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Vibrating socks to improve gait in Parkinson's disease

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In patients with Parkinson's disease (PD), treatment of walking problems – and in particular freezing of gait (FOG) – can be very challenging [1]. Most patients continue to experience debilitating gait impairments despite optimal pharmacotherapy. Non-pharmacological interventions, such as external cueing, are therefore recognized as an element of the management of gait impairments in PD [1]. External cues that act as temporal or spatial stimuli can help to shift from automatic control of gait towards goal-directed control of walking, thereby bypassing the defective basal ganglia circuitry. Visual and auditory external cues have been studied extensively, and different ambulatory cueing devices have been developed in recent years [2]. Despite their effectiveness, some patients emphasize being reluctant to use 'visible' cueing devices such as laser-shoes (for visual cueing) or even earplugs (for rhythmic auditory cueing) because of the associated stigma. Additionally, salient visual or auditory cues may interfere with situational awareness, potentially creating hazardous situations [3]. Hence, there is a clear need for a more discrete, safe and effective cueing method.

Tactile cueing has great potential in this respect because – in contrast to auditory or visual cueing – bystanders cannot notice it. Prior studies showed positive effects when rhythmic tactile cues were applied to the arm, yielding improvements of step length and turning speed [3–5]. We hypothesized that tactile cueing applied to the feet might be even more effective in improving walking, because it could directly help to pace the act of stepping exactly there where the steps are being generated. We therefore developed a prototype of 'vibrating socks' that use a flat vibratory motor to provide a modest rhythmic vibration medially at the arch underneath the patient's feet. This vibration is alternating between both feet, with a frequency that can be adjusted to a speed that is most convenient for the patient. Using an external control and radio receiver, the signal is transmitted in an open-loop manner. All hardware is held in place using an elastic bandage, which can be comfortably worn within the patient's regular shoes. Fig. 1 depicts this self-developed prototype.

As a proof of concept, a case study was performed in a 67-year old man with PD (Hoehn & Yahr stage 3). He presented with marked gait impairments, including FOG, which were partially resistant to dopaminergic medication. With limited success, he used both visual and auditory external cues in daily life to improve his functional mobility. We evaluated the vibrating socks in the dopaminergic OFF state (after 12 hours withdrawal of dopaminergic medication). As shown in video 1 of the Supplementary material, the vibrating socks improved his gait performance significantly. The intake of dopaminergic medication was only resumed after finishing the gait tests. Both video fragments were captured with a time difference of 10 minutes in between. Therefore, the influence of the levodopa cycle of action and associated fluctuations are considered negligible. Without the tactile cues, gait was severely hypokinetic with short, shuffling steps and episodes of FOG. Gait performance improved with tactile cueing, using a frequency range of 100–120 vibrations/minute. An appropriate frequency was determined in consultation with the patient and adjusted as tests progressed to accommodate for fatigue. Improvement by the vibrating socks was objectively verified using the timed-up and go test (4 minutes and 59 seconds when vibration was switched off, 19 seconds when vibration was switched on) and the 10 m walking test (this improved from an average of 5 minutes and 51 seconds–12 seconds upon using the device). Using a 7-point scale, the patient ranked gait as highly improved and the user friendliness of the prototype as very convenient.

This case study indicates the potential of external cueing using vibrating socks as a feasible tool for gait rehabilitation in PD patients. Obviously, structured evaluation in a larger cohort is necessary.

Overall, these results indicate that external cueing using vibrating socks could be a feasible tool for gait rehabilitation in PD patients, with the ultimate goal of an enhanced quality of life. Patients with sensory impairments, i.e. due to sensory neuropathy, are expected to experience no benefit from using this cueing methodology. For these patients applying the stimuli to another body part (i.e. the knee or upper limb) might be a solution. Although the patient was specifically asked to forgo any conscious use of compensatory strategies, we cannot rule out the effect of other compensatory strategies on gait performance in this case study. We have started an extended study that focuses on determining how many patients can improve using this method and to evaluate how long any effects can be maintained. Additionally, it will be interesting to see if this tactile cueing method can also afford relief in FOG patients who fail to respond to other cueing modalities.

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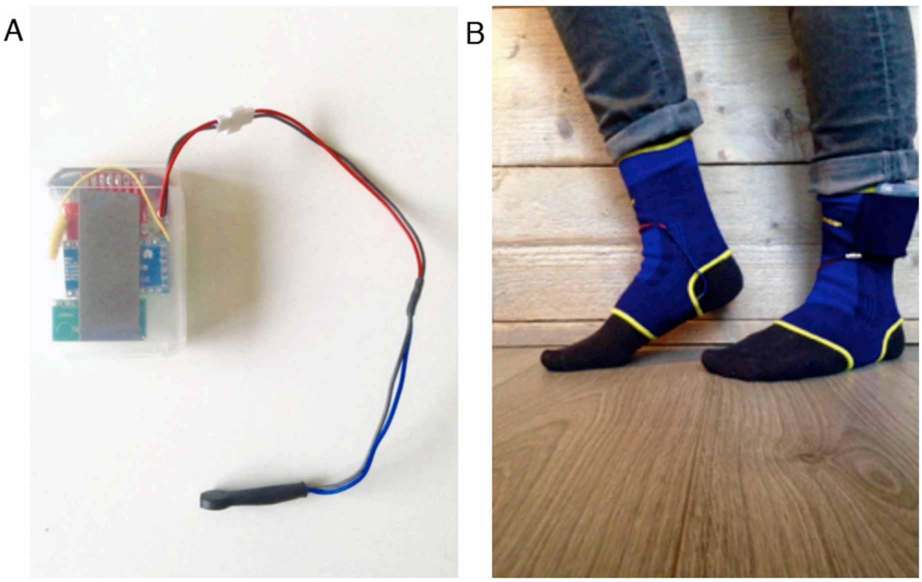

Fig. 1. The vibrating sock for tactile cueing. A: Hardware used for the device. The microcontroller board, radio receiver and motor controller are packaged in a plastic holder, leading up to the flat vibration motor. B: Practical application of the tactile cueing device to the patient's feet, using the elastic bandage to affix the necessary hardware safely.

Declaration of competing interest

Prof. Bloem currently serves as Associate Editor for the Journal of Parkinson's disease, serves on the editorial of Practical Neurology and Digital Biomarkers, has received honoraria from serving on the scientific advisory board for Abbvie, Biogen, UCB and Walk with Path, has received fees for speaking at conferences from AbbVie, Zambon, Roche, GE Healthcare and Bial, and has received research support from the Netherlands Organization for Scientific Research, the Michael J Fox Foundation, UCB, Abbvie, the Stichting Parkinson Fonds, the Hersenstichting Nederland, the Parkinson's Foundation, Verily Life Sciences, Horizon 2020, the Topsector Life Sciences and Health, and the Parkinson Vereniging. All other reports no disclosures.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.parkreldis.2019.10.021.

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