

## Full-Length Article

**Validity and Inter-rater Reliability of the SOAR Tool during Ambulation in Individuals with Parkinson Disease**Kristen Prejean Barta<sup>1</sup>, Carolyn Da Silva<sup>2</sup>, Shih-Chiao Tseng<sup>2</sup>, and Toni Roddey<sup>2</sup><sup>1</sup>The University of St. Augustine for Health Sciences, United States of America<sup>2</sup>Texas Woman's University, United States of America**Abstract**

Parkinson disease (PD) leads to neurological impairments yet the auditory system remains intact. Rhythmic Auditory Stimulation (RAS) and Patterned Sensory Enhancement (PSE) have been shown to impact gait in PD. Music therapists (MT) can individualize auditory protocols but for a physical therapist (PT) to incorporate PSE into treatment, a new tool is needed. The Synchronized Optimization Auditory Rehabilitation (SOAR) tool, is a new software created to simulate PSE techniques and allow for customization depending on the individual's reaction to the cue. The purposes were to evaluate the validity of the SOAR tool with RAS and the inter rater reliability between disciplines' application of the SOAR tool. During testing day one the MT measured gait parameters during no auditory cueing, RAS, and SOAR tool. On testing day two the PT measured the same gait parameters while only using the SOAR tool. A moderate to high correlation between RAS and the SOAR tool was found on all spatiotemporal parameters tested. The inter rater reliability between the MT and PT was high on all parameters of gait. These findings suggest the SOAR tool is an additional auditory cue delivery method that PTs could use in the treatment of individuals with PD when auditory cues are deemed appropriate. The new method facilitates a PT's ability to use auditory cues when a MT is not an available member of the interdisciplinary rehabilitation team.

**Keywords:** *Parkinson's disease, RAS, PSE, gait*multilingual abstract | [mmd.iammonline.com](http://mmd.iammonline.com)**Introduction**

Parkinson disease (PD) is a progressive neurological condition of the basal ganglia, which influences the descending motor pathways for movement control. [1,2] A decrease in the basal ganglia's control leads to bradykinesia, rigidity, tremor and postural instability. [3] These impairments are observed during ambulation as dysfunctional patterns resulting from the inability to move in a fluid manner. Gait parameters have been shown to be indicators of the severity of disease, as demonstrated by the increased variability of a person's step length and velocity, 20% decrease in step length compared to healthy controls, and decreased activity with difficulty maintaining minimum physical activity recommendations. [4-9] As the disease progresses, an individual's ability to maintain independence and safety declines.

Despite this population having a disruption in motor

coordination, the auditory system remains intact and properly receives information from the environment. The basal ganglia receive sensory information and improvements in movement have occurred with auditory facilitation as the external cues have been reported to improve the impaired internal motor response. [10,11] In an attempt to bypass the dysfunction, the input system receives auditory information through the striatum to ultimately project to the premotor cortex. [12-16] Auditory information has been shown to impact sequencing, timing, and behavioral response selection of movement. [17,18] Utilization of sound to promote functional movement patterns relies on this auditory system to facilitate activation of the motor systems. [12]

Rhythmic Auditory Stimulation (RAS) is a form of auditory cueing that uses a fixed repetitive tempo. [19] Individuals with PD have shown immediate gains in stride length, cadence regulation and symmetry with RAS set at a tempo 10% faster than preferred walking cadence. [18] When RAS is delivered at percentages slower and faster than a preferred gait speed, cadence and velocity have immediate changes, but improvements are noted only at quicker tempos of 107.5% and 115% above preferred speed. [20] Hausdorff et al. [21] also found that the use of RAS is more beneficial when the pace is set between 100 to 110% above preferred walking speed for stride length and swing time. Additionally, individuals with PD who completed an exercise program

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using quicker tempo RAS, demonstrated an overall 25% increase in stride length and cadence on flat and incline surfaces as compared to a control group without auditory cueing during testing 24 hours later, indicating a potential carryover effect. [22]

Patterned Sensory Enhancement (PSE) is an enhanced auditory technique which possibly impacts the spatiotemporal parameters and force patterns of a movement.[19] Research has suggested that PSE, through interventions that melodically, rhythmically, and tonally facilitate improved functional movement, might result in improved movement outcomes.[23] Basic PSE tools have now become available in the treatment of gait dysfunction by physical therapists (PTs) for their patients.[24] Preliminary research has suggested that through music, re-organization within the brain is possible and volitional movements can be initiated even when the stimulus is removed.[25] Music has other benefits over RAS as it has been shown to improve happiness measures when used during therapy and improve adherence to exercise programs and quality of life.[26-28] A recent study found that individuals with PD perceived improve motor function during ambulation using customized music and preferred this technique over RAS from an emotional aspect.[29] Despite its potential, few advancements have been made to improve the effectiveness of music protocols used by PT's. In the rehabilitation setting, PTs and music therapists (MT) work synchronously and asynchronously to promote functional mobility in persons with movement disorders. Currently, PTs rely on MTs to provide individualized auditory protocols and the limitation is that MTs are not always an available member of the rehabilitation team. The emotionally pleasing musicality aspect, which patients respond to, is often unavailable. Prerecorded music and metronomes can fall short as tools to address gait in people with PD. For a PT to independently incorporate PSE into treatment of persons with PD, a new tool is needed. Further, the reliability and validity of the new PSE tool in the PD population when administered by a PT must be examined.

There were two purposes of this study. The first was to evaluate the concurrent validity of a new PSE tool with RAS. And the second purpose was to assess the inter rater reliability between MT's and PT's application of the new PSE tool. Both purposes used the spatiotemporal parameters of gait for comparison. The hypotheses were that there would be a moderate correlation between the 2 intervention strategies and a high level of inter rater reliability between the disciplines.

## Methods

### Participants

Twenty participants were recruited. The sample size required to demonstrate adequate power was calculated using GPower,

and 20 participants were determined to be an appropriate number to determine significance and account for attrition.[22,30-35] The inclusion criteria was a diagnosis of PD and a Hoehn and Yahr classification of I - IV with the ability to walk independently for at least 10 minutes over a leveled surface.[36] Exclusion criteria was a deep brain stimulator, any acute orthopedic injury, a surgery within 2 months of data collection, a hearing impairment not corrected by a hearing aide, or a complete dependence on an assistive device for walking any distance. Individuals were excluded for these reasons to decrease the risk of compounding effects of an additional treatment or limitation in walking that would not be impacted with an auditory cueing strategy. The study was approved by two Internal Review Boards and all individuals signed an informed consent.

## Instruments

### *Synchronized Optimization Auditory Rehabilitation (SOAR) tool*

Utilizing the SOAR tool is a new approach created to simulate PSE techniques used by a MT for treating movement dysfunctions. The SOAR tool is the first of its kind and was created by a MT using software through Ovation<sup>1</sup> that allows individualized musical compositions to be created in real time. The SOAR tool uses an innovative process in recording and play back that is specifically designed so that PSE can be manipulated by a therapist through touch screen technology.

The SOAR tool uses a digitally recorded instrumental composition of a generic genre along with instrumental tracks that include the trombone, piano, guitar, clarinet, upright bass, and saxophone. Each PSE instrumental track, in theory, corresponds with a specific portion of the gait cycle. Each tempo is initiated through a single drum beat to establish the pace while the remaining instrumental tracks can be started and stopped as needed during observational gait analysis. This flexibility allows for immediate adjustments during gait assessment and training. The instrumental tracks were recorded separately yet are heard as a melody, regardless of the number played. This technology allows the melody to be customized to a person depending on the person's reaction to the auditory cue. A pilot study demonstrated that the SOAR tool impacted ambulation after training, but currently this is the first study assessing the methodology of this approach to delivering PSE.[37]

### *Zeno Walkway System (Zeno) with ProtoKinetics Movement Analysis software (PKMAS)<sup>2</sup>*

Computerized walkway systems are reliable and valid for obtaining information about the gait cycle.[34,35,38,39] The Zeno with PKMAS is a system that has high levels of

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<sup>2</sup> ProtoKinetics, 60 Garlor Dr., Havertown, PA 19083

consistency with the GAITRite<sup>3</sup> and uses similar components.[40] The GAITRite has been validated for assessing spatiotemporal parameters when compared to motion analysis systems and being able to discriminate between healthy and PD populations.[34,35,41,42]

## Procedures

Participants completed 2 days of testing, first with an experienced MT and second with a PT within 1 to 5 days. On both days, all 20 participants were tested within 2 hours of taking their PD medication to better align with previous research assessing the effects of RAS during ambulation. Participants were randomly assigned to a group, “control-RAS-SOAR” or “control-SOAR-RAS”, to minimize the confounding effects of a carryover response. The control condition was no auditory cueing and the participants walked at their preferred walking speed across the Zeno. The instructions promoted uniformity and encouraged the participants to walk through the entire length of the mat at a consistent pace. Individuals completed 3 passes that were averaged for data analysis. The measurements were processed using PKMAS and the determined cadence was used to establish the tempo for the auditory cues. The preset tempos available for the SOAR tool were 45, 57, 72, 89 and 108 beats per minute (bpm). If a participant’s cadence fell between 2 pre-established tempos on the SOAR tool, the higher tempo was used if the participant was deemed safe when walking at that tempo. The RAS and SOAR tool used identical tempos, maintaining consistency between the 2 conditions, and each were tested with 3 passes over the Zeno that were averaged.

On the first day of testing, participants worked with the MT and completed all 3 conditions. The control occurred first to establish the bpm and then participants practiced a walking trial to RAS or SOAR tool for 10 minutes with sitting rest breaks as needed. The surface was level, and the participants were instructed to start, stop randomly, and turn throughout the trial. The participants’ tempo for the RAS condition was set to the corresponding preset tempo using a metronome. During the SOAR tool-walking portion of the trials, the MT adjusted the instrumental combination to maximize the person’s overall quality of gait pattern. Observational gait analysis was used to assess changes in the participants’ walking pattern such as changes in festination, trunk posture, heel strike, and arm swing. Various combinations were trialed, until the best gait the MT determined pattern. To decrease the influence of prompts other than the auditory cues, no additional verbal cues were given. Once the MT felt the participants’ gait was maximized and the participants reported feeling comfortable with the cue, testing on the Zeno was completed while listening to the auditory cue. The

combination of instrumental threads chosen was recorded and placed in a secured envelope by the MT.

Between the 2 tests (RAS or SOAR), participants completed a washout period of 1 hour. After the washout period, the participants completed the same sequence of walking, rest and then testing trials with the other auditory cue.

Within 1 to 5 days of the first session, the PT who was blinded to the initial results and instrumental tracks chosen by the MT and only given the tempo used on the first day tested the participants. The PT only measured the control condition of no auditory cueing and the SOAR tool in that order for all participants. The first condition was measured using the same procedures as the first day with the MT and included 3 passes on the Zeno. Next, the participants completed 10 minutes of walking while the PT played various combinations of instrumental threads. The PT observed the same spatiotemporal variables along with gait quality. With the PT blinded to the combination chosen by the MT, the tracks were chosen based on movement response. Once the PT determined the optimal gait pattern using the SOAR tool, the participants completed walking passes on the Zeno.

## Data Analysis

All statistical analyses were calculated using SPSS 25 software (SPSS, Inc., Chicago, IL).

To determine the strength of the relationship of gait parameters administered by the MT between RAS and the SOAR tool, parametric Pearson’s correlations with bootstrapping were used,  $\alpha = 0.05$ . [43]

To evaluate the reliability of the same gait measures between the MT and PT using the SOAR tool, intra-class correlation coefficient (ICC) (2,k) values were calculated,  $\alpha = 0.05$ . ICC values were analyzed according to the following criteria:  $\leq 0.49$  was deemed low reliability, 0.50 to 0.69 as moderate, 0.70 to 0.89 as high, and 0.90 to 1.0 as very high reliability. [44]

## Results

Twenty participants completed the study, see Table 1. The mean and standard deviations of the dependent variables are illustrated in Table 2. The PD medications reported by the participants were Sinemet, Mirapex, Azilect, and Amantadine.

<sup>3</sup> CIR Systems, Inc., 12 Cork Hill Rd., Franklin, NJ 07416

**Table 1: Participant Demographics (N = 20)**

Characteristic	MEAN (SD)	
Gender (male, female)	10,10	
Age	72.95 (7.1)	
Years with PD	4.05 (3.12)	
Hoehn and Yahr stage (n)		
I		5
II		4
III		8
IV		3
Assistive device (n)		
Straight cane		2
Rolling walker		1
Cadence tested (n)		
89 beats/minute		16
108 beats/minute		4

**Table 2. Dependent Variable Means and Standard Deviations (N=20)**

Measure	MT	MT	MT	PT	PT
	NO CUE	RAS	SOAR	NO CUE	SOAR
Velocity <sup>a</sup>	0.89 (0.31)	0.94 (0.32)	0.95 (0.33)	0.94 (0.25)	0.96 (0.28)
Cadence <sup>b</sup>	104.18 (13.27)	105.95 (9.53)	107.5 (11.34)	109.08 (8.79)	106.0 (8.93)
Left step length <sup>c</sup>	50.56 (13.02)	52.52 (13.97)	52.92 (13.88)	51.56 (10.92)	54.01 (12.39)
Right step length <sup>c</sup>	51.50 (12.71)	53.61 (13.32)	53.68 (13.49)	52.11 (10.47)	54.68 (12.29)
Step width <sup>c</sup>	8.36 (2.9)	8.65 (2.41)	8.54 (2.43)	7.86 (2.74)	8.28 (2.82)
% Stance left	67.68 (5.67)	67.17 (6.37)	67.46 (6.33)	67.06 (4.89)	67.09 (5.94)
% Stance right	67.71 (5.67)	67.29 (6.27)	67.46 (6.38)	69.33 (13.41)	70.38 (19.52)
% Swing left	32.32 (5.67)	32.83 (6.37)	32.54 (6.33)	32.94 (4.89)	32.91 (5.94)
% Swing right	32.29 (5.67)	32.71 (6.27)	32.54 (6.38)	30.67 (13.41)	29.63 (19.53)
% SLS left	32.31 (5.72)	32.59 (6.2)	32.42 (6.21)	32.64 (4.55)	33.05 (4.58)
% SLS right	32.3 (5.61)	32.78 (6.33)	32.45 (6.21)	32.89 (4.92)	33.11 (4.95)

<sup>a</sup>meters/second, <sup>b</sup>steps/minute, <sup>c</sup>centimeters  
 Abbreviations: SLS, single leg stance

**Validity**

There were significant correlations between RAS and the SOAR tool administered by the MT for all gait variables: velocity ( $r = 0.96, P = 0.01$ ), cadence ( $r = 0.86, P = 0.01$ ), left and right step length respectively ( $r = 0.94$  and  $0.96, P = 0.01$ ), step width ( $r = 0.90, P = 0.01$ ), percentage time in stance phase for left and right leg respectively ( $r = 0.98$  and  $r = 0.90, P = 0.01$ ), percentage time in swing phase for left and right leg respectively ( $r = 0.98$  and  $r = 0.90, P = 0.01$ ), and percentage time in single leg stance for left and right leg respectively ( $r = 0.98$  and  $r = 0.98, P = 0.01$ ).

**Reliability**

Inter rater reliability ICC values for the 2 disciplines were significant ( $P < 0.001$ ) and high for the following gait variables: velocity (ICC = 0.94 range [0.84 to 0.97]), cadence (ICC = 0.79 range [0.54 to 0.91]), left step length (ICC = 0.92 range [0.82 to 0.97]), right step length (ICC = 0.89 range [0.75 to 0.96]), step width (ICC = 0.95 range [(0.87 to 0.98)], percentage stance left leg (ICC = 0.99 range [0.97 – 0.99]), percentage swing left leg (ICC = 0.99 range [0.97 to 0.99]), percentage left single leg stance (ICC = 0.97 range [0.91 to 0.99]), percentage right single leg stance (ICC = 0.97 range [0.93 to 0.99]). The inter rater reliability ICC values for right lower extremity percentage stance and swing phase were

significant ( $P < 0.006$ ) and moderate: (ICC = 0.70 range [0.24 to 0.88]) and (ICC = 0.70 range [0.24 to 0.88]) respectively.

## Discussion

This study describes the validity of a new tool in auditory cueing for people with PD and the ability of a PT, not trained in the musical field, to reliably use it. Given the novelty of the SOAR tool, this is the first study assessing its validity and reliability. RAS has been studied and has demonstrated its ability to effectively promote changes in the spatiotemporal parameters of gait in the PD population.[18-21] The simplicity of RAS has made it an ideal choice for PTs when implementing auditory cues during therapy sessions. A meta-analysis by Spaulding et al.[45] concluded that auditory cueing had a positive impact on velocity, cadence and stride length, but more research was needed to address the usability of various forms of auditory cueing, carryover effects, and social impact on the user.

The results suggest a moderate to high correlation between RAS and the SOAR tool on gait. RAS is the gold standard for PT auditory cueing in this population and the findings indicate the possibility of the SOAR tool being another effective method of delivery. With the ability to provide individualized auditory cueing, the SOAR tool may have some advantages of further improving gait patterns and providing input more amenable to patient use.

The interrater reliability between the MT and PT of administering the SOAR tool was high. These preliminary findings suggest the usability of this new auditory tool by PTs since the PT was able to use the software equipment and develop a musical piece that affected the gait pattern to a similar degree as the MT. Outside of the initial training sessions prior to data collection, neither PT in the study was skilled in musical composition or performance and relied on observed performance to determine the best composition. The importance of the findings promotes the use of auditory cueing in a larger population who would benefit from this intervention strategy. Currently, PTs are limited to RAS when a MT is not part of the rehabilitation team. The SOAR tool could provide another avenue to address the shortage of auditory cueing being used in rehabilitation. To the author's knowledge, there is no published research comparing the inter rater reliability of a MT and PT using RAS.

## Limitations

The preset tempos did not allow for flexibility during testing or uniform percent of increase in tempo above a participant's preferred walking speed driving the researchers to use the same tempo for both RAS and the SOAR tool. Another limitation of the tempo settings was the maximum 108 bpm that 9 of the participants exceeded. When measured using either auditory stimulus, some of these participants showed

lower velocity and slower cadence yet this change supports the theory that auditory cueing can impact gait cadence, both positively and negatively.

Additionally, some participants demonstrated variability of the spatiotemporal parameters of the control condition between the testing days. Because PD is a progressive condition, changes in function over time can be expected. The investigators attempted to reduce the risk of extreme physical changes by scheduling the second day within 5 days of the first as it is not expected a person would decline that rapidly without an unusual circumstance.

The final limitation to this study was that only the spatiotemporal parameters of stepping were measured. PSE techniques are believed to influence qualities of gait that are outside of stepping such as arm swing, trunk extension, and heel strike. While these changes were noted through observational gait analysis, there was no quantitative data to assess these variations.

## Conclusion

Auditory cueing has been shown to be an important and effective training method to improve the gait pattern in individuals with PD. The results of this study suggest that the SOAR tool is a valid tool when compared to RAS, and its administration is reliable between MTs and PTs. The clinical implication of these findings is that a PT could use auditory cueing in the form of a PSE when deemed appropriate for a patient. The SOAR tool is important because playing a random song, not customized to a person's needs, will not specifically and consistently activate the motor drivers necessary to produce a desired action. Currently, if a MT is not part of the rehabilitative team at a facility, a PT is limited to a metronome for auditory cueing. The potential exists to positively influence an individual with PD's gait pattern with the more customized approach of the SOAR tool. Additionally, the SOAR tool provides people the preferred musicality along with clinical feasibility to reach desired treatment outcomes. The findings of this study support the use of the SOAR tool for gait intervention by a PT when RAS and PSE are deemed appropriate.

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