Neurophysiologie Clinique/Clinical Neurophysiology (2009) **39**, 283—290

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ORIGINAL ARTICLE/ARTICLE ORIGINAL

Sensations and reaction times evoked by electrical sinusoidal stimulation

Types de sensations et temps de réaction à des stimuli sinusoïdaux

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Received 5 March 2009; accepted 25 October 2009
Available online 6 November 2009

KEYWORDS
Perception;
Reaction times;
Electric current;
Sensations;
Sensory fibers;
Pain

Summary
Objective. — To determine whether 5 Hz and 2000 Hz sinusoidal electric currents evoke different sensations and to indirectly evaluate which peripheral nerve fibers are stimulated by these different frequencies.
Methods. — One hundred and fifty subjects chose three among eight descriptors of sensations evoked by 5 Hz and 2000 Hz currents and the results were submitted to factor analysis. In 20 subjects, reaction times to 5, 250 and 2000 Hz currents were determined at 1.1x ST and reaction times to 5 Hz currents were also determined at 2x ST.
Results. — Responses were grouped in four factors: Factor 1, which loaded mainly in descriptors related to tweezers stimulation, was higher than the other factors during 2000 Hz stimulation at 1.5x ST. Factor 2, which loaded mainly in descriptors related to needle stimulation, was higher than the other factors during 5 Hz stimulation. Factor 1 increased and Factor 2 decreased with an increase in 5 Hz intensity from 1.5 to 4x ST. Reaction times measured from the fastest responses were significantly different: 0.57 s (0.16 to 1.60), 0.34 s (0.12 to 0.71) and 0.22 s (0.08 to 0.35) for 5, 250 and 2000 Hz, respectively, and 0.22 s (0.11 to 0.34) for 5 Hz at 2x ST.
Conclusions. — Sinusoidal electrical stimulation of 5 Hz and 2000 Hz evoke different sensations. At juxta-threshold intensities, RT measurements suggest that 2000 Hz stimulates Aβ-fibers, 250 Hz Aβ- or Aϑ-fibers, 5 Hz Aβ-, Aϑ- or C-fibers. The fiber type, which was initially stimulated by the lower frequencies, depended on inter-individual differences.

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doi:10.1016/j.neucli.2009.10.001

MOTS CLÉS
Perceptions ;
Temps de réaction ;
Courant électrique ;
Sensations ;
Fibres nerveuses sensitives

Résumé
Objectifs. — Déterminer si des stimulations au moyen de courants électriques sinusoïdaux à 5hz et 200 Hz évoquent différentes sensations et identifier quels types de fibres nerveuses périphériques sont stimulées par ces différentes fréquences.
Méthodes. — Cent cinquante sujets étaient invités à choisir trois parmi huit descripteurs des sensations évoquées par des courants de 5 Hz et 2000 Hz. Les résultats ont été soumis à une analyse factorielle. Chez 20 sujets, nous avons mesuré les temps de réaction à des courants de 5, 250 et 2000 hertz appliqués à 1,1 fois le seuil sensitif ainsi qu'aux courants de 5 Hz à deux fois le seuil sensitif.
Résultats. — Les réponses ont été regroupées en quatre facteurs : Le Facteur1, correspondant principalement à des sensations de pincement, était plus représenté que les autres facteurs pendant les stimulations à 200 Hz à 1,5 fois le seuil ; Le Facteur2, correspondant principalement à des sensations de piqûre, dominait les autres facteurs pour des stimulations à 5 Hz. L'importance du Facteur 1 augmentait et celle du Facteur2 diminuait lors d'une augmentation d'intensité des stimuli à 5 Hz de 1,5 fois à quatre fois le seuil. Les temps de réaction mesurés à partir des réponses les plus rapides étaient significativement différents : 0,57 s (0,16 à 1,60), 0,34 s (0,12 à 0,71) et 0,22 s (0,08 à 0,35) pour les réponses aux stimulations à 5, 250 et 2000 Hz respectivement et 0,22 s (0,11 à 0,34) lorsque des stimuli à 5 Hz étaient appliqués à deux fois le seuil.
Conclusions. — Des stimulations électriques sinusoïdales à 5 Hz et 2000 Hz évoquent différentes sensations. Pour des intensités juxtaliminaires, les temps de réaction suggèrent que les stimulations à 2000 Hz stimulent des fibres Aβ, à 250 Hz des fibres Aβ ou A∂, à 5 Hz des fibres Aβ, A∂ ou C. Le type de fibres initialement stimulées par les fréquences les plus faibles était variable d'un individu à l'autre.

Introduction

Peripheral nerves are composed of nervous fibers of different diameters, which can be stimulated by electrical currents applied to the skin. It is well-known that, especially for short pulse durations, electrical rectangular pulses of increasing intensities first stimulate thick, and then thin fibers [3,12,37]. This recruitment of sensory fibers has both sensory and perceptual consequences [7,33].

It was suggested that current perception threshold (CPT) to sinusoidal electrical currents of 5, 250 and 2000 Hz relates to stimulation of C, A∂- and Aβ-fibers, respectively [4]. However, the basis for this statement is not clear.

Both the evaluation of drug effects in normal subjects [17,18,30,36] and the effect of ischemia [2] are suggestive of the selective character of sinusoidal stimuli. Recently, a correlation was reported in normal subjects between thermal thresholds and 5 Hz stimulations, as well as between vibratory thresholds and 2000 Hz stimulations [19]. These findings are in keeping with some previous observations [20,22,27] but at odds [29,35], or just in partial agreement with others [6,25].

The same measurements in patients with peripheral neuropathies also gave variable results. While some authors found that 5 Hz stimuli could be useful in the evaluation of C-fibers [20,22,27], others found that it might not be the case [29,35]. In some of these reports, comments can be found on the sensations that were evoked by the stimuli, suggesting a correlation between 5 Hz stimuli and thin fiber system activation [6]. On the other hand, there seems to be some agreement that 2000 Hz stimuli activate the thick fiber system, although there is still debate on whether only the thick fiber system is stimulated [5,6,35].

The aim of our study is to determine what the relationships are between the frequency of sinusoidal stimulation and the types of sensory-nerve fibers that are stimulated. We first evaluated the relationship between percepts and stimulus frequency and tried to determine whether different sensations were evoked by 5 Hz and 2000 Hz sinusoidal currents. Second, we examined whether these percepts were coherent with the expectations on what fiber systems are stimulated. Third, we examined the effect of increasing the intensity of 5 Hz stimuli. Fourth, we measured the reaction times to the different frequencies as an indirect way to evaluate what types of fibers are stimulated. Preliminary observations based on part of this material were previously published [23,24,31].

Methods

General procedures

This project was approved by the Federal University of São Paulo's Ethic Committee and all volunteers signed an informed consent. Volunteers were recruited mainly among people from the University (students and health professionals) through personal contact with the involved researchers.

All experiments were conducted in a sound attenuated and at ambient temperature room ($23.7 \pm 1.9^{\circ}$C). Volunteers sat in a comfortable armchair with hands resting on the chair's arm. For stimulation, the distal phalanx of the left index finger was first cleaned with alcohol embedded gauze and then wiped with dry gauze. Stimulation was provided through gold electrodes that were applied to the medial and lateral surfaces of the phalanx with a thin amount of conductive gel. For Experiment II, two recording electrodes