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Technical note

Towards the enhancement of body standing balance recovery by means of a wireless audio-biofeedback system

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ABSTRACT

Human maintain their body balance by sensorimotor controls mainly based on information gathered from vision, proprioception and vestibular systems. When there is a lack of information, caused by pathologies, diseases or aging, the subject may fall. In this context, we developed a system to augment information gathering, providing the subject with warning audio-feedback signals related to his/her equilibrium. The system comprises an inertial measurement unit (IMU), a data processing unit, a headphone audio device and a software application. The IMU is a low-weight, small-size wireless instrument that, body-back located between the L2 and L5 lumbar vertebrae, measures the subject's trunk kinematics. The application drives the data processing unit to feeding the headphone with electric signals related to the kinematic measures. Consequently, the user is audio-alerted, via headphone, of his/her own equilibrium, hearing a pleasant sound when in a stable equilibrium, or an increasing bothering sound when in an increasing unstable condition.

Tests were conducted on a group of six older subjects (59y-61y, SD = 2.09y) and a group of four young subjects (21y-26y, SD = 2.88y) to underline difference in effectiveness of the system, if any, related to the age of the users. For each subject, standing balance tests were performed in normal or altered conditions, such as, open or closed eyes, and on a solid or foam surface.

The system was evaluated in terms of usability, reliability, and effectiveness in improving the subject's balance in all conditions. As a result, the system successfully helped the subjects in reducing the body swaying within 10.65%-65.90%, differences depending on subjects' age and test conditions.

1. Introduction

The visual, the proprioception and the vestibular systems work to provide standing balance [1,2], so that when one or more of these systems are under sufferance (because of pathologies, diseases, or other reasons) balance capabilities can be reduce, even severely, in effectiveness.

The amount of reduction differs because of number/amount of the systems involved, and can be age-related (because of senescence).

Pathologies of the ear, brain, or sensory nerve can cause dizziness, which affects 47% of men and 61% of women over 70 years of age [3], causing the 25% of falls [4]. Fall-related injuries in older people are a major global health problem, and consequences of falling can psychological produce fear of falling again and depression, which can lead to social isolation [5]. A sedentary life style and drug usage can induce a slowdown of reflexes even in young people [4] (statistics not yet available).

When the sense of balance is reduced because of system issue(s), subjects tend to compensate by means of other systems, as it can be when information from the vestibular system increases in importance if the visual system is limited or absent. Key enabling technology (KET) can provide the subject with information no more or insufficiently supplied by the vestibular system [6–10].

Within this frame, here we propose an audio-biofeedback-based technology (ABF-T) as a KET useful to provide subjects with audio signals coded on the basis of his/her measured standing balance.

The ABF-T consists of wearable devices, or wearables, which are a belt-worn inertial measurement unit (IMU) plus a headphone, and desktop hardware, which comprises a data receiving station and a personal computer. In particular, the wearables are battery-powered low-weight, low-size, operator-independent, and low-cost

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