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(54) **A DEVICE FOR CONDITIONING BALANCE AND MOTOR CO-ORDINATION**

VORRICHTUNG ZUR KONDITIONIERUNG DES GLEICHGEWICHTS UND DER BEWEGUNGSKOORDINATION

DISPOSITIF POUR CONDITIONNER L'EQUILIBRE ET LA COORDINATION MOTRICE

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(73) Proprietors:
- **Alma Mater Studiorum -Universita' di Bologna**
  40126 Bologna (IT)
- **Oregon Health and Sciences University**
  Portland, OR 97201 (US)

(72) Inventors:
- **CHIARI, Lorenzo**
  I-40050 Monte San Pietro (IT)
- **HORAK, Fay, B.**
  Portland, OR 97212 (US)
- **CAPPELLO, Angelo**
  I-40138 Bologna (IT)
- **DOZZA, Marco**
  I-40055 Castenaso (IT)

(74) Representative: **Lanzoni, Luciano**
Bugnion SpA
Via Goito 18
40126 Bologna (IT)

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Description

Technical field

[0001] The present invention relates to a device for conditioning balance and motor co-ordination.

[0002] In particular, it relates to a device which can be worn by a user, for quantifying, improving and training posture, balance and motor co-ordination in humans.

Background art

[0003] The erect position typical of mankind is intrinsically unstable due to the action of gravity and maintaining it, that is to say, the ability to keep one's balance, is a basic requirement for body movement.

[0004] Closely linked to this are the abilities to carefully control one's posture and to effectively co-ordinate the movements of the different parts of the body.

[0005] Therefore, the control of balance, posture and co-ordination have a role of central importance in the wider context of motor control and substantially depend on the subject's perception of the spatial positioning of his/her body or part of it.

[0006] It is known that ageing and any neural, muscular or skeletal disorder which compromises the senses may, in practice, result in a diminished motor ability and, in particular, a higher risk of postural instability and falls.

[0007] For this reason, the invention of systems for training, maintaining, rehabilitating or monitoring motor ability which have positive effects on balance, posture and motor co-ordination is currently strategic in a society in which the average age is gradually increasing.

[0008] Devices have been invented which help maintain balance, for people with motor difficulties and, in particular, devices able to provide the user with information about the spatial orientation of at least one part of his/her body.

[0009] Consider, for example, the device described in US patent 6546291, which generally comprises an acquisition system, preferably wearable by the user, for detecting the spatial orientation and movement of the user or part of his/her body.

[0010] US 5 694 340 describes a device measuring acceleration along three orthogonal axes and providing sound feedback according to the direction and intensity of the detected accelerations.

[0011] The acquisition system communicates, by means of a communication interface and an encoder, with a stimulator apparatus connected to the user's nervous system.

[0012] The stimulator apparatus comprises at least one electrode, located close to one of the user's nerves, by means of which a signal, suitably generated by the encoder according to the spatial orientation detected, stimulates said nerve, providing the user with an indication of his/her spatial orientation.

[0013] The device has several disadvantages, in particular direct stimulation of the nerve is not always easy to achieve and correct positioning of the electrode for this purpose may be awkward and ineffective, particularly in the case of elderly users.

[0014] The device also being dedicated to people with motor difficulties, these people may find it difficult to position and secure the stimulating electrodes on the body and guarantee that they remain in the correct position.

Disclosure of the invention

[0015] The aim of the present invention is to produce an improved device for conditioning balance and motor action which, by means of a control signal, provides the user with an indication of his/her position without acting directly on the user's nerves, that is to say, a substantially non-invasive device for conditioning balance and motor action.

[0016] Another aim of the present invention is to produce a device which is easy to use and easy to wear even for persons with motor deficiencies.

Brief description of the Drawings

[0017] The technical features of the present invention, in accordance with the above-mentioned aims, are set out in the claims herein and the advantages more clearly illustrated in the detailed description which follows, with reference to the accompanying drawings, which illustrate a preferred embodiment of the invention without limiting the scope of the inventive concept, and in which:

- Figure 1 is a schematic view of a device for conditioning balance and motor action in accordance with the present invention;
- Figure 2 is a schematic illustration of a method for management of the parameters of the control signal in the device

illustrated in Figure 1;

- Figures 3a to 3d are schematic illustrations of a preferred trend of the parameters forming the control signal in the device illustrated in Figure 1.

Detailed Description of the Preferred Embodiments of the Invention

[0018] With reference to the accompanying drawings, the numeral 1 denotes a device for conditioning the balance of a user 2.

[0019] The device 1, which can be completely worn by the user 2, comprises a system 3 for the acquisition of information relative to the kinematics of a part 4 of the body of the user 2.

[0020] In more detail, the system 3 preferably has an accelerometric sensor 5 or accelerometer of the substantially known type (for example, biaxial or triaxial), connected to the torso of the user 2 and fitted with a preamplifier 6.

[0021] With a set direction T of feed of the data flow, the system 3 comprises, downstream of the accelerometer 5 preamplifier 6, an amplifier 7 and a filter 8 for conditioning an electrical signal generated by the accelerometer 5.

[0022] The accelerometer 5 translates the accelerations of the torso of the user 2 into electrical signals which, suitably conditioned, become intelligible to a processing system 9 connected to the acquisition system 3 and located downstream of the latter according to the direction T.

[0023] In alternative embodiments, not illustrated, the acquisition system 3 comprises a number of accelerometric sensors 5 and relative preamplifiers 6, amplifiers 7 and filters 8, greater than one according, for example, to the accuracy of the measurements to be taken or the anthropometry of the user 2.

[0024] The preamplifiers 6, amplifiers 7 and filters 8 are substantially of the known type and therefore not described in detail.

[0025] Is should be observed that the sensors 5 may be attached to any part 4 of the body of the user 2 depending on the area of the body to be improved, trained or subjected to posture analysis.

[0026] The processing system 9 comprises an analogue - digital converter 10 which receives at input the signal generated by the accelerometer 5.

[0027] Downstream of the converter 10, relative to the direction T, the system 9 comprises an electronic card 11 of the substantially known type, which, as described in more detail below, calculates the volume, frequency and balance of a control or feedback signal, derived from the electrical signal generated by the devices upstream.

[0028] In greater detail, using a suitable software not described in detail, the card 11 generates a stereophonic sound consisting of two sound waves.

[0029] The sound waves have their frequency and volume modulated and the stereophonic sound is suitably balanced between two audio channels, right and left, linked to respective earphones 12 and 13, right and left respectively, by way of example with reference to Figure 1, which can be worn by the user 2. The right and left channels can be modulated independently of one another.

[0030] Advantageously, in the preferred embodiment, these sound waves are of the sinusoidal type, yet can assume any trend suitable for transmission of the information, as described below.

[0031] Downstream of the card 11 according to the direction T, the device 1 comprises an audio amplifier 14, of the known type, through which the stereophonic sound reaches the earphones 12 and 13.

[0032] The earphones 12 and 13 respectively consist of sound transducers 15 and 16 which comprise for example, in alternative embodiments not illustrated, acoustic boxes which the user can wear at the ears.

[0033] The transducers 15 and 16, together with the respective connecting cables and the audio amplifier 14, form means 17 for communication between the processing system 9 and the user 2 to substantially feed the information about the kinematics of the user's body to the user 2, encoded in a feedback signal defined by the stereophonic sound.

[0034] In practice, the definition of the feedback signal is such that it provides the user 2 with the above-mentioned kinematic information relative, for example, to substantially horizontal movements of the torso.

[0035] Generally speaking, the accelerations of the body are separated into anteroposterior AP, corresponding to forward A and backward P movements of the torso (or other body segment considered), and mediolateral ML, corresponding to torso movements to the right R or to the left L, and the stereophonic sound is encoded, modulated and balanced between the earphones 12 and 13 on the basis of these.

[0036] The sound dynamics inform the user 2 about his/her movement and, in particular, inform the user about movements of which he/she may not otherwise be aware, so that the user can correct his/her position.

[0037] Figures 3a and 3b illustrate, by way of example, a preferred trend of the volume V and frequency F of the stereophonic sound depending on AP accelerations, whilst Figure 3c illustrates a preferred trend of the volume V for ML accelerations to the right R and to the left L by the user 2.

[0038] Again by way of example, Figure 3d illustrates balancing B of the stereophonic sound between the right and left earphones 12 and 13 according to ML accelerations by the user 2.

[0039] The maximum volume is generated by the maximum torso accelerations, whether they are AP or ML.

[0040] As schematically illustrated in Figure 2, in the case of forward movements the frequency F of the sound increases, whilst in the case of backward oscillations the frequency F of the sound is reduced.

[0041] It should be observed that an acceleration by the user 2 to the right R causes an increase in the volume in the right VR earphone 12, whilst an acceleration to the left L causes an increase in the volume in the left VL earphone 13. In this way, the user 2 can recognise lateral accelerations by listening to the balance of the sound between the two earphones 12 and 13, right and left.

[0042] With reference to Figures 3a to 3d, to prevent excessive information feedback to the user 2, the device 1 may advantageously be programmned to consider the existence of a reference region RR, with amplitude between a value RR_0 and a value RR_1, about the natural posture of the body of the user 2, in which small swaying movements in the torso are completely normal even in perfectly healthy people.

[0043] Indeed, maintenance of the erect position is normally the result of a combination of accelerations according to a plurality of angles and directions.

[0044] The region RR is used as a reference for generation of the feedback signal and is expressed in terms of AP and ML accelerations.

[0045] The amplitude of the region RR depends, for example, on the anthropometry of the user 2 and may be defined according to his/her height with a substantially known inverted pendulum model.

[0046] With reference to Figure 2, it may be seen that a safety region SR is also defined, its amplitude between a value SR_0 and a value SR_1, depending, in accordance with substantially known methods, on the dimensions of the feet 18 of the user 2.

[0047] The limits of the safety region SR represent the maximum travel of the body of the user 2 before the projection of his/her centre of mass leaves a support base formed by the feet 18.

[0048] In the region RR the processing system 9 generates a sound, for example, with a frequency value F equal to f_0=400Hz and a predetermined volume value V in both earphones 12 and 13.

[0049] By way of example, a set of equations designed to define the frequency F and volume V of the feedback signal are shown below.

[0050] With reference to Figures 3a and 3c, the volume V of the sound may be planned and regulated with a sigmoid law of this type:

$$Volume = \frac{Vl \times A_i^{\,k}}{A_i^{\,k} + m^k} + c$$

where A_i is the acceleration measured along two axes (i=AP, ML), k=3 for a forward A oscillation, k=2.5 for a backward P or mediolateral oscillation, m=3, $V1$=0.5 and c is a constant offset which fixes the minimum volume V of the sound.

[0051] With reference to Figure 3b, the frequency F of the sound for anteroposterior AP accelerations may be planned and regulated, for example between 150 Hz and 1000 Hz, with a linear sectional law of this type:

$$f = \begin{cases} 250\dfrac{A_{AP} - SR_0}{RR_0 - SR_0} + 150 & for\ A_{AP} \in [SR_0, RR_0] \\ f_0 & for\ A_{AP} \in RR \\ 600\dfrac{A_{AP} - RR_1}{SR_1 - RR_1} + 400 & for\ A_{AP} \in [RR_1, SR_1] \end{cases}$$

[0052] With reference to Figure 3d, balancing of the sound between the two earphones 12 and 13 may be regulated by increasing the volume relative to the side with the prevailing inclination using an exponential law:

$$\dot{w} = 1 - e^{-10d}$$

where d is the distance between the limits of the reference region RR and the limits of the safety region SR.

[0053] The volume in the right earphone 12 and the volume in the left earphone 13 may, therefore, be regulated with laws of this type:

$$VL = (1 + w)\,V$$

$$VR = (1 - w)V$$

[0054] In the case of oscillations close to the reference region RR, the value of w is set at 0.

[0055] Advantageously, in alternative embodiments which are not described, the volume V, frequency F and balancing of the sound are regulated by functions with a different equation and so a different form.

[0056] The invention brings important advantages.

[0057] The use of an audio signal as feedback for the device user guarantees its practical and simple use.

[0058] Advantageously, the device allows the acquisition of automatisms for keeping one's balance without any direct stimulation of the user's nervous system.

[0059] The device 1 can also be used by healthy individuals unaffected by particular pathologies, to prevent any postural errors in a non-invasive manner or to boost control or coordination of a part of the body, for example, with reference to a sporting technique.

[0060] The invention described is suitable for evident industrial applications and may be subject to modifications and variations without thereby departing from the inventive concept. Moreover, all of the details of the invention may be substituted by technically equivalent elements.

Claims

1. A device for conditioning the balance and motor coordination of a user (2), comprising:

- a system (3) for the acquisition of information relative to the kinematics of at least one part (4) of the body of the user (2),
- a processing system (9) connected to the acquisition system (3) for encoding the information in a stereophonic sound,
- means (17) of communication operating between the processing system (9) and the user (2), to provide the user (2) with the information, the processing system (9) comprising an electronic card (11) for modulating the frequency and volume of the stereophonic sound according to an anteroposterior oscillation of the part (4) of the body and for activating the means (17) of communication,

wherein the means (17) of communication comprise a first and a second sound transducer (15, 16),
the device being **characterised in that** the electronic card (11) is designed to balance the stereophonic sound between the first and the second sound transducers (15, 16) in such a way that the user (2) can recognise lateral accelerations by listening to the balance of the sound between the two sound transducers (15, 16).

2. The device according to claim 1, **characterised in that** the electronic card (11) is designed to modulate the volume of the stereophonic sound according to a mediolateral oscillation of the part (4) of the body.

3. The device according to claim 1 or 2, **characterised in that** the stereophonic sound is generated by said electronic card (11) and consists of two sound waves, and **in that** the electronic card (11) modulates the frequency and volume of the sound waves and balances the stereophonic sound between two audio channels, right and left, linked to respective earphones (12,13) which can be worn by the user (2) and each consisting of one of said sound transducers (15, 16), the electronic card (11) modulating the right and left channels independently of one another.

4. The device according to claim 4 1, **characterised in that** the first and the second sound transducers (15, 16) comprise a first and a second earphone (12, 13).

5. The device according to any of the previous claims, **characterised in that** the acquisition system (3) comprises at least one accelerometric sensor (5) attachable to the part (4) of the body.

6. The device according to claim 5, **characterised in that** the accelerometric sensor (5) is of the biaxial type.

7. The device according to claim 5, **characterised in that** the accelerometric sensor (5) is of the triaxial type.

8. The device according to any of the claims from 1 to 7, **characterised in that** the part (4) of the body comprises the torso of the user (2).

9. The device according to any of the claims from 1 to 8, **characterised in that** the acquisition system (3), the processing system (9) and the means (17) of communication can be worn by the user (2).

10. A method for conditioning balance and motor co-ordination of a user, comprising the steps of:

- providing a device according to any of the previous claims, wherein the device comprises a left and a right earphone (12, 13) consisting of said first and second sound transducers (15, 16);
- making a user (2) wear said earphones at the ears, in such a way that the user (2) can recognise lateral accelerations by listening to the balance of the sound between the two earphones (12, 13).

Patentansprüche

1. Vorrichtung zur Konditionierung des Gleichgewichts und der Bewegungskoordination eines Benutzers (2), Folgendes beinhaltend:

- ein System (3) zur Erfassung von Informationen bezüglich der Kinematik zumindest eines Körperteils (4) des Benutzers (2),
- ein Verarbeitungssystem (9), das mit dem Erfassungssystem (3) verbunden ist und dazu dient, die Information in einen Stereoton zu kodieren,
- Kommunikationseinrichtungen (17), die zwischen dem Verarbeitungssystem (9) und dem Benutzer (2) wirksam sind, um dem Benutzer (2) die Information bereitzustellen, das Verarbeitungssystem (9) das eine Elektronikkarte (11) zur Modulation der Frequenz und der Lautstärke des Stereotons entsprechend einer anterior-posterioren Schwankung des Körperteils (4) und zur Aktivierung die Kommunikationseinrichtungen (17) beinhaltet,

worin die Kommunikationseinrichtungen (17) einen ersten und einen zweiten Schallwandler (15, 16) beinhalten, wobei die Vorrichtung **dadurch gekennzeichnet ist, dass** die Elektronikkarte (11) dafür ausgelegt ist, den Stereoton zwischen dem ersten und dem zweiten Schallwandler (15, 16) derart auszubalancieren, dass der Benutzer (2) laterale Beschleunigungen durch Hören der Balance des Klangs zwischen den zwei Schallwandlern (15, 16) erkennen kann.

2. Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** die Elektronikkarte (11) dafür ausgelegt ist, die Lautstärke des Stereotons entsprechend einer mediolateralen Schwankung des Körperteils (4) zu modulieren.

3. Vorrichtung nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** der Stereoton durch die genannte Elektronikkarte (11) erzeugt wird und aus zwei Schallwellen besteht, und dass die Elektronikkarte (11) die Frequenz und die Lautstärke der Schallwellen moduliert und den Stereoton zwischen zwei Audiokanälen, einem rechten und einem linken, ausbalanciert, die mit entsprechenden Ohrhörern (12, 13) verbunden sind, die der Benutzer (2) tragen kann und jeweils aus einem der genannten Schallwandler (15, 16) bestehen, wobei die Elektronikkarte (11) den rechten und den linken Kanal unabhängig voneinander moduliert.

4. Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** der erste und der zweite Schallwandler (15, 16) einen ersten und einen zweiten Ohrhörer (12, 13) beinhalten.

5. Vorrichtung nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das Erfassungssystem (3) zumindest einen Beschleunigungsmesssensor (5) beinhaltet, der an dem Körperteil (4) angebracht werden kann.

6. Vorrichtung nach Anspruch 5, **dadurch gekennzeichnet, dass** der Beschleunigungsmesssensor (5) ein Drei-Achsen-Beschleunigungsaufnehmer ist.

7. Vorrichtung nach Anspruch 5, **dadurch gekennzeichnet, dass** der Beschleunigungsmesssensor (5) ein Zwei-Achsen-Beschleunigungsaufnehmer ist.

8. Vorrichtung nach einem der Ansprüche von 1 bis 7, **dadurch gekennzeichnet, dass** der Körperteil (4) den Rumpf des Benutzers (2) beinhaltet.

9. Vorrichtung nach einem der Ansprüche von 1 bis 8, **dadurch gekennzeichnet, dass** das Erfassungssystem (3), das Verarbeitungssystem (9) und die Kommunikationseinrichtungen (17) vom Benutzer (2) getragen werden können.

10. Verfahren zur Konditionierung des Gleichgewichts und der Bewegungskoordination eines Benutzers, folgende Schritte beinhaltend:

- Bereitstellen einer Vorrichtung nach einem der vorhergehenden Ansprüche,

worin die Vorrichtung einen linken und einen rechten Ohrhörer (12, 13) beinhaltet, die jeweils aus dem ersten bzw. dem zweiten Schallwandler (15, 16) bestehen;

- Anlegen der Ohrhörer an den Ohren des Benutzers (2), damit diese so getragen werden, dass der Benutzer (2) laterale Beschleunigungen durch das Anhören der Klangbalance zwischen den zwei Ohrhörern (12, 13) erkennen kann.

Revendications

1. Un dispositif pour conditionner l'équilibre et la coordination motrice d'un utilisateur (2), comprenant :

- un système (3) pour l'acquisition d'informations relatives à la cinématique d'au moins une partie (4) du corps de l'utilisateur (2),
- un système de traitement (9) relié au système d'acquisition (3) pour encoder les informations sous forme d'un son stéréophonique,
- moyens (17) de communication agissant entre le système de traitement (9) et l'utilisateur (2), pour fournir à l'utilisateur (2) lesdites informations, le système de traitement (9) comprenant une carte électronique (11) destinée à moduler la fréquence et le volume dudit son stéréophonique en fonction d'une oscillation antéropostérieure de la partie (4) du corps et à activer les moyens (17) de communication,

où les moyens (17) de communication comprennent un premier et un deuxième transducteur sonore (15, 16), le dispositif étant **caractérisé en ce que** la carte électronique (11) est destinée à équilibrer le son stéréophonique entre les premier et deuxième transducteurs sonores (15, 16) de manière à ce que l'utilisateur (2) puisse reconnaître des accélérations latérales en écoutant l'équilibre du son entre les deux transducteurs sonores (15, 16).

2. La dispositif selon la revendication 1, **caractérisé en ce que** la carte électronique (11) est destinée à moduler le volume du son stéréophonique en fonction d'une oscillation médio-latérale de la partie (4) du corps.

3. Le dispositif selon la revendication 1 ou 2, **caractérisé en ce que** le son stéréophonique est généré par ladite carte électronique (11) et consiste en deux ondes sonores, et **en ce que** la carte électronique (11) module la fréquence et le volume des ondes sonores et équilibre le son stéréophonique entre deux canaux audio, droit et gauche, reliés à des écouteurs (12, 13) respectifs qui peuvent être portés par l'utilisateur (2) et constitués chacun par un desdits transducteurs sonores (15, 16), la carte électronique (11) modulant les canaux droit et gauche indépendamment l'un de l'autre.

4. Le dispositif selon la revendication 1, **caractérisé en ce que** les premier et deuxième transducteurs sonores (15, 16) comprennent un premier et un deuxième écouteur (12, 13).

5. Le dispositif selon l'une quelconque des revendications précédentes, **caractérisé en ce que** le système d'acquisition (3) comprend au moins un capteur accélérométrique (5) pouvant être associé à la partie (4) du corps.

6. Le dispositif selon la revendication 5, **caractérisé en ce que** le capteur accélérométrique (5) est de type biaxial.

7. Le dispositif selon la revendication 5, **caractérisé en ce que** le capteur accélérométrique (5) est de type tri-axial.

8. Le dispositif selon l'une quelconque des revendications de 1 à 7, **caractérisé en ce que** la partie (4) du corps comprend le torse de l'utilisateur (2).

9. Le dispositif selon l'une quelconque des revendications de 1 à 8, **caractérisé en ce que** le système d'acquisition

(3), le système de traitement (9) et les moyens (17) de communication peuvent être portés par l'utilisateur (2).

10. Un procédé pour conditionner l'équilibre et la coordination motrice d'un utilisateur, comprenant les phases consistant à :

- prévoir un dispositif selon l'une quelconque des revendications précédentes, où le dispositif comprend des écouteurs gauche et droit (12, 13) constitués par lesdits premier et deuxième transducteurs sonores (15, 16) ;
- faire porter à un utilisateur (2) lesdits écouteurs au niveau des oreilles, de manière à ce que l'utilisateur (2) puisse reconnaître des accélérations latérales en écoutant l'équilibre du son entre les deux écouteurs (12, 13).

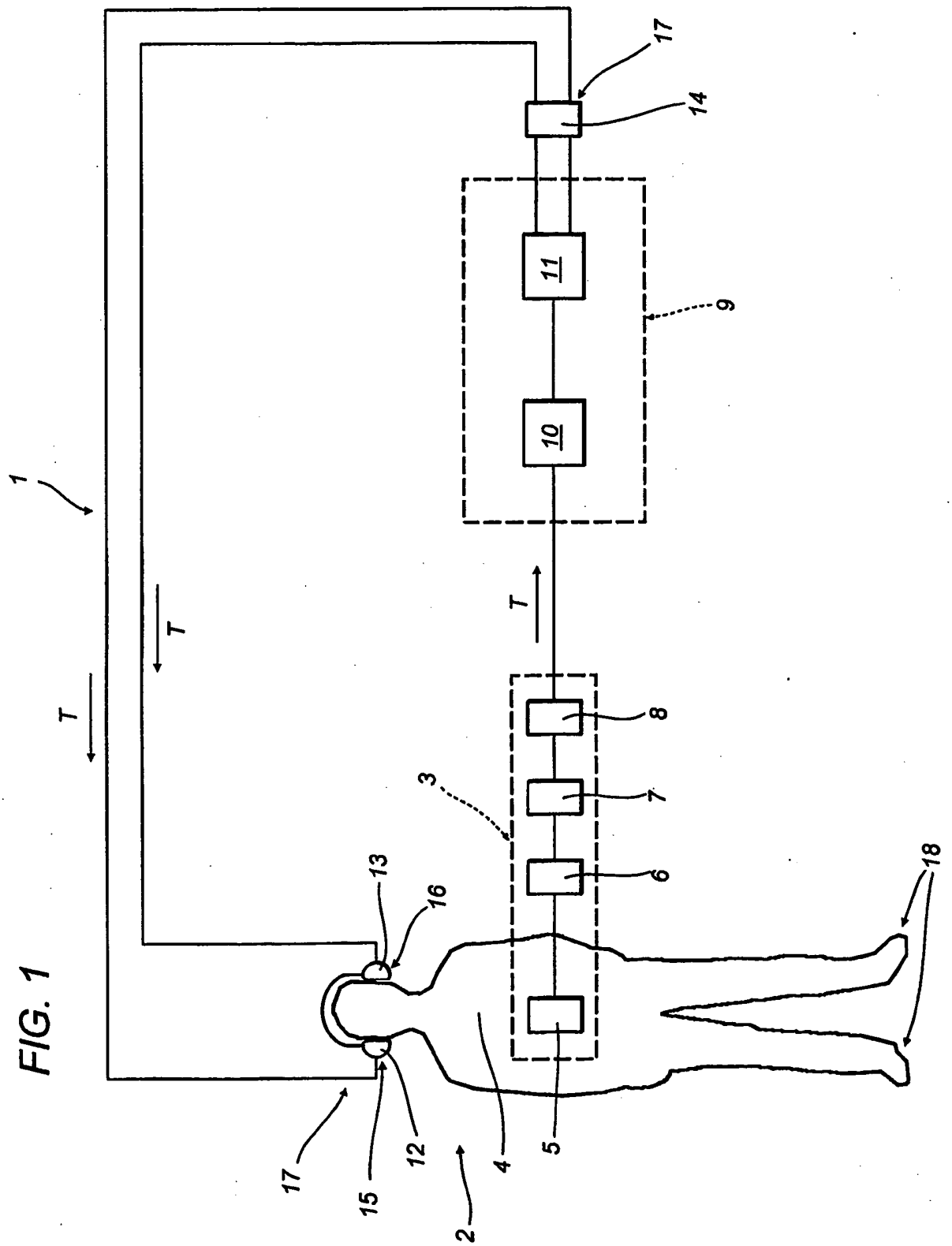
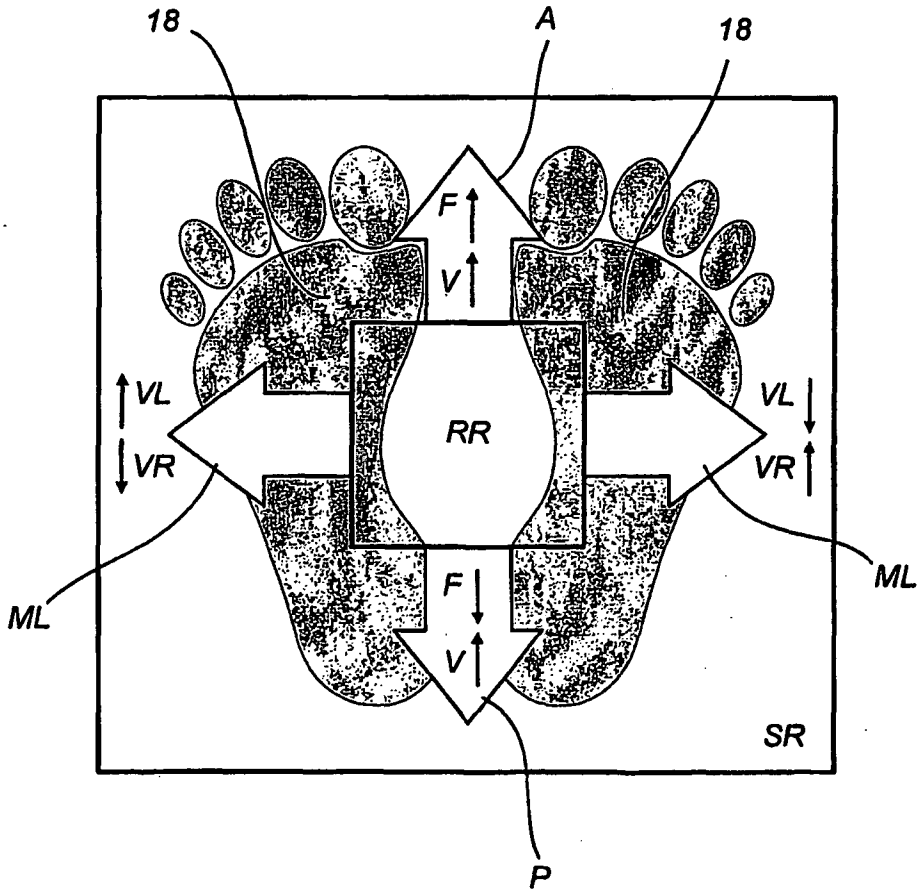


FIG. 1

FIG. 2



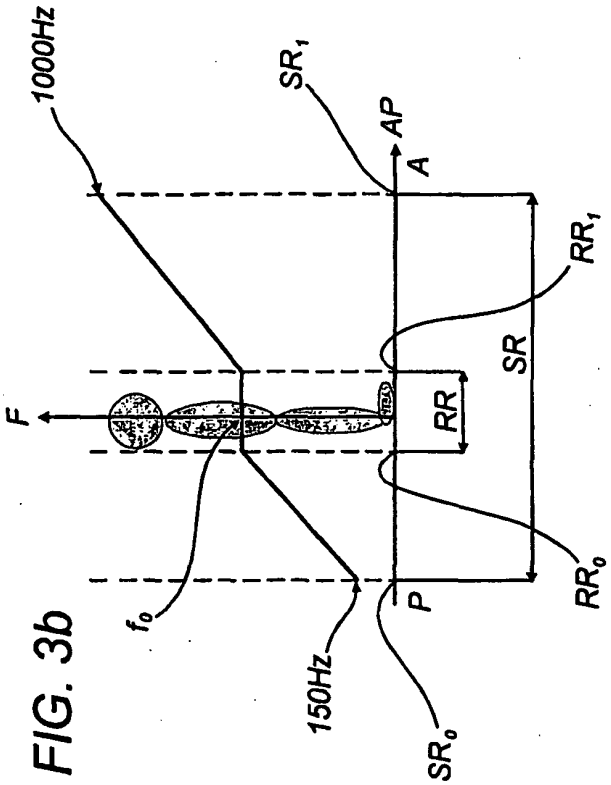


FIG. 3b

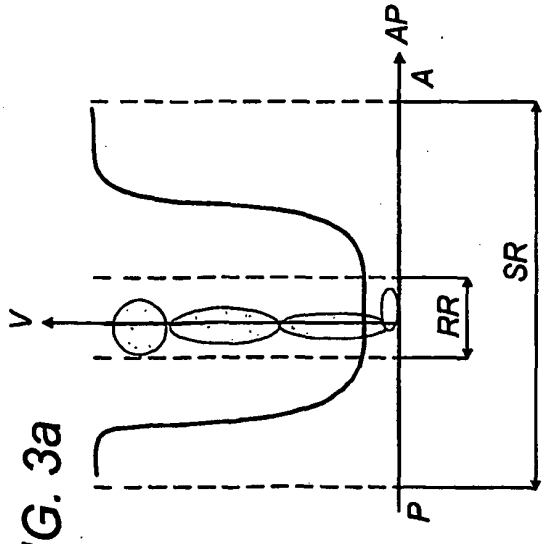


FIG. 3a

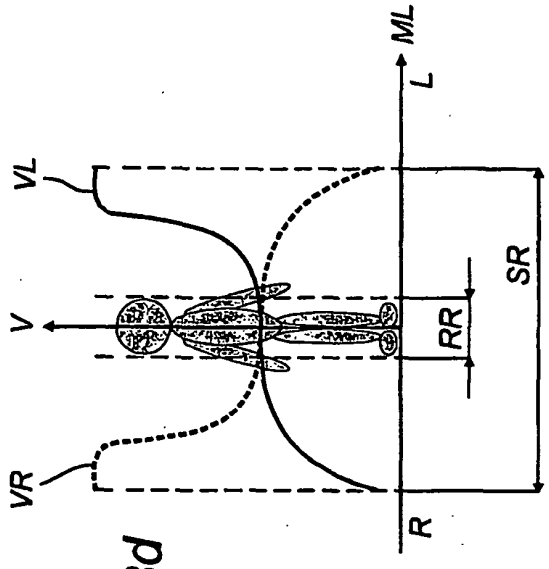


FIG. 3d

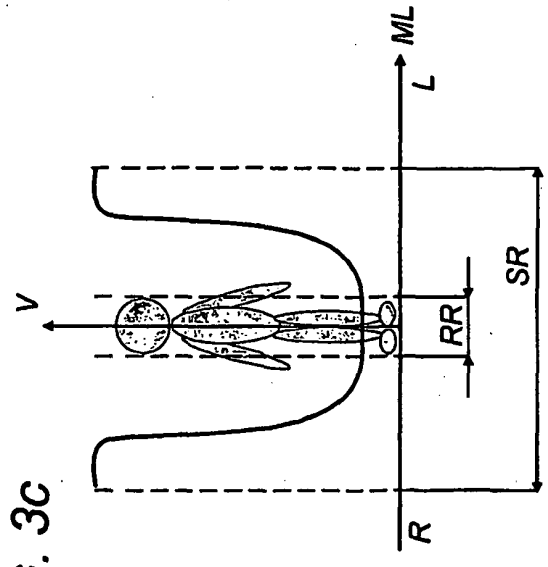


FIG. 3c

REFERENCES CITED IN THE DESCRIPTION

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- US 6546291 B **[0009]**
- US 5694340 A **[0010]**

专利名称(译)	一种用于调节平衡和运动协调的装置		
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当前申请(专利权)人(译)	母校STUDIORUM -UNIVERSITA“博洛尼亚 俄勒冈健康科学大学		
[标]发明人	CHIARI LORENZO HORAK FAY B CAPPELLO ANGELO DOZZA MARCO		
发明人	CHIARI, LORENZO HORAK, FAY, B. CAPPELLO, ANGELO DOZZA, MARCO		
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摘要(译)

用于调节用户（2）的平衡和马达协调的装置包括用于获取与用户（2）的身体的至少一个部分（4）的运动学相关的信息的系统（3），处理接口（9）连接到采集系统（3）以编码信号中的信息，一对耳机（12,13）在处理接口（9）和用户（2）之间操作，以向用户馈送信号由可以在音频信道中传输的立体声声音适当地定义。