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Karavirta

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(54) **PHYSIOLOGY-BASED SELECTION OF PERFORMANCE ENHANCING MUSIC**

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(51) **Int. Cl.**

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| ***G06F 16/68*** | (2019.01) |
| ***A61B 5/0205*** | (2006.01) |
| ***G06Q 50/22*** | (2018.01) |
| ***G06Q 30/06*** | (2012.01) |
| ***A61B 5/024*** | (2006.01) |
| ***H04R 1/10*** | (2006.01) |
| ***A61B 5/00*** | (2006.01) |
| ***A61B 5/11*** | (2006.01) |
| ***G16H 40/67*** | (2018.01) |
| ***G16H 50/30*** | (2018.01) |
| ***G16H 20/30*** | (2018.01) |
| ***G16H 10/60*** | (2018.01) |

(52) **U.S. Cl.**

CPC ............ ***G06F 16/636*** (2019.01); ***A61B 5/024*** (2013.01); ***A61B 5/0205*** (2013.01); ***A61B 5/11*** (2013.01); ***A61B 5/486*** (2013.01); ***G06F 16/23*** (2019.01); ***G06F 16/686*** (2019.01); ***G06Q 30/0631*** (2013.01); ***G06Q 50/22*** (2013.01); ***G16H 10/60*** (2018.01); ***G16H 20/30*** (2018.01); ***G16H 40/67*** (2018.01); ***G16H 50/30*** (2018.01); ***H04R 1/1091*** (2013.01); *H04R 2499/11* (2013.01)

(58) **Field of Classification Search**

CPC ................................................. G06F 17/30764

See application file for complete search history.

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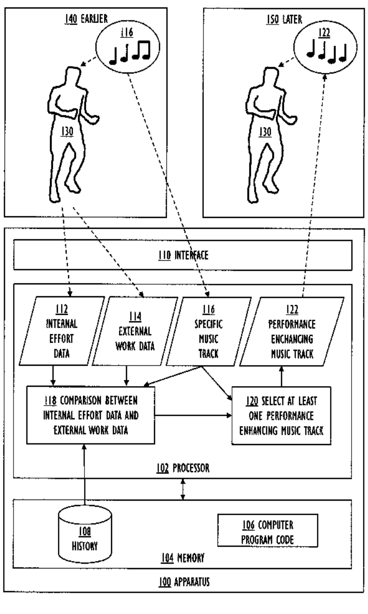
(57) **ABSTRACT**

Physiology-based selection of performance enhancing music for a specific individual is disclosed. Internal effort data and external work data both measured from a user performing an exercise while listening to a specific music track are obtained. The internal effort data describes a measured bodily input of the user, and the external work data describes a measured output effect of the user. A comparison between the internal effort data and the external work data is performed. At least one performance enhancing music track for the user is selected based on the comparison.

**19 Claims, 7 Drawing Sheets**



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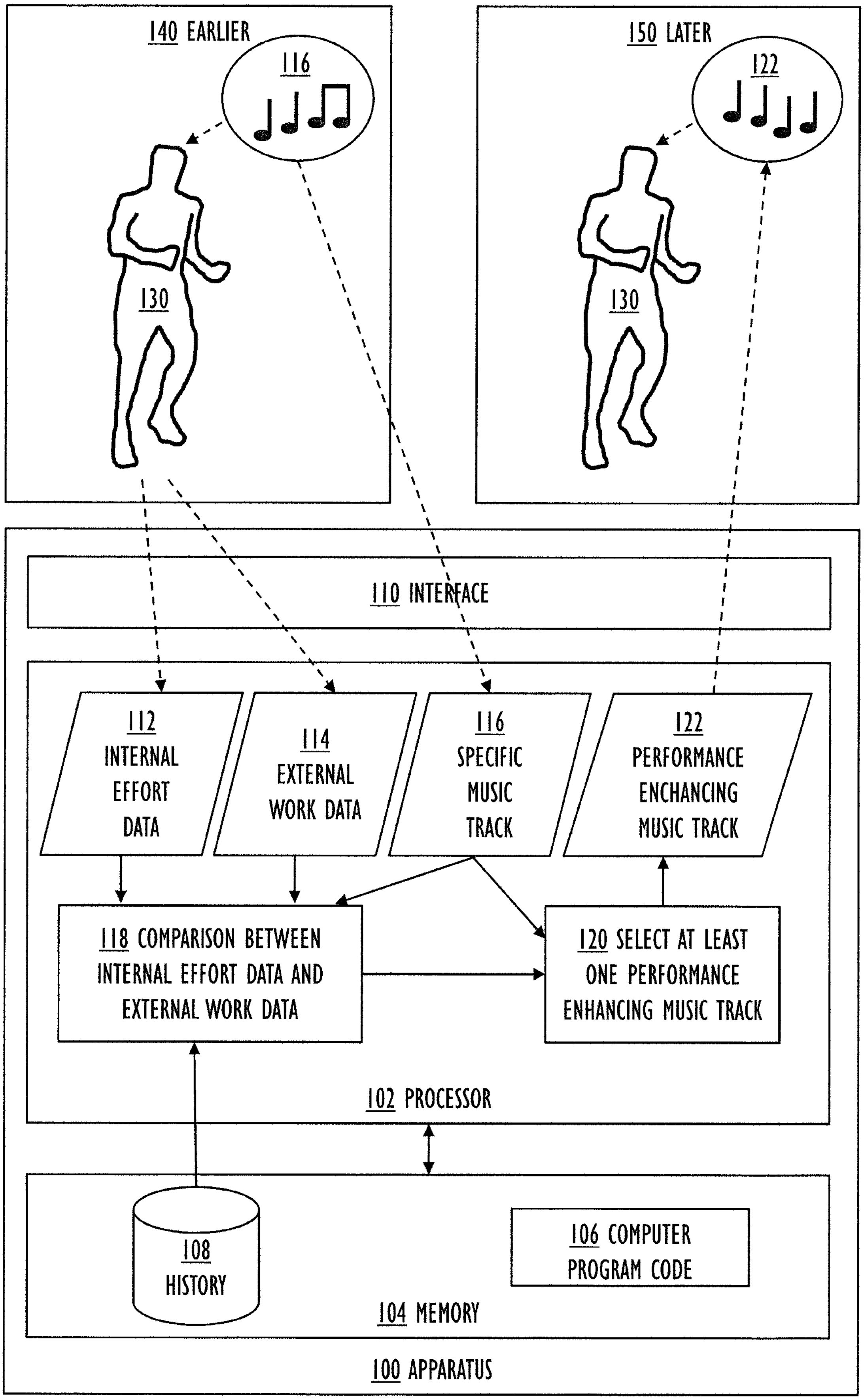
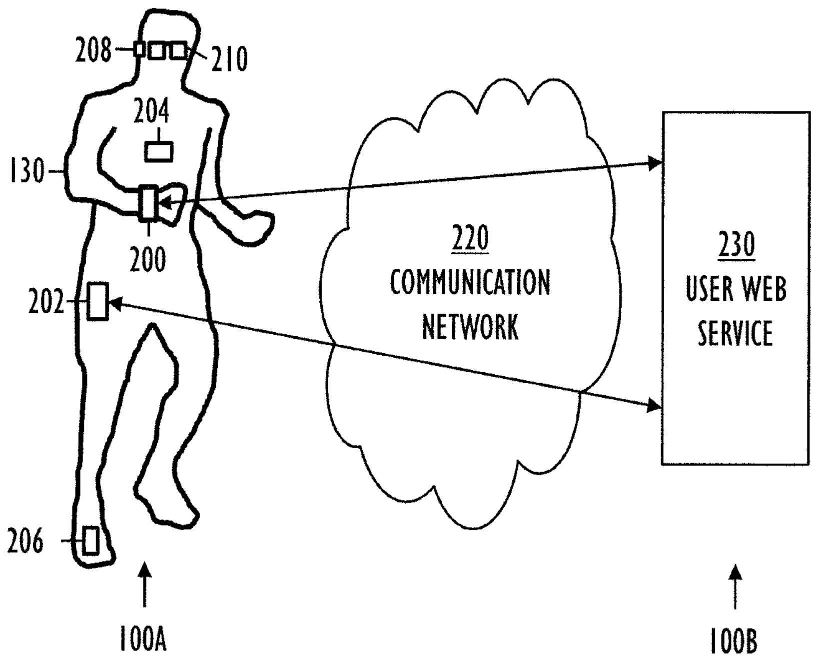
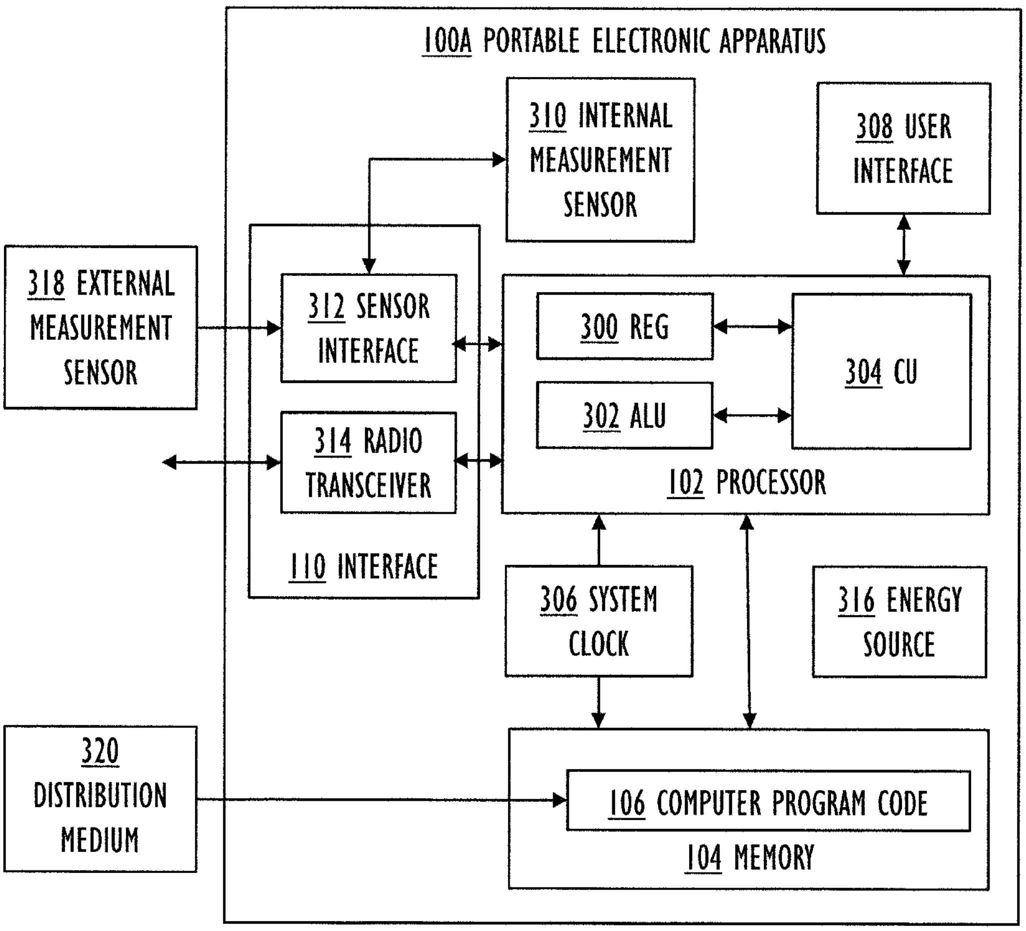

140 EARLIER
116
130
150 LATER
122
130
110 INTERFACE
112 INTERNAL EFFORT DATA
114 EXTERNAL WORK DATA
116 SPECIFIC MUSIC TRACK
122 PERFORMANCE ENCHANCING MUSIC TRACK
118 COMPARISON BETWEEN INTERNAL EFFORT DATA AND EXTERNAL WORK DATA
120 SELECT AT LEAST ONE PERFORMANCE ENHANCING MUSIC TRACK
102 PROCESSOR
108 HISTORY
106 COMPUTER PROGRAM CODE
104 MEMORY
100 APPARATUS

FIG. 1



208
210
204
130
200
202
206
220
COMMUNICATION
NETWORK
230
USER WEB
SERVICE
100A
100B


FIG. 2



100A PORTABLE ELECTRONIC APPARATUS
310 INTERNAL MEASUREMENT SENSOR
308 USER INTERFACE
318 EXTERNAL MEASUREMENT SENSOR
312 SENSOR INTERFACE
314 RADIO TRANSCEIVER
110 INTERFACE
300 REG
302 ALU
304 CU
102 PROCESSOR
306 SYSTEM CLOCK
316 ENERGY SOURCE
320 DISTRIBUTION MEDIUM
106 COMPUTER PROGRAM CODE
104 MEMORY


FIG. 3

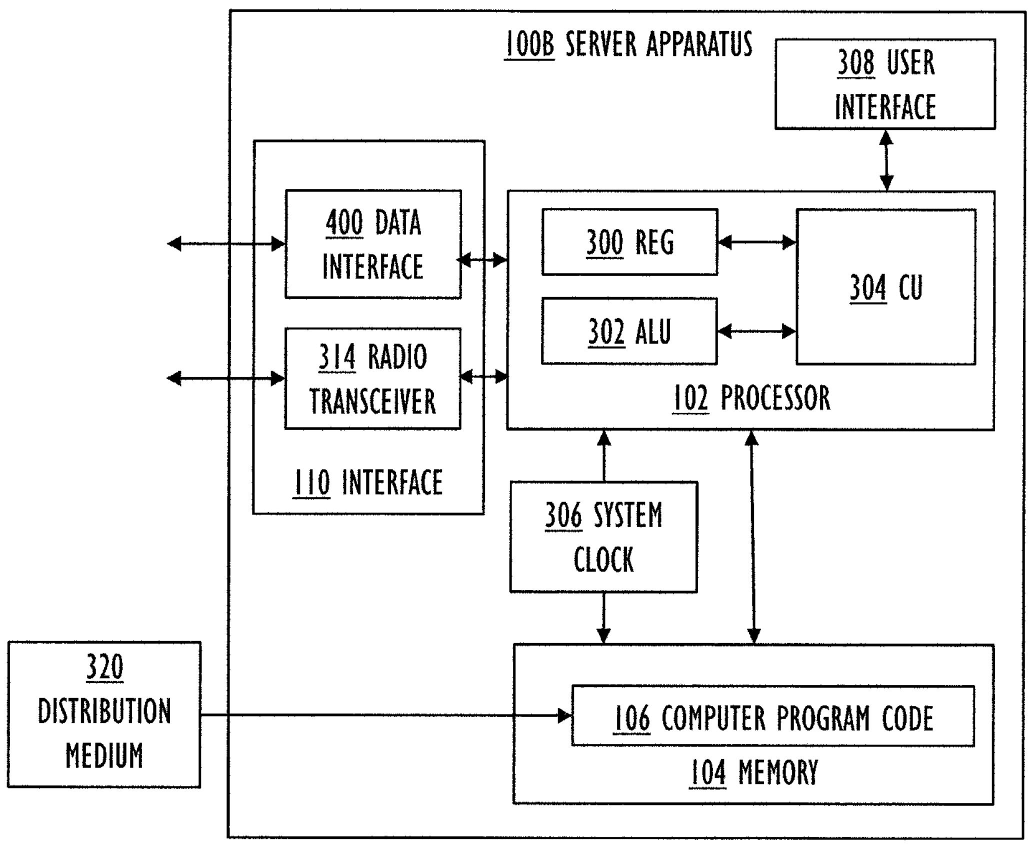

100B SERVER APPARATUS
308 USER INTERFACE
400 DATA INTERFACE
314 RADIO TRANSCEIVER
110 INTERFACE
300 REG
302 ALU
304 CU
102 PROCESSOR
306 SYSTEM CLOCK
320 DISTRIBUTION MEDIUM
106 COMPUTER PROGRAM CODE
104 MEMORY

FIG. 4

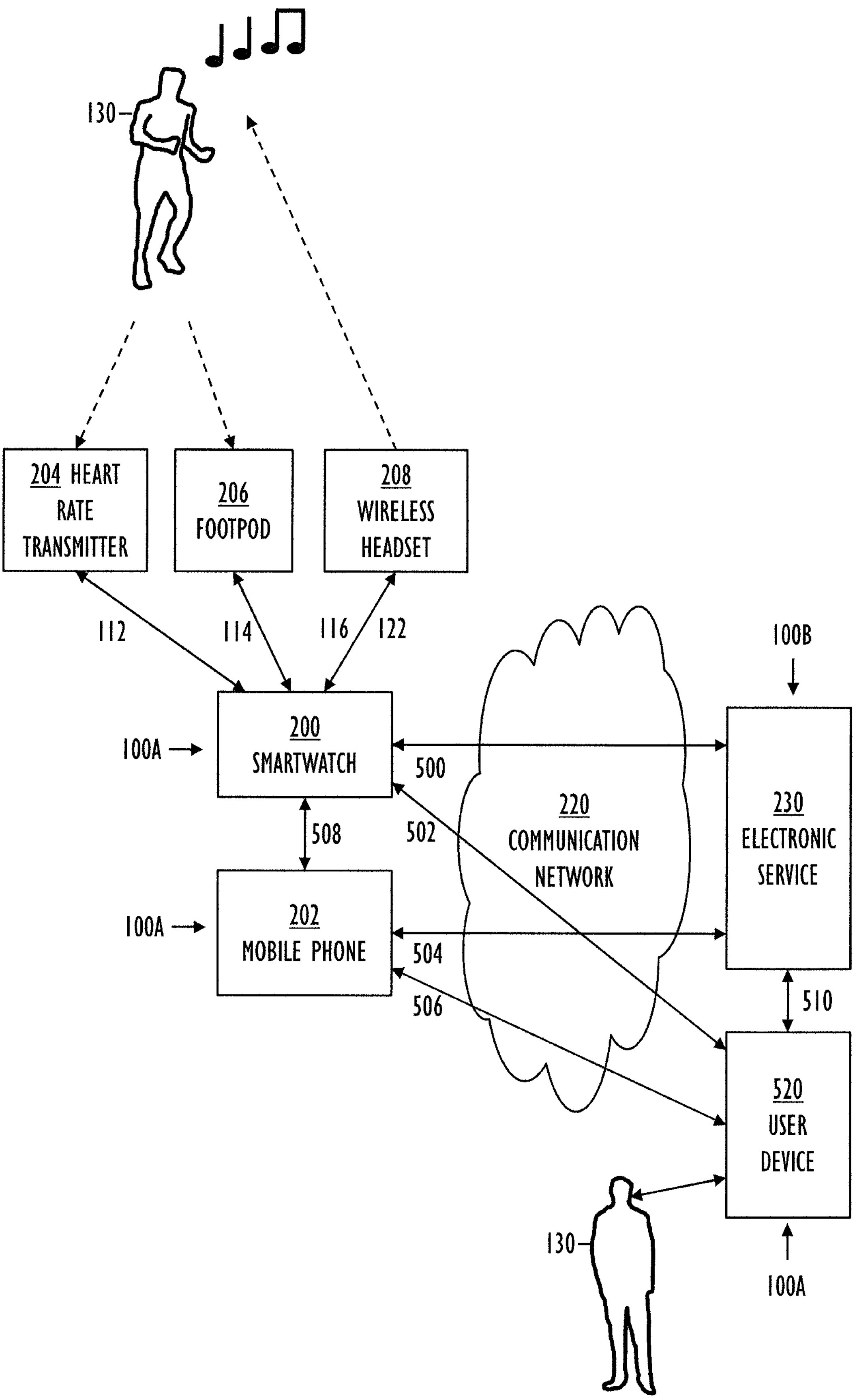

130
204 HEART RATE TRANSMITTER
206 FOOTPOD
208 WIRELESS HEADSET
112
114
116
122
100B
100A
200 SMARTWATCH
500
508
502
220 COMMUNICATION NETWORK
230 ELECTRONIC SERVICE
100A
202 MOBILE PHONE
504
506
510
520 USER DEVICE
130
100A

FIG. 5

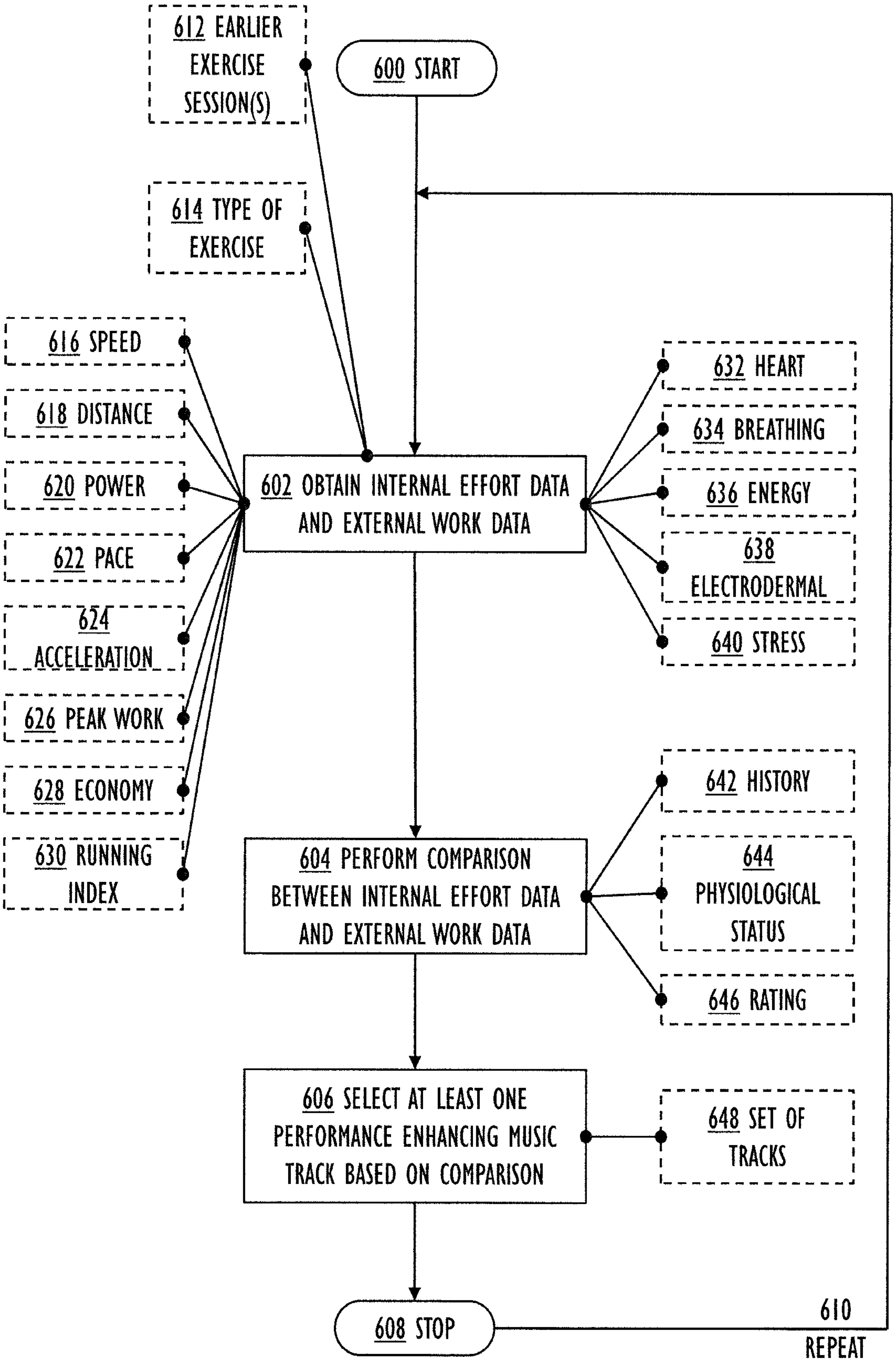

612 EARLIER EXERCISE SESSION(S)
600 START
614 TYPE OF EXERCISE
616 SPEED
618 DISTANCE
620 POWER
622 PACE
624 ACCELERATION
626 PEAK WORK
628 ECONOMY
630 RUNNING INDEX
602 OBTAIN INTERNAL EFFORT DATA AND EXTERNAL WORK DATA
632 HEART
634 BREATHING
636 ENERGY
638 ELECTRODERMAL
640 STRESS
604 PERFORM COMPARISON BETWEEN INTERNAL EFFORT DATA AND EXTERNAL WORK DATA
642 HISTORY
644 PHYSIOLOGICAL STATUS
646 RATING
606 SELECT AT LEAST ONE PERFORMANCE ENHANCING MUSIC TRACK BASED ON COMPARISON
648 SET OF TRACKS
608 STOP
610 REPEAT

FIG. 6

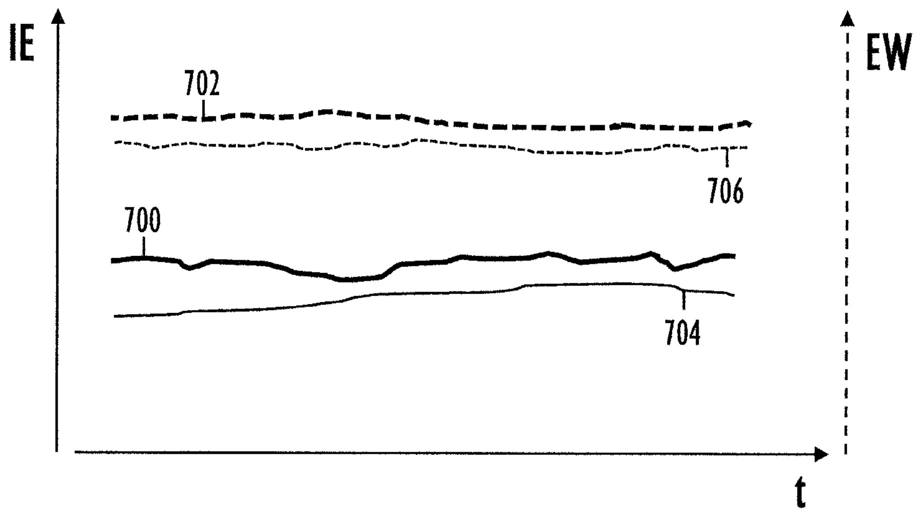



FIG. 7

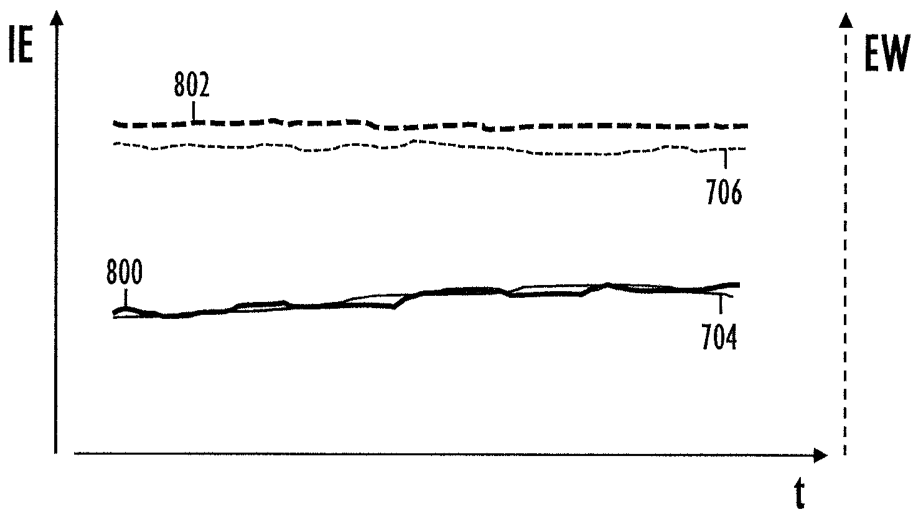



FIG. 8

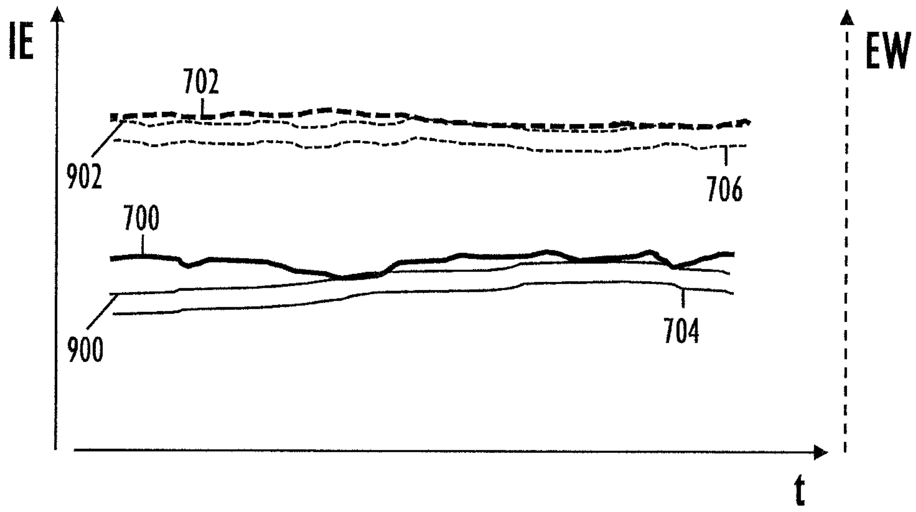



FIG. 9

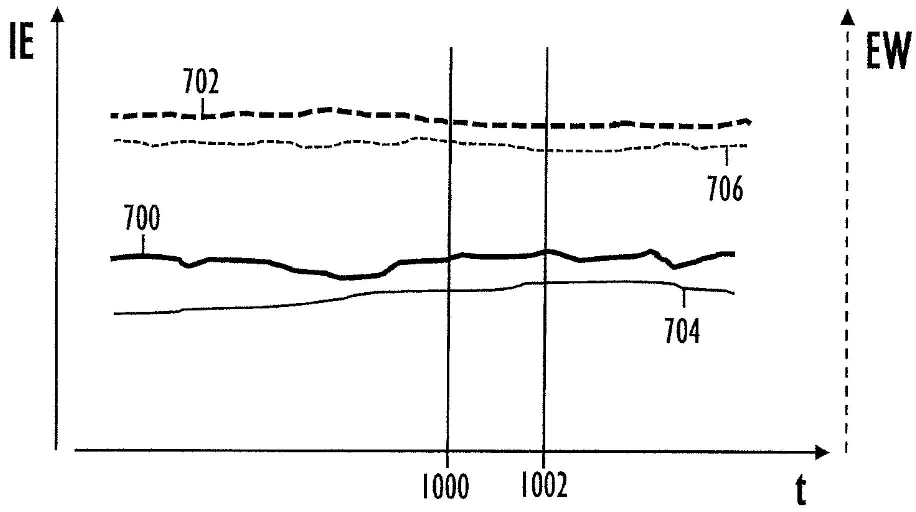



FIG. 10

# PHYSIOLOGY-BASED SELECTION OF PERFORMANCE ENHANCING MUSIC

## BACKGROUND

### Field

The invention relates to an electronic apparatus, computer program and method in an electronic apparatus for selection of performance enhancing music.

### Description of the Related Art

Music has both ergogenic (performance enhancing) and psychological (e.g. mood enhancing) effects during a physical exercise. The impact of a particular type of music or song depends on internal and external factors that are highly individual. A psychometric instrument has been developed in the scientific literature in order to rate the motivational qualities of music. However, this rating system involves manual work by the user. Therefore, there is a need to automatically identify user-specific music that produces the most favorable effects during the exercise.

## SUMMARY

The present invention seeks to provide an improved electronic apparatus, computer program and method in an electronic apparatus for selection of performance enhancing music.

According to an aspect of the present invention, there is provided an electronic apparatus comprising: an interface; one or more processors; and one or more memories including computer program code, the one or more memories and the computer program code configured to, with the one or more processors, cause the apparatus at least to: obtain, with the interface, internal effort data and external work data both measured from a user performing an exercise while listening to a specific music track, the internal effort data describing a measured bodily input of the user, and the external work data describing a measured output effect of the user; perform a comparison between the internal effort data and the external work data; and select at least one performance enhancing music track for the user based on the comparison.

According to another aspect of the present invention, there is provided a non-transitory computer-readable storage medium comprising a computer program comprising computer program code which, when loaded into an electronic apparatus cause the apparatus at least to: obtain internal effort data and external work data both measured from a user performing an exercise while listening to a specific music track, the internal effort data describing a measured bodily input of the user, and the external work data describing a measured output effect of the user; perform a comparison between the internal effort data and the external work data; and select at least one performance enhancing music track for the user based on the comparison.

According to another aspect of the present invention, there is provided a method in an electronic apparatus, comprising: obtaining internal effort data and external work data both measured from a user performing an exercise while listening to a specific music track, the internal effort data describing a measured bodily input of the user, and the external work data describing a measured output effect of the user; performing a comparison between the internal effort data and the external work data; and selecting at least one performance enhancing music track for the user based on the comparison.



## BRIEF DESCRIPTION OF THE DRAWINGS

Example embodiments of the present invention are described below, by way of example only, with reference to the accompanying drawings, in which

FIGS. **1**, **2**, **3**, **4** and **5** illustrate example embodiments of an electronic apparatus;

FIG. **6** is a flow-chart illustrating further example embodiments; and

FIGS. **7**, **8**, **9** and **10** illustrate example embodiments of a comparison between internal effort data and external work data.

## DETAILED DESCRIPTION

The following embodiments are only examples. Although the specification may refer to "an" embodiment in several locations, this does not necessarily mean that each such reference is to the same embodiment(s), or that the feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments. Furthermore, words "comprising" and "including" should be understood as not limiting the described embodiments to consist of only those features that have been mentioned and such embodiments may contain also features/structures that have not been specifically mentioned.

FIG. **1** illustrates example embodiments of an electronic apparatus **100**. It should be noted that while FIG. **1** illustrates various example embodiments of the apparatus **100**, it is only a simplified block diagram that only shows some structures and functional entities. The connections shown in FIG. **1** are logical connections; the actual physical connections may be different. It is apparent to a person skilled in the art that the described apparatus **100** may also comprise other functions and structures. The same applies to FIGS. **2**, **3**, **4** and **5** as well. It should be appreciated that details of some functions, structures, and the protocols used for communication are irrelevant to the actual invention. Therefore, they need not be discussed in more detail here.

The apparatus **100** comprises an interface **110**, one or more processors **102**, and one or more memories **104** including computer program code **106**.

The interface **110** is an electronic interface utilized to obtain various data, internally and/or externally.

The term 'processor' **102** refers to a device that is capable of processing data. Depending on the processing power needed, the apparatus **100** may comprise several processors **102** such as parallel processors or a multicore processor. When designing the implementation of the processor **102**, a person skilled in the art will consider the requirements set for the size and power consumption of the apparatus **100**, the necessary processing capacity, production costs, and production volumes, for example.

The term 'memory' **104** refers to a device that is capable of storing data run-time(=working memory) or permanently (=non-volatile memory). The working memory and the non-volatile memory may be implemented by a random-access memory (RAM), dynamic RAM (DRAM), static RAM (SRAM), a flash memory, a solid state disk (SSD), PROM (programmable read-only memory), a suitable semiconductor, or any other means of implementing an electrical computer memory.

The processor **102** and the memory **104** may be implemented by an electronic circuitry.

The computer program code **106** may be implemented by software and/or hardware.

In an example embodiment, the software may be written by a suitable programming language, and the resulting executable code **106** may be stored on the memory **104** and run by the processor **102**.

In an example embodiment, the functionality of the hardware may be designed by a suitable hardware description language (such as Verilog or VHDL), and transformed into a gate-level netlist (describing standard cells and the electrical connections between them), and after further phases the chip implementing the processor **102**, memory **104** and the code **106** of the apparatus **100** may be fabricated with photo masks describing the circuitry.

The one or more memories **104** and the computer program code **106** are configured to, with the one or more processors **102**, cause the apparatus **100** at least to implemented the following three-phase sequence of operations:

1) Obtain, with the interface **110**, internal effort data **112** and external work data **114** both measured from a user **130** performing an exercise while listening to a specific music track **116**, the internal effort data **112** describing a measured bodily input of the user **130**, and the external work data **114** describing a measured output effect of the user **130**;
2) Perform a comparison **118** between the internal effort data **112** and the external work data **114**; and
3) Select **120** at least one performance enhancing music track **122** for the user **130** based on the comparison **118**.

Favorable effects of performance enhancing (motivational) music include, for example, faster self-selected pace with similar rating of perceived exertion (RPE), improved economy of locomotion, decreased heart rate and blood pressure, and improved mood. By systematically analyzing the physiological effects of particular song or type of music, the performance enhancing music may be identified and used individually for each user during training.

The following papers, incorporated herein by reference, explain in more detail the ways the music may enhance performance:

Alisa Yamasaki, Abigail Booker, Varun Kapur, Alexandra Tilt, Hanno Niess, Keith D. Lillemoe, Andrew L. Warshaw, Claudius Conrad: The impact of music on metabolism, Nutrition, Volume 28, Issue number 11-12, 2012; and

Costas I. Karageorghis and David-Lee Priest: Music in the exercise domain, a review and synthesis (Parts I and II), International Review of Sport and Exercise Psychology, Vol. 5, No. 1, March 2012.

In an example embodiment, two different performance enhancing features of music may be distinguished:

1) Improved Economy of Locomotion During Submaximal Effort

Heart rate will be measured as the principle physiological parameter, and heart rate will be used together with pace, speed or power output data, to assess physical performance (aerobic capacity and economy). Music will be identified as motivational if it leads to improved economy.

2) Improved Performance During Maximal Effort

The maximal work output and/or maximal (peak) heart rate will be analyzed during sprint, high intensity interval or maximal strength training sessions when a certain song or certain type of music is played. If a song elicits higher performance than average the music will be identified as motivational.

In an example embodiment, music tracks that are identified as motivational in each category will be used more often during similar sessions whereas other music tracks are not played again or are not played as often. In an example embodiment, the impact of each music track may be updated each time it plays during exercise so that the motivational rating follows the changes in individual preferences over time.

The beneficial effects of music during exercise are twofold. Firstly, it will make the exercise more enjoyable by distracting attention from the pain or uncomfortableness of exercise, especially in untrained or less active individuals. Secondly, it will improve performance during training, thus leading to more effective training sessions and improved training benefits. It may also directly improve performance during a competition or race (if allowed).

In an example embodiment, performance enhancing music will be automatically selected for the user **130** for each training session so that the user **130** will get most out of each sessions and a more enjoyable training experience.

In an example embodiment, a sensor measures heart rate and another sensor detects external work (a stride sensor attached on the foot, GPS, or pedals for power measurement). A web based or offline music player may be used with an adequate selection of music. Headphones or other means of listening may be used. Physiological and physical measurement data will be analyzed in relation to each piece of music and in relation to the purpose (improved economy of locomotion during submaximal effort, or improved performance during maximal effort) and the resulting motivational index may be updated and stored locally or in an online source. The present coaching applications using music are quite basic at the moment and do not seem to use real time data analysis when selecting music. In the prior art, motivational qualities of music may be identified by self-selecting the preferred music during training. This is manual, time-consuming and only applies to the particular songs that are listed. The user may also manually rate each song based on his/her preference or rating of perceived exertion while the song is playing during exercise but this substantially disturbs the training session. Also, there may be individual physiological benefits of a certain type of music that the user is not conscious of.

In an example embodiment, in addition to being automatic from the user's point of view, the present example embodiments may be used during any music track that is played during exercise, not just the ones that have been rated before. Furthermore, it directly determines the physiological benefit of each music track by measuring physiological and physical parameters during exercise, and thus, does not solely rely on user's conscious choices.

FIG. **1** illustrates the temporal order of events: earlier **140**, the user **130** listens to the specific the music track **116**, and, later **150**, the user **130** listens to the performance enhancing music track **122**. The user **130** may listen to the music track **116**, **122** with a loudspeaker, headphones, wireless headset, earbuds, or any other suitable equipment enabling the listening during the exercise.

In an example embodiment, the internal effort data **112** comprises at least one of a heart activity of the user **130**, a breathing activity of the user **130**, an energy consumption of the user **130**, an electrodermal activity status **130** of the user **130**, a stress of the user **130**.

In an example embodiment, the external work data **114** comprises at least one of a speed of the user **130**, a distance traveled by the user **130**, a power outputted by the user **130**, a pace of the user **130**, an acceleration of the user **130**, a peak work output by the user **130**, an economy of motion status of the user **130**, a running index of the user **130**.

In an example embodiment, historical internal effort data **108** and historical external work data **108** from at least one earlier exercise session by the user **130** are taken into account in the comparison **118**.

FIG. **7** illustrates a further example embodiment. The x axis illustrates the time, the y axis illustrates both the internal effort IE and the external work EW, and curves **700**, **702**, **704**, **706** illustrate internal effort data as a function of time with solid lines and external work data with dotted lines.

In the example embodiment, the comparison **118** indicates that the specific music track **116** is performance enhancing provided that, as compared to the historical internal effort data **704** and the historical external work data **706**, the internal effort data **700** indicates an increase in the measured bodily input of the user **130** and the external work data **702** indicates an increase in the measured output effect of the user **130**. As can be seen from FIG. **7**, there is a notable difference between the internal effort data **700** and the historical internal effort data **704**, and also between the external work data **702** and the historical external work data **706**.

FIG. **8** illustrates an alternate example embodiment, wherein the comparison **118** indicates that the specific music track **116** is performance enhancing provided that, as compared to the historical internal effort data **704** and the historical external work data **706**, the internal effort data **800** indicates an equal measured bodily input of the user **130**, but the external work data **802** indicates a higher measured output effect of the user **130**. As can be seen from FIG. **8**, there is not a significant difference between the historical internal effort data **704** and the internal effort data **800**.

FIG. **9** illustrates a further example embodiment, wherein, for the comparison **118**, the internal effort data, the historical external work data, the historical internal effort data and the historical external work data are calibrated in view of a physiological status of the user **130** during the measurement. Let us suppose that the non-calibrated data is shown in FIG. **7**. Now, in FIG. **9**, the internal effort data **700** and the external work data **702** remain the same, but the calibration has moved both the historical internal effort data **704** and the historical external work data **706** to a higher level, the calibrated values being shown with reference numerals **900** and **902**. A typical scenario, illustrated by the FIG. **9** may be, for example: the physiological status of the user **130** during the latter measurement was "normal", whereby no calibration was necessary, whereas the physiological status of the user **130** during the earlier measurement indicated a "down" condition, meaning that his/her performance was poorer than in the normal condition. As a result of this processing, the historical data **900**, **902** was calibrated to a higher level so that the new and the older data are comparable with each other. In a way, the day-to-day variation may be removed with the calibration.

In an example embodiment, the physiological status of the user **130** is determined based on at least one of data relating to the exercise session, data relating to a health status of the user **130**, data relating to an overtraining status of the user **130**. For example: the data relating to the exercise session may include data about the exercise frequency and exertion level, the data relating to the health status may indicate whether the user **130** is healthy, sick or convalescent, and the data relating to the overtraining status may indicate whether the user has exercised within his/her recovery capacity or whether the user has exceeded the recovery capacity.

FIG. **10** illustrates another example embodiment, wherein a standard condition **1000-1002** is detected in the internal effort data **700** and the external work data **702**, and the standard condition **1000-1002** is also detected in the historical internal effort data **704** and the historical external work data **706**, whereupon the comparison **118** utilizes the internal effort data **700**, the external work data **702**, the historical internal effort data **704** and the historical external work data **706** measured during the standard condition **1000-1002**. The standard condition may relate to an elapsed time of exercise, for example. In the example embodiment of FIG. **10**, the standard condition is a time range beginning at time **1000** after the start of the exercise and ending at time **1002**. The time range may be any suitable time range such as 1 minute, 2 minutes, 3 minutes, 5 minutes, 10 minutes etc. The standard condition may, additionally, or instead of, relate to a detected condition in the internal effort data **112** and/or external work data **114**. For example, the detected condition may be such that a heart rate of the user **130** (featured in the internal effort data **112**) needs to reach a certain level.

Note that FIGS. **7**, **8**, **9** and **10** illustrate just one example embodiment of the structure of the internal effort data **112** and external work data **114**: the data **112**, **114** may comprise a plurality of values as a function of time, or, alternatively/additionally, the data **112**, **114** may comprise single values, data sets, statistical values, formulas, or values that characterize a total amount, an average amount or a representative amount of internal effort/external work. The comparison **118** operation may utilize various mathematical operations but also various methods for data analysis (including statistical analysis). An algorithm may identify a relationship (such as a correlation) between the internal effort data **112** and the external work data **114** caused by the specific music track **116**.

FIG. **2** illustrates an example embodiment wherein the electronic apparatus **100** is a part of configuration comprising various parts, designed and manufactured by the Applicant, Polar Electro Oy. As shown, the electronic apparatus **100** may be a user apparatus **100**A handled by the user **130**, and/or a server apparatus **1006** such as a user web service **230** providing service to the user **130**.

The user **130** may be provided with a user apparatus **100**A, which may be a single apparatus or a set of separate apparatuses, possibly being wearable and/or portable. With the user apparatus **100**A, the user **130** may monitor training parameters that characterize the physiological state during the exercise in real-time. The physiological state may be detected from one or more performance metrics, such as by monitoring how the heart rate changes as the exercise session progresses.

The user apparatus **100**A may comprise a wrist-worn apparatus **200** such as a sports watch or a smartwatch.

Furthermore, the user **130** may be provided with a heart rate transmitter **204** strapped around the chest, and possibly also with a shoe-mounted stride sensor **206**. The user **130** may also carry a wireless headset **208**, and/or smartglasses **210**. The accessories **204**, **206**, **208**, **210** may communicate wirelessly with the wrist-worn apparatus **200**.

Additionally, or alternatively, the user apparatus **100**A may comprise a portable communication apparatus **202** of the user **130**. A non-exhaustive list of the types of the portable communication apparatus **202** includes: a mobile phone, a smartphone, a tablet computer, a phablet, a general-purpose mobile computing device. In an example embodiment, the portable communication apparatus **202** is a general-purpose off-the-shelf computing device, as opposed to a purpose-build proprietary equipment, whereby research &

development costs will be lower as only the special-purpose software (and not the hardware) needs to be designed, implemented and tested. The portable communication apparatus **202** may employ a suitable operating system such as iOS, Android, or Windows Phone, for example.

Various accessories may be flexibly used as needed, i.e. all of them are not necessarily needed all the time, or by all users **130**, or in all use cases.

However, in an example embodiment, the user apparatus **100**A may also be interpreted as a circuitry implementing the required functionality within some suitable equipment.

The user apparatus **100**A may store the exercise data, which the user (exerciser) **130** may use in post-analysis of the performed exercise. In an example embodiment, the post-analysis is processed in the user apparatus **100**A.

In another embodiment, the exercise data is transferred from the user apparatus **100**A to a user web service **230** through a communication network **220**, and the post-analysis is carried out in the user web service **230**.

If the wrist-worn apparatus **200** does not have a direct Internet access capability, the wrist-worn apparatus **200** may access the Internet (e.g. the user web service **230**) via the portable communication apparatus **202** coupled to the wrist-worn apparatus **200**, via a Bluetooth connection, for example. The portable communication apparatus **202** may be associated to the same user **130** as the wrist-worn apparatus **200**.

The user web service **230** may comprise exercise data user accounts (UA), each exercise data user account comprising exercise data associated with a specific user **130**. As such, there may be different user accounts for different users. An example embodiment of such a user web service **230** may be a Polar Personal Trainer (PTT), Polar Flow or iFIT service which comprises a database for storing the plurality of user accounts. In an example embodiment, the user web service **230** may require that the user **130** first connects to the user web service **230** by applying a user name and a password, or other identification means. The training/exercise data in the user account may have been stored during or after the exercise. The user account may additionally store physiological data of the user **130** and user attributes obtained from the exerciser **130** and/or the exercise device, such as name, gender, age, weight, height, image, status, motto, fitness level, training schedule, maximum oxygen intake (VO2Max), maximum heart rate (HRMax), performance zones (heart rate zones, speed zones), aerobic and anaerobic thresholds etc. Note that the described embodiments relating to the selection of the performance enhancing music are tied to the user; the music chosen is not generic, but user specific. One implementation of this may be such that the user is identified by a user identifier (which may be globally unique, or unique within a chosen domain) in the apparatus **100**, and the internal effort data **112**, external work data **114**, the specific music track **116** and the performance enhancing music track **122** are specific for the user **130** identified by the user identifier.

FIG. **3** illustrates example embodiments of the user apparatus **100**A, whereas FIG. **4** illustrates example embodiments of the server apparatus **1006**.

In an example embodiment, the server apparatus **100**B may be implemented by a suitable computing resource or a combination of various computing resources.

In an example embodiment, the computing resource **100**B may be implemented as a single server computer or as a cluster of computers. The server is a part of the client-server computing model that acts as distributed application which partitions tasks or workloads between the provider of a resource or service, called server, and the service requester, called client. The server **100**B may serve a number of apparatuses **100**A, **200**, **202**. The server computer **100**B may be a host that is running one or more server programs which share their resources with clients **100**A, **200**, **202**. The client **100**A, **200**, **202** may request a service function or content from the server **100**B. Also, the client **100**A, **200**, **202** may initiate a communication session with the server **1006** which awaits incoming requests.

In an example embodiment, the electronic service **230**/**100**B may also operate according to the cloud computing model, at least in part. Naturally, besides these example embodiments of the electronic service **230**/**100**B, other feasible computing architectures may be utilized as well to implement the hardware and software of the electronic service **230**/**100**B. Consequently, besides operating according to the client/server architecture, push technology may be utilized as well. In push technology, the request for a transaction is initiated by the electronic service **230**/**100**B, whereas with the pull technology the request for the information is initiated by the client **100**A, **200**, **202**.

The user apparatus **100**A may comprise a user interface **308**, the interface **110**, the one or more processors **102**, and the one or more memories **104** including the computer program code **106**.

The user interface **308** implements exchange of graphical, textual and/or auditory information with the user **130**. The user interface **308** may be realized with various techniques, such as the display, means for producing sound, a keyboard, and/or a keypad, for example. The means for producing sound may be a loudspeaker or a simpler means for producing beeps or other sound signals. The keyboard/keypad may comprise a complete (QWERTY) keyboard, a mere numeric keypad or only a few push buttons and/or rotary buttons. In addition, the user interface **308** may comprise other user interface components, for example various means for focusing a cursor (mouse, track ball, arrow keys, touch sensitive area etc.) or elements enabling audio control, or a fingerprint sensor enabling control with a fingerprint pattern of the users **130** finger(s).

The interface **110** of the user apparatus **100**A may be implemented by a sensor interface **312** and/or a radio transceiver **314**. The interface **110** of the server apparatus **1006** may be implemented by a data interface **400** (such as a network interface card) and/or a radio transceiver **314**.

The sensor interface **312** may be utilized to obtain the internal effort data **112** and the external work data **114** measured relating to the user **130**. The sensors may produce the data **112**, **114** from users physical activity such as sports-, exercise-, or activity-related data.

In an example embodiment, the user apparatus **100**A may further comprise one or more internal measurement sensors **310**, and/or the apparatus **100**A may be communicatively coupled with one or more external measurement sensors **318**.

As illustrated in FIG. **3**, the sensors **310**, **318** may be internal measurement sensors **310** (within the apparatus **100**A) and/or (wireless) external measurement sensors **318** (outside of the apparatus **100**A). The apparatus **100**A may comprise, as the sensor interface **312**, a transceiver for communicating with the wireless external measurement sensor(s) **318**, or even just a receiver for receiving measurements from the wireless external measurement sensors **318**. For the internal measurement sensors **310**, the interface **312** may be a suitable hardware communication interface such as a wired interface or an appropriate communication bus, for example.

The following is a non-limiting list of possible types of the physical activity data (also known as physiological sensor data or exercise data) that may be detected by the sensors **310**, **318** or that the apparatus **100**A may determine on the basis of the physical activity data: heart rate zones, heart rate samples, heart rate variation samples, heart beat interval samples, breathing activity, fat consumption rate, calorie/energy consumption rate, consumed amount of calories/energy, stress of the user, activity zones, activity samples, speed and/or pace samples, power samples, acceleration of the user, peak work output, economy of motion of the user, cadence samples, altitude samples, temperature samples, location samples, distance elapsed, time elapsed, pedal index, left-right balance, running index, training load, galvanic skin response samples, electrodermal activity status, fluid balance, skin temperature samples, heading samples and/or bike angles. The location data may comprise satellite positioning data, such as, GPS positioning data, or any other data that allows the determination of the location of the exerciser during the exercise at any given time. The movement indoors may be detected via indoor location tracking methods, such as mapping techniques including measuring Earth's magnetic fields or radio frequency signals.

A non-exhaustive list of sensors **310**, **318** includes heart activity sensors, motion sensors, location sensors, swimming sensors and bike sensors, as well as other sensors gathering information regarding the exercise. Besides these, sensors **310**, **318** may comprise any sensors that are needed for detecting a given exercise data type, such as temperature sensor for detecting ambient temperature or skin temperature.

The heart activity sensors may be configured to determine heart activity, such as heart rate, Heart Beat Interval (HBI) and/or Heart Rate Variability (HRV), for example. The heart activity sensors include, but are not limited to, a cardiovascular sensor (such as an electrocardiogram ECG sensor), an optical heart activity sensor such as a PPG (photoplethysmography) sensor, or a bioimpedance plethysmography. The optical heart activity sensor may detect the heart activity of the user by optical heart rate measurement, which may comprise sending a light beam towards skin of the user and measuring the bounced and/or emitted light from the skin of the user. The light beam may alter when travelling through veins of the user and the alterations may be detected by the optical heart rate activity sensor. Further, besides these types of heart activity sensors, also other types of biosignal measurement sensors may be embedded into the heart activity sensors. These types include but are not limited to the following: a Laser Doppler-based blood flow sensor, a magnetic blood flow sensor, an Electromechanical Film (EMFi) pulse sensor, a polarization blood flow sensor. In an example embodiment, the heart activity sensor may produce raw measurement data of the heart activity and/or it may process the measurement data into heart activity information, such as heart rate for example. This means that the sensor(s) **310**, **318** in general may comprise data processing capabilities. Further, the raw measurement data and/or processed information may be processed by the apparatus **100**A and/or transmitted to an external device, such as the portable communication apparatus **202**, or even to the user web service **230**, as was explained earlier.

Motion sensors may be configured to measure motion induced by the user **130** to the apparatus **100**A by moving hand (or other body parts such as chest or ankle to which the motion sensor is attached to). The motion sensor may use other motion data, such as location data of the user, to determine motion of the user. In an example embodiment, the motion sensor comprises at least one of the following: an accelerometer, a magnetometer, and a gyroscope. The motion sensor may further comprise sensor fusion software for combining the accelerometer data and gyroscope data so as to provide physical quantities, such as acceleration data, velocity data, or limb trajectory data in a reference coordinate system having orientation defined by a predetermined gyroscope orientation.

Location sensors may utilize GPS (Global Positioning System) or other satellite-based, or radio system-based system for locating the user and measuring various parameters (speed, distance, location, route) relating to the movement of the user.

Swimming sensors may measure swimming specific parameters such as number of strokes or distance, for example.

Bike sensors may be sensors attached to various parts of the bike for measuring speed, cadence, or power, for example.

The gathered sensor information may be utilized to calculate further physical activity data of the user such as total energy consumption, an energy consumption speed, an activity level, a cumulated activity, for example.

Described physical activity data and sensor data may be used to generate the internal effort data **112** and the external work data **114**.

The radio transceiver **314** may comprise a cellular radio transceiver and/or a non-cellular radio transceiver. In an example embodiment, the cellular radio transceiver **314** may be interoperable with various wireless standard/non-standard/proprietary cellular radio networks **220** such as any mobile phone network, which may be coupled with a wired network such as the Internet.

In an example embodiment, the wireless communication network **220** comprises any mobile phone network, regardless of the generation (such as 2G, 3G, 4G, beyond 4G, 5G etc.) such as GSM (Global System for Mobile Communications), GPRS (General Packet Radio Service), EGPRS (Enhanced GPRS), WCDMA (Wideband Code Division Multiple Access), UMTS (Universal Mobile Telephone System), 3GPP (The 3rd Generation Partnership Project), IMT (International Mobile Telecommunication), LTE (Long Term Evolution, LTE-A (LTE-Advanced), Mobile WiMAX, and other radio systems (in their present forms and/or in their evolution forms).

In an example embodiment, the communication network **220** supports the use of subscriber identity module (SIM), which may be an integrated circuit storing subscriber data, which is network-specific information used to authenticate and identify the subscriber on the cellular network. The subscriber identity module may be embedded into a removable SIM card. Consequently, the apparatus **100**A may include the SIM card (and a SIM card reader). Alternatively, the apparatus **100**A may include a virtual or software SIM card.

In an example embodiment, the wireless communication network **220** comprises a wireless local area network (WLAN), a hotspot, or an access point, all of which may provide Internet access through the use of a router connected to a link to an Internet service provider.

In an example embodiment, the non-cellular radio transceiver **314** may utilize a short-range wireless technology, a Bluetooth standard, a Bluetooth low energy (BLE) standard, a wireless local area network (WLAN) standard, a Wi-Fi (or WiFi) standard, a IEEE (Institute of Electrical and Electronics Engineers) 802.11 standard or its evolution versions (IEEE 802.11ac etc.), for example), a proprietary short-range radio technology.

In an example embodiment, a system clock **306** constantly generates a stream of electrical pulses, which cause the various transferring operations within the apparatus **100** to take place in an orderly manner and with specific timing.

In an example embodiment, the processor **102** may be implemented as a microprocessor implementing functions of a central processing unit (CPU) on an integrated circuit. The CPU is a logic machine executing a computer program code **106**. The computer program code **106** may be coded as a computer program using a programming language, which may be a high-level programming language, such as C, or Java, or a low-level programming language, such as a machine language, or an assembler. The CPU may comprise a set of registers **300**, an arithmetic logic unit (ALU) **302**, and a control unit (CU) **304**. The control unit **304** is controlled by a sequence of the computer program code **106** transferred to the CPU from the (working) memory **104**. The control unit **304** may contain a number of microinstructions for basic operations. The implementation of the microinstructions may vary, depending on the CPU design. The microprocessor **102** may also have an operating system (a dedicated operating system of an embedded system, a real-time operating system, or even a general-purpose operating system), which may provide the computer program code **106** with system services.

A non-exhaustive list of implementation techniques for the processor **102** and the memory **104** includes, but is not limited to: logic components, standard integrated circuits, application-specific integrated circuits (ASIC), system-on-a-chip (SoC), application-specific standard products (ASSP), microprocessors, microcontrollers, digital signal processors, special-purpose computer chips, field-programmable gate arrays (FPGA), and other suitable electronics structures.

In an example embodiment, the processor **102** and the memory **104** of the apparatus **100** are a part of a microcontroller. In an example embodiment, the sensor interface **312**, and/or the radio transceiver **314** also belong to the microcontroller.

In an example embodiment, the sensor interface **312**, the radio transceiver **314**, the processor **102** and the memory **104** are separate entities, communicatively coupled together by an appropriate serial bus, for example. In general interfaces between the various elements may be implemented with suitable interface technologies, such as a message interface, a method interface, a sub-routine call interface, a block interface, an appropriate serial/parallel bus, or any hardware/software means enabling communication between various sub-units of the apparatus **100**.

An example embodiment provides a computer-readable medium **320** for the apparatus **100** comprising a computer program comprising the computer program code **106**. Said computer program code **106**, when loaded into the apparatus **100** and executed in the apparatus **100**, causes the apparatus **100** to perform the operations required to implement the described example embodiments. In an example embodiment, the computer program code **106** may be in source code form, object code form, executable file, or in some intermediate form. The computer-readable medium **320** may comprise at least the following: any entity or device capable of carrying computer program code **106** to the apparatus **100**, a record medium, a computer memory, a read-only memory, an electrical carrier signal, a telecommunications signal, and a software distribution medium. In some jurisdictions, depending on the legislation and the patent practice, the computer-readable medium **320** may not be the telecommunications signal. In an example embodiment, the computer-readable medium **320** may be a non-transitory computer readable storage medium.

In an example embodiment, the apparatus **100**A may further comprise an independent energy source **316**. In an example embodiment, the energy source **316** may be an electric battery converting stored chemical energy into electrical energy. The electric battery **316** may be rechargeable. In an example embodiment, the apparatus **316** may comprise a power interface to receive electrical energy for charging the battery **316**. The power interface may couple the apparatus **100**A to mains electricity, to a charger connector in a vehicle, or to some other power source enabling the charging of the battery **316**. In addition to, or instead of, the battery **316**, the apparatus **100** may comprise another portable energy source such as a solar cell **316** converting the energy of light directly into electricity by the photovoltaic effect, or a a fuel cell **316** converting the chemical energy from a fuel into electricity through a chemical reaction with oxygen or another oxidizing agent.

FIG. **5** illustrates the operation environment of FIG. **2** from a slightly different perspective. The apparatus **100** functionality may be implemented in one specific component, or distributed among a number of different components: into the user apparatus **100**A such as the smartwatch **200**, mobile phone **202** and/or a computing device **520**, and/or into the server apparatus **100**B such as the electronic service **230**. Besides these, the apparatus **100** functionality may be implemented in another device, such as in the wireless headset **208**. As shown, the apparatuses **100**A, **100**B may communicate **500**, **502**, **504**, **506**, **508**, **510** with each other.

Next, let us study FIG. **6**, which is a flow chart illustrating further example embodiments. The operations are not strictly in chronological order, and some of the operations may be performed simultaneously or in an order differing from the given ones. Other functions may also be executed between the operations or within the operations and other data exchanged between the operations. Some of the operations or part of the operations may also be left out or replaced by a corresponding operation or part of the operation. It should be noted that no special order of operations is required, except where necessary due to the logical requirements for the processing order. In an example embodiment, the method illustrated in FIG. **6** may be implemented by an electronic apparatus. In an example embodiment, the method may be implemented by the described electronic apparatus **100**/**100**A/**100**B.

The method starts in **600**.

In **602**, internal effort data and external work data both measured from a user performing an exercise while listening to a specific music track are obtained. The internal effort data describes a measured bodily input of the user, and the external work data describes a measured output effect of the user.

In **604**, a comparison between the internal effort data and the external work data is performed.

In **606**, at least one performance enhancing music track for the user is selected based on the comparison.

The method ends in **608**, or, alternatively, the operations **602**-**604**-**606** and the supplementary operations may be repeated **610** as required.

The already described example embodiments of the apparatus **100**/**100**A/**100**B may be utilized to enhance the method with various further example embodiments.

Next, let us study further example embodiments of the method and the apparatus **100**/**100**A/**100**B with reference to FIG. **6**.

In an example embodiment, the internal effort data **112** comprises at least one of a heart activity **632** of the user, a breathing activity **634** of the user, an energy consumption **636** of the user, an electrodermal activity status **638** of the user, a stress **640** of the user.

In an example embodiment, the external work data **114** comprises at least one of a speed **616** of the user, a distance **618** traveled by the user, a power **620** outputted by the user, a pace **622** of the user, an acceleration **624** of the user, a peak work output **626** by the user, an economy of motion status **628** of the user, a running index **630** of the user.

In an example embodiment, historical internal effort data **642** and historical external work data **642** from at least one earlier exercise session **612** by the user are taken into account in the comparison **604**.

In an example embodiment, for the comparison **604**, the internal effort data, the historical external work data, the historical internal effort data and the historical external work data are calibrated in view of a physiological status **644** of the user during the measurement.

In an example embodiment, a playback of the specific music track **116** is repeated consecutively during the exercise, and the internal effort data **112** and external work data **114** are both measured from the user **130** performing the exercise while listening to the consecutively repeated specific music track **116**. With this example embodiment, the effect of the specific music track **116** may become more apparent.

In an example embodiment, a playback of the specific music track **116** is repeated consecutively during more than one separate exercise session, and the internal effort data **112** and external work data **114** are both measured from the user performing the exercise in the more than one separate exercise sessions while listening to the specific music track **116**. This example embodiment may also clarify the effect of the specific music track **116** as multiple measurement results are obtained and compared.

In an example embodiment, the specific music track **116** is added to a set **648** of performance enhancing music tracks, if the comparison **604** indicates that the specific music track is performance enhancing.

In an example embodiment, at least one music track similar to the specific music track **116** is added to a set **648** of performance enhancing music tracks, if the comparison **604** indicates that the specific music track **116** is performance enhancing. Each music track may have a number of different parameters, with which music tracks may be classified, grouped or tagged. The parameters may define one or more of the following features: a rhythm (beat or tempo) of the music track **116**, **122**, a dynamic range of the music track **116**, **122**, an audio spectrum of the music track **116**, **122**, a genre of the music track **116**, **122**, musicality (harmony, melody) of the music track **116**, **122**, cultural impact of the music track **116**, **122**, and association of the music track **116**, **122**.

In an example embodiment, a performance rating **646** is assigned for the specific music track **116** based on the comparison **604**. The performance rating **646** may be a Boolean value (performance enhancing/not performance enhancing) or a scale (for example: 1=very performance enhancing, 2=performance enhancing, 3=no effect). In an example embodiment, in order to assign the performance rating **646** for the specific music track **116**, besides the comparison **604**, also at least one performance rating for the specific music track **116** originating from at least one earlier exercise session is taken into account. In this way, the performance rating becomes more accurate.

In an example embodiment, a type **614** of the exercise is detected, and the specific music track **116** is associated with the type of the exercise. In an example embodiment, a specific type of the internal effort data **112** and a specific type of the external work data **114** are selected based on the type **614** of the exercise and used in the comparison **604**. The type of the exercise may refer to the sport, such as running, bicycling, skiing etc. or to the structure/effect of the exercise, such as interval, long slow distance etc. Music may be played during all types of training sessions: free sessions with self-selected pace, long endurance sessions, high intensity interval sessions, strength training sessions, and the physiological effects of each music track is analyzed in this context. In an example embodiment, the type of the exercise refers to a predetermined heart rate range. The heart range may be determined by a range related to the maximum heart rate of the user. Polar Sport Zones, for example determined the following ranges: maximum—90-100% of the maximum heart rate, hard—80-90% of the maximum heart rate, moderate—70-80% of the maximum heart rate, light—60-70% of the maximum heart rate, and very light—50-60% of the maximum heart rate.

In an example embodiment, the specific music track **116** has been selected for the listening based on the type of the exercise **614**. In this way, the music may be better suited to the nature of the type. For example: interval training may require faster beat, whereas long slow distance is better served with moderate beat.

It will be obvious to a person skilled in the art that, as technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the example embodiments described above but may vary within the scope of the claims.

What is claimed is:

**1**. A wrist-worn electronic apparatus comprising:

a wireless interface;

an optical heart activity sensor;

a location sensor;

a music player;

one or more processors; and

one or more memories including computer program code,

the one or more memories and the computer program code configured to, with the one or more processors, cause the apparatus to perform operations comprising:

obtaining, internal effort data from an optical heart activity sensor and external work data from a location sensor both measured from a user performing an exercise while listening to a specific music track played with the music player and outputted through the wireless interface to one of a loudspeaker, headphones, wireless headset, earbuds, the internal effort data describing a measured bodily input of the user, and the external work data describing a measured output effect of the user;

performing a comparison between the internal effort data and the external work data, wherein the comparison detects that the specific music track is performance enhancing if a relationship indicating an improved economy of locomotion during submaximal effort between the internal effort data and the external work is identified, wherein the comparison takes historical internal effort data and historical external work data from at least one earlier exercise session by the user into account; and adding the specific music track to a set of performance enhancing music tracks if the comparison detects that the specific music track is performance enhancing.

**2**. The apparatus of claim **1**, wherein the comparison indicates that the specific music track is performance enhancing provided that, as compared to the historical internal effort data and the historical external work data, the internal effort data indicates an increase in the measured bodily input of the user and the external work data indicates an increase in the measured output effect of the user.

**3**. The apparatus of claim **1**, wherein the comparison indicates that the specific music track is performance enhancing provided that, as compared to the historical internal effort data and the historical external work data, the internal effort data indicates an equal measured bodily input of the user, but the external work data indicates a higher measured output effect of the user.

**4**. The apparatus of claim **1**, wherein, for the comparison, the internal effort data, the historical external work data, the historical internal effort data and the historical external work data are calibrated in view of a physiological status of the user during the measurement.

**5**. The apparatus of claim **4**, wherein the physiological status is determined based on at least one of data relating to the exercise session, data relating to a health status of the user, data relating to an overtraining status of the user.

**6**. The apparatus of claim **1**, wherein a playback of the specific music track is repeated consecutively during the exercise, and the internal effort data and external work data are both measured from the user performing the exercise while listening to the consecutively repeated specific music track.

**7**. The apparatus of claim **1**, wherein a playback of the specific music track is repeated consecutively during more than one separate exercise session, and the internal effort data and external work data are both measured from the user performing the exercise in the more than one separate exercise sessions while listening to the specific music track.

**8**. The apparatus of claim **1**, wherein at least one music track similar to the specific music track is added to a set of performance enhancing music tracks, if the comparison indicates that the specific music track is performance enhancing.

**9**. The apparatus of claim **1**, wherein a performance rating is assigned for the specific music track based on the comparison.

**10**. The apparatus of claim **9**, wherein, in order to assign the performance rating for the specific music track, besides the comparison, also at least one performance rating for the specific music track originating from at least one earlier exercise session is taken into account.

**11**. The apparatus of claim **1**, wherein a type of the exercise is detected, and the specific music track is associated with the type of the exercise.

**12**. The apparatus of claim **11**, wherein a specific type of the internal effort data and a specific type of the external work data are selected based on the type of the exercise and used in the comparison.

**13**. The apparatus of claim **11**, wherein the specific music track has been selected for the listening based on the type of the exercise.

**14**. The apparatus of claim **1**, wherein the internal effort data comprises at least one of a heart activity of the user, a breathing activity of the user, an energy consumption of the user, an electrodermal activity status of the user, a stress of the user.

**15**. The apparatus of claim **1**, wherein the external work data comprises at least one of a speed of the user, a distance traveled by the user, a power outputted by the user, a pace of the user, an acceleration of the user, a peak work output by the user, an economy of motion status of the user, a running index of the user.

**16**. The apparatus of claim **1**, wherein the internal effort data comprises a heart rate of the user, and the external work data comprises at least one of a speed of the user, a distance traveled by the user, a pace of the user, an economy of motion status of the user, a running index of the user.

**17**. The apparatus of claim **1**, wherein a standard condition is detected in the internal effort data and the external work data, and the standard condition is also detected in the historical internal effort data and the historical external work data, whereupon the comparison utilizes the internal effort data, the external work data, the historical internal effort data and the historical external work data measured during the standard condition.

**18**. A non-transitory computer-readable storage medium comprising a computer program comprising computer program code which, when executed by an electronic apparatus causes the apparatus to perform operations comprising:

obtaining, internal effort data from an optical heart activity sensor and external work data from a location sensor both measured from a user performing an exercise while listening to a specific music track, the internal effort data describing a measured bodily input of the user, and the external work data describing a measured output effect of the user;

performing a comparison between the internal effort data and the external work data, wherein the comparison detects that the specific music track is performance enhancing if a relationship indicating an improved economy of locomotion during submaximal effort between the internal effort data and the external work is identified, wherein the comparison takes historical internal effort data and historical external work data from at least one earlier exercise session by the user into account; and

adding the specific music track to a set of performance enhancing music tracks if the comparison detects that the specific music track is performance enhancing.

**19**. A method in an electronic apparatus, comprising:

obtaining internal effort data from an optical heart activity sensor and external work data from a location sensor both measured from a user performing an exercise while listening to a specific music track, the internal effort data describing a measured bodily input of the user, and the external work data describing a measured output effect of the user;

performing a comparison between the internal effort data and the external work data, wherein the comparison detects that the specific music track is performance enhancing if a relationship indicating an improved economy of locomotion during submaximal effort between the internal effort data and the external work is identified, wherein the comparison takes historical internal effort data and historical external work data from at least one earlier exercise session by the user into account; and

adding the specific music track to a set of performance enhancing music tracks if the comparison detects that the specific music track is performance enhancing.

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| 专利名称(译) | 基于生理的性能增强音乐选择 | | |
| 公开(公告)号 | [US10579670](US10579670) | 公开(公告)日 | 2020-03-03 |
| 申请号 | US14/876272 | 申请日 | 2015-10-06 |
| [标]申请(专利权)人(译) | 博能电子公司 | | |
| 申请(专利权)人(译) | Polar Electro Oy公司 | | |
| 当前申请(专利权)人(译) | Polar Electro Oy公司 | | |
| [标]发明人 | KARAVIRTA LAURA | | |
| 发明人 | KARAVIRTA, LAURA | | |
| IPC分类号 | G06F16/635 A61B5/024 G16H50/30 G16H20/30 G16H10/60 G06Q50/22 G06Q30/06 G16H40/67 A61B5/0205 G06F16/23 G06F16/68 A61B5/11 A61B5/00 H04R1/10 | | |
| CPC分类号 | G06F16/686 G16H40/67 A61B5/024 G06F16/636 G06F16/23 A61B5/486 G06Q30/0631 G16H10/60 A61B5/0205 G06Q50/22 H04R1/1091 G16H20/30 G16H50/30 A61B5/11 H04R2499/11 | | |
| 其他公开文献 | US20170097994A1 | | |
| 外部链接 | [Espacenet](Espacenet) | | |


摘要(译)

公开了针对特定个人的基于生理的性能增强音乐的选择。 获得内部努力数据和外部工作数据，两者都是从用户一边听特定音乐曲目一边进行锻炼而测得的。 内部努力数据描述了用户测量的身体输入，而外部工作数据描述了用户测量的输出效果。 进行内部工作量数据和外部工作数据之间的比较。 基于该比较，为用户选择至少一个性能增强的音乐曲目。