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Article

The efficacy of audio and visual cueing on gait performance in Parkinson's patients

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Abstract: Motor dysfunction, specifically gait disturbances, is a primary symptom of Parkinson's disease and significantly affects the independence of the patient. The typical treatment involves pharmacological drugs, primarily Levodopa. However, in recent years an innovative approach using sensory cueing techniques have been reported to be beneficial in managing Parkinson's. This literature review summarizes the evidence regarding the efficacy of audio and visual cueing techniques on gait performance in Parkinsonian patients.

Keywords: Parkinson's disease, Music therapy, Auditory cueing, Visual cueing, Gait rehabilitation.

1. Introduction

Parkinson's disease is a neurodegenerative disorder characterized by the degeneration of dopaminergic neurons in the substantia nigra [1, 2]. The degeneration of the neurons causes a loss of dopamine in the brain leading to motor impairments (bradykinesia, gait dysfunction, and postural instability), cognitive impairment, and mood disorders [1]. Parkinson's decreases the quality of life and affects the daily activities of the patient [2]. Patients lose their independence and must rely on caregivers or walking aids for support due to alterations in gait and lack of stability. As a result, patients that are diagnosed resort to pharmacological or surgical treatments, but the balance and gait deficits are resistant to these remedies [2]. Recently, patients have turned to allied health services, such as occupational and physical therapy, but also external cueing techniques to compensate for the motor impairments. The two most common types of cueing techniques used are visual cueing and audio cueing.

Before these alternative treatments were studied, physical therapy was thought to be the critical component in treating Parkinson's, then the drug Levodopa became available and was believed to be a cure [3]. However, it became apparent that Levodopa's efficacy does not last indefinitely [3] and has led science to study alternative methods such as cueing. Studies have discussed that auditory cueing may elicit sensations related to emotions which may distract the patient from sensations such as fatigue [2]. It is also thought that audio cueing stabilizes the internal rhythm when music is used as an external rhythmic timekeeper, thus improving gait performance [4]. Studies of visual cueing, such as floor markers, have been reported to be effective in regulating stride length in patients but only certain visual stimuli, for example, transverse lines are more effective than zig zag or parallel lines [3]. The purpose of this review is to summarize the evidence regarding the efficacy of audio and visual cueing as an innovative approach to combating the motor dysfunctions in Parkinson's, specifically with respect to improving gait.

2. Methods

Articles were gathered for this literature review searching PubMed of the National Library of Medicine and Google Scholar. The search strategy involved using the key words Parkinson's disease, music therapy, auditory cueing, visual cueing, and gait rehabilitation. The criteria for selecting the articles included articles that conducted controlled trials using audio or visual cueing, or both. These articles included a small group of participants in their trials along with cognitive and motor tests that involved gait as an outcome variable. A database of over 100 articles were considered for this literature review.

3. Audio Cueing

3.1. Rhythmic Auditory Stimulation

Rhythmic auditory cueing has gained popularity in the last decade. Bella and associates [5] tested two different theories: one, if there was a link between rhythmic auditory stimulation (RAS) and the sensorimotor skills of the patients in a non-cued trial and two, whether patients could synchronize their step to a faster or slower beat in a cued trial. They asked patients to undergo a one-month training program with three sessions per week. In the non-cued condition, patients walked for one minute at their preferred cadence. In the cued conditions, patients were asked to walk with a musical stimulus without any instruction to synchronize their steps to the beat. The song was presented at two different rates, 10% faster and 10% slower relative to the patient's preferred cadence [5]. A total of 14 patients were asked to walk along to a common German folk song that was presented without the lyrics and the beat emphasized. For each condition the patient performed two trials, one in which the participant walked clockwise and then walked counter-clockwise. According to Bella et al [5], Parkinsonian patients displayed a shorter stride length, shorter stride time, faster cadence, and slower speed prior to the training compared to the control group. It was concluded at the end of the trial that gait speed increased from 898.9mm/sec to 952.7mm/sec and stride length increased from 1011.7mm to 1057.5mm in the non-cued gait conditions based on the patient's preferred cadence and was still significant one month after [5] (Table 1). In the cued conditions, only half of the patients improved their synchronization accuracy from 22.7% to 24.9% when they stepped to a beat that was 10% faster than their preferred cadence as opposed to a slower beat. This conclusion was also determined by McIntosh et al [6] (Table 1).

McIntosh and colleagues [6] conducted a similar study using RAS. Their study consisted of 21 patients, some patients were on medication (ON) during the duration of the training program and others were not (OFF). All subjects completed four different conditions walking 30m in the following order: (1) at their own maximal speed with no external rhythm (baseline); (2) in time to RAS matched in tempo to each patient's baseline cadence; (3) in time to RAS set at a tempo 10% faster than baseline; (4) with no external rhythm to check for immediate carry over effect [6]. The baseline results showed a decreased velocity and shorter stride length in both ON and OFF patients. In the matched RAS condition, ON patients showed significant improvements in stride length (from 0.86m at baseline to 1.02m), speed (from 0.70 to 0.95m/s), and cadence (from 98 to 108 steps/min) (Table 1). The OFF patients showed slight improvements but were not significant. Overall, 19 of the 21 patients were able to increase their step frequency and retain their step/beat phase coupling after a 10% increase in the RAS tempo thus agreeing with that of Bella and colleagues [5].

Thaut et al [7] also sought to determine the effects of using RAS as an alternative strategy to improve gait in Parkinson's patients. Their study involved an experimental group of 15 subjects, and a control group that was divided into a self-paced group and a non-trained group, each had 11 subjects. All groups participated in a pre and posttest that was three weeks apart. The non-trained group were instructed to carry out their normal day-to-day activities during the three weeks apart. The experimental group were instructed to exercise everyday using a prescribed program with the aid of RAS. In the self-paced group, subjects participated in the same exercise program but without RAS. The exercise program consisted of walking on a flat surface, stair stepping, and stop-and-go exercises [7]. These exercises were presented with a rhythmic beat in three different tempos: normal, quick, and fast. Subjects were able to slect from four categories of music: folk, classic, jazz, or country. During the first week, the normal tempo was taken as a baseline, the quick tempo was presented as 5-10% faster beat, and the fast was presented at an additional 5-10% faster than the quick beat. Each consecutive week, the normal tempo become the quick, the quick tempo become the fast, and the fast tempo was an even faster tempo. The rate at which the tempos increased was based on how well each patient could match each tempo. All subjects were instructed to exercise on their own. After the three weeks, Thaut and associates [7] revealed that the experimental group demonstrated an increase in velocity in the flat walk by 25% and the incline walk by 26% (Table 1). The experimental group also showed improvements in stride length by 12% and a faster cadence by 10% (Table 1). The self-paced grouped did show some improvements but only in stride length by 8% and the non- trained grouped showed significant decreases in all gait variables. As mentioned by Bella et al [5], McIntosh et al [6], and Thaut et el [7], the use of RAS has shown improvements in gait performance, however, some studies conclude the use of auditory stimuli has not been beneficial as an adjunct therapy for Parkinson's patients.

3.2. Music Therapy

Conversely, Brown and associates [8] sought to determine the effect of concurrent music on gait performance in patients with Parkinson's in single- and dual-task contexts. They allowed patients to select their own music for enjoyability and familiarity. Since music can stimulate movement, Brown and colleagues [8] hypothesized that spatial and temporal gait parameters would improve in both conditions when concurrent music was used. Subjects completed four different conditions six times each for a total of 24 trials. The conditions are as follows: (1) no music, no task; (2) music, no task; (3) no music, cognitive task; (4) music, cognitive task. The cognitive task consisted of subtracting by three's aloud from a random number selected. A new number was selected for each trial. After all trials were performed, Brown et al [8] concluded that when participants performed the single-task trials, they only showed a slight decrease in performance in stride length from 1.35m in non-music trials to 1.33m in music trials, and slower gait speed from 1.29m/s in non-music trials to 1.27m/s in music trials (Table 1). They also determined that when participants completed the dual-tasks, there was a significant decrease in gait speed from 1.03m/s in the non-music trial to .99m/s in music trials and stride length from1.27m in non-music trials to 1.23m in music trials [8] (Table 1). A similar study was conducted by Mak et al [9] that also came to this same conclusion.

Mak and associates [9] conducted a study that also added a concurrent cognitive task to determine if it would improve the gait performance of Parkinson's patients. However, Mak et al also used visual cueing as part of the experiment. A total of 15 participants were included in this study. Half of the experiment involved a serial subtraction while instructed to walk. The subtraction task required participants to count backwards by three's from a random number selected between 60 and 100. After this trial was conducted, Mak and colleagues [9] concluded there was a significant decrease in stride length by 20.5cm, smaller cadence by 16.6steps/min, and slower gait velocity by 33.7cm/s (Table 1). This part of the study concludes with that of Brown and associates [8]. The other half of the experiment is discussed in the visual cueing portion of the review.

Table 1. Studies of the effect of auditory cues

Study	Results
Bella et al [5]	Non-cued conditions: significant improvement in stride length (from 1011.7mm to 1057.5mm), and gait speed (from 898.9mm/sec to 952.7mm/sec) Cued conditions with 10% faster beat: only half improved in their synchronization accuracy after a 1 month follow up (from 22.7% to 24.9%)
McIntosh et al [6]	Significant improvement with RAS found in stride length (from 0.86m at baseline to 1.02m with RAS), speed (from 0.70 to 0.95m/s), and cadence (from 98 to 108 steps/min). The healthy control group also showed a significant improvement in speed and cadence, but not in stride length. In a follow-up trial without RAS, these improvements persisted with a small decay rate
Thaut et al [7]	Significant improvement with RAS in gait velocity (by 25%), stride length (by 12%), and faster cadence (by 10%)
Brown et al [8]	Single-task: performance declined slightly in stride length (from 1.35m in non-music trials to 1.33m in music trials), and slower gait speed (from 1.29m/s in non-music trials to 1.27m/s in music trials) Dual-task: significant decline in stride length (from1.27m in non-music trials to 1.23m in music trials), and significant decline in gait speed (from 1.03m/s in non-music trial to .99m/s in music trials)
Mak et al [9]	Cognitive task: significantly shorter stride (by 20.5cm), smaller cadence (by 16.6 step/min), and slower gait velocity (by 33.7cm/s)

3.3. Efficacy of Audio Cueing

According to Bella et al [5] who determined that only half of the patients benefitted from the auditory cued beat that was 10% faster, was due largely impart to individual differences in sensorimotor skills. This study demonstrates that patients who are more impaired in terms of gait and poorest in synchronization accuracy, will more likely benefit from the use of RAS [5]. However, other studies showed that more patients were able to benefit from the use of rhythmic auditory stimulation, specifically to a beat that was 10% faster than their preferred cadence [5-7]. McIntosh and colleagues [6] also stated that patients who exercised daily while listening to music in conjunction with RAS, showed more significant and lasting results. Although, it is not exactly clear on how the use of RAS is able to improve gait dysfunction in Parkinson's patients [3]. Thaut and colleagues [7] proposed that RAS provides an external rhythm that balances the faulty internal rhythm of the basal ganglia and therefore improving gait performance.

Brown and associates [8] proposed the reason Parkinson's patients performed significantly less in the concurrent cognitive dual-task was because the task imposed additional cognitive demands that might have interfered with the attentional control of gait [9]. They also suggested that since the patients selected their own music, the subjects were more actively focused on the music rather than walking. Parkinson's patients assign greater attentional resources into controlling their gait but when another task is added to that it can overload their cognitive function [8, 9]. Brown and colleagues [8] expected there to be a greater arousal due to patients selecting the music, however it might have affected the availability of attentional resources serving as a source of resource depletion leading to a decrease in gait performance. Overall, from the studies of Bella et al [5], McIntosh et el [6], and Thaut et al [7] it can be concluded that the use of certain auditory cues have been beneficial in combatting the gait dysfunctions in Parkinson's patients. To further evaluate the efficacy of audio cueing, more studies should be conducted to determine which audio cues provide the most benefits for Parkinson's patients. All therapies mentioned are shown in the table at the end of the literature review.

4. Visual Cueing

4.1. Lights

Studies of visual cueing have also had promising results in improving gait dysfunction in Parkinson's. Mak and colleagues [9] incorporated audio and visual cueing into their study by simulating traffic lights and sounds also while patients performed a cognitive task. After patients had performed the subtraction trial mentioned earlier, they were asked to complete two more conditions with traffic lights; (1) a static red light with 1Hz rhythmical auditory beat and (2) a static green light with 13Hz rhythmical auditory beat [9]. In the static red conditions, patients were asked to 'wait and prepare to walk' upon the appearance of the signal. These signals were given prior to initiation and lasted five seconds and were termed preparatory audio-visual (AV) cues. In the static green light conditions, patients were instructed to start walking when these signals were "on" and to complete their walk in the time it took them to complete their baseline walk. These signals were given continually while walking and were termed ongoing AV cues. Both tasks included the serial subtraction. All participants were able to watch and listen to the AV cues before testing so they could estimate the time it would take them to complete the walk. Results showed that when traffic lights were provided, patients demonstrated a significantly longer stride length by 8.8cm, larger cadence by 9.5steps/min, and faster velocity by 17.1cm/s [9] (Table 2).

Azulay et al [10] conducted a study back in 1999 that also concluded the use of visual cues improved gait performance. As opposed to using traffic lights, Azulay and associates [10] tested two different visual stimuli: normal lighting and stroboscopic illumination that consisted of three flashes. In both conditions, there were white transverse lines placed on the floor 45 meters apart that were used as visual cues. Results proved that under normal lighting conditions, visual cues made significant improvements in gait velocity from 0.76m/s at baseline to 0.82m/s with visual cue and stride length from 0.93 to 0.97m, but not cadence in Parkinson's patients [10] (Table 2). When stroboscopic illumination and visual cues were used, improvement was suppressed.

4.2. Step Length Markers

Lewis and associates [11] tested the use of stride length markers in patients with Parkinson's as opposed to using lights as cues. Their study consisted of 32 subjects, 16 experimental patients and 16 control patients. Each participant was instructed to walk up and down a 10m runway in three conditions: (1) a baseline walk; (2) using step length markers; and (3) with a subject-mounted light device. During the baseline walk, subjects were simply asked to walk to the end of the runway and walk back. For the step length condition, white stripes of tape were placed along the runway, perpendicular to the walking path at intervals corresponding to a normal step length for each individual as determined by their height [11]. Patients were instructed to walk to the end of the runway and back by stepping over the lines. The subject-mounted light device was a laser device attached to the subject. The device projected two laser lines in front of the participant approximately 50cm wide and spaced the same step length apart as indicated by the markers. In this condition, participants were instructed to step up to the line as they walk along the runway. In both conditions of using visual cues, the results showed significant improvements in stride length from 0.42m before the therapy to 0.47m after and gait speed from 0.83 to 0.97m/s, but not cadence (Table 2). Almeida et al [12] also came to this conclusion with the use of step length markers (Table 2).

Table 2. Studies of the effect of visual cues

Study	Results
Mak et al [9]	Simulated traffic lights: significantly longer stride length (by 8.8cm), larger cadence (by 9.5 step/min), and faster gait velocity (by 17.1cm/s)
Azulay et al [10]	Under normal lighting, visual cues induced a significant improvement in gait speed (from 0.76m/s at baseline to 0.82m/s with visual cue) and stride length (from 0.93 to 0.97m), but no significant improvement in cadence in PD patients. With stroboscopic illumination and visual cues, this improvement was suppressed.
Lewis et al [11]	Significant improvement of stride length (from 0.42m before the therapy to 0.47m after) and gait speed (from 0.83 to 0.97m/s) but no significant improvement in cadence (from 117 to 121 steps/min).
Almeida et al [12]	Significant improvement in step length (from 63.9cm at baseline to 69.4cm), and faster gait velocity (from 119.2cm/s to 128.3cm/s)

4.3. Efficacy of Visual Cues

In the use of visual cueing, most studies consisted of marking the floor in precise measurements for step length using transverse lines [10-12], or using a variation of lights [9, 10]. In the study conducted by Azulay and associates [10], they used a combination of transverse lines and lights that produced positive results in improving stride length, and gait velocity. The greatest improvements were shown under normal lighting as opposed to the stroboscopic simulation. Azulay et al [10] also concur with Thaut et al [7] in that external stimuli, in this case floor markers, balance the defective internal decisions of the basal ganglia. Mak and colleagues [9] used a combination of audio and visual cues by simulating traffic lights and sounds that demonstrated positive results in gait. Their patients were allowed to watch and listen to the audio and visual cues before performing the trials. Mak et al [9] proposed that the use of the preparatory cues is what allowed the Parkinson's patients to execute a dual-task more effectively. The authors also gave the participants ongoing cues which could have increased the attention level of the patients and prioritization of the walking task leading to an improved gait performance [9]. According to Rubinstein and colleagues [3], a possibility of how visual cues improve gait is it helps to fill in for the motor set deficiency by providing a visual data on the appropriate step length. Another theory proposed by the authors is that visual cues help the patients focus their attention on gait and thus it is no longer an automatic task that is being processed by the defective basal ganglia [3]. Overall, it can be concluded that the use of different visual cues are beneficial in improving gait performance as mentioned by Mak et al [9], Azulay et al [10], and Lewis et al [11]. More studies should be conducted to further evaluate the use of visual cues as an alternative method for treating Parkinson's. All therapies mentioned are shown in the table at the end of the review.

5. Summary and Practical Applications

Since Parkinson's has become a growing disorder in the last decade, it has led science to study different methods for combating the motor dysfunctions of Parkinson's patients and stray away from the conventional approach of physical therapy. These new approaches have shifted towards different cueing techniques, audio and visual cueing, and have shown positive results in gait performance. Certain studies showed that audio cueing and rhythmic stimulation improved patient's stride length and gait velocity [5-7]. Other studies reported the placement of floor markers, specifically transverse lines, and traffic lights improved stride length as well gait velocity [9-12]. As science continues to expand on the efficacy of cueing techniques, more studies should be conducted with different parameters tested and studies that combine the conventional physical therapy with different cueing techniques to further asses efficacy and determine which cues are most effective. In addition, the hypotheses stated by the studies mentioned in the review should also be explored as to gather a better understanding of the phenomenon's and/or mechanisms that are taken place in the brain of a Parkinson's patient.

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