate or severe fatigue.

[0133] One advantage of measuring the loss of convergence using the camera is that the user could suppress one of the images of the R/L eye instead of having double vision, leading to incorrect result, whereas measuring with the camera the convergence of the both eye provides correct results in any cases.

[0134] Advantageously, the device of the invention can be used for a specific process of delivery a lens or service for attenuating visual fatigue.

[0135] For example, if the distance is in the risk range, antifatigue lens, lens reducing glare, lens reducing reflection, or visual training may be proposed to the user.

[0136] The visual fatigue determining device may be a smartphone and used sense pupilla microflucation.

[0137] We having the user look away, while a smartphone is tracking one eye pupilla at close distance (10cm-15cm). Doing that, one has a very high resolution of one eye and track with accuracy the pupilla size and resolves black iris eyes concerns, even without IR source. Software within the smartphone analyses microfluctuation and give fatigue results on the display.

[0138] As illustrated on figure 4, the invention further relates to a method of determining the visual fatigue level of a user, comprising:

- a visual behavior data receiving step S1, and
- a processing step S3.

[0139] During the visual behavior data receiving step, visual behavior data indicative of the visual behavior of the user

are received, typically by the communication component of the visual fatigue determining module 10 from the communication unit 38 of the visual fatigue determining device 20.

[0140] The received data are processed during the processing step to generate visual fatigue information indicative of the visual fatigue level of the user.

[0141] The method may further comprise, prior to the processing step, an activity data providing step S2. During the activity data providing step S2 activity data indicative of the activity of the user are provided.

[0142] During the processing step S3 the visual fatigue information may be generated based on the visual behavior data and the activity data.

[0143] The invention also relates to a method for improving a visual fatigue determining module according to the invention.

[0144] As illustrated on figure 5, the method for improving a visual fatigue determining module comprises:

- a subjective fatigue level data providing step S10,
- a subjective visual behavior data receiving step S11, and
- an adapting step S12,

[0145] Subjective fatigue level data indicative of a subjective fatigue level are provided during the subjective fatigue level data providing step. The subjective fatigue level data may be provided by the user or a third party. As indicated previously such data relates to a subjective indication of the visual fatigue level of the user.

[0146] Together with the Subjective fatigue level data, subjective visual behavior data are received during the subjective visual behavior data receiving step S11. The subjective visual behavior data are indicative of at least one visual behavior parameter of the user in the subjective fatigue level.

[0147] The computer executable instructions for processing the visual behavior data are adapted based on the subjective fatigue level data and the subjective visual behavior data during the adapting step S12.

[0148] The invention has been described above with the aid of embodiments without limitation of the general inventive concept.

[0149] Many further modifications and variations will suggest themselves to those skilled in the art upon making reference to the foregoing illustrative embodiments, which are given by way of example only and which are not intended to limit the scope of the invention, that being determined solely by the appended claims.

[0150] In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that different features are recited in mutually different dependent claims does not indicate that a combination of these features cannot be advantageously used. Any reference signs in the claims should not be construed as limiting the scope of the invention.

Claims

1. A visual fatigue determining module configured to determine visual fatigue level of a user, the module comprising at least:

   - a communication component configured to receive from a visual fatigue determining device, visual behavior data indicative of the at least one visual behavior parameter of the user,
   - a memory configured to store computer executable instructions; and
   - a processor for executing the computer executable instructions, wherein the computer executable instructions comprises instructions for:
   - processing the visual behavior data to generate visual fatigue information indicative of the visual fatigue level of the user.

2. The visual fatigue determining module according to claim 1, wherein the communication component is further configured to receive activity data indicative of the activity of the user and wherein both the visual behavior data and activity data are processed to generate visual fatigue information.

3. The visual fatigue determining module according to claim 1 or 2, wherein the processing of said visual behavior data is done by comparing said visual behavior data with a predetermined threshold value.

4. The visual fatigue determining module according to claims 2 and 3, wherein the predetermined threshold value is adapting based on the activity data.

5. The visual fatigue determining module according to claims 3 or 4, wherein the visual fatigue information is an alert information.

6. The visual fatigue determining module according to any of the preceding claims, wherein the instructions for processing the visual behavior data are arranged to generate visual fatigue information indicative of an anticipated visual fatigue level of the user.

7. The visual fatigue determining module according to any of the preceding claims, wherein the eye data comprise data relating to the pupil and/or vergence micro fluctuation of the user and/or the near point of convergence of the user, and/or microfluctuations of eyemovements and/or accomodation microfluctuations.

8. A visual fatigue determining device comprising at least one sensor configured to sense at least one visual behavior parameter indicative of the visual behavior of the user when wearing the visual fatigue determining device and a communication unit configured to communicate visual behavior data indicative of the sense visual behavior parameter to a visual fatigue determining module according to any of claims 1 to 7.

9. The visual fatigue determining device according to claim 8, wherein the communication unit is further configured to receive from the visual fatigue determining module information indicative of the visual fatigue level of the user.

10. The visual fatigue determining device according to the preceding claim, further comprising an output unit arranged to output a signal to the user based on the information indicative of the visual fatigue level of the user received from the visual fatigue determining module.

11. The visual fatigue determining device according to any of claims 8 to 10, further comprising at least one activity input unit configured to collect activity information indicative of the activity of the user and the communication unit is further configured to communicate the activity information indicative to the visual fatigue determining module.

12. The visual fatigue determining device according to any of claims 8 to 11, wherein the visual fatigue determining device is one of the devices comprised in the list consisting of a head mounted device, a smartphone and a touch pad.

13. Method of determining the visual fatigue level of a user, comprising:

- a visual behavior data receiving step during which visual behavior data indicative of the visual behavior of the user are received,
- a processing step during which the visual behavior data are processed to generate visual fatigue information indicative of the visual fatigue level of the user.

14. The method according to claim 13, further comprising:

- an activity data providing step, during which activity data indicative of the activity of the user are provided, and wherein during the processing step the visual fatigue information are generated based on the visual behavior data and the activity data.

15. Method for improving a visual fatigue determining module according to any of claims 1 to 8, wherein the method comprises:

- a subjective fatigue level data providing step during which subjective fatigue level data indicative of a subjective fatigue level are provided, for example by the user of the visual fatigue determining module,
- a subjective visual behavior data receiving step during which subjective visual behavior data indicative of at least one visual behavior parameter of the user in the subjective fatigue level are provided,
- an adapting step during which the computer executable instructions for processing the visual behavior data are adapted based on the subjective fatigue level data and the subjective visual behavior data.

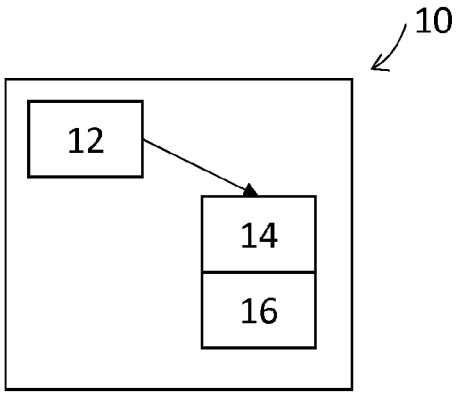

Figure 1

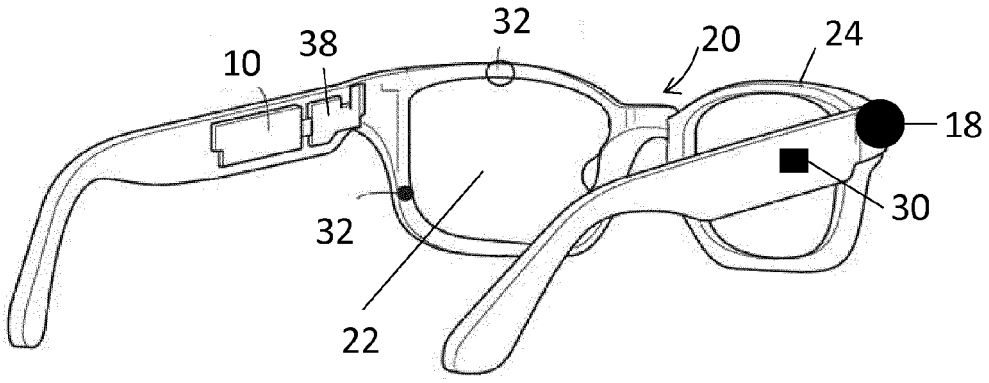

Figure 2

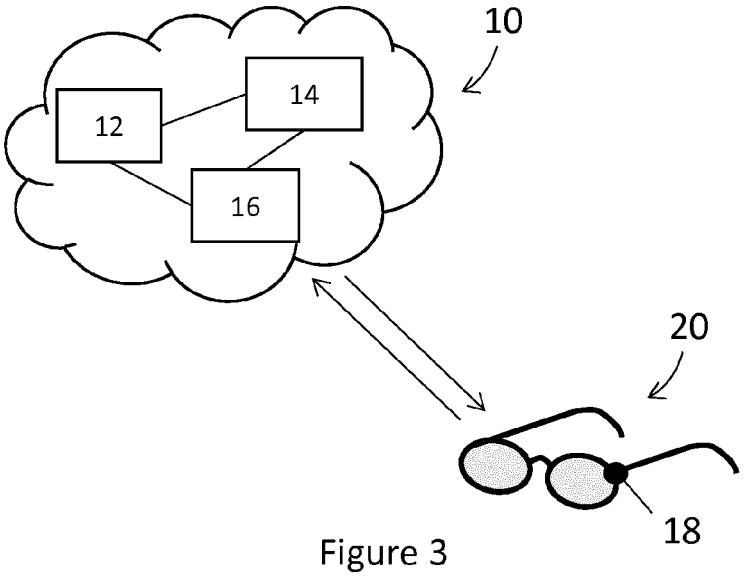

Figure 3

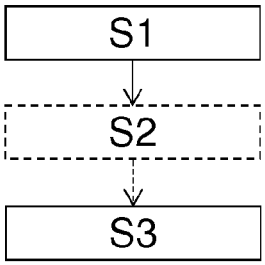

Figure 4

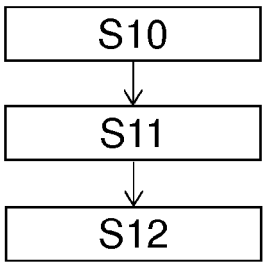

Figure 5

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EUROPEAN SEARCH REPORT

Application Number
EP 15 30 6071

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 8 610 585 B1 (KIELBASA MATTHEW [US] ET AL) 17 December 2013 (2013-12-17) * abstract * * column 5, line 14 - column 6, line 25; figures 3,8 * * column 6, line 56 - column 7, line 12 * * column 7, line 19 - line 24 * * column 7, line 46 - line 53 *	1,3,5,6, 8-10,12, 13	INV. G08B21/06
X	US 2014/152444 A1 (LEE HWAL LY [KR]) 5 June 2014 (2014-06-05) * abstract * * paragraph [0024] - paragraph [0035]; figures 1-3 *	1,3, 5-10,12, 13	
X	US 2006/214807 A1 (TENGSHE VISHWAS V [US] ET AL) 28 September 2006 (2006-09-28) * abstract * * paragraph [0022] - paragraph [0023]; figure 2 * * paragraph [0025] - paragraph [0028] * * paragraph [0034]; figures 3,4 * * paragraph [0043] - paragraph [0044] *	1,3, 5-10,12, 13	TECHNICAL FIELDS SEARCHED (IPC) G08B

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~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
Munich	11 September 2015	Heß, Rüdiger

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
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EPO FORM 1503 03.82 (P04C01)

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EUROPEAN SEARCH REPORT

Application Number
EP 15 30 6071

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 10 2008 007149 A1 (VOLKSWAGEN AG [DE]) 2 October 2008 (2008-10-02) * abstract * * paragraph [0009] - paragraph [0013] * * paragraph [0016] * * paragraph [0035] * * paragraph [0041] * * paragraph [0052] * * paragraph [0057] - paragraph [0060] * * paragraph [0062] - paragraph [0069] * * paragraph [0079] - paragraph [0085]; figures 3,4 * * paragraph [0098] * -----	1-3, 5-11,13, 14	

TECHNICAL FIELDS SEARCHED (IPC)

~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
Munich	11 September 2015	Heß, Rüdiger

CATEGORY OF CITED DOCUMENTS

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D : document cited in the application
L : document cited for other reasons

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Application Number

EP 15 30 6071

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-14

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 15 30 6071

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-14

   Determining a visual fatigue level based on received visual behaviour data of a user

1.1. claims: 8-12

   Detecting a visual behaviour parameter by means of a sensor worn by the user and communicating it to a module by means of a communication unit

   ---

2. claim: 15

   Adapting the processing of the visual behaviour data based on subjective fatigue level data and subjective visual behaviour data

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Please note that all inventions mentioned under item 1, although not necessarily linked by a common inventive concept, could be searched without effort justifying an additional fee.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 15 30 6071

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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11-09-2015

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		WO 2006123365 A1	23-11-2006
DE 102008007149 A1	02-10-2008	NONE	

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82