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Augmented Reality and Parkinson's Disease

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Parkinson's Disease (PD) is a movement disorder associated with untimely deterioration of neurons in the motor control areas of the brain (primarily the basal ganglia). Akinesia, or freezing gait, is a common symptom of PD. It is characterized by a progressive shortening of stride length, and eventually the total inability to initiate and sustain ambulation. This is one of the most debilitating symptoms of the disease, usually resulting in greatly reduced social and physical activity.

Parkinson's symptoms are most commonly treated pharmacologically with variants of L-dopa, a chemical precursor of the neurotransmitter dopamine. L-dopa treatment can be quite effective for overcoming akinesia, but it typically has at least two undesirable characteristics: (1) its effects are widely variable throughout the course of the day (the "on/off" response), and (2) over time increasingly more severe dyskinesia (exaggerated, uncontrollable movement) may result, often to the point of being as difficult to manage as the akinesia itself, and sometimes resulting in profound weight loss due to constant exertion.

It has been known for some time akinetic PD patients can often walk up stairs and step over objects with little effort, even though they may be totally unable to initiate walking on open ground, a phenomenon known as kinesia paradoxa. In 1967 James Martin [1] demonstrated PD patients could often sustain near-normal walking in the presence of objects placed across their paths about a stride length apart.

Until recently kinesia paradoxa has been merely an interesting phenomenon with very little clinical utility (aside from canes with horizontal extensions sometimes used to trigger a step at a time). The emergence of HMD technologies, which permit the presentation of apparently space-stabilized virtual objects within the patient's visual field, has made it possible to exploit the phenomenon as a viable treatment method [2, 3, 5].

Augmented Reality Therapy. Prior to exploring the use of head-mounted computer graphics imagery, co-investigator Thomas Riess, himself a Parkinson's sufferer since his mid-30s, had developed and tested numerous approaches to presenting effective visual cues. These included running shoes with playing cards attached via wires, so there was always a card in front of the leading foot, as well as various mechanical devices that rotated small physical objects through the user's visual field.

Our initial attempts to evoke paradoxical walking with head-mounted image displays used the Virtual Vision Sport, a commercial field-multiplexed video viewing system in which a portion of one visual field is occupied by an occlusive (and collimated) reflection of a small LCD panel mounted in the brow piece. Continuous graphical animations of virtual objects (bars) scrolling at approximately normal walking speed served as the initial visual stimuli. Presenting the virtual images to the nondominant eye and scrolling the objects towards the subject along a virtual ground plane resulted in the perception of objects stabilized appropriately as the subject walked over them.

Cueing Device Requirements. These investigations have revealed a number of display requirements to achieve the optimal desired effect. Among these are adequate vertical fields-of-view to include several virtual "objects" extending in a column toward the horizon; adaptive placement of the field, lower for initiating gait and higher for sustaining gait; proper image collimation and perspective to support the illusion of objects on the floor; and movement of the cues down the visual field at apparent stride-length intervals to simulate the user's walking speed.

As a general rule we have found the greater the degree of akinesia a subject is experiencing (that is, the harder it is to walk unassisted), the more realistic the virtual cues must appear. The realism required here is not object photorealism, however, but "interactive realism." That is, run-time modification of cue spacing to suit walking speed and stride length, along with appropriate changes in perspective with head tilt, appear to be much more effective in sustaining visually cued walking than is graphical realism of the stimulus objects.

What Next?

To create a product effective and easy to use for this target population, operationally simpler and less obtrusive HMDs are required. This development effort has culminated in a lightweight pair of sun goggles reflecting in the central field-of-view a sequentially firing LED array mounted vertically at the periphery. Prototype devices have been produced by Riess's California-based company, HMD Therapeutics, and are currently undergoing clinical evaluation.

In addition to enabling normal gait in akinetic conditions, Riess has found that similar visual cues can also have a profound calming effect on the dyskinesia induced by long-term use of L-dopa. A second prototype device designed for this objective is also currently undergoing clinical evaluation.

These findings, and the compelling effects we have observed in using simple techniques to produce optical flow in the peripheral visual field, suggest kinesia paradoxa may work by enhancing visual feedback about self-motion. Indeed, a tight coupling of the brain's visual and motor systems appears to be essential for smooth natural gait, and some subset of the motor control problems exhibited by people with PD may result from the faulty interplay of motor and sensory (in this case, visual) processes.

As advanced human interface technologies evolve we should expect to see many novel therapeutic applications. With luck, the pursuit of those applications will also advance our understanding of the underlying natural phenomena. C

References

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