A Systematic Review of Wearable Devices for Improving Speech in Parkinson's Disease

Ramya Konnai, Ph.D., CCC-SLP
Senior Speech Language Pathologist, HFHS

Chayadevie Nanjundeswaran, Ph.D., CCC-SLP
Associate Professor, East Tennessee State University

Balaji Rangarathnam, Ph.D., CCC-SLP
Assistant Professor, East Carolina University

Disclosure

- All authors have no financial or non-financial disclosures

INTRODUCTION

- Challenges in behavior therapy:
  - Deficits in sensory perception and internal cueing in Individuals with PD (IwPD)[1]
  - Impaired online auditory feedback and proprioceptive feedback[2]
  - Adherence to intensive speech therapy
- Limited info on carryover of therapy effects in real life environment

1) Ho, A. K., Bradshaw, J. L., Iansek, R., & Alfredson, R. (1999). Speech volume regulation in Parkinson's disease: Effects of implicit cues and explicit instructions. *Neuropsychologia*, *37*(13), 1453-1460.
2) Ho, A. K., Bradshaw, J. L., & Iansek, R. (2000). Volume perception in parkinsonian speech. *Movement Disorders*, *15*(6), 1125-1131.

INTRODUCTION

- Growing interest in wearable devices
  - Assessing carry over of therapy benefits
  - Detecting dysfunction that is not evident in clinic
  - Remote monitoring of health condition/vocal function
  - Simplify patient participation
  - Allow for feedback during daily activities and not just in the clinic

INTRODUCTION

- 73 technology based devices available for PD (22 wearable; 38 non-wearable; 13 hybrid) Godinho et al. *Journal of NeuroEngineering and Rehabilitation* (2016) 13:24
  - Gait training, assessing tremor, bradykinesia, dyskinesia, feedback about posture, physical activity, falls

OBJECTIVE

To systematically review the evidence for currently available wearable assistive devices to improve speech outcomes in individuals with PD.

CLINICAL QUESTION

"What is the evidence for the use of currently available wearable assistive devices to improve speech characteristics in individuals with PD?"

METHODS

- Wearable devices were defined as “electronic technology designed to be worn on the body or embedded into watches, clothing and others and allows portability.”

METHODS

- Search engines: Pubmed, Google Scholar and Cochrane databases

- Search terms: “Parkinson’s disease, Assistive devices, Wearable devices, Speech Amplification devices, Altered Auditory Feedback, Tactile feedback, Visual feedback, Biofeedback, Speech intelligibility, Speech rate, Vocal intensity, and Lombard effect.”

METHODS

Inclusionary criteria:

- Participants with PD with and without DBS
- Articles published in the English language since the year 2000
- Currently available in the market
- Speech outcome measures

METHODS

- 21 articles short listed to 6 articles
- Four devices identified
  - SpeechVive™
  - Voxlog
  - Small talk and school DAF
  - SpeechEasy

SpeechVive™

Image courtesy: www.speechvive.com

How it works?

Image courtesy: http://www.speechvive.com/how-it-works.html

"SpeechVive is a prosthetic device engineered to make talking louder and more clearly, easy."

Evidence for SpeechVive™ Study #1

JSLHR

Research Article

Laryngeal Aerodynamics in Healthy Older Adults and Adults With Parkinson's Disease

Deborah Matheron,[a,b] Elaine T. Stathopoulos,[a] Jessica E. Huber,[c] and Joan E. Sussman[a]

Journal of Speech, Language, and Hearing Research • Vol. 60 • 507–524 • March 2017

SpeechVive Study #1

Matheron et al., (2017)

- Purpose:

1) To investigate whether healthy older adults (HOAs) and individuals with PD (IwPD) show similar laryngeal aerodynamics at comfortable vocal intensity

2) To assess the laryngeal aerodynamic adjustments utilized by both groups to increase Sound Pressure Level (SPL)

- how HOAs and IwPD would increase their SPL in the presence of speech babble

SpeechVive™ Study #1

Matheron et al., (2017)

- Subjects
  - 42 individuals with PD (34 men; 8 women; mean 70 years of age)
  - 20 (10 men and 10 women) age matched controls
- Speech task:
  - SPL measured in *"buy pop or pop a papa"*
  - Multitalker babble to one ear activated when speaking at a pre-set level
  - Babble amplitude was adjusted to elicit 3-5 dB above each participant's SPL in quiet.

SpeechVive™ Study #1

Matheron et al., (2017)

RESULTS:

- Mean SPL in quiet was 94.1 dB for controls and 95.6 dB for PD group (no statistical difference)

- Speech in noise resulted in a significant gain of 2.59 dB for PD group and 1.88 dB for controls compared to speech in quiet.

SpeechVive™ Study #1

Matheron et al., (2017)

Study Criticisms:

- Unnatural sentence production task
- Limited to one session
- High dB values (95 dB for PD) at baseline (i.e. SPL in Quiet)
- Normal mean dB SPL in speech for older (mean: 72 years) males is 65.8 (SD=4.9) and older females is 66.4 (SD= 4.0)

Goy, H., Fernandes, D. N., Pichora-Fuller, M. K., & van Lieshout, P. (2013). Normative voice data for younger and older adults. *Journal of Voice*, *27*(5), 545-555.

SpeechVive™ Study #2

Journal of Communication Disorders 52 (2014) 44–64

Contents lists available at ScienceDirect

Journal of Communication Disorders

Research paper

The effect of increased vocal intensity on interarticulator timing in speakers with Parkinson's disease: A preliminary analysis

Kelly Richardson [a,*], Joan E. Sussman [a,1], Elaine T. Stathopoulos [a,1], Jessica E. Huber [b,2]

[a] University at Buffalo, Department of Communicative Disorders & Sciences, 3435 Main St., 122 Cary Hall, Buffalo, NY 14214, USA
[b] Purdue University, Department of Speech, Language, and Hearing Sciences, 500 Oval Dr., Heavilon Hall 202B, West Lafayette, IN 47907-2038 USA

SpeechVive™ Study #2

Richardson et al., (2014)

- Purpose:

1) To examine the effects of lombard elicited changes in vocal intensity
2) Examine the effects of increased vocal intensity on interarticulatory timing (voicing initiation and termination) in IwPD

SpeechVive™ Study # 2

Richardson et al., (2014)

Subjects:

- 10 individuals with PD (8 men and 2 women; mean age of 74 years; H& Y from 2-4.5)

Stimuli:

- Multitalker babble to one ear activated when speaking
- Babble amplitude was adjusted to elicit 3 dB above each participant's SPL in quiet.
- Babble amplitude adjusted bi-weekly

SpeechVive™ Study #2

Richardson et al., (2014)

- Speech task:
  - Six sentences with words with voiceless consonants (p, t, k) followed by high vowels (i, u) randomly presented with the carrier phrase “it’s a again”.
  - Three repetitions of each sentence resulted in 18 sentences per participant per session.

Feedback protocol:

- Eight weeks of feedback; wore device for 2-8 hours per day during conversation and 30 min of oral reading 5 days per week

SpeechVive™ Study #2

Richardson et al., (2014)

- Outcome measures: SPL, Voice Onset Time (VOT), percent voicing, VOT ratio, and speech intelligibility.
  - VOT and % voicing are two common acoustic measures of interarticulatory timing
- Vocal intensity (measured pre-treatment, immediately post treatment and 4 weeks after post treatment at home and clinic)
- Speech Intelligibility: Sentences from Sentence Intelligibility Test (SIT) used. Percent intelligible score obtained by averaging % of words correctly identified by 2 SLPs.

SpeechVive™ Study #2

Richardson et al., (2014)

RESULTS:

- Significant session effect with Mean SPL increase of 2.9 dB SPL (range: 1.6-3.3).
- Effects not retained. Mean SPL decrease of 2.53 dB (range: 1.2-3.13) after 4 weeks.
- Mean speech intelligibility scores increased from 93% at the onset of treatment to 98% immediately post-treatment.
- Six of the 10 speakers showed improved temporal coordination between the laryngeal and supralaryngeal mechanisms (interarticulator timing) in response to treatment.

SpeechVive™ Study #2

Richardson et al., (2014)

Study Criticisms:

- Stimuli limited to unnatural sentence production
- Small sample size (10 subjects)
- No mention of how much data was collected at home vs. clinic.

SpeechVive™ Study # 3

Journal of Communication Disorders 48 (2014) 1–17

Contents lists available at ScienceDirect

Journal of Communication Disorders

Increased vocal intensity due to the Lombard effect in speakers with Parkinson's disease: Simultaneous laryngeal and respiratory strategies

Elaine T. Stathopoulos [a,*], Jessica E. Huber [b,1], Kelly Richardson [a,2], Jennifer Kamphaus [a,2], Devan DeCicco [a,2], Meghan Darling [b,1], Katrina Fulcher [a,2], Joan E. Sussman [a,2]

[a] University at Buffalo, Department of Communicative Disorders & Sciences, 3435 Main Street, Cary Hall, Rm 122, Buffalo, NY 14214, USA
[b] Purdue University, Department of Speech, Language, and Hearing Sciences, 500 Oval Drive, Heavilon Hall 202B, West Lafayette, IN 47907-2038, USA

SpeechVive™ Study # 3

Stathopoulos et al., (2014)

- Purpose:

1) Would individuals with PD increase their vocal intensity when speaking in a noisy environment?
2) Examine the underlying respiratory and laryngeal strategies to regulate vocal intensity

SpeechVive™ Study # 3

Stathopoulos et al., (2014)

- Subjects: 33 individuals with PD (27 men and 6 women; mean age for men was 69 and mean age for women was 75; H&Y varied between 1 and 4.5)
- Stimuli:
  - Multitalker babble noise to one ear activated when speaking at a pre-set level
  - Noise amplitude was adjusted to elicit 3 dB above each participant's SPL in quiet.

SpeechVive™ Study # 3

Stathopoulos et al., (2014)

- Speech Task: Natural connected speech (2 min monologue on topic of their choice)
- Measured in clinic; 1 session

RESULTS:

- Significant increase of SPL (2 dB increase) with SpeechVive in 26/33 individuals
- Use of laryngeal and respiratory strategies varied among speakers

SpeechVive™ Study # 3

Stathopoulos et al., (2014)

Study criticisms:

- Data collected in one session
- Mean baseline vocal intensity was 79.1 dB SPL which is high for individuals with PD
- Good sample size (n=33)
- Meaningful stimuli (natural connected speech)

VOXLOG
(Sonvox AB, Umea, Sweden)

Voxlog- how it works?

- enables long term registration of
  - voice use regarding voice sound level (dB SPL)
  - phonation frequency (Hz)
  - phonation time (percent time spent phonating during the registration period), and
  - level of environmental noise (dB SPL)
- an accelerometer and a microphone worn in a neck collar
- Feedback signal is delivered through a tactile vibration from the box.

Voxlog

- Feedback can be configured regarding
  - threshold level
  - activation time
  - direction
  - rest time
  - duration of the feedback signal
- Data can be stored up to a week and can be transferred to a PC with the accompanying software for analysis

Voxlog Study

Effects of Tactile Biofeedback by a Portable Voice Accumulator on Voice Sound Level in Speakers with Parkinson's Disease

*,†Ellika Schalling, *Joakim Gustafsson, ‡Sten Ternström, *Frida Bulukin Wilén, and *,†Maria Södersten,
*†‡*Stockholm, Sweden*

Journal of Voice, Vol. 27, No. 6, pp. 729-737
0892-1997/$36.00

http://dx.doi.org/10.1016/j.jvoice.2013.04.014

Voxlog study

Schalling et al., (2013)

- Subjects: 6 subjects with PD (5 males; 1 female) ages between 64- 73 years
- Vibrotactile feedback for 3-7 days (23.3-67.8 hours)

Duration of VoxLog Registrations During Weeks 1 and 3 Without Feedback and Week 2 With Feedback

Subject	Week 1, Number of Days (hours) For Registration 1 With VoxLog (Without Feedback)	Week 2, Number of Days (hours) For Registration 2 With VoxLog (With Feedback)	Week 3, Number of Days (hours) For Registration 3 With VoxLog (Without Feedback)
1	4 (32.1)	6 (67.8)	5 (28.5)
2	4 (38.3)	6 (62.9)	4 (47.5)
3	1 (8.3)	5 (26.1)	3 (9.6)
4	4 (18.4)	3 (27.3)	2 (22.1)
5	4 (40.9)	7 (72.6)	1 (9)
6	4 (38.1)	4 (48.5)	5 (40.5)
Mean	3.5 (29.4)	5.1 (50.9)	3.3 (26.2)

Voxlog Study Results

Schalling et al., (2013)

Measurement and Condition	S1	S2	S3	S4	S5	S6	Mean
Mean voice SL dB SPL (field)							
Week 1 (field) with VoxLog (without feedback)	75.4	79.3	75.6	81.5	74.5	82.6	78.2
Week 2 (field) with VoxLog (with feedback)	77.4	82.4	76.7	82.5	77.1	82.3	79.7*
Week 3 (field) with VoxLog (without feedback)	77.1	81.9	72.2	83	79.9	83.2	79.5
Mean voice SL dB SPL (studio)							
Registration 1 of spontaneous speech, studio setting with VoxLog	71.3	74.2	68.5	77.2	71.1	78.9	73.5†
Registration 2 of spontaneous speech, studio setting with VoxLog	70.5	70.8	68.4	82.5	72.7	78.5	73.8‡

- 1.5 dB increase with feedback; lost when feedback removed
- Background noise was around 64-66 dB
- Mean Phonation time was 4.5%

Voxlog study criticism

Schalling et al., (2013)

Study Criticisms:

- Small sample size
- Data collected varied between 1-7 days
- 1.5 dB improvement in dB SPL with feedback may not be clinically significant
- Baseline mean dB SPL for subjects itself was 78.2dB which is high for PD individuals
- Meaningful stimuli (conversation); data from the field

Small talk and School DAF (Casafuturatech)

Small talk- $2495

Image courtesy: http://www.casafuturatech.com/smalltalk-anti-stuttering-device/

School DAF- $295

Image courtesy: http://www.casafuturatech.com/school-daf/

Small talk

- Small talk provides two types of Altered Auditory Feedback(AAF)- Delayed Auditory Feedback (DAF) and Frequency Altered feedback (FAF)
- Works with all standard headphones and mic
- Has a push-to-talk button that eliminates background noise
- Can plug into telephones

School DAF

- Provides one type of AAF- DAF
- Works with all standard headphones and microphones

Small talk/School DAFStudy

Lowit, Anja and Dobinson, Corinne and Timmins, Claire and Howell, Peter and Kröger, Bernd (2010) The effectiveness of traditional methods and altered auditory feedback in improving speech rate and intelligibility in speakers with Parkinson's disease. International Journal of Speech-Language Pathology, 12 (5). pp. 426-436. ISSN 1754-9507 , http://dx.doi.org/10.3109/17549507.2010.497559

Small talk/School DAF Study

Lowit et al., (2010)

- Purpose: To compare the effects of Traditional Therapy (TT) and AAF treatment

  on speech rate and intelligibility in PD
- Subjects: 10 subjects with PD (6 males; 4 females) with mean age of 62 years, H& Y varied between 1-5,

  dysarthria severity varied between mild to severe
- Speech Tasks: Reading “cherry passage” and monologue

Small talk/School DAF Study

Lowit et al., (2010)

- TT: inserting pauses or stretching out articulation, volume/intonation variation, carry over
- AAF therapy with 3 feedback conditions:
  - No Feedback (NF)
  - DAF (150ms delay), and
  - FSF (1/2 octave upward shift) Choice of Small talk/School DAF depended on subject
- 1x weekly for 50-60 minutes for 6 weeks at home

Small talk/School DAF Study

Lowit et al., (2010)

- Each subject received both treatment types separated by 6 weeks of no treatment
- Speech outcomes: Speech Rate (SR) and Speech Intelligibility (SI)
  - SR measured as number of syllables/sec including pauses
  - SR calculated only for reading due to high variability with monologue

Small talk/School DAF Study

Lowit et al., (2010)

- SI measured in reading through Direct Magnitude estimation and using 9 point Likert scale
- RESULTS:
  - No significant difference in either SR or SI for traditional speech therapy and with AAF (i.e. speakers did not benefit from AAF as a group).
  - Some individuals benefitted (3/10 showed improved SI with AAF)

Small talk/School DAF Study

Lowit et al., (2010)

- Number of speakers changed their preferred AAF settings over time- Habituation effect?
- SI improved with the no feedback for some speakers after the 1st Rx phase- Placebo effect of devices?
- Results not affected by severity of dysarthria

Small talk/School DAF Study

Lowit et al., (2010)

- Small talk has small buttons and dials which was found to be difficult for PD patients with fine motor problems to maneuver
- Small sample size
- 6 sessions may not have been enough for some subjects

SPEECHEASY

Treating Festinating Speech with Altered Auditory Feedback in Parkinson's Disease: A Preliminary Report

Emily Q. Wang, Ph.D.
Leo Verhagen Metman, M.D., Ph.D.
Bryan A. Bernard, Ph.D.

Rush University Medical Center, Chicago, Illinois

Journal of Medical Speech-Language Pathology
Volume 16, Number 4, pp. 275–282

SpeechEasy

Wang et al., (2008)

- Purpose: To investigate the effects of AAF on Speech Rate (SR) and Speech Intelligibility (SI) in PD
- Subjects: 9 subjects (8males, 1 female) between ages of 52 and 81 years, H&Y between 2 and 3, 4 subjects had DBS
- Speech Tasks: Reading, controlled monologue, picture description, and 30 s conversation sample.

SpeechEasy

Wang et al., (2008)

- AAF using SpeechEasy:
  - DAF: 50-220ms
  - FAF: 500Hz; unilateral and connected to the computer in clinic
- Six testing conditions: 2 baseline, 2 placebo (no battery, only loudness setting without feedback), and 2 feedback
  - Conditions randomized except initial baseline
- One session of feedback in clinic

SpeechEasy

Wang et al., (2008)

Speech Outcomes:

- SI was measured using UPDRS-III item 18 (0-4 rating) by 20 graduate student clinicians
- SR was rated as slow, normal, fast

Results:

- SI improved for monologue under AAF* but not for reading
  - No significant difference in SI between AAF and placebo
- SR was unchanged for monologue but statistically significant for reading

SpeechEasy

Wang et al., (2008)

Study Criticisms:

- No significant difference in SI and SR between placebo and AAF conditions suggesting that the device benefits are equivalent to a placebo effect
- One session of feedback only. Long term effects of the device not known.
- Effects of device in real life environment not known
- Small sample size

CONCLUSION

- SpeechVive is relatively more studied compared to other devices, with 1/3 studies using a meaningful stimuli (i.e. natural connected speech)
- Only 3 out of 6 studies measured data outside of the clinic
  - In-clinic dB measures are higher than at home in PD*
- Long-term effects of devices in real life environment is not known

* Searl, J & Dietsch, A (2011). *In-Clinic vs. At-Home Voice Intensity Estimates in Parkinson Disease.* Poster presented at ASHA, SanDiego, CA

CONCLUSION

- Vocal intensity gain was limited (1.5 dB with Voxlog & 2-3 dB with SpeechVive) compared to therapy (5- >10 dB in clinic) Ramig, Shapir, Fox & Countryman, 2011

Conclusion

- SR is not improved by AAF devices
- SI was not improved or only as good as placebo
- Level of evidence was 2b (Individual cohort study or low quality randomized controlled trials) for all 6 studies

Conclusion

- Overall, limited number of studies on speech outcomes and small sample sizes suggest the need for more evidence on the benefit of wearable devices in PD population
- More research looking at frequency and dose of feedback to facilitate motor learning (performance vs. retention), will the devices enhance effects of therapy?