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VIBRATORY EVOKED POTENTIALS

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The sense of vibration forms a part of proprioceptive sense and difficulties related to the sense of vibration are frequent indicators of neurological disorders. In classical clinical practice the sense of vibration is typically examined using a vibratory fork. The vibratory fork does not provide quantitative information about the sense of vibration, obtained information is subjective and the method is not applicable to people suffering from disorders of consciousness and little children [1]. Apart from the classical vibratory fork that vibrates at only one frequency, there is a quantitative vibratory fork, Rydel-Seiffer tuning fork, which uses special extensions to adjust the frequency from 64 Hz to 128 Hz [2, 3, and 4]. Both types of vibratory forks provide only subjective information about the sense of vibration so it is not possible to perform longitudinal monitoring of changes of the sense of vibration. The sense of vibration is also tested using quantitative sensory testing (QST). The technique is based on the examination of the sense of vibration and heat on the skin, however, it depends on the cooperation and the subjective assessment of examinee and there is no uniform interpretation of obtained results among research groups [5, 6, and 7]. Aforementioned methods have unstandardised parameters of examination and depend on the active cooperation and the subjective assessment of examinee so it is necessary to standardise the method for examining the sense of vibration to obtain quantitative information suitable for further analysis.

In addition, aforementioned methods do not provide information about the functional integrity of the whole vibratory sensory pathway. The application of vibratory stimulators, used in neurophysiological testing, was therefore introduced [8]. Neurophysiological testing is based on recording the electrical activity of the brain, which can be spontaneous (electroencephalogram – EEG) or it can reflect a response to a certain stimulus (evoked potentials). The evoked potentials method has a broad applicability in medicine and in various scientific fields. It is used to assess somatosensory and motor pathways as well as higher cognitive functions. The method itself is completely noninvasive and is independent of educational and cultural influences [9].

The research performed using vibratory stimulators utilised various parameters of stimuli (stimulus duration, stimulus frequency, site of stimulation). Stimulating the muscles of forearm using stimuli of different frequencies (40 Hz, 80 Hz, 160 Hz), Münte evoked the first component 50 ms after the start of the stimulus [10]. Hämäläinen et al. investigated the stimulation of middle finger using pulses with low (24 Hz) and high (240 Hz) frequency and also registered the first evoked response as a positive peak emerging 45 ms after the start of the stimulus, with the activity localised in the contralateral primary sensory cortex [11].

In order to reach diagnosis in many systematic and neurological disorders, it is important to examine the functional integrity of the whole vibratory sensory pathway, from sensors in the skin, mechanoreceptors, up to sensory cortical regions, where information about peripheral and early cortical components is especially important. Research conducted so far resulted principally in later cortical components (around 50 ms); however, none of the studies provided information about peripheral and early cortical components.

Somatosensory evoked potentials are evoked potentials elicited using electrical stimuli, which excite sensory pathways that are anatomically almost identical to vibratory sensory pathways. They are used in everyday clinical practice and they show clearly recognisable peripheral and early cortical components. Therefore, there is a question why vibratory evoked potentials are unable to register peripheral and early cortical components and trace the activity along the whole vibratory sensory pathway.

The evoked potentials method is based on the fact that the average value of electrical activity of the brain that is elicited by repetitive stimuli is equal to the activity that emerges as a response to a single stimulus, but only if all stimuli are identical (by ignoring the influence of noise). Knowing the fact that vibratory receptors generate action potentials that are synchronous to the vibratory stimulation, it is doubtful why the induced activity cannot be registered along the whole sensory pathway, as it is the case with somatosensory evoked potentials, where even the earliest components can be easily and uniquely registered. Moreover, the response of mechanoreceptors responsible for the sense of vibration depends on the parameters of stimulation and the same stimulus should generate the same evoked response [12, 13]. All mentioned leads to the conclusion that the problem of registering the activity elicited by the vibratory stimulation along the whole vibratory sensory pathway occurs because repetitive vibratory stimuli do not have the same characteristics, which causes the inadaquate activation of vibratory receptors and the generation of action potentials with different characteristics. The inadequate activation of receptors causes asynchronous propagation of action potentials through the system and prevents the measurement of peripheral components and early cortical components of response. A late cortical response is actually the result of late cortical integration of information arriving asynchronously to the primary sensory cortex.

Vibratory stimulators which are primarily in usage have the constant amplitude of vibratory stimulus. This amplitude presents the amount of energy that is delivered to the tissue through the vibratory stimulus [8], but this is not an adequate measure since the geometrical relationship between the vibratory applicator and the tissue (examinee) is not constant. Due to this fact, even though the same amount of energy is delivered each time, the energy is not delivered entirely to the tissue and the amount of delivered energy depends on a mutual relationship between the applicator and the tissue. This causes the change in parameters between successive stimuli, and, because of the absence of identical stimuli, the unique evoked response cannot evolve. A Pacinian corpuscle, a mechanoreceptor sensitive to a vibratory stimulus, reacts to the component of pressure and is it necessary to construct a vibratory stimulator that enables the generation of successive vibratory stimuli with equal pressure characteristics of vibratory applicator.

Therefore, at the Faculty of Electrical Engineering and Computing of the University of Zagreb the vibratory stimulator was constructed, as shown in Figure 1. The main characteristic of the stimulator is maintaining the same pressure characteristics of vibratory applicator, instead of the constant amplitude of vibratory stimulus. This enables the generation of identical stimuli, with well-defined parameters, which can induce the appropriate evoked response of vibratory sensory pathway. The vibratory stimulator has very precisely defined parameters of stimuli. It is possible to choose between two waveforms (sinusoidal and triangular), to choose the frequency in the range between 30 and 300 Hz, to choose the duration of stimulus from 10 ms to 500 ms and to choose different amplitude/intensity of pressure.

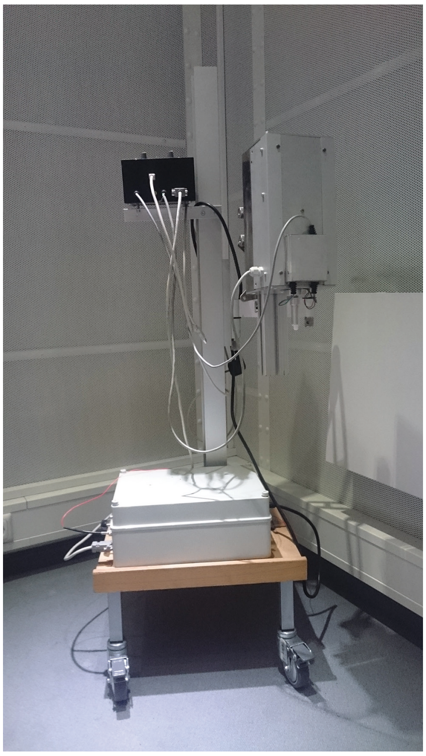

Fig. 1: Vibratory stimulator

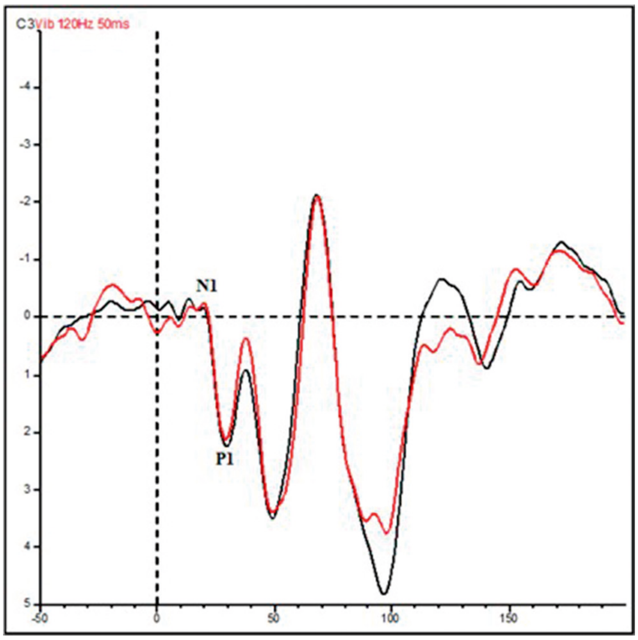

Fig. 2: Vibratory evoked potentials induced by stimulating a right hand with a vibratory stimulus

Measurements performed using the newly constructed vibratory stimulator in the Laboratory for Cognitive and Experimental Neurophysiology, the Department of Neurology, the University Hospital Centre Zagreb, have shown that for obtaining the reliable and repeatable response, which is shown in Figure 2, the stimulus with the following characteristics is necessary:

Stimulation frequency: 120 Hz

The electrical activity of the brain elicited by the vibratory stimulus with the frequency of 120 Hz shows the most resembling features as the already well known electrical activity of the brain elicited by electrical stimulation. The evoked response is composed of early components (N1, P1) and a late cortical component. When stimulating with the frequency of 120 Hz, several mechanoreceptors are active, mostly Pacinian corpuscles, with a contribution from Meissner's corpuscles, making the response to this frequency very pronounced, with the highest amplitude and with clearly distinguishable main components, and also the chosen frequency is in accordance with the available literature [14].

Stimulus duration: 50 ms

Comparing Figures 3.a and 3.b it can be seen that vibratory stimuli with the duration of 10 ms and 50 ms induce the main components of response with approximately the same latencies, so it is necessary to determine which of those durations results in a more sizeable response. It can be seen

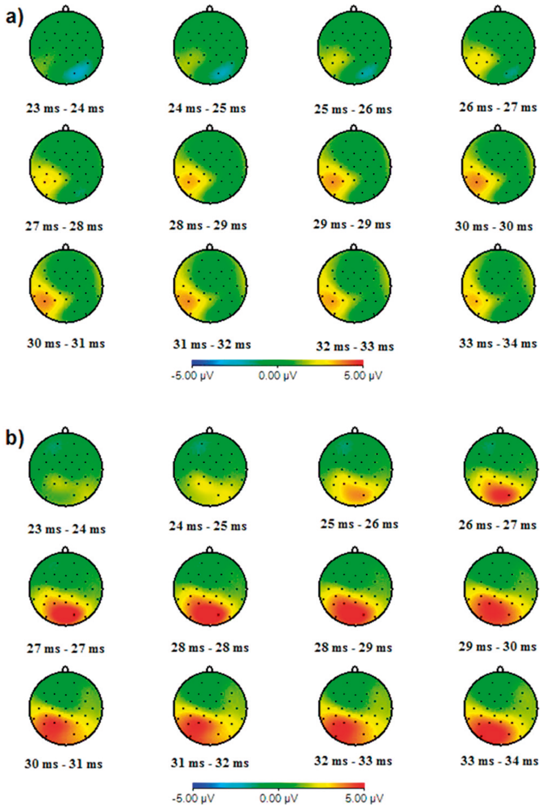

Fig. 3: Vibratory evoked potentials induced by vibratory stimulus with duration: a) 10 ms and b) 50 ms

that the vibratory stimulus with the duration of 50 ms induces the response of higher intensity, making the duration of 50 ms more eligible for further examination. The longer duration of stimulus ensures the longer exposure of the primary sensory cortex to information about the sense of vibration, which results in the stronger activation of the sensory cortex and in the stronger intensity of induced activity.

Site of stimulation: wrist

A hand has a broad representation in the somatotopic organization and a strong lateralization in the sensory region of the cortex. Wrist stimulation ensures a large enough stimulation area to activate the suitable number of Pacinian corpuscles, which have a small spatial density.

The evoked response induced by stimuli with aforementioned parameters can be uniquely registered using surface electrodes positioned above the appropriate sensory cortex. This confirms the efficiency of vibratory stimulation in the activation of vibratory sensory pathway for a particular hand and the capability of observing the functionality of vibratory sensory pathway using the evoked potentials method, which provides us with a noninvasive and quantitative insight, because the results of evoked potentials method are presented uniquely with measured values (latency, amplitude).

The existence of uniquely measured values of evoked response allows the quantitative longitudinal monitoring of examinee and also the comparison between different examinees, which was not possible so far due to lack of clearly defined and quantified early parameters of evoked response.

The presented method of vibratory stimulation is in the process of implementation into the everyday clinical practice, where it will contribute to the timely discovery and to monitoring the course of different neurological disorders.

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