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Communication

Peripheral tactile sensory perception of older adults improved using subsensory electrical noise stimulation

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ABSTRACT

Loss of tactile sensory function is common with aging and can lead to numbness and difficulty with balance and gait. In previous work we found that subsensory electrical noise stimulation (SENS) applied to the tibial nerve improved tactile perception in the soles of the feet of healthy adults. In this work we aimed to determine if SENS remained effective in an older adult population with significant levels of sensory loss.

Older adult subjects ($N=8$, female = 4, aged 65–80) had SENS applied via surface electrodes placed proximally to the medial and lateral malleoli. Vibration perception thresholds (VPTs) were assessed in six conditions, two control conditions (no SENS) and four SENS conditions (zero mean $\pm 15\,\mu$A, $30\,\mu$A, $45\,\mu$A and $60\,\mu$A SD). VPT was assessed at three sites on the plantar aspect of the foot.

Vibration perception was significantly improved in the presence of $\pm 30\,\mu$A SENS and by 16.2 ± 2.4% (mean ± s.e.m.) when optimised for each subject. The improvement in perception was similar across all VPT test sites.

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1. Introduction

Aging is associated with a gradual decline in sensory perception and is seen as a normal part of the aging process. Loss of peripheral sensory perception, defined as the presence of one or more complete bilateral peripheral neurologic deficits, has a prevalence of 26% for 65–74 year olds and 54% for those aged 85 and older [1]. Functionally, these peripheral sensory deficits are manifest as numbness in the extremities, restless legs, subjective trouble with gait and balance and reduced quality of life [1].

We previously presented a new mechanism for improving sensory perception [2,3]. We postulated that the application of subsensory electrical noise stimulation (SENS) to a peripheral nerve could promote greater synchronisation of action potentials and lead to improved sensitivity. We tested this hypothesis with a group of healthy younger adults with no sensory deficit. SENS was applied to the tibial nerve via two surface electrodes placed proximally to the medial and lateral malleoli. Mechanical vibration was then applied to the hallux (big toe) with increasing intensity until perceived by the subject. We found that vibration perception was improved by ~16% in this group.

In this paper we extend this research to determine if a similar perceptual enhancement may be achieved in a population with age related sensory deficit. Our primary hypothesis is that SENS will improve vibration perception of older adults with age related neuropathy, and secondly that this older group will experience a greater change in vibration perception in comparison to younger adults. Finally, we hypothesise that sensory enhancement is

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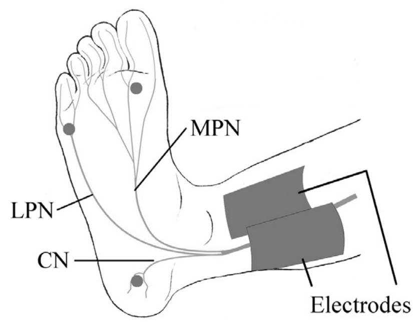

Fig. 1. Electrode placements, sites of SENS application and vibration testing sites with associated nerve branches (LPN: Lateral Plantar Nerve, MPN: Medial Plantar Nerve, CN: Calcaneal Nerve).

consistently and evenly distributed distal to the site of SENS application. As an unbalanced effect could be detrimental to the user, this is an important factor that may prohibit the use of this intervention as a treatment.

2. Materials and methods

2.1. Subjects

Eight adults aged > 65 (4 women and 4 men; age 73.3 ± 5.75 years [mean ± SD]) exhibiting clinically significant levels of neuropathy (VPT > 25 V [4]) were recruited to take part in this study. Exclusion criteria included a history of nerve damage, cardiovascular disease, seizures, falls, diabetes and presence of implants. Participants provided informed written consent to the procedures, which were approved by the NUI Galway Research Ethics Committee.

2.2. Electrical noise stimulation

Electrical noise stimulation was applied as previously [2,5,6] via two UltraStim (Nidd Valley Medical Limited, Bordon, UK) surface electrodes (5 cm × 10 cm) placed proximally to the medial and lateral malleoli (Fig. 1). The constant-current stimulus was generated using a LabVIEW program, (National Instruments Corporation, Austin, Texas, USA) digital-to-analogue converter and custom voltage-to-current conversion circuitry.

2.3. Vibration perception threshold

Vibration was applied using a Horwell Neurothesiometer (Scientific Laboratory Supplies Limited, East Riding Yorkshire, UK), a clinical tool that vibrates at a constant frequency of 50 Hz. With the vibrating head of the Neurothesiometer applied to the skin, vibration amplitude is manually increased from zero until first perceived by the subject. This point is known as the vibration perception threshold (VPT) and is expressed in volts by convention (where 1 V equates to a 5 µm displacement).

2.4. Experimental procedure

Initially, SENS was applied with gradually increasing amplitude until perceived by the subject, or until the maximum intensity planned for the study had been reached (zero mean ± 60 µA SD).

The main experiment used six test conditions - two control conditions, where SENS was not applied, and four SENS conditions with different amplitude (zero mean ± 15, 30, 45 and 60 µA SD).

To test the hypothesis that all distal neural traffic is affected by SENS, three anatomical sites were chosen for VPT measurement as they are served by three distinct branches of the tibial nerve (Fig. 1). The sites identified and their relative tibial nerve branches were the 1st Metatarsophalangeal Joint (MTPJ) and Medial Plantar Nerve; 5th MTPJ and the Lateral Plantar Nerve; and the centre of the Calcaneus and the Calcaneal Nerve.

One investigator selected the control/SENS condition and a second investigator performed vibration perception testing. Both the investigator using the Neurothesiometer and subject were blind to the control/SENS level. VPT measurements were repeated three times for each of the six control/SENS conditions. Testing condition order (control/SENS) was randomly selected, as was the order of VPT test site.

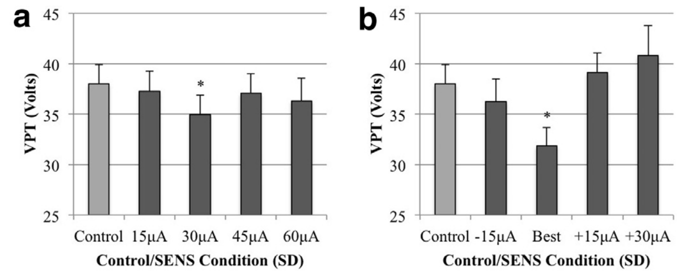

Fig. 2. Vibration perception thresholds (VPT) with and without the addition of SENS. (a) Comparison of control and SENS conditions across the entire foot of all subjects and (b) when optimised. (Error bars are s.e.m., $*p < 0.05$).

2.5. Statistical analysis

All statistics were calculated using SPSS v.17 (IBM, Armonk, New York, USA). Control conditions were initially compared using an ANOVA to determine the repeatability of VPT testing. VPT results were tested for order effects using a two-tailed Pearson correlation. VPT during the application of SENS was compared to control conditions using repeated-measures ANOVA. Repeated-measures ANOVA compared changes in perception at the different VPT test sites.

3. Results

3.1. Perception of SENS

At the commencement of the experiment SENS was applied with increasing amplitude to the maximum level used in the study (± 60 µA). None of the subjects perceived the application of SENS at any amplitude level or reported any sensation at the electrode sites over the course of the study.

3.2. Repeatability and order effect

No difference was found between VPTs recorded in both control zero SENS conditions ($p = 0.861$). The order of Control/SENS presentation had no effect on VPT measures ($p > 0.05$ at all test sites).

3.3. Effect of SENS on VPT

The average VPT for the entire foot was significantly lower than control conditions with the application of SENS across all amplitudes ($p = 0.022$), and also at 30 µA alone (Fig. 2a). While all sites experienced improved perception with 30 µA SENS, this only reached significance at the calcaneus ($p = 0.045$, Fig. 3). No significant difference was found in the effect of SENS at the different VPT test sites when 30 µA SENS was applied ($p = 0.967$). All participants had an improved average VPT (i.e. across all test sites) with the application of SENS for at least one noise level.

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