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Tremor and Other Hyperkinetic Movements

Brief Reports

# Virtual Reality Feedback Cues for Improvement of Gait in Patients with Parkinson's Disease

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## Abstract

**Background:** Our aim was to study the effects of visual feedback cues, responding dynamically to patient's self-motion and provided through a portable see-through virtual reality apparatus, on the walking abilities of patients with Parkinson's disease.

**Methods:** Twenty patients participated. On-line and residual effects on walking speed and stride length were measured.

**Results:** Attaching the visual feedback device to the patient with the display turned off showed a negligible effect of about 2%. With the display turned on, 56% of the patients improved either their walking speed, or their stride length, or both, by over 20%. After device removal, and waiting for 15 minutes, the patients were instructed to walk again: 68% of the patients showed over 20% improvement in either walking speed or stride length or both. One week after participating in the first test, 36% of the patients showed over 20% improvement in baseline performance with respect to the previous test. Some of the patients reported that they still walked on the tiles in their minds.

**Discussion:** Improvements in walking abilities were measured in patients with Parkinson's disease using virtual reality visual feedback cues. Residual effects suggest the examination of this approach in a comprehensive therapy program.

**Keywords:** Parkinson's disease, gait disorders, visual cues, virtual reality

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## Introduction

People with Parkinson's disease (PD) typically show a combination of rest tremor, rigidity, hypokinesia, and postural instability. As the disease progresses, gait is affected, resulting in decreased stride length and walking speed. Levodopa and dopamine agonists, particularly effective in early stages of the disease, lose efficacy with disease progression. Recent functional neurosurgery studies demonstrate beneficial effects of pallidotomy and subthalamic nucleus (STN) stimulation on motor symptoms in PD.[1,2] Studies on the effects of STN stimulation on gait have shown improvement ranging from 36% to 68% on the Unified Parkinson's Disease Rating Scale gait sub-score scale.[3–5] A common non-pharmacological approach to treating gait difficulties in PD is physical therapy. This used to be the principal treatment modality prior to the levodopa era and was renewed when the responsiveness to medications was found to decrease with time.[6–8] However, due to conflicting results concerning the efficacy of physical therapy,[9,10] there is not yet consensus as to whether it should be routinely prescribed within a rehabilitation program for patients with PD.[9–12]

Neurophysiological studies have suggested that internal cue production is defective in PD patients.[13–15] On the other hand, several studies have demonstrated that external stimuli, such as auditory, visual, and cutaneous cues, enhance gait performance in such patients.[16–21] It has been hypothesized that external sensory cues help patients with PD switch from one movement component of a sequence to the next, bypassing the defective internal trigger from the pallidum to the supplementary motor area.[22,23]

Early devices for providing external stimuli employed open-loop strategies that imposed a sensory signal on the patient, generated by an external source, which is not affected by the patient's own motion, such as fixed-velocity (treadmill-like) visual cues.[24,25] A study of the closed-loop effects of real-world visual cues on the regulation and stabilization of gait[26] has led to the development of a portable feedback control augmented reality apparatus that displays a virtual tiled floor responding dynamically to the patient's self-movement. In a previous preliminary study on patients with PD taken off their medications[27] we found that the closed-loop device improved gait in these patients beyond the effects of the open-loop version, which was found to cause frustration, and even freezing of gait, in some of the patients. Gait improvement was also found in patients with multiple sclerosis using the same device.[28] The purpose of the present study was to investigate the on-line and residual effects of the closed-loop apparatus on patients with PD on their regular medication schedule.

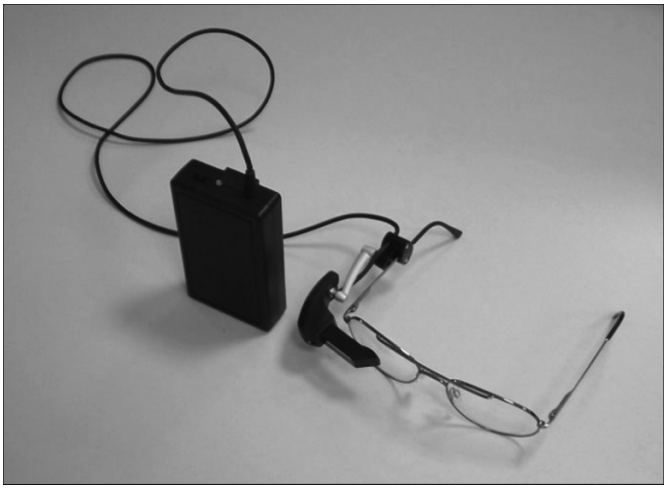

Figure 1. **Visual-feedback Virtual Reality Device Used in Tests.**

## Methods

### *Subjects*

Twenty-seven patients were recruited, but only 20 patients completed the study; 15 men and five women, average age 71.25 years, mean disease duration 5.28 years, and Hoehn–Yahr[29] range 2.5–4 participated in the study. Participants were on their regular anti-parkinsonian medication. Patients with considerable visual deficit not compensated by correction, ocular movement dysfunction, and gait disturbances due to neuromuscular diseases were excluded. Disease-related disability was assessed using the Hoehn and Yahr scale. All patients provided signed informed consent, and the local Ethics Committee approved the study according to the Helsinki agreement.

### *Assessment of ambulation*

Assessment of patient ambulation was based on walking speed (m/second) and stride length (m), calculated directly from measurements of time and number of steps needed to complete a fixed straight track of 10 m.

### *Virtual reality apparatus*

Visual cues were generated by a belt-mounted unit, housing motion sensors and digital processing components, and delivered by a micro-display (Figure 1). The display, attached to the eyeglasses frame, provides the patient with a virtual tiled floor in a checkerboard arrangement, responding dynamically to the patient's own motion, meaning that the patient has the ability to dynamically change walking skills and quality in response to external cues; much like walking on a real floor, fixed in space. The small size of the display and the see-through feature of its enclosure ensure that the field of view is effectively unobstructed.

### *Procedure*

All tests were performed at the Carmel Medical Center, Haifa, Israel, between September 2010 and December 2011 at about the same time in the afternoon. Examination comprised five stages, each consisting of the patient walking a straight track of 10 m: baseline, online display off, online display on, residual effects, and examination. At each stage, the length of time to complete the 10-m track and the number of steps were recorded four times and averaged. At the start of each stage, the patient was instructed to "walk normally", so as to reduce motivational factor.

Stage 1: Walking without the device for measurements of baseline performance.

Stage 2: Walking with the device placed on the patient, but with the display turned off, in order to measure the pre-conditioning effect.

Stage 3: Walking with the display turned on in order to produce and measure the on-line effect of the virtual tiled floor. Patients were instructed to "walk on the virtual tiles", using their imagination in trying to "reach for the next tile" with each of their feet. No further restrictions, regarding stepping on tiles of specific color or not stepping on tile edges were imposed or suggested.

Stage 4: Walking without the device after a 15-minute break, in order to measure the short-term residual effect of the visual feedback cues.

Stage 5: Re-evaluation of baseline performance without the device 1 week after the first examination, in order to measure the long-term residual effect of the visual feedback cues.

Wilcoxon's signed rank test was used to compare between speed and stride length at each stage compared to baseline speed and stride length levels, respectively. Also Pearson correlation tests were used to correlate between the Hoehn–Yahr scale and both speed and stride length separately.

## Results

The clinical test results are given in Table 1.

With the device mounted on, but the display turned off, the patients showed 1.75% ($p$=0.126) improvement in walking speed and 2.61% improvement ($p$=0.073) in stride length, on average, with respect to the baseline performance. These changes represent a negligible

Table 1. Test Results for Patients with PD: Walking Speed (m/second), and Stride Length (m)

| Patient | | | | Baseline | | Display Off | | Display On | | 15-min Residual | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Age/Sex | DD | H–Y | Speed | Stride Length | Speed | Stride Length | Speed | Stride Length | Speed | Stride Length |
| 1 | 80 M | 10 | 3.5 | 0.782 | 0.500 | 0.752 | 0.488 | 0.790 | 0.677 | 0.867 | 0.533 |
| 2 | 75 F | 3 | 2.5 | 0.669 | 0.408 | 0.628 | 0.400 | 0.627 | 0.400 | 0.747 | 0.435 |
| 3 | 77 M | 3 | 3 | 0.848 | 0.476 | 0.816 | 0.465 | 0.954 | 0.541 | 1.059 | 0.588 |
| 4 | 61 M | 1 | 3 | 1.066 | 0.526 | 1.071 | 0.526 | 1.310 | 0.625 | 1.147 | 0.571 |
| 5 | 79 F | 19 | 3.5 | 0.680 | 0.408 | 0.686 | 0.400 | 0.618 | 0.444 | 0.735 | 0.426 |
| 6 | 83 M | 5 | 2.5 | 0.675 | 0.426 | 0.746 | 0.444 | 0.606 | 0.454 | 0.815 | 0.454 |
| 7 | 67 M | 10 | 3 | 1.229 | 0.645 | 1.368 | 0.694 | 1.426 | 0.769 | 1.530 | 0.741 |
| 8 | 60 M | 1 | 3 | 1.100 | 0.606 | 0.980 | 0.555 | 1.373 | 0.769 | 1.238 | 0.667 |
| 9 | 53 F | 3 | 3 | 1.074 | 0.625 | 1.161 | 0.645 | 1.100 | 0.588 | 1.314 | 0.645 |
| 10 | 62 M | 5 | 3 | 1.291 | 0.645 | 1.316 | 0.667 | 1.356 | 0.667 | 1.517 | 0.741 |
| 11 | 68 M | 9 | 3 | 0.980 | 0.513 | 1.021 | 0.526 | 1.358 | 0.714 | 1.285 | 0.588 |
| 12 | 80 M | 4 | 2.5 | 0.829 | 0.500 | 0.933 | 0.526 | 1.151 | 0.588 | 1.033 | 0.571 |
| 13 | 78 F | 5 | 2.5 | 0.602 | 0.417 | 0.694 | 0.435 | 0.752 | 0.454 | 0.849 | 0.500 |
| 14 | 77 M | 5 | 2.5 | 0.818 | 0.513 | 0.946 | 0.556 | 1.063 | 0.645 | 1.104 | 0.588 |
| 15 | 73 M | 1 | 3 | 0.539 | 0.308 | 0.591 | 0.339 | 0.808 | 0.476 | 0.873 | 0.500 |
| 16 | 70 M | 3.5 | 3.5 | 0.370 | 0.200 | 0.232 | 0.150 | 0.380 | 0.208 | 0.375 | 0.227 |
| 17 | 61 F | 7 | 2.5 | 0.422 | 0.323 | 0.460 | 0.333 | 0.439 | 0.333 | 0.440 | 0.345 |
| 18 | 74 M | 5 | 3 | 0.154 | 0.376 | 0.133 | 0.427 | 0.294 | 0.343 | 0.282 | 0.374 |
| 19 | 72 M | 5 | 3.5 | 0.027 | 0.028 | 0.022 | 0.026 | 0.020 | 0.025 | 0.033 | 0.030 |
| 20 | 75 M | 1 | 4 | 0.389 | 0.263 | 0.486 | 0.357 | 0.525 | 0.408 | 0.479 | 0.357 |
| Mean | 71.25[1] | 5.27 | 3.0 | 0.727 | 0.435 | 0.752 | 0.448 | 0.847 | 0.506 | 0.886 | 0.494 |
| *p* Value | | | | | | 0.126[2] | 0.073[3] | 0.002[2] | 0.002[3] | 0.000[2] | 0.000[3] |

DD: Disease Duration (years); H–Y: Hoehn–Yahr Staging; PD: Parkinson's Disease.
"Display off" columns present walking speed and stride length results for patients wearing the device with the display turned off. "Display on" columns show on-line performance results with the display turned on. "15-min Residual" columns present performance results after a 15-minute break, when patients walked freely with the device taken off.
[1]Mean age.
[2]Compared to baseline speed.
[3]Compared to baseline stride length.

"placebo" effect. Turning the display on, there was a significant improvement in both walking speed ($p$=0.002) and stride length ($p$=0.002) compared to baseline, where 65% of the patients improved either their walking speed or their stride length or both by over 10%, and 55% of the patients showed over 20% improvement. Following the 15-minute break, there was still a significant improvement in walking speed ($p$=0.000) and stride length ($p$=0.000), compared to baseline, where 85% of the patients showed over 10% improvement

and 65% showed over 20% improvement in either walking speed or stride length or both, without the device. The differences between residual and on-line performance can be attributed to burdening and learning effects associated with using the device for the first time, and are expected to diminish with further training. There was no significant correlation between Hoehn–Yahr scale at enrollment and either walking speed change ($p$=0.446) or stride length change ($p$=0.685) at the different stages.

One week after participating in the first test (where the patient used the device for approximately 20 minutes), 11 of the patients returned for another "baseline" test. Of these patients, 64% showed over 10% improvement and 36% showed over 20% improvement in their baseline performance. Two of the patients reported that, a week later, they still walked on the virtual tiles in their minds.

## Discussion

In this study we found that the on-line visual feedback-induced improvement in the walking abilities of patients on their regular medication schedule (56% of the patients showing over 20% improvement in either walking speed or stride length) is similar to that found in our previous study[27] on patients taken off their medication for 12 hours (57% of the patients improving by over 20%). Furthermore, the present study shows that, following virtual reality (VR) training, PD patients experience a sustained improvement in their walking abilities. This finding is in line with a recent case study, showing a sustained improvement in a single subject following 1-month training with visual cues placed on the ground.[30]

Patients' medications were unchanged during the study and subjects were individually examined with the VR device for walking performance on a unified planned time-table. Stages 1–4 of the measurements were taken in one clinical visit, and whole improvement results were related to the baseline, which was also carried out with the medication unchanged during the same visit. The last stage of measurement was 1 week after, without changes in medications. So the entire improvement was most probably attributed to the device.

The fact that PD patients on a regular medication schedule, trained with a visual feedback VR device for less than 20 minutes, have a persistent significant improvement in both stride length and walking speed with only a slight decline is particularly encouraging. Some patients described it as a sensation of walking on the tiles in their mind. This interesting "learning process" can be supported by animal model studies suggesting that basal ganglia provide an internal non-specific cue to trigger movements and imply that PD involves a deficiency in this cueing.[13] However, PD patients typically rely upon external visual cues.[16] It is possible that such external cues perpetuate imprinting of an internal cue, forming a "cue memory" that helps to maintain certain motor skills.

Using the VR device, walking on a flat surface aims to provide the patients with a simple training tool to improve motor skills, first by walking on ground, as evaluated in this study. However, similar training on a larger scale might also have an effect on postural stability and on more complex walking tasks, such as performing accurate strides before and during turning or avoiding stumbling on obstacles. The effect of VR training on freezing of gait in PD should also be interesting to look at, mainly because freezing responds poorly to medication. These aspects should be investigated further.

Since PD is a chronic progressive disease, we suggest that the visual feedback VR technique should be examined as a long-term procedure in addition to physical therapy to maintain gait and postural performances in PD patients.

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