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Design of Reaction Time Measuring Device

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Abstract

At present, the concept of reaction time measurement is used as one of the methods of psychological testing. Its usage spectrum, however, covers rehabilitation medicine, neurosciences and similar. Available systems used to measure reaction time deal with complex reaction time, i.e. the time between generating the stimuli and respective reaction via effector. Typical limitation is the design of these devices, which usually fits specific application, but it is not reusable for other applications. The goal of this paper is to introduce concept of device measuring reaction time of both upper and lower limbs, to visual or acoustic stimuli. Design of the device allows for application independence, i.e. it is reusable for wide range of different applications. This independence is supported by open software platform, including base set of testing tasks. In case of measurement of upper limb reaction time, the device allows measurement of individual components of the reaction time, opening new capabilities for deeper understanding of human sensory systems with respect to the speed of reaction to external stimuli.
KEY WORDS: *device, measurement, myopotentials, reaction time*

1. Introduction

Recording of reaction time is one of important methods of cognitive and experimental psychology. Reaction time evaluation found use in many applications, where except for experimental science and medicine, it is also used as an indicator during selection of candidates for pilots, drivers, security staff etc. [1].

From the perspective of reaction time measurement, the so-called complex (overall) reaction time RT_T, is obtained, which is calculated as the sum of perception time t_P and muscle response time t_M. Decision time t_D is then covered in the total reaction time. If the used device can record time t_D independently, the overall reaction time can be expressed as:

$$RT_T = t_P + t_D + t_M. \quad (1)$$

The most frequently used RT_T and associated tasks are the so-called Simple Response Time (SRT) task and Choice Response Time (CRT) task. SRT measurement is based on tasks where reaction time to single stimuli is monitored. In case of visual or acoustic stimuli, the subject react to only this one stimuli. By contrast, CRT measurement is based on the principle of multiple stimuli, where each requires exactly one reaction. From this follows that SRT and CRT are different, where reaction to simple stimuli is by nature faster as in case of CRT [2]. Nevertheless, both the times are used to describe cognitive capabilities of individuals or monitored group, whether together or separately, depending on specific scientific question.

In case of measurement of these times by single device, it is possible to directly compare the times within one or multiple studies. However, in most cases it is not possible to perform exact inter-study comparison with respect to the variability of measured values, caused by usage of various measurement concepts, non-uniform tasks, different hardware solutions and others.

In general, available devices utilize principle of reaction time measurement to specified stimuli. With respect to this, these devices are oriented to specific domain and it is not possible to use them for measurement to other, more complex or specific tasks [3]. Reaction time evaluation is based on device hardware components, i.e. dependent on fabrication of the very device. Most devices and measurement concepts are, consequently, able to measure only overall reaction time. Similarly, these devices and measurement principles (mostly software solutions) are measuring RT_T with considerable variability. This is because mostly the RT_T components are not recorded but only RT_T as a whole. The most significant variability can be introduced by t_M, which depends for example on reference position of limb as the effector. In fact, there are numerous devices based on pushing buttons but the limb reference position is not considered thus the distance from target sensor may change, eventually changing the time of motor reaction, e.g. [5, 6]. This way, it is also not possible to detect other RT_T components. The situation is similar with respect to other SW-based concepts [4], which use for example monitoring of response to visual stimuli by mouse, where the actual cursor position may, again, introduce measurement error.

Among the studies it is then often difficult to distinguish which type of reaction time is measured and what are its components. At present, there are devices eliminating the above mentioned limitations to significant extent, but these are mostly costly and allow measurement based on available task set.

To precisely measure reaction time, this paper introduces a concept of device capable to measure individual components of complex reaction time, serving primarily for performance and psychological testing of subjects, but suitable for wide range of applications.

2. Materials and Methods

Based on the defined limitations, base concept of device for measuring reaction time was proposed. The device was proposed to measure user's reaction to external optoacoustic stimuli, i.e. to determine time needed to evaluate stimuli with engagement of specific motor units to perform required movement. The proposed concept can, unlike typical reaction time measurement devices, deduce change in the decision making process, introduction new variable into the measurement process. This property is ensured by continuous monitoring of limb position during the measurement. Apart from measuring reaction time or change in decision making, the device was also proposed to indirectly measure efferent pathway.

A. Design Solution

Device design considers user's ergonomic requirements, simulating control elements of a means of transport. The device consists of two main parts. To measure reaction time of upper limb to optic and acoustic stimuli, USB Button box with sliding touch plates is used (Fig. 1), measurement of feedback from lower limb to optic stimuli are recorded by pedals (Fig. 2).

Fig. 1 Device visualization as USB box decomposition with sliding touch plates. *1* - touch plates; *2* - numeric keyboard; *3* - electromyographic measurement unit; *4* - frame; *5* - cover; *6* - buttons; *7* - control unit; *8* - button cover; *9* - connection element; *10* - micro switches; *11* - LED strips.

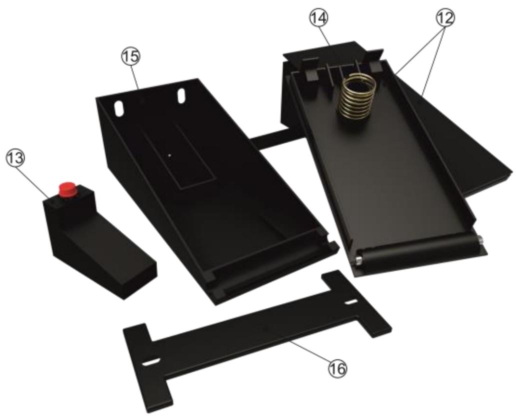

Fig. 2 Pedals decomposition. *12* - pedals; *13* - sliding block; *14* - pushing spring; *15* - device cover; *16* - connecting slat.

The main construction elements of the box are device body and sliding part, containing two touch plates *1*, numeric keyboard *2* and electromyographic measurement unit *3*. Device body consists of frame *4*, transparent upper case *5*, three illuminated buttons *6* and electronic control unit *7* (Fig. 1).

Each button consists of dome-shaped transparent cover *8* and connection element *9* with one RGB diode located in its center. The purpose of the element is mechanical connection of button cover with four micro switches *10* build into the device frame (Fig. 1). The reason for suing such excessive amount of micro switches is to increase overall button resistance force from 2.5 to 10 N and to prevent no switching in cases where the acting force on the button is not orthogonal to the button surface. The micro switches are connected in parallel. There are two advantages of this connection. The first is increase in device reliability, i.e. if any of the switches stops working, its measurement function is replaced by the next switch in the connection. The second indisputable advantage is improvement in the measurement device quality. It is enough to gently push the button to switch and the control unit evaluates that as logical one, i.e. response to external stimuli.

The device frame includes, apart from three sets of micro switches, also the same amount of 12V LED RGB strip sets *11* (Fig. 1), buzzer and command and control unit Arduino Mega. LED strips are to allow optically independent three color fields located on the upper transparent cover with high diffraction property. The division of the cover into color fields as well as individual illumination of the buttons enables testing of subjects independently from external source of optical stimuli. Because the USB port of control unit does not support higher input power needed for LED strips, it was necessary to use 12V direct current transformer as additional energy source. The connection between the source, control unit and LED strip was realized by N-Mosfet. The protection of control unit was proposed by 5V optocouplers for cases of N-Mosfet failure. If the control unit needs to light the LED strip, it sends 5V signal from digital output to optocoupler, where the optic element excites light ray to photosensitive component, opening the input for signal into Mosfet and, secondarily, opening 12V source for LED strips. This way, penetration in the other way from 12V source to control unit is avoided.

Touch plates are, similar to buttons, attached to sliding part of the device via set of four micro switches located at the edges of respective plate. Due to ergonomic reasons, the front edge of a plate has rounded design. The plates are made from transparent material, also illuminated by set of RGB LED strips. The task of the plates is to determine position of upper limb before sending visual stimuli, to which the reaction time is measured. Plates' illumination informs the subject whether the measurement device recognizes limb position in default phase before the next measurement. Between the touch plates there is numerical keyboard and two electromyographic measurement units build into the main cover.

The device to measure reaction time of lower limb contains two pedals, each for one limb. The pedals *12* (Fig. 2) in neutral position are 20° to horizontal line. The construction of the pedals accounts for different limb weight of various measured subjects. The element to set resistance force against the weight of lower limb in neutral position is the sliding block *13* (Fig. 2).

To increase the resistance, the block slides by pushing matrix, reducing the length of pushing spring *14* attached to pedal body, increasing the resistance of the device. In opposite case, by releasing the pushing matrix, the block slides into its previous position by the pressure of the spring relying on the pedal body. The pedal will never exceed maximum allowed angle due to securing geometry of the body – the device cover *15*. In the sliding block, there is micro switch build in to record change in pedal angle within the range of 2.5°. To protect the sensors, there are stop geometries created between the frame and pedal. The connection between left and right pedal into single peace is assured by connecting slats *16*.

B. Software and experimental task setup

Microprocessor and graphical user interface (GUI) comprise the device software part, both programmed in C\#. Microprocessor uses program, which captures individual hardware components, defines their logic and the very measurement of reaction time. The program waits for delivery of an input from GUI. The GUI and microprocessor communicate via serial communication channel implemented by the means of USB 3.0.

Because the microcontroller Arduino Mega used in the presented system has no integrated real time clock, it was necessary to set it up. The necessity of this step stems from the fact, that in case of accurate reaction time measurement it is important to consider hardware processing time of system requests, data transfer speed and similar. Time synchronization (i.e. time setup on the microprocessor) was implemented so that immediately after connection of the device to PC and opening of serial USB port, system time is sent through communication interface to microprocessor to eliminate transfer delay.

It is possible to exemplify the principle of reaction time measurement with this device on software, which generates five color patterns in five areas of a monitor. Exactly one pattern produces the necessity of motor reaction with exactly one upper or lower limb.

After the check of correct placement of upper limbs on reference areas, a task is generated which, at the same time, marks start of measurement (S, start), where the reference time is set to 0 ms (see Fig. 3). In case of visual tasks, time t_P is eliminated, as the subject perceives the tasks immediately after its generation. Between the start of measurement and upper limb reaction (HW, hand response), time t_D is measured. The interval between raising the hand from reference area and pushing the button (PB, push button) is marked as t_M. This time depends, besides other things, on the arm trajectory. Variability related to adjusting the limb was eliminated by monitoring reference position of the hand. After pushing the button, the hand returns, i.e. adjusts back to reference area (HP, hand positioning). After the detection of correct hand position, new task is generate within the interval of 2 – 5 seconds. Start of new task in random time was used to minimize learning process that could occur if there was fixed time interval between HP – S phases. User defined number of process repetitions takes place between test start (B, beginning) and its end (E, end).

In case of lower limb reaction measurement, both limbs are placed on the pedals. After task generation, where response of lower limb is expected, the goal is to press respective pedal. In this case, complex reaction time is measured, i.e. time from task generation until motor reaction by effector.

The above-described concept and task type was used for experimental verification of device functionality and identification of its limitations. The described software solution is not limiting and new task types can be included as per the purpose of the measurement.

3. Device Functionality Verification

Device functionality verification was performed on series of experimental measurements, from which follow the next findings.

From EMG signal on Fig. 3 it is apparent, that muscle activity is provable before releasing the hand from reference plate. From this point of view, description of activity between muscle activation and plate release is difficult. If the subject is determined about task solution, this time interval should be in narrow range of values and its size would reflect only physical condition of measured subject. However, it is possible that, at some times, muscles are activated even though the subject hesitates about task solution and his or her hand stays on reference surface for longer time, or the limb is not raised (see Fig. 4). Based on EMG signal, therefore, it is not possible to decide about the boundary between t_D and t_M. Considering that, raising the hand from reference surface is monitored. From this point until pushing the button, time t_M is measured. The measured EMG signal can then serve the post-hoc analysis to deepen the understanding of reaction time.

In case of lower limbs, with respect to the absence of reference areas, it is not possible to decide on the boundary between t_D and t_M. For this purpose, EMG signal record of both lower limbs is used, which allows the determination of approximate boundary between individual times.

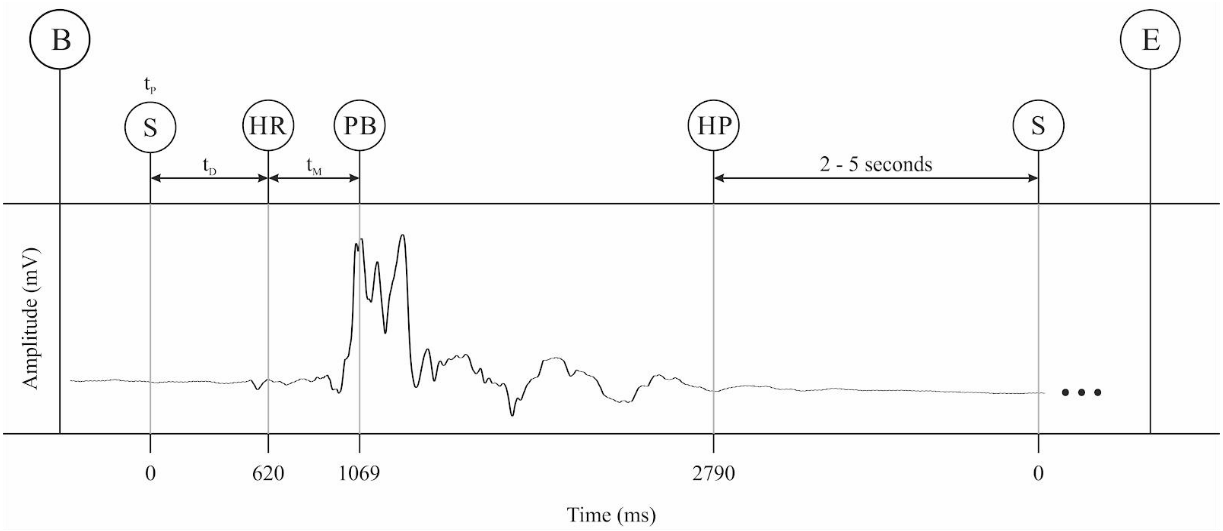

Fig. 3 Example of performed measurement with EMG signal demonstration and description of individual task phases from the perspective of upper limb measurement of reaction time. Phases B and E mark the beginning and end of measurement, phase S marks start of the task, phase HR shows hand reaction, phase PB marks pushing the button, phase HP shows hand return into initial position, i.e. adjusting the hand into reference position.

Considering the above mentioned limitation, the boundary is only approximate but it allows indicative insight into the issue of decision making – reaction in case of lower limb.

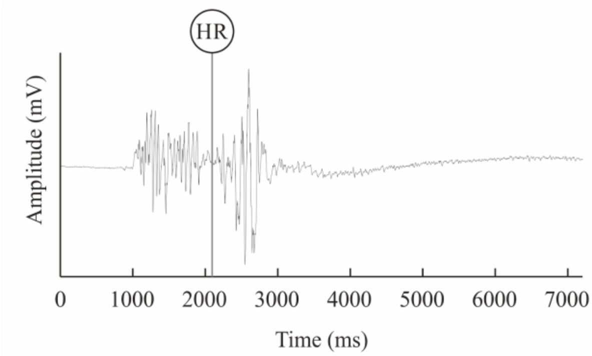

Fig. 4 Example of muscle activity measurement by the means of EMG record. During muscle activation, reaction of upper limb is marked (HR), i.e. the time when the subject raised his or her hand from the plate

4. Conclusions

The system for reaction time measurement is, according to the presented technical solution, able to detect motoric activity of upper and lower limb in response to visual or acoustic stimuli. The system is intended for measurement of complex reaction times during performance of psychological testing of subjects.

The research oriented to measure reaction time, i.e. the study of human reaction speed, is applied especially in the domain of transport (both ground and air) with the goal to reduce transport accident rate. In the aviation, in particular with respect to the character of the industry staff, there are high requirements placed on the personnel [6]. The demanding character requires new tools and procedures, which could assure selection of suitable candidates, capable of adequate reactions to emerging situation whilst carrying out their daily tasks. The proposed concept of device, which allows exploration of human sensory system via reaction to external stimuli, can serve these transport applications, but due to the combination of both upper and lower limb monitoring and the open software platform, the device is no limited to any particular application. The device is suitable for other medical applications requiring accurate measurement of reaction time, such as in neurology or rehabilitation.

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