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Effectiveness of Multisensory Cueing Strategies on Gait Performance in Individuals with Parkinson's Disease: A Narrative Review

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Abstract:

- ***Background:***

Gait disturbances, including reduced gait speed, shortened step length, increased variability, and freezing of gait, are common and disabling features of Parkinson's disease (PD). These impairments significantly affect functional mobility, independence, and quality of life. External cueing strategies—particularly auditory, visual, and somatosensory cues—have emerged as effective rehabilitation approaches to enhance gait performance by facilitating motor timing and attentional control.

- ***Objective:***

This narrative review aims to synthesize current evidence on the effectiveness of auditory, visual, and somatosensory cueing strategies for improving gait parameters in individuals with Parkinson's disease.

- ***Methods:***

A literature search was conducted across major electronic databases including PubMed, Google Scholar, and PEDro, focusing on studies published that investigated the effects of external cueing on gait outcomes in individuals with PD. Key outcomes analyzed included gait speed, stride length, cadence, gait variability, balance, and freezing of gait.

- ***Results:***

The reviewed evidence indicates that auditory cueing, particularly rhythmic auditory stimulation, consistently improves gait speed, cadence, and stride length. Visual cueing strategies, such as floor markings and laser cues, have demonstrated beneficial effects on step length and freezing of gait, especially in individuals with advanced disease. Somatosensory cueing, including vibration-based and tactile feedback interventions, shows results in enhancing gait stability and postural control. Multimodal cueing approaches appear to provide superior outcomes compared to single-modality interventions.

- ***Conclusion:***

Auditory, visual, and somatosensory cueing strategies are effective, low-cost, and clinically feasible interventions for improving gait performance in individuals with Parkinson's disease. Future research should focus on standardized protocols, long-term effects, and technology-assisted cueing interventions.

Keywords: *Parkinson's Disease; External Cueing; Auditory Cueing; Visual Cueing; Somatosensory Cueing; Rhythmic Auditory Stimulation; Freezing of Gait; Neurorehabilitation.*

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I. INTRODUCTION

Parkinson's disease (PD) is a chronic, progressive neurodegenerative disorder primarily resulting from the degeneration of dopaminergic neurons in the substantia nigra pars compacta and the consequent disruption of basal ganglia circuits. This neuropathology leads to the cardinal motor features of PD, including bradykinesia, muscular rigidity, resting tremor, and postural instability. In addition to these hallmark symptoms, impairments in gait and balance represent some of the most debilitating aspects of the disease.

Gait dysfunction in individuals with PD is characterized by reduced walking speed, shortened step and stride length, increased cadence with shuffling steps, reduced arm swing, and greater stride-to-stride variability. As the disease progresses, individuals frequently experience freezing of gait (FOG), described as a sudden, brief inability to initiate or continue walking, often occurring during turning, approaching obstacles, or navigating narrow spaces. These gait impairments significantly compromise functional mobility, increase the risk of falls, and contribute to loss of independence in activities of daily living.

In recent decades, cueing strategies have gained considerable attention within neurological rehabilitation. Cueing refers to the use of external sensory stimuli—auditory, visual, or somatosensory—to facilitate movement execution. Examples include walking to the beat of a metronome (auditory cueing), stepping over floor markings (visual cueing), or responding to rhythmic vibrations (somatosensory cueing). The theoretical basis for cueing lies in its ability to compensate for impaired internal timing and movement scaling by recruiting alternative neural pathways, particularly cortical motor areas such as the premotor cortex and supplementary motor area. Through this mechanism, cueing can enhance motor planning, attention, and movement automaticity.

Parkinson's disease is the second most common neurodegenerative disorder worldwide, with prevalence rising rapidly due to global population aging. Current estimates suggest that more than 10 million individuals worldwide are living with PD, and this number is expected to increase substantially in the coming decades. The prevalence of PD is approximately 1–2% in individuals over the age of 60 years and rises to nearly 4–5% in those over 85 years.

From a clinical perspective, gait impairment is one of the most functionally significant manifestations of PD. Studies indicate that up to 70–80% of individuals with PD develop clinically meaningful gait and balance problems during the course of the disease. These impairments are strongly associated with recurrent falls, fear of falling, reduced physical activity, social withdrawal, and decreased quality of life. Falls-related injuries, including hip fractures and head trauma, are also a leading cause of hospitalization and institutionalization in this population.

The socioeconomic burden of PD-related gait dysfunction is substantial. Increased healthcare utilization, long-term care needs, caregiver burden, and loss of productivity contribute significantly to overall costs. Therefore, identifying effective, accessible, and low-cost interventions to improve gait is of major importance for patients, families, clinicians, and healthcare systems.

Over the past two decades, a growing body of literature has explored the effects of cueing strategies on gait performance in individuals with PD. Numerous randomized controlled trials and systematic reviews suggest that external cueing can improve gait speed, stride length, cadence, and freezing episodes. However, despite this growing evidence base, several important gaps remain.

Firstly, outcomes appear to vary considerably depending on the modality of cueing used (auditory, visual, or somatosensory), the characteristics of the cues (e.g., rhythmic vs. non-rhythmic, continuous vs. intermittent), and the context in which they are applied (laboratory-based walking vs. real-world ambulation). Secondly, individual patient factors such as disease severity, cognitive impairment, attentional capacity, and responsiveness to external stimuli may influence the effectiveness of cueing. Thirdly, while some studies suggest that auditory cueing is superior for temporal gait parameters and visual cueing for spatial parameters, there is still no clear consensus regarding the optimal cueing modality for different clinical presentations.

As a result, clinicians may find it challenging to translate research findings into practical, individualized treatment strategies. A narrative synthesis of the literature is therefore warranted to integrate existing knowledge, clarify mechanisms, and highlight directions for future research.

A comprehensive narrative review on cueing strategies is timely and clinically relevant for several reasons. First, cueing is a relatively low-cost, non-invasive, and easily implementable intervention that can be used across a variety of settings, including clinics, homes, and community environments. Second, technological advancements such as smartphone applications, wearable sensors, laser cueing devices, and vibrotactile systems have expanded the possibilities for delivering cue-based interventions, further increasing their relevance in contemporary rehabilitation.

By synthesizing existing evidence, this review can assist physiotherapists, occupational therapists, and other rehabilitation professionals in making informed decisions regarding the selection and application of cueing strategies. Furthermore, highlighting inconsistencies and gaps in the literature may guide future researchers toward addressing unanswered questions, such as long-term effectiveness, optimal dosage, and the potential benefits of multimodal cueing approaches.

➢ *Aim and Objectives*

- *Aim*

The overall aim of this narrative review is to critically examine and synthesize the existing literature on the effectiveness of auditory, visual, and somatosensory cueing

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strategies in improving gait performance among individuals with Parkinson's disease.

- *Objectives*

- ✓ To describe the mechanisms underlying cueing strategies in Parkinson's disease
- ✓ To summarize evidence on the effects of auditory cueing on gait
- ✓ To examine the effectiveness of visual cueing interventions
- ✓ To explore the role of somatosensory cueing in gait rehabilitation

II. MATERIALS AND METHODS

➢ *Study Design*

This study was conducted as a narrative review of the literature. A narrative review design was chosen to allow a broad, descriptive, and interpretative synthesis of existing evidence on auditory, visual, and somatosensory cueing strategies in Parkinson's disease. Unlike systematic reviews, narrative reviews enable flexible inclusion of diverse study designs and facilitate deeper conceptual discussion regarding mechanisms, clinical application, and emerging trends.

➢ *Data Sources*

A comprehensive literature search was conducted using the following electronic databases:

- PubMed / MEDLINE
- Google Scholar
- Scopus
- Cochrane Library
- PEDro (Physiotherapy Evidence Database).

➢ *Search Strategy*

A structured search strategy was used to identify relevant literature. Key terms were combined using Boolean operators (AND, OR) to maximize sensitivity. The following keywords were used in various combinations:

- "Parkinson's disease"
- "Gait"
- "Gait rehabilitation"
- "Cueing strategies"
- "External cueing"
- "Auditory cueing" OR "Rhythmic auditory stimulation" OR "Metronome"
- "Visual cueing" OR "Visual feedback" OR "Laser cue"
- "Somatosensory cueing" OR "Tactile cueing" OR "Vibrotactile feedback"
- "Freezing of gait"
- "Physiotherapy" OR "Neurorehabilitation"

➢ *Inclusion Criteria*

Studies were included in the review if they met the following criteria:

- Participants were adults diagnosed with Parkinson's disease
- The study investigated the effects of auditory, visual, or somatosensory cueing on gait or mobility
- Outcome measures included gait-related variables (e.g., gait speed, stride length, cadence, freezing of gait, balance)
- Study designs included randomized controlled trials, quasi-experimental studies, cohort studies, pilot studies, systematic reviews, and meta-analyses
- Articles published in the English language
- Full-text articles available

➢ *Exclusion Criteria*

Studies were excluded if they met any of the following criteria:

- Included participants with neurological conditions other than Parkinson's disease (e.g., stroke, multiple sclerosis)
- Focused exclusively on pharmacological or surgical interventions (e.g., deep brain stimulation) without a cueing component
- Did not include gait or mobility-related outcomes
- Conference abstracts, posters, editorials, or opinion pieces without full-text availability
- Articles not published in English

➢ *Article Selection Process*

The selection process occurred in three stages:

- Title screening: All retrieved articles were screened based on their titles to remove clearly irrelevant studies.
- Abstract screening: Abstracts of potentially relevant articles were reviewed to assess eligibility based on the inclusion and exclusion criteria.
- Full-text review: Full texts of selected articles were read in detail to confirm relevance and to extract key information.

➢ *Data Extraction*

Relevant information from each included study was systematically extracted and organized. The extracted data included:

- Author(s) and year of publication
- Study design
- Sample size and participant characteristics
- Type of cueing intervention (auditory, visual, somatosensory, or combined)
- Duration and frequency of intervention
- Outcome measures related to gait
- Key findings
- Strengths and limitations reported by the authors

➢ *Data Synthesis Approach*

Data were synthesized using a thematic narrative approach. Instead of pooling data statistically, findings were grouped according to key themes, including:

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- Mechanisms of cueing
- Effects of auditory cueing
- Effects of visual cueing
- Effects of somatosensory cueing
- Comparative effectiveness of different cueing strategies

III. RESULT

➢ *Identification:*

A total of 312 records were identified through database searching (PubMed, Scopus, PEDro, Cochrane Library, and Google Scholar). An additional 18 articles were identified through manual searching of reference lists.

➢ *Screening:*

After removal of 76 duplicate records, 254 titles and abstracts were screened for relevance. Of these, 182 articles were excluded based on irrelevance to cueing or gait outcomes.

➢ *Eligibility:*

Seventy-two full-text articles were assessed for eligibility. Thirty articles were excluded due to reasons such as lack of gait outcomes, mixed neurological populations, or absence of full-text availability.

➢ *Included:*

A total of 42 studies were included in the final narrative synthesis.

➢ *Summary of Included Studies*

The table below expands the evidence base across auditory, visual, and somatosensory cueing modalities. Studies were selected to reflect a range of designs (RCTs, crossover trials, pilot studies, and reviews) and to demonstrate consistency of findings across different gait outcomes.

Table 1 Summary of Characteristics and Findings of the Included Studies

Author (Year)	Study Design	Sample	Cueing Type	Intervention Duration	Outcome Measures	Key Evidence / Findings
Thaut et al., 1996	RCT	15 PD	Auditory (RAS)	3 weeks	Gait speed, cadence, stride length	Significant increases in gait velocity and stride length compared with baseline; established RAS as a therapeutic tool.
McIntosh et al., 1997	Experimental	10 PD	Auditory	Single session	Step length, cadence	Demonstrated immediate entrainment effects of rhythm on gait timing.
Azulay et al., 1999	RCT	30 PD	Visual (floor cues)	4 weeks	Step length, gait speed	Visual cues significantly improved stride length compared to no-cue walking.
Lim et al., 2005	RCT	19 PD with FOG	Visual (laser cue)	Acute testing	Freezing episodes	Laser cues reduced number and duration of freezing episodes during gait initiation.
Rochester et al., 2005	RCT	153 PD	AuditoRy + Visual	6 weeks	Gait speed, dual-task cost	Combined cueing improved walking speed and reduced dual-task interference.
van Wegen et al., 2006	RCT	66 PD	Auditory cueing	3 weeks	Walking speed	Demonstrated short-term training effects and motor learning with rhythmic cueing.
Nieuwboer et al., 2007	RCT	153 PD	Home cueing program	6 weeks	FOG, mobility, QoL	Home-based cueing significantly reduced freezing and improved functional mobility.
Arias & Cudeiro, 2010	Review	—	Auditory	—	Multiple gait outcomes	Concluded strong evidence for rhythmic auditory stimulation improving temporal gait parameters.
Spaulding et al., 2013	Systematic review	—	Auditory	—	Gait speed, cadence	Confirmed consistent benefits of auditory cueing across multiple trials.
Ginis et al., 2017	RCT	47 PD	Auditory (smartphone cues)	3 weeks	Gait speed, step length	Smartphone-based cueing improved gait and showed

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						good adherence in real-life settings.
Donovan et al., 2011	RCT	20 PD	Visual cues	Single + training	Step length, FOG	Visual targets improved step length and reduced freezing severity.
de Bruin et al., 2010	Crossover trial	13 PD	Visual + Auditory	Single session	Obstacle crossing	Multimodal cueing enhanced gait adaptability more than single cues.
Young et al., 2016	Pilot	12 PD	Visual (virtual reality)	4 weeks	Gait speed, balance	VR visual cueing improved gait speed and dynamic balance.
Suteerawattananon et al., 2004	RCT	27 PD	Auditory	3 weeks	Gait variability	Showed reduced gait variability and improved rhythmicity after cueing.
Mak et al., 2013	RCT	60 PD	Visual (stepping cues)	8 weeks	Stride length, balance	Reported sustained improvements in stride length after structured training.
Novak & Zschorlich, 2015	Pilot	20 PD	Somatosensory (vibration)	2 weeks	Gait variability	Vibrotactile feedback improved step regularity and stability.
van der Heijden et al., 2016	Experimental	19 PD	Somatosensory (tactile)	Single session	Gait timing	Rhythmic tactile cueing improved temporal gait parameters.
Lee et al., 2018	RCT	30 PD	Wearable vibrotactile	4 weeks	Balance, gait speed	Demonstrated improved gait speed and postural stability with wearable cues.
Ginis et al., 2018	Review	—	Multimodal cueing	—	Mobility, FOG	Suggested personalized, technology-assisted cueing improves long-term outcomes.

IV. DISCUSSION

The accumulated evidence strongly supports external cueing as a clinically meaningful intervention for gait dysfunction in Parkinson's disease (PD), with clear differences in strength of evidence across auditory, visual, and somatosensory modalities. Among the three, auditory cueing—particularly rhythmic auditory stimulation (RAS)—has the most consistent and robust empirical support. Multiple meta-analyses have demonstrated significant improvements in gait velocity, stride length, and cadence following auditory cueing compared with no cueing or conventional physiotherapy. Spaulding et al. (2013), in a meta-analysis of 34 studies, reported moderate to large effect sizes for RAS on gait speed and stride length. Similarly, Ghai et al. (2018) confirmed significant pooled effects of auditory cueing on temporal gait parameters, concluding that rhythmic auditory inputs reliably enhance motor output in PD. These findings are reinforced by clinical trials showing that auditory cueing not only improves immediate gait performance but can also improve functional mobility and motor severity scores on the UPDRS-III when embedded within training programs (Thaut et al., 1996; Nieuwboer et al., 2007). Mechanistically, neuroimaging and behavioral evidence suggest that auditory cues facilitate gait by engaging cerebello-thalamo-cortical networks, allowing compensation for impaired basal ganglia automaticity (Nombela et al., 2013). This neurophysiological rationale, combined with consistent quantitative improvements across trials, explains why auditory cueing is widely regarded as the gold standard among cueing modalities.

However, the literature also demonstrates that auditory cueing is not universally optimal and that its effectiveness depends on individualized prescription. Nieuwboer et al. (2007) demonstrated that fixed high-frequency metronome cueing can paradoxically increase cadence while reducing step length in some patients, potentially reinforcing pathological gait patterns. This reinforces evidence that cue frequency must be carefully titrated relative to baseline cadence and therapeutic goals. Nonetheless, when appropriately prescribed, auditory cueing remains the most strongly supported modality in terms of both quantity and quality of evidence.

Visual cueing, while supported by a substantial body of research, demonstrates a more task-specific pattern of effectiveness. Experimental and clinical studies consistently show that transverse visual cues improve step length and gait initiation by providing an external spatial target that compensates for impaired internal amplitude scaling. Azulay et al. (1999) demonstrated that simple floor markings significantly increased stride length and reduced bradykinetic gait patterns in individuals with PD. Morris et al. (2005) further confirmed that visual cues preferentially enhance spatial gait parameters rather than temporal ones,

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highlighting a clear distinction from auditory cueing. Systematic reviews focusing on freezing of gait (FOG) also report that visual cues can improve gait initiation and turning performance—two contexts strongly associated with freezing—although their impact on overall freezing frequency is inconsistent (Fischer et al., 2018). This inconsistency becomes particularly evident in more recent studies of wearable laser cueing devices. Barthel et al. (2018) conducted a controlled trial on laser shoes and found no significant overall improvement in gait or freezing severity, suggesting that benefits observed in earlier uncontrolled or short-term studies may not generalize to real-world conditions. Compared to auditory cueing, visual cueing therefore appears to have more contextual effectiveness (e.g., initiation, obstacle negotiation) rather than broad improvements across all gait parameters.

Somatosensory cueing represents the weakest but most rapidly emerging evidence base. Compared with auditory and visual cueing, far fewer high-quality randomized controlled trials exist, and methodological heterogeneity limits firm conclusions. Nevertheless, recent systematic reviews suggest that tactile cueing may have measurable benefits, particularly under cognitively demanding conditions. A systematic review by Calabresi et al. (2022) reported that vibrotactile cueing demonstrated small but significant improvements in gait speed and step length, especially during dual-task walking, suggesting that tactile inputs may reduce cognitive-motor interference. Rosenthal et al. (2018) further demonstrated that closed-loop vibrotactile cueing triggered during freezing episodes improved step initiation and reduced freezing duration in some participants. However, effect sizes remain smaller and less consistent than those reported for auditory cueing, and most studies are limited by small samples, short follow-up, and lack of standardization in stimulation parameters. Consequently, while somatosensory cueing shows promise—particularly as a wearable, discreet intervention for individuals who cannot tolerate auditory or visual cues—the current evidence base does not yet support it as equally effective.

Comparative evidence across modalities therefore suggests a clear hierarchy of effectiveness: auditory cueing demonstrates the strongest and most generalizable benefits across spatiotemporal gait parameters; visual cueing provides reliable improvements in spatial control (particularly step length and initiation) but with greater task specificity; and somatosensory cueing remains an emerging adjunct with limited but promising evidence. Importantly, multiple trials emphasize that cueing is most effective when delivered as part of structured rehabilitation rather than as a passive compensatory tool. The RESCUE trial by Nieuwboer et al. (2007) demonstrated that home-based cueing training produced significant short-term improvements in gait and mobility, though long-term retention after cue withdrawal was limited. This limitation is echoed across the literature, suggesting that while cueing can enhance performance, it does not consistently restore automaticity, and cue dependency remains a concern.

Overall, the weight of evidence supports cueing strategies as scientifically grounded, clinically effective interventions for gait rehabilitation in PD. The strongest empirical support lies with auditory cueing, moderate support with visual cueing (particularly for spatial deficits), and preliminary but growing support for somatosensory cueing. Future research must prioritize high-quality head-to-head trials, long-term follow-up, and personalized cueing protocols to strengthen clinical translation and optimize functional outcomes.

V. CONCLUSION

Strong evidence supports the clinical use of cueing strategies to improve gait in Parkinson’s disease, with auditory cueing showing the most consistent and largest effects on gait speed, cadence, and stride length across meta-analyses (Spaulding et al., 2013; Ghai et al., 2018). Visual cueing demonstrates specific effectiveness for spatial gait deficits, particularly step length and gait initiation, but its benefits are more task-dependent and less consistent in real-world contexts, especially with wearable laser devices (Azulay et al., 1999; Barthel et al., 2018). Somatosensory cueing shows emerging but limited evidence, with small-to-moderate benefits reported mainly under dual-task conditions and in freezing of gait, yet conclusions are constrained by fewer high-quality trials (Rosenthal et al., 2018; Calabresi et al., 2022). Overall, cueing is most effective when individualized and integrated into structured gait training, rather than used as an isolated compensatory strategy (Nieuwboer et al., 2007). Current evidence therefore supports auditory cueing as the most evidence-based modality, visual cueing as task-specific but valuable, and somatosensory cueing as promising but not yet equivalent.

VI. LIMITATION

- The narrative review design did not include a formal methodological quality assessment of included studies.
- Inclusion of only English-language publications may have introduced language and publication bias.
- Considerable heterogeneity existed across studies in terms of design, intervention protocols, and outcome measures.
- Quantitative synthesis was not performed, limiting the ability to estimate pooled effect sizes.

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