A Digital Game to Support Voice Treatment for Parkinson's Disease

Markus Krause
University of Hannover
Research Group HCI
Hannover, Germany
markus.krause@hci.uni-hannover.de

Jan Smeddinck
University of Bremen
TZI Research Group Digital Media
Bremen, Germany
smeddinck@tzi.de

Ronald Meyer
University of Bremen
TZI Research Group Digital Media
Bremen, Germany
romeyer@tzi.de

CHI'13 Extended Abstracts, April 27 – May 2, 2013, Paris, France.
ACM 978-1-4503-1952-2/13/04.

Abstract
Parkinson's disease causes a wide range of motor impairments that also affect speech. Even patients with mild speech motor disabilities do suffer from symptoms such as reduced dynamics, melody, tone, pace and continuity of speech. Besides invasive or drug based treatments, effective logopedic treatments do exist. However, constant training is a key factor for this type of therapy. Digital games can be one way to enhance patient's motivation for repetitive exercises both in therapy sessions and in prolonged use at home. This paper examines the possibilities of such a digital logopedic game developed for PD patients and reports first promising study results that indicate an increased peak voice loudness of the players' voice when playing the game.

Author Keywords
Games for health; serious games; voice treatment; Parkinson's disease; visual complexity; accessibility; entertainment

ACM Classification Keywords
K.4.2 [Computers and Society]: Social Issues – Assistive technologies for people with disabilities; K.8.0 [Personal Computing]: General – Games

Introduction

Neurodegenerative diseases such as Parkinson's disease (PD) do affect communicative skills in various ways. Common conditions for PD include speech (*dysarthria*) and voice disturbances (*dysphonia*). Dysarthria is a disorder of speech due to lesions or lacking innervations of central brain nerves. Dysphonia is the disability to produce voice phonemes using the vocal organs. Patients with these conditions most often suffer from *hypophonia* [4]. Hypophonia is a whispering voice and monotonic speech, resulting from the inability to control the vocal musculature. A main issue for patients having these symptoms is a change in their social relations. Speech disorders contribute substantially to disability, and patients as well as their relatives consider speech difficulties to be responsible for social isolation [9,12]. Continuous and intensive voice treatment can significantly improve these conditions [10]. One key factor for improvement is the ability of such treatments to enhance (increase) voice loudness [10].

A key challenge for continuous training is motivation. Patients of continuous logopedic therapy are often bored, distracted, or restless if therapy elements consist of repetitive elements [5]. Hoque et al. combined speech therapy and game elements for children with autism [5]. Other studies already revealed promising results hinting at the usefulness of games as elements of PD treatment in general [1]. Results of both studies indicate that players are more engaged, competitive and cheerful in comparison to other patients taking speech therapy. This work describes a game that was designed to support the therapy of speech motor disabilities, focusing on training voice loudness (perceived strength of a sound) and volume (measurable sound pressure). We also report results from a first experimental application of the game in physiotherapy sessions with PD patients.

Game Design for Voice Treatment

A central requirement for successful logopedic interventions is continuity, which depends on the motivation of the patient [7]. Digital games have the potential to provide lasting motivation. In our proposed approach the player uses his/her voice to control a digital game. The player's task is to break different items by holding a tone. The player has to hold an "a"-phoneme with given intensity and for a certain duration. The game contains four item types, each with its own intensity amp and duration d which are required in order to break it.

Table 1 lists the item types currently implemented in the game, together with their d value and a dB modifier. The amp value for each item type is calculated by subtracting a modifier value (as given in the table) from the initial maximum intensity amp_{max} for each player. This value is calibrated during a warm up phase before the actual game.

Item Type	Duration (ms)	Modifier (dB)	Score
Porcelain vase	4000	0	20
Beer jug	3500	5	15
Milk glass	2500	10	10
Martini glass	2000	15	5

Table 1: Each item type has an associated score. This score is given to the player if he/she breaks an item of that type. The duration is the time for which the player has to hold the tone. The modifier value is subtracted from the initially measured maximum intensity for the current player.

Every item type also has an attached score value that is given to the player when breaking an item of that type. The goal of the game is to break objects with ones voice and thereby reaching a total score of 300. If the player breaks an item it disappears and a new one is randomly selected. The player does not have a time limit to break an item. Figure 1 shows a screenshot of the game.

Figure 1: The character on the left changes her facial expression with rising intensity. The interface on the right shows current and desired intensity and provides feedback on the remaining time needed to break the item on the table.

Experiment Design

The experiment was conducted at a local physiotherapy group of the *Deutsche Parkinson Vereinigung e.V.* in Bremen, Germany. One week before the experiment, all participants were informed about the upcoming opportunity to play the game and were invited to register as participants on a voluntary basis. The experiment was conducted with individual participants following a short break after a gymnastics workout session, so they were warmed up and already had increased respiratory activity before the test. The therapists who lead the gymnastics group adapted the exercises in order to prepare the participants for vocal exercises, by including limbering-up and stretching exercises for the chest.

Following a greeting and the gathering of consent, the participants completed a voice self-assessment test (Voice Handicap Index-10 (VHI) [11]), before playing the game. Since all participants were German the validated translation of the VHI by Nawka et al. was used [8]. The experiment started with a calibration phase. The players were asked to hold an “a” as loud and long as possible. A continuous time series of the players attempts was recorded to determine the initial maximum intensity value amp_{max} (intensity peak of this series). A continuous time series of voice intensity was recorded during game play for each player and item. During the game the players had to break enough items to reach a total score of 300 points (approximately 24 items). After playing, the participants completed a German version of the Game Experience Questionnaire (GEQ) [6] and a Borg RPE (rating of perceived exertion)[2]. Only the core module of the GEQ was used and the categories flow and immersion were removed, since previous experiments with similar user groups had indicated problems with understanding the questions in these categories in relation to therapy games which were designed following a casual games style. This precaution was taken to avoid invalid responses and bias which might carry over to other parts of the questionnaire that were generally understood.

The suggested five point Likert scale was scaled up to a seven point scale using a proportional transformation

[3]. The scaling was also informed by previous experiments which showed a tendency of the target group to select options closer to the center of the scale than what was normally to be anticipated. For the reported experiment this behavior was not observed. During the session, an experiment conductor was present. The conductor was seated behind the participants and provided support if necessary. The distance between microphone and the head of the participants was ~50 cm (19.7") and participants were asked to keep the distance from the microphone constant. We kept the distance constant to achieve more accurate measurements from the phone. The experiment setup can also be seen in Figure 2.

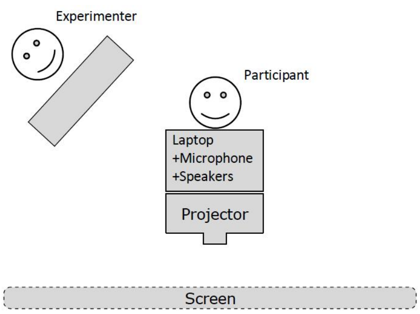

Figure 2: Schematic view of the experiment setup. The experimenter was placed behind the participant. The distance between participant and microphone was ~50 cm (19.7").

Participants

Eight participants with different levels of severity of PD took part in the study. The mean age of the cohort was 70.75 years (SD=7.42) with the oldest participant being 79 and the youngest being 56 years of age. Four of the participants were male and four were female. The average time of being affected by Parkinson's disease was 6.75 years (SD=5.82), with the longest period being 20 years and shortest being one year. Only one of the eight participants (p8) had previously completed a voice therapy (a Lee Silverman Voice Treatment® (LSVT) [10]). It lasted four weeks and was finished one year before his participation in the experiment. No software or computer devices were used for this LSVT treatment, which was conducted in a clinic environment. No participant had speech or voice therapy during the two weeks of the experiment. Seven of eight participants stated that they would consider using a computer for speech or voice therapy at home.

Results

The game mechanics were intuitively understood. All participants immediately grasped the idea of the game without training. All participants reached the game goal of gathering 300 points. The mean time required for achieving this goal was 8 minutes and 30 seconds (510 seconds) (SD=172), with the longest duration being 778 seconds and the minimum duration being 335 seconds. In general the participants perceived the game relatively well according to the results of the GEQ, as indicated in Figure 3.

The results for the VHI-10 test showed only a *moderate abnormality* in the mean. The mean value for the group of participants was 16.875 (SD=9.41) with a maximum value of 28 (*severe abnormality*) and a minimum value of 1 (*almost no abnormality*). The mode was 11. The rating of 28 by P4 is likely an outlier. The VHI-10 score reflects the perception of the handicap. As a former stage actor, P4 is especially aware of the unreliability of his voice as he had to retire from stage.

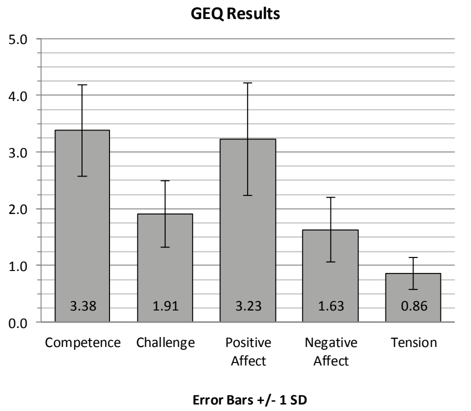

Figure 3: The resulting means from the GEQ show high scores for the categories *competence* and *positive affect*. Since the target group of PD patients consists mostly of older adults, a high level of competence is important, as it suggests that the participants were not intimidated by the technology.

All participants achieved higher intensity maxima during game play than during the calibration, as depicted in Figure 4. The participants achieved a significantly higher average intensity peak while playing (Mean=76.68, SD=9.59) than in the calibration phase (Mean=66.26, SD=8.45), with $t(7)=-5.66$, $p<0.001$, and $d=1.15$. However, the participants achieved the game goals with very different intensity peak improvements. The smallest improvement relative to the calibration was 4.93 dBr while the largest was 20.09 dBr. P5 increased his peak value from 60.5 dB to 80.59 dB. A normal conversation ranges around 60 dB. The mean value for improvement was 10.42 dBr (SD=5.21). A gain of 10 dB would be perceived as two times as loud. During game play the highest participant voice intensity value measured was 90.00 dB, the maximum that could be measured with the microphone used in the study. The lowest maximum participant voice intensity was 62.94 dB.

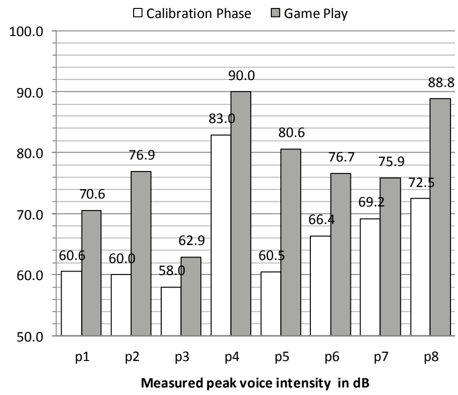

Figure 4: The measured peak voice intensity in dB for each player during the calibration and later during game play. The maximum measurable sound intensity was 90dB.

Conclusion and Future Work

Continuous logopedic therapy can be an effective treatment for speech and voice disturbances from neurodegenerative diseases. Integrating such training into a digital game can help to provide motivation for the support of existing therapy programs or extend the treatment at home. This study provided first insights indicating the feasibility of integrating voice intensity and loudness exercises into a digital game for PD patients. The participants of an initial evaluation indicated a general acceptance of the game design and statistically significant improvements of average peak voice loudness during game play as compared to previously calibrated limits hint at the game being a useful tool for vocal training. As there was a significant positive correlation between scores on the VHI-10 measure and those on the *positive affect* in the GEQ measure (r=.7, p=.007) we suggest a further investigation of the game quality. A comparative study between the game and a training tool with the same functionality, but without game elements could provide insight into the actual impact of a game based approach. The potential of such logopedic games to offer guidance and feedback concerning the exercises and to lead to increased efforts by the patients to perform well requires further exploration featuring experimental setups which account for warm-up effects and observe the game in regular use over extended periods of time. Furthermore, the current version of the game supports only intensity as input. Measures of frequency and voice pitch could be integrated in future systems and would allow for the creation of more versatile exercises. The current game mechanics can be extended to use voice pitch as an additional parameter and could cover all measurements used in the Lee Silverman Voice Treatment®. Personalization and automatic adaption beyond the initial calibration should be implemented in order to optimize player engagement and training effectiveness.

References

[1] Assad, O., Hermann, R., Lilla, D., et al. Motion-Based Games for Parkinson's Disease Patients. *ICEC'11*, Springer Berlin Heidelberg (2011), 12.

[2] Borg, G. Perceived exertion as an indicator of somatic stress. *Scandinavian journal of rehabilitation medicine 2*, 2 (1970), 92–98.

[3] Colman, A.M., Norris, C.E., and Preston, C.C. Comparing Rating Scales of Different Lenghts. *Psychological Reports 80*, (1997), 355–362.

[4] Ho, A., Iansek, R., and Bradshaw, J. Motor instability in parkinsonian speech intensity. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology 14*, 2 (2001), 109–116.

[5] Hoque, M.E., Lane, J.K., Kaliouby, R. El, Goodwin, M., and Picard, R.W. Exploring speech therapy games with children on the autism spectrum. *INTERSPEECH'09*, International Speech Communication Association (2009).

[6] IJsselsteijn, W., Kort, Y. de, and Poels, K. The Game Experience Questionnaire: Development of a self-report measure to assess the psychological impact of digital games. *Manuscript in preparation*, 2008.

[7] Jost, W.H. *Therapie des idiopathischen Parkinson-Syndroms*. Uni-Med, Bremen, Germany, 2005.

[8] Nawka, T., Wiesmann, U., and Gonnermann, U. Validierung des Voice Handicap Index (VHI) in der deutschen fassung. *Hno 51*, 11 (2003), 921–930.

[9] Oxtoby, M. *Parkinson's disease patients and their social needs : a survey of patients in contact with the Parkinson's Disease Society*. Parkinson's Disease Society, London, United Kingdom, 1982.

[10] Ramig, L.O., Sapir, S., Countryman, S., et al. Intensive voice treatment (LSVT®) for patients with Parkinson's disease: a 2 year follow up. *Journal of Neurology, Neurosurgery & Psychiatry 71*, 4 (2001), 493–498.

[11] Rosen, C., Lee, A., Osborne, J., and Murry, T. Development and Validation of the Voice Handicap Index-10. *The Laryngoscope 114*, 9 (2004), 1549–1556.

[12] Scott, S. and Caird, F. Speech therapy for Parkinson's disease. *Journal of Neurology, Neurosurgery & Psychiatry 46*, (1983), 140–144.