Sing for Your Saunter

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Participants:

People with Parkinson disease (PD) will be recruited through the Movement Disorders Clinic at Washington University in St. Louis School of Medicine and through flyers via the American Parkinson Disease Association. Age- and gender-matched controls will be recruited through the Washington University Older Adults Participant Pool and the Research Participant Registry. Additional recruitment occurred through advertisements, flyers, and social media.

Inclusion Criteria: 1) at least 30 years of age, 2) right-handed (criterion for MRI), 3) normal to corrected hearing, 4) able to walk for 10 continuous minutes independently, and 5) willing and able to provide informed consent. Additional inclusion criteria for people with PD included: 1) diagnosis of idiopathic, typical Parkinson disease according to the UK Brain Bank Criteria, 2) Hoehn & Yahr stages 2-3 (mild to moderate disease severity), 3) score of ≥ 1 on the Movement Disorders Society Unified Parkinson Disease Rating Scale – Part III – Motor Aspects (MDSUPDRS-III)[31] item #10 indicating observable gait impairment; 4) a score of 1 or less on item # 7 on the New Freezing of Gait Questionnaire (nFOG-Q), indicating that the freezing episodes are not moderately or significantly disturbing to daily walking, 5) stable on all PD medications for at least 2 months prior to study entry.

Exclusion Criteria: 1) diagnosis of any other neurological condition; 2) significant cognitive impairment (i.e., Mini-Mental Status Examination (MMSE) score of <24); 3) other medical conditions that might interfere with ability to safely participate.

This study will be approved by the Institutional Review Board (IRB) of Washington University in

St. Louis School of Medicine.

Study design:

All participants will come to the lab for a single session lasting 2-3 hours. The session involves behavioral assessments and motor assessments. People with PD will be tested while on their normal anti-PD medications to represent everyday conditions. Evaluations will be scheduled at the time of day identified by each individual as their optimal ON period when their medications worked best.

Motor Assessments:

Motor assessments will consist of several walking trials under varied conditions. Gait data will be recorded using the Mobility Lab System gait and posture analysis system (APDM, Inc., Portland, OR). This system is designed to quantify human movement and is equipped with six wearable Opal sensors placed on the wrists, feet, sternum, and lumbar spine. It is lightweight and wireless, allowing full freedom of movement and continuous monitoring of ambulation over long distances.

All walking trials will be performed in a 30m hallway in which participants walked continuously in an ellipse. A tone produced by the APDM software will indicate the start and end of each trial. In each condition, participants will perform three 30-second trials. All participants will be

followed by a trained physical therapist during walking trials to reduce fall risk during the intervention.

Uncued walking: Baseline walking trials will be done in silence and used to represent 'normal' baseline walking and to provide a point of comparison for the other conditions. Participants will be asked to walk at their preferred walking speed.

These trials will be averaged to determine baseline walking cadence and then used to calculate four individualized cue rates: 90%, 100%, 110%, and 120% of uncued cadence. Cues will be prerecorded on a piano keyboard and were rounded to the nearest five beats per minute increment.

During calculation of cue rates, participants will select a cue song from a curated catalogue of 10 songs compiled by a music therapist. These commonly known songs will be selected for having characteristics appropriate for gait training such as 4/4 timing, beat salience, familiarity, and simple lyrics. Participants will be asked to select the song most familiar to them.

The songs available will be as follows: "I've Been Working on the Railroad", "You Are My Sunshine", "This Land is Your Land", "Skip to My Lou", "She'll Be Coming Around the Mountain", "Don't Sit Under the Apple Tree", "When the Saints Go Marching In", "You Can't Hurry Love", "When Johnny Comes Marching Home Again", and "Seventy-Six Trombones." All cued musical stimuli will be recorded on a keyboard using single notes. Only the chorus will be played to keep cues simple and repetitive to facilitate motor synchronization.

Once participants select a song, they will be given the song lyrics to review. To ensure each participant knows the lyrics, participants will then be asked to sing the song aloud without reading the lyrics. Participants will then practice singing the lyrics aloud while walking to familiarize them with performing the two tasks simultaneously.

Cued walking: Cues will be delivered from a laptop with external speakers. Tempos will be presented in randomized blocks and two cue types (Music and Mental) were randomized within each tempo.

- **Music:** This condition represents traditional cueing techniques in which music played and participants were asked to walk to the beat. Each song will be played once through before the starting tone sounded and participants began walking to the music. Participants will be monitored to ensure that they are not singing during this condition and that they walk on the underlying beat rather than the melody.

- **Mental:** This condition represents our experimental cueing paradigm in which participants were asked to mentally sing while walking without music playing. Each song will be played once through, then turned off before the starting tone sounds and participants begin walking and mentally singing. To ensure that participants are correctly doing the task, participants will be asked to confirm that they were mentally singing in their heads after each trial. Participants will be instructed not to move their mouths during the task and this will be carefully monitored.

Each participant will complete a total of 27 walking trials of 30 seconds each. Upon completion of all walking trials, each participant's optimal tempo (i.e., the tempo with the longest stride length) will be determined by averaging stride length across the music and mental trials within each tempo.

Analysis:

T-tests will be used to compare baseline characteristics between groups. Repeated measures (RM) ANOVAs will be used to compare gait characteristics (velocity, stride length variability) across conditions (uncued, music, mental) and between groups (PD, control). For cued conditions, the optimal tempo (those at the tempo that elicited the longest strides for each participant) for each individual will be used for analysis. For significant main effects of condition, adjusted pairwise comparisons will be used to indicate differences between conditions.