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Does a Customized Musical Song Promote a More Positive Experience Vs. Rhythmic Auditory Stimulation when Used to Enhance Walking for People with Parkinson's Disease?

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Abstract

External auditory cueing has been shown to improve gait for individuals with Parkinson's disease (PD). Rhythmic Auditory Stimulation (RAS) uses a fixed beat while other strategies rely on a musical composition. Despite the extensive research on mobility with auditory cues, there has been little research that addresses the perceived benefits of music and the preferred method of stimulation. The Synchronized Optimization Auditory Rehabilitation (SOAR) tool is a new approach to simulate auditory cueing in the form of music. The purpose of this study was to answer the question, "Do participants report a higher level of satisfaction and motivation when using the SOAR tool as compared to RAS or no auditory cue during ambulation?" Participants ambulated with no auditory cueing, metronome, and music customized by the SOAR tool. The investigator asked open-ended questions during a semi-structured face-to-face interview session with each participant after the training. All participants preferred music to RAS and felt music best impacted walking. The emerging themes were auditory effects and utility that included the subthemes of motor impact, nonmotor impact, and issues within the testing and home environment. The perception was that music contributed to improved spatio-temporal parameters, balance, coordination, motivation, and happiness.

Keywords: Parkinson's disease, rhythmic auditory stimulation, pattern sensory enhancement, perception, gait.

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Resumen

Se ha demostrado que la percepción de la señal auditiva mejora la marcha en las personas con le enfermedad de Parkinson (PD). La Estimulación Auditiva Rítmica (RAS) utiliza un ritmo fijo mientras que otras estrategias se basan en una composición musical. A pesar de la extensa investigación disponible sobre movilidad con señales auditivas, existe poca investigación dirigida a los beneficios percibidos de la música y a los métodos de estimulación preferidos. La herramienta Optimización de la Rehabilitación Auditiva Sincronizada (SOAR) es un nuevo enfoque para simular señales auditivas en forma de música. El objetivo de este estudio fue dar respuesta a la pregunta: ¿Reportan los participantes un nivel más elevado de satisfacción y motivación cuando utilizan la herramienta SOAR en comparación con el RAS o sin señal auditiva durante la marcha? Los participantes caminaron sin señal auditiva, metrónomo, y música personalizada por la herramienta SOAR. El investigador formuló preguntas abiertas durante una entrevista semiestructurada con cada participante después del entrenamiento. Todos los participantes prefirieron música a RAS y encuentraron que la música tiene un impacto mejor para la marcha. Los temas que aparecieron fueron los efectos de la audición y su utilidad, que incluyó otros temas como el impacto sobre el movimiento, impacto sobre otras áreas no motrices y otros aspectos durante las pruebas y en el hogar. La percepción fue que la música contribuyó a mejorar parámetros espacio-temporales, equilibrio, coordinación, motivación y felicidad.

Palabras clave: *enfermedad de Parkinson, estimulación auditiva rítmica, modelo de mejora sensorial, percepción, marcha.*

Introduction

External cueing has been shown to be an effective strategy for individuals with Parkinson's disease (PD) to improve spatio-temporal parameters and functional gait (Thaut et al., 1992; McIntosh et al., 1997; Thaut et al., 1996; Morris et al., 1994; Behrman et al., 1998; Howe et al., 2003; Kadivar et al., 2011; Spaulding et al., 2013; Harro et al., 2014; Bukowka et al., 2016; Lirani-Silva et al., 2019). The pathophysiology of PD results from a progressive disruption of dopamine within the basal ganglia. Dopamine reduction leads to the four cardinal signs of PD: bradykinesia, tremor, rigidity, and postural instability (Ta-rakad & Jankovic, 2017). As the disease progresses, and production of dopamine is furt- her reduced, these characteristics increase in severity, resulting in safety issues, loss of independence and a decline in quality of life.

In individuals with PD, the reduced ability to create appropriate motor responses are due to the overactivation of pathways that inhibit movement, leading to timing deficits within the motor system. However, the auditory system remains relatively intact, and can properly receive information from the enviroment. The auditory stimulus provides an additional method to activate the motor system, by using a loop to the cerebellum and thalamus, which indirectly activates the premotor cortex through the temporal and parietal lobes (McIntosh et al., 1997; Freeland et al., 2002; Grahn & Brett, 2007; Petzinger et al., 2013; Stegemöller, 2014; Dalla Bella et al., 2015). In theory, predictable auditory cues promote temporal expectations resulting in more normalized movements. When the somatosensory system provides information to the brain these cues can potentially help regulate timing by influencing the basal ganglia-supplementary motor cortex-premotor cortex circuit

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which could assist in planning and ultimately executing a motor function (Ashoori et al., 2015).

Individuals without hearing impairments use cues from surrounding sounds for a variety of functional activities. Whether an auditory stimulus alerts a person of a car approaching, soothes a distressed infant or motivates one during recreational exercise, it is a tool that can be used to adjust motor actions. Individuals in a comatose state underwent music therapy for eight twelve-minute sessions and physiological changes occurred. When a therapist sang a wordless song, changes in heart rate and respiratory rate corresponded with the tempo of the song. Another interesting observation of the study found that these participants did not have the same response to talking, indicating that the body systems possibly respond more to rhythm rather than spoken sound (Aldridge et al., 1990). In individuals with an intact central nervous system, functional magnetic resonance imaging (fMRI) revealed that areas of the brain were activated when introduced to auditory stimuli (Chen et al., 2008). As individuals listen to a musical rhythm in a static position, with or without anticipation of the upcoming required motor task, the supplementary motor cortex, mid-premotor cortex and cerebellum have been shown by fMRI to be stimulated. This finding, in combination with previous work showing involvement of the basal ganglia and these structures in response to a motor task, points to the potential impact auditory stimulus can have on the areas of the brain that control motor movements (Zatorre et al., 2007).

Auditory cues have been shown to be an effective strategy to improve the spatio-temporal parameters of gait in individuals with PD. These cues can be delivered in the form of rhythmic auditory stimulation (RAS) or patterned sensory enhancement (PSE). RAS is an auditory cue in the form of a repetitive beat or sound, such as a metronome, and PSE is the use of harmony and melodies to impact movement and quality (Thaut et al., 2014). Improvements have been found in velocity, cadence, step length, single and double limb support, and muscle activation when RAS and PSE have been used during gait in individuals with PD. The most commonly studied intervention is RAS with a tempo set at a slightly higher percentage of preferred walking speed. Individuals with PD have shown improvements in various gait functions immediately after feedback and with training, suggesting the powerful impact auditory cues can have on mobility (Thaut et al., 1992; Morris et al., 1994; McIntosh et al., 1997; Behrman et al., 1998; Thaut et al., 1996; Howe et al., 2003; Fernández-del-Olmo & Cudeiro, 2003; Hausdorff et al., 2007; Bryant et al., 2009; Thaut et al., 2010; Kadivar et al., 2011; Spaulding et al., 2013; Harro et al., 2014; Dalla Bella et al., 2015; Bukowka et al., 2016; Lirani-Silva et al., 2019).

Despite the research on mobility with RAS and music in the PD population, there has been little research that addresses the emotional aspect of music and the preferred method of stimulation. In a randomized controlled trial, Pacchetti el al. (2000) compared music therapy and physical therapy over a three-month intervention period in individuals with idiopathic PD. The music therapy group showed significant improvements in the motor subsection of the Unified Parkinson's disease rating scale and Happiness Measure after intervention, while the physical therapy group did not. Findings also report that music can improve perception of motor improvement after listening sessions in individuals with PD (Nombela et al., 2013). The theory that music has an emotional effect in addition to motor effect is noteworthy. Incorporating music into therapy has also been shown to increase adherence to a program and improve quality of life measures (Pohl et al., 2003). At the current time, the authors found no other research that assesses the user's perception of how music or auditory cues impacts ambulation in the PD population.

The Synchronized Optimization Auditory Rehabilitation (SOAR) tool incorporates an approach that simulates techniques used by a music therapist during sessions with patients who have gait dysfunctions. The SOAR tool, created by a music therapist, uses playback methodology through Ovation[1] that allows a therapist to move beyond simple metronome type strategies and create musical pieces individualized to the person's needs in real time. This new process encourages the auditory system to facilitate movements that improve stepping strategies and thus impact the quality of the gait pattern. The theory relies on the concept that musical cueing is more complex than the repetitive clicks of RAS, which is not music. Potential improvement is possible because the SOAR tool allows customization to the specific issues of each person. The technique integrates music technologies using a new process in recording and playback. These are specifically designed so that the music therapist can manipulate PSE through a computerized software system (Barta et al., 2016). The software system could potentially allow a physical or occupational therapist to stimulate the auditory drivers for the motor system more specifically by customizing the sensory input using the SOAR tool to facilitate more predictable gait parameter improvements during treatment sessions.

The SOAR tool uses a digitally recorded instrumental composition of a generic genre. The instrumental tracks include the trombone, piano, guitar, clarinet, upright bass, and saxophone. Each PSE track, in theory, corresponds with a specific portion of the gait cycle. The varying tempos are initiated through a single drum beat to establish the pace, serving the purpose of RAS. The remaining instrumental tracks can be started and stopped through a touch screen, allowing immediate real-time adjustments during gait assessment and training. The instrumental tracks were recorded separately, resulting in the composition being heard as a melody, regardless of the number of tracks played. This technology makes it possible to customize a melody depending on the impairments presented, as well as to modify it in real time based on a person's reaction to the auditory cue (Barta et al., 2016).

The purpose of this study was to assess participants' (with PD) perception of his or her experience using RAS and the SOAR tool during ambulation. The research question was, "Do participants report a higher level of satisfaction and motivation when using the SOAR tool as compared to RAS or no auditory cue during ambulation?"

Methods

Participants

Convenience sampling was used to recruit people from local physicians' offices, local PD support groups, community exercise groups, and word of mouth. Information regarding the study was distributed through flyers and

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informational announcements. The inclusion criteria included persons with a diagnosis with PD, Hoehn and Yahr classification of I to IV, and ability to walk independently for at least 10 minutes over a level tiled surface without an assistive device (Hoehn & Yahr, 1967). The exclusion criteria were individuals with a deep brain stimulator, an acute orthopedic injury or surgery within two months of data collection, a hearing impairment not corrected by a hearing aid, complete dependence on an assistive device for walking any distance, or those who had used the SOAR tool in a previous pilot study. All participants and caregivers signed an informed consent form approved by the Institutional Review Boards of Texas Woman's University and University of St. Augustine prior to starting data collection.

Equipment

The SOAR tool provided the music that was played through a desktop computer using Ovation software. Two speakers were attached to the computer to play the music at an appropriate volume wherever the participant was in the room. The same computer used a free metronome program to provide the other auditory cue.

Research design

This study utilized a qualitative research approach using coding and triangulation to assess the participants' and caregivers' perception of the SOAR tool and RAS. The investigator asked open-ended questions during a semi-structured face-to-face interview session with each participant (Patton, 2015). If the caregiver was present and willing to be interviewed, the investigator asked separate questions of him or her. The interview occurred simultaneously with another data collection and within one to five days after each participant completed gait training using RAS and the SOAR tool by a music therapist. The two types of auditory cues were given in a random order, and the tempo was determined by the participant's cadence during a measured walk across a computerized walkway system (Bilney et al., 2003; Egerton et al., 2014). The participants walked to RAS and the SOAR tool five to 10 minutes to become accustomed to the cue and develop a walking pattern in synchrony with the tempo. Modifications to the SOAR tool track combination were made until the most optimal gait pattern was determined through observational gait analysis by the music therapist. Music therapists are trained professionals in movement analysis pertaining to auditory cueing. The combination of instrumental tracks used for each participant was different based on the individual's clinical presentation during gait (Thaut et al., 2014).

The focus of the questions was on self-perception of functional change during walking, enjoyment while using each intervention (SOAR tool and RAS), and feelings about which would more likely be used for independent exercise. The caregiver was asked about his or her perception of the participant's level of enjoyment and likelihood of compliance at home, as well. The interview questions are listed in Appendix A.

All interviews were audio recorded and transcribed verbatim. The transcriptions were emailed or mailed, depending on participants' preference, for member checking to confirm that the report accurately portrayed their perceptions and intended meaning (Patton, 2015).

Data Analysis

Qualitative data were analyzed using a content analysis approach. Independent coding

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occurred first by KB and CDS of the transcripts of three participants, to facilitate consistency and trustworthiness coding (Patton, 2015). The rest were completed by KB through line-by-line coding to identify codes of the remaining 17 interviews. Index cards were created with the coded words and phrases for sorting. Together, KB and CDS used the individual note cards to complete the sorting process and identify categories, subthemes, and themes by visually laying all cards into columns on a large table. The notecards were clustered by similar participant responses and then compared to determine how the groups were related. As like tendencies emerged, possible subthemes and categories were written on a dry-erase board. Comparison of the categories that emerged lead to the overarching themes, or major elements, that developed from the qualitative data. (Creswell, 2018; Patton, 2015; Smith & Furth, 2011; Elo & Kyngäs, 2008). KB and CDS determined that data saturation had occurred after reviewing the 20 transcripts of the participants (Fusch & Ness, 2015; Guest et al., 2006).

Results

The participants consisted of 20 individuals with PD. The mean age of the participants was 72.9 years old, the mean years since diagnosis was four, and there were 10 females and 10 males. Three caregivers participated in the interview process, two wives and one daughter. The participants were typically able to answer in a short period of time, averaging seven minutes. All three caregivers provided more information than their loved one, providing more detailed descriptions of how the auditory cue impacted movement. Seventeen of the participants reported that they preferred the music to the metronome. The other three individuals stated that they preferred no auditory cue, and no one reported a preference to the metronome. All three caregivers reported they liked the music better and felt that it impacted walking the most of the three conditions.

The questions that were most difficult for some participants to answer involved reflecting on the change in walking pattern or quality of movement. Most participants discussed how a particular auditory cue impacted how they walked but some could not differentiate or were not able to verbalize what they felt. If a participant provided a non-descriptive answer, the investigator would ask for clarification without providing additional prompts. For example, if the response was "better," then the investigator would ask *how* it was better. The investigator was cautious to not influence thoughts or responses of the participants.

The two themes that emerged through data analysis were *auditory cues* and *utility*. The two themes evolved from reports of how RAS and SOAR were perceived to change motor and emotional elements and the feasibility of using the auditory cues. Within these two themes were two sub-themes for *auditory cues*: *motor impact on walking* and *nonmotor impact*, and two sub-themes for *utility*: *testing issues* and *home issues*. These led to several categories and sub-categories. Figure 1 illustrates the results of the qualitative data.

The larger sub-theme within the theme *auditory effects* was *impact* on the motor system. The influence of music was the category that was reported to have the greatest impact by the participants and the caregivers. While the metronome was reported to help with stepping strategies during walking, by increasing the length and speed, walking with the music was what people reported to change the

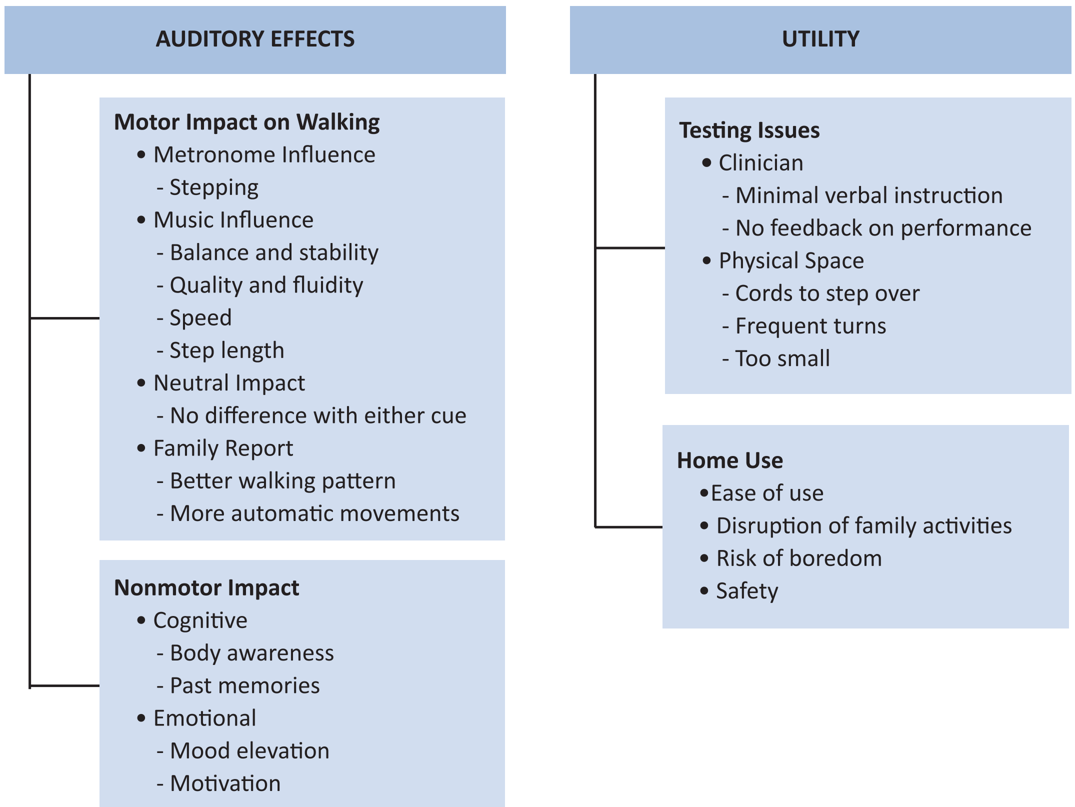

FIGURE 1**. Data Analysis results with auditory effects and utility as themes and related sub-themes, categories and sub-categories.**

quality of movement with one participant clearly stating, "Music improves quality of gait." Another participant described this change by stating,

"…I felt like after a minute or so it changed everything about my body. It [music] helped with rigidity. It helped with fluidity. It changed everything about the way I was moving."

One participant even stated, "Actually, it [music] kind of pulled me along," suggesting that the music gave her a sensation of forward movement to facilitate her gait progression. The motor impact of music even moved beyond simple stepping strategies with some participants reporting perceived improvements in balance, stability and coordination during walking. Walking is a complex task that incorporates balance and the ability to reciprocally move the lower extremities. The ability of the participant to potentially increase step length and speed could be in combination with perceived improvements in these areas. The caregivers also perceived a difference in the walking pattern and automaticity of the movements. One participant's wife said,

"I think his walking was smoother, if there is such a thing. He looked more natural with the music. With the metronome, and maybe it's just my perception, was that it was too rigid." The daughter, who stated during the walking sessions that she is constantly reminding her dad to move his arms, said,

"…that without the music he was barely moving his arm, his arm was basically straight. And after that [music] he did it automatically without me saying anything!"

The reported changes of the participants were consistent with previous research using auditory cues to influence walking. Most participants reported that the cues were helpful and changed their walking pattern. Objectively measured improvements in spatio-temporal parameters of gait in individuals with PD is documented in the literature and the categories within the *motor impact on walking* subtheme of the qualitative data are in alignment. (Thaut et al. 1996; Howe et al. 2003; Hausdorff et al., 2007; Lohnes & Earhart, 2011, Dalla Bella et al., 2015; Benoit et al., 2014). The uniqueness of this study was that the participants were not aware of the measured changes from the computerized walkway and were only reporting on how they felt their walking changed.

Despite the positives perceived by most participants, there were four people who did not notice a difference in walking between the two auditory cues. They reported noticing a difference from no auditory input to RAS or SOAR, but they did not perceive improvements of the music over the metronome or vice versa. Most were open to the idea that there might have been a change in their walking pattern; any change, if present, was just not noticeable to them.

The *nonmotor impact* was an interesting result found during the analysis process. The questions were meant to target the participants' perception of how the spatio-temporal parameters of gait changed with each auditory cue. The two categories that emerged from the sub-theme of *nonmotor impact* were *cognitive* and *emotional*, although the interview did not directly address these areas. In the cognitive category, participants discussed having a past knowledge of music, whether it be from marching band, military or dance. The music was stated to be easier to follow or made them remember a past life experience. Some participants stated that the music gave them more awareness of their body in general. One participant said that the music had a lasting effect that she felt for a while after testing. She stated, "After a bit on the music I actually felt myself kind of internally in my head almost singing to the rhythm." Another reported, "The music makes me want to get into the rhythm more." The other main category that emerged under the *nonmotor impact* was the emotional component. Ten individuals reported that the music was motivating and made them feel better. For example, two individuals stated the following, suggesting that music could be a more positive experience for the user.

"Music makes it more interesting, more entertaining. And it sort of lifts your spirits to hear a melody line or harmony line."

"So the music actually made me feel, you are going to laugh, but the music made me feel happy. You know, it was like a light, airy melody that made me kind of want to skip along!"

The benefits of music therapy have been reported in healthcare across other populations such as psychiatric conditions, depression, and pain management. The use of music has facilitated improvements in these conditions on participant subjective reports (Silverman, 2006; Godi et al., 2016; Magee, 2002; Krout, 2001). Pacchetti el al. (2000) reported improvements in the Happiness Measure after three months of music therapy including singing and playing musical instruments in individuals with PD. While these studies indicate the positive effect music can have on the emotional state of a person, none focused on the perceived impact of physical mobility during ambulation in the PD population.

The other theme was *utility* and participants' ability and motivation to incorporate auditory cues into their walking programs. Some participants discussed the limitations of the lab testing environment. The room, 20 feet in length, caused the participants to have to make frequent turns. The limited space may have decreased participants' ability to focus on the auditory cue when walking because of the external distractions. Additionally, due to the nature and purpose of the study, there was no formal training or verbal instruction given on how to walk with the auditory cue. The investigators did not provide any instruction other than "walk with the beat/music" and some participants stated they did not know if they were doing it correctly. Similarly, the investigators did not give any feedback on how well or poorly participants walked with either auditory cue. This lack of feedback was done purposefully so as not to sway the individual's perception of either cue before the interview occurred. This deliberate withholding of information could have led to some participants not having a good understanding of how their walking changed with each cue.

The final sub-theme was the auditory cues' ability to be incorporated into home use. Despite most participants preferring the music, there was a reported risk of boredom if the musical piece was the same day after day. Boredom, along with the music being difficult or potentially unsafe to use, were limiting factors to incorporating music into a home exercise program. One participant highlighted an area of concern when discussing the practicality of using an auditory cue in the community. Her statement below sheds light on issues that would need to be addressed before issuing an auditory cue as a home program.

"It concerns me a little bit about traffic if I'm outside. I kind of want to have my senses going, but you know, you can find better places to walk too. The trail, for example."

Discussion

This study aimed to assess if individuals with PD perceived walking with a customized musical piece to be a better experience than walking with a metronome or without any auditory cues. Although there is ample research to support the use of auditory cueing during ambulation in the PD population, there is little to no documented research indicating how these interventions are perceived or preferred. RAS has been shown to increase velocity, step length and cadence in individuals with PD (Behrman et al., 1998; Morris et al., 1994; Thaut et al., 1996; Howe et al., 2003; Hausdorff et al., 2007; Picelli et al., 2010). Likewise, there is supporting research of using PSE, melodies and harmonies, to have similar impacts on walking in this population (Wittwer et al., 2013; Bukowska et al., 2016). While researchers have acknowledged that these interventions serve a valuable role in rehabilitation, there is inconclusive evidence as to if these methods are perceived as beneficial from the user's end.

The participants in this study reported positive experiences using an auditory cue during ambulation from a motor standpoint, with music being the preference of most. The music added not only perceived motor benefits to spatio-temporal gait parameters, but also benefits to balance, coordination and continuity of movement. The responses of the participants and their caregivers aligned with what is typically observed during walking with auditory cues in the presentation of longer step lengths, faster velocity, and improvements in stability and overall quality of movement. The results of this study suggest that individuals with PD and their caregivers perceived a positive change in these parameters, as well.

Another aspect of the music that may make it superior to RAS is its impact on a patient's motivation. A participant stated in an interview that "the music motivates people to move," indicating music's potential to support compliance with home exercise programs. In the field of rehabilitation, noncompliance is an issue that clinicians deal with often (Sluijs et al., 1993). Adherence to a home exercise program is influenced by how helpful a client feels the program is as well as the program being able to fit into their everyday schedule (Sluijs et al., 1993; Campbell et al., 2001). Having a tool or intervention that improves motivation to move and be active could improve compliance. The statement "it definitely makes me feel happier" supports the notion that a patient may be willing to exercise because the music has a positive emotional impact. Cavanaugh et al. (2015) found that individuals with PD have difficulty maintaining the recommended daily steps for physical activity. Results of this study are promising because research has shown that individuals with PD can be successful in using auditory cues in a home-based intervention program. Significant improvements in gait speed and stride length have been demonstrated in this population when RAS or another form of musical cue was used on a home basis during daily activities (Bryant et al., 2009; Ginis et al., 2016). In the RESCUE trial, patients with PD received external cueing in the form of auditory, visual or vibratory cues in the home environment during functional tasks and showed significant improvements after training, and at a three month follow up, in velocity, step length, and fear of falling (Nieuwboer et al., 2007). Providing a motivational and enjoyable method for encouraging activity could lead to better outcomes in compliance and overall activity level.

There were limitations to this study. The first is that the interviews occurred one to five days after the initial use with the music therapist. This delay could have resulted in some individuals not accurately remembering how they felt when using each auditory cue. The questions focused on how participants perceived each cue to change gait pattern. With the delay in questioning, some participants may have provided less detailed responses. Another limitation was the questions. The purpose of the study was to determine if individuals with PD perceived a higher level of satisfaction and motivation in walking with the metronome or a customized musical piece, and the questions focused on changes in walking pattern with each auditory cue. The weakness of the questions became apparent after a few interviews because participants were reporting an emotional improvement as well with the music over the metronome. Due to the lack of qualitative research experience of the interviewer, the questions were not modified midway through data collection, and the same format of questioning continued for all participants. More questions could have been developed to assess this domain further to potentially capture more detailed and productive emotional responses to the music.

Conclusion

Auditory cues, administered through RAS and PSE, have demonstrated improvements in the spatio-temporal parameters of gait in individuals with PD. To the authors' knowledge there is no current research that specifically assesses the perceived improvements in ambulation, with the use of auditory cues, in individuals with PD. Most of the participants in this study indicated a preference to auditory cues given in a musical form over RAS. The perception of most of the participants was that music contributed to improved spatio-temporal parameters, along with balance, coordination, motivation and overall happiness. The findings from this study suggest that this music tool could offer improvements to intervention beyond physical performance. Since individuals with PD perceive music as more motivating and better than RAS, it could lead to improved outcomes in ambulation and compliance in home exercise programs. Music could be the catalyst to stimulate motivation as well as motion.

Appendix A: Interview Questions

Participant Questions

1) Tell me how you felt when using the metronome during walking?
2) Tell me how you felt when using the music during walking?
3) Tell me how you walked differently when using the metronome as compared to the music?
4) Which method would you be more likely to use when exercising at your own home?
5) Can you think of any reasons why the metronome/music would be hard to use when exercising at home?

Caregiver questions

1) Tell me how (name of participant) walked differently when using the metronome as compared to the music?
2) Which method (either metronome or music) do you think would be more motivating for (name of participant)?
3) Can you think of any reasons why the metronome/music would be hard to use when exercising at home for (name of participant)?

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