Activity-Based Telerehabilitation for Mobility Function in Older Adults: Module for Automatic Tracking of Performance... Tony Szturm and James Peters

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**Background and Overview**

Among older persons, the ability to walk remains a critical element of most basic and instrumental activities of daily life, and early decrements in mobility functions are prognostic of future adverse health events. Many view walking as a complex motor skill that is tightly linked to cognitive functioning. Gait impairment and cognitive problems, common with aging, frequently coincide in elderly people and have a great impact on quality of life and everyday functioning. Because sensory, cognitive, and motor systems are parts of a highly integrated distributed network system, disruption in any one system would degrade the overall accuracy and speed of information processing, planning of willed actions and execution of mobility behaviors.

An activity-based telerehabilitation system and associated tools for balance and mobility are being developed and validated. Telerehabilitation systems are collections of rehabilitation services provided remotely through the use of pervasive computer and telecommunication technologies. The core of our system, referred to as Tele-gaming, includes an interactive, engaging exercise/cognitive game-based platform using digital media and innovative computer input devices. The combined use of physical movements with interactive games containing: a) gaze control; b) psychomotor tasks; c) specific goals; and d) graded spatiotemporal accuracy, represents functional balance-mobility training with a wide scope of sensory-motor and cognitive experiences (individual or combined tasks).

Assessment and monitoring are critical features embedded into the therapeutic Tele-gaming platform. Automatic tracking of performance during exercise and activities is possible with use of an instrumented, interactive game, with an assessment module that we have developed. This provides a log of compliance, results, process measures (event-based data analysis), and used to quantify capacity to adapt balance, gaze stability and mobility for many visual-spatial and psychomotor tasks.

Electronic records are thus obtained which form the basis of a “mobility function” database. Design and development of a function Portal will provide a knowledge base that will serve as an aid for health care providers in assessing the severity and treatment needs of each individual, and to guide progression of their healthcare. With a linkable repository (including life-role participation measures) and results of data mining, it will then be possible to identify and implement optimal intervention strategies for people with sensory cognitive or motor impairments due to aging or neurological deficits.

**Examples of Tele-gaming Activities and Assessment**

![Figure 1: Adapted head tracking input device for use in therapeutic exercise gaming and assessment. Participant stands or walks on the treadmill. Two flat monitors (standard Windows OS) are placed at eye level approx. 100cm in front of subject to stretch computer (visual) display area. Subject wears the gaming head tracking adapted mouse. Selected head motions are “slaved to vertical/horizontal computer cursor or game sprite motion. Subject can interact with any commercial video game or our instrumented games while standing on a fixed surface, compliant sponge surface or while moving and walking (treadmill at different controlled speeds). Centre of vertical pressure (Cop) is also recorded using a flexible pressure mapping system (Vista Medical see Desai Szturm etal, Physical Therapy, May 2010). This is done for fixed and compliant surfaces. The treadmill can also be instrumented with a custom pressure mat secured to the treadmill base beneath the belt; thus temporal gait parameters and COP can be recorded for analysis. Foot pressure insoles are also available. We also use a 6-DOF position tracker (miniBird, Ascension Tech.) to track trunk motions.](image-url)
Figure 2: Example plots of computer target cursor motion and head motion obtained during predictable (sinusoidal) visual tracking tasks of subject in Figure 1. Subject is asked to move the head in concert with the moving computer cursor (open and closed loop modes are available). Each plot displays (i) the target cursor trajectory - sinusoidal waveform 0.04 Hz, and (ii) overlapping the trajectory of the actual head motion. Left plot is task performed while standing on fixed surface and right while standing on a sponge pad (increased balance demands).

![Figure 2](image)

Figure 3. Left side is vertical foot-surface contact pressures and COP position (black circle between foot imprints) obtained from a 16 x16 sensor mat (Vista Medical). Each pressure cell covers a surface area of 2.8 cm squared. Right side show X-Y plot of COP position during head tracking tasks of Figure 2 (i) left on fixed surface, and (ii) right compliant sponge surface.

![Figure 3](image)
A number of researchers and clinicians have used computer-based proxies to probe and evaluate visual attention, processing speed, cognitive inhibition, and other attentional & executive functions. Visual attention and tracking requires both foveal and peripheral search mechanisms and the ability to select relevant information and discriminate irrelevant information. One such test, Useful Field of View (UFOV) is an objective, computer-based test of visual attention and processing speed. We have used a modified version of the UFOV test to evaluate visual attention, together with gaze controls, balance and mobility functions. The goal of the “instrumented” game is to move a paddle (game sprite) to catch objects (targets) moving vertically top to bottom or horizontally left to right. The target objects appear every 2 seconds at random locations on the monitor from centre to edge. Task complexity is configurable to be: (a) a “simple” task (i.e., involving a single target object to catch, which was a bright colored circle), or (b) a “complex” task (i.e., the same as (a) but, in addition to circles (designated targets); other shaped objects also randomly appear, such as triangles or rectangles). These other-shaped objects served as distracters (cognitive interference).

Figure 4: Example raw and “parsed’ contextual game event plots obtained from instrumented game assessment module. During game play the software generates a logged game file to record (80 Hz) the following signals associated with actions performed by a player with respect to game play events: (a) coordinates and timing of each object (game events, specific task goals), (b) coordinates of the game sprite (paddle), i.e. head motions.

LEFT PANEL: Continuous trajectories of all game paddle movements for one complete game of 120 seconds duration (x-axis). Each game event is 2 seconds in length; thus, recording includes a total of 60 game movements; random presentation of left and right head rotations (slaved to game paddle; medium and large amplitudes (1/3 to full screen movements). The y-axis is the magnitude of paddle motion, where zero = left edge of the display, maximum = right edge...

MIDDLE PANEL: Plots of all “parsed contextual game events”, obtained from raw motion data in the Left Panel). Time zero is the onset of target appearance (event onset); the end of event is time when target disappears (2 seconds).

RIGHT PANEL: “Sorted” parsed contextual events and grouped into “functional” bins, which represent movement direction (up=left rotations, down=right rotations) for medium amplitude game movements (1/3 to ½ of display height). Thus, in one game session of 2 minutes, we can obtain repeated measures of multiple “functional” events. Data analysis methods are then used to quantify various performance and process measures of parsed and sorted player actions.

Note: COP (standing pressure mat) and temporal gait parameters) custom treadmill pressure mats) can also be recorded during Tellegaming sessions.