On the Use of a Serious Game for Recording a Speech Corpus of People with Intellectual Disabilities

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Abstract

This paper describes the recording of a speech corpus focused on prosody of people with intellectual disabilities. To do this, a video game is used with the aim of improving the user's motivation. Moreover, the player's profiles and the sentences recorded during the game sessions are described. With the purpose of identifying the main prosodic troubles of people with intellectual disabilities, some prosodic features are extracted from recordings, like fundamental frequency, energy and pauses. After that, a comparison is made between the recordings of people with intellectual disabilities and people without intellectual disabilities. This comparison shows that pauses are the best discriminative feature between these groups. To check this, a study has been done using machine learning techniques, with a classification rate superior to 80%.

Keywords: Pronuntiation Training, Intellectual disabilities, Down Syndrome, Prosody

1. Introduction

People with intellectual disability (ID), including Down syndrome people (DS), show a wide range of language difficulties (Cleland et al., 2010). The speech of ID people usually presents multiple disorders affecting the different components of language (syntax, semantics, phonology and pragmatics) (Martin et al., 2009) (Chapman, 1997). In particular, prosody is also affected (Stojanovik, 2011) conditioning their communicative potential. There is some research on linguistic deficits on ID people (Tsakiridou, 2006) but speech corpora that permit to compare and analyze the problems of this population are scarce. The CHILDES database (MacWhinney, 2000) or the Alborada corpus (Saz et al., 2010) have recordings of people with different typologies of intellectual disability, but, these corpora don't focus on prosody. It is quite difficult to obtain a representative ID's speech corpus focused on prosody, among other reasons, because ID people have a variability in their speech competences: some prosodic aspects could be relegated by the difficulties with other linguistic components like articulatory or syntactic. Other cognitive difficulties like their attentional problems or their impairments with the auditory memory make it difficult to obtain linguistic materials that prompt their prosodic competences avoiding their other linguistic or cognitive difficulties. In this paper we present a procedure to collect samples of ID's utterances related with their prosodic competences that are recorded in a controlled scenario.

The present work is framed in a research project [1] whose goal is to develop a serious video game for people with intellectual disabilities for they to practice oral pronunciation. The main objective of the video game is that users to improve their prosodic skills both in comprehension and in production through different activities. Additionally it is expected that players improve their general communicative and socio-emotional competences by solving understanding tasks with multiple choice answers. The game is based in the graphic adventure metaphor (Adams, 2013). Players get involved in a mysterious story in which they play the role of a hero who is responsible for saving the city. To accomplish the mission they have to perform properly different activities in which they practice pronunciation and the understanding of meanings of prosody in context. The interface of the video game has been designed taking into account the special characteristics of the users such as: poor short term memory, difficulties for integrating information that comes from different channels simultaneously, attention deficit (Pazos González et al., 2015). The result is that we have observed a high degree of engagement in the usability test that we have performed with real users (Corrales, 2015). This high degree of engagement, in combination with the fact that the video game records the vocal turns of the users give us the opportunity to compile a speech corpus of intellectual disabled people which is a need for the state of the art.

In order to analyze the samples of the corpora, we also have recorded people without ID interacting with the same video game. The result is that we have a collection of utterances that permit to compare the prosodic profile of different kinds of people in the same communicative context. An analysis of the prosodic acoustic characteristics of the voice of the different groups will shed light into the most problematic aspects of the ID voice to be corrected with the training.

The structure of the paper is as follows. First the video game is described in section 2, presenting its architecture, the interface and the training activities. Section 3 details

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the recording campaign and section 4 presents the results both the usability test and the collected corpus. We end the paper with the conclusions and future work.

2. Game description

The video game has the structure of a graphic adventure game, including conversations with characters, getting and using items and navigating through scenarios. Players have to use the mouse to interact with the elements of the game. The development of the video game is based on multimedia learning, presenting visual and verbal materials together simultaneously (Mayer, 2002). In this way, the users do not depend only on the textual channel to receive important information, as it can be completed by information with images, because this information modality has lower difficulties for people with intellectual disabilities (Chapman and Hesketh, 2001). In fact, it has been shown that using images to support and complement verbal information is a better educational strategy than using only verbal information (Buckley and Sacks, 2002).

Players go through different scenarios where they have to do some actions, like solving an activity or using an item. The main innovation is that players have to record sentences using their voice in some activities. The speech therapist or teacher decides if the player has done it correctly or not. In other activities, an audio is played in the context of a conversation and the player has to choose between some options to continue this conversation (comprehension activities).

At the beginning of the game, the configuration screen is shown, where players can introduce a user name and configure their game profile. They can select an avatar, which represents the player in the game, the difficulty level and reader profile (reader/non reader). Then, a video is played to introduce the story of the game: the player has to get a magic stone to restore order in the city.

2.1. Arquitecture

Figure 1 shows the system architecture. Two users interact with the system: the player and the trainer. The player is normally a child with language deficits, specifically in prosodic comprehension and production. The trainer is typically a helper (teacher, speech therapist, family) that helps the player during game sessions. When trainer and player are working together on a game activity, the trainer will help the player in the correct use of voice and also to configure the system. Production and prosodic activities allow the trainer to evaluate the players, making them repeat the exercise when the result is not correct. The role of the trainer is essential to maximize the educational potential of the game. The trainer supports and guides players during the game, adapts the difficulty level, encourages players to continue when they have difficulties and help them to solve such difficulties as understanding the story and the activities.

The application has a multimodal interface, as much for input as for output. Input is performed using voice and mouse. On voice training exercises, players will have to use their voice. Output is performed using visual and sound channels. The sound output channel is used for the

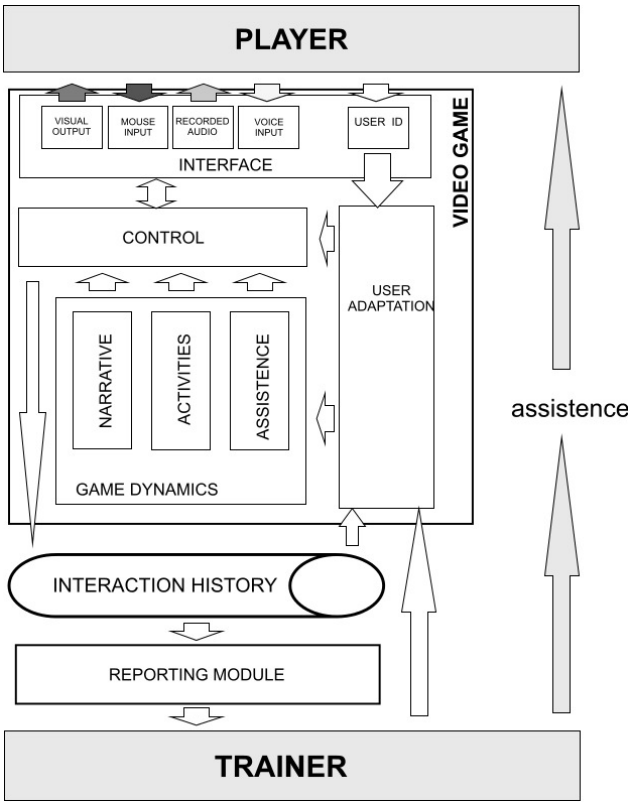

Figure 1: System architecture

voiceover that narrates the story, to play character voices and to play the voice of the virtual assistant. In any case, a recorded voice is used instead of TTS, as it allows emotions to be included that synthetic voices cannot yet express.

Due to the variety of users that intellectual disability includes and their respective cognitive abilities, it is necessary for the video game to be able to adapt to the user needs. Inside the target user group, two profiles, reader and non reader, have been defined, as the reading difficulty is an important aspect. In this way, the activities have more visual and audio instructions for non reader users. Also, three difficulty levels have been implemented. These levels affect the complexity of the activities and the instructions that players receive. The classification of the users into one profile or another has to be defined by the person who takes the role of the trainer during the game session.

2.2. Interface

The development of the scenarios, items and characters has a uniform design, close to cartoons, but without making them too childish (Figure 2). Bright colors are used in accordance with the scenarios represented in the game. A simple text font is used, with a larger size than usual to make it easier to read. An important issue is that the sound instructions use simple and brief language to improve understanding. The sentences have been revised by experts to guarantee that they are in accordance with the cognitive level of Down syndrome users. Another important aspect is the inclusion of visual clues on the game scenarios to help players identify the next goal, to avoid players getting stuck.

Figure 2: Game screen

During the game session, information about user interaction is stored, as well as the audio recordings of the production activities. This information can be used by the speech therapist to analyze the evolution of the user in successive game sessions and the audio recordings increase the speech corpus. This user interaction log has information about game time, the attempts to complete a task, number of mouse clicks or the helps showed to the user.

2.3. Activities

These activities are included in the general context of the game and players need to solve them in order to progress in the game. Three activity types are defined to practice speech, communication and prosodic skills:

- Comprehension activities that are focused on lexical semantic comprehension and on improving of prosodic perception in specific contexts, like making a question or asking something politely.
- Production activities that are focused on oral production, so the players are encouraged by the game to train their speech, keeping in mind prosodic aspects like intonation, expression of emotions or syllabic emphasis.
- Visual activities focused on improving specific aspect of prosody, with the corresponding visual response to the user voice input and other activities designed to add variety to the game and to reduce the monotony feeling while the player is playing.

Some activities focus on lexical-semantic comprehension and on improving of prosodic perception in specific contexts. Other activities focus on oral production, so the player is encouraged by the game to train his speech, keeping in mind prosodic aspects like intonation, expression of emotions or syllabic emphasis. In the activities, the player is introduced by the game into different conversations with game characters, where the player has to choose between different options to continue the dialogue or to record some sentences related with the dialogue context, depending on the activity.

User	City	Age	Type	Gender
U1	Valladolid	21	WISC IV (35/40-50/55)	Male
U2	Valladolid	18	DS - WISC IV: CI 42	Male
U3	Barcelona	16	DS	Male
U4	Valladolid	18	DS - WISC IV: CI 46	Female
U5	Valladolid	21	DS - WISC IV: CI 54	Male
U6	Barcelona	13	DS	Male
U7	Barcelona	23	DS - RPM 20	Male
U8	Valladolid	21	DS - WISC IV: CI 40	Female
U9	Valladolid	21	WISC IV (40-55)	Female
U10	Barcelona	26	DS - RPM 20	Male
U11	Valladolid	23	WISC IV: (35-49)	Female
U12	Valladolid	19	DS	Female
U13	Valladolid	22	DS - WISC IV (35/40-50/55)	Female
U14	Valladolid	16	DS - WISC IV CI 43	Female
U15	Barcelona	21	DS - RPM 22	Male
U16	Valladolid	20	DS - WISC IV CI 54	Male
U17	Valladolid	21	WISC IV (35/40-50/55)	Male
U18	Barcelona	25	DS - RPM 15	Female
U19	Valladolid	15	WISC IV: CI 42-55	Female
U20	Valladolid	18	WISC IV: CI 46	Female
U21	Barcelona	25	DS - RPM 19	Male
U22	Valladolid	18	WISC IV: CI 63	Male
U23	Valladolid	17	DS -WISC IV CI 46	Female
U24	Barcelona	24	DS - RPM 28	Male
U25	Barcelona	30	DS - RPM 18	Male

Table 1: Location, age, type and degree of disability and gender of video game users. The user type is defined using two methods: WISC(Wechsler Intelligence Scale for Children)(Wechsler, 2003) and RPM(Raven's Progressive Matrices)(Raven and Court, 1998). DS in type means that this users has Down syndrome

3. Recording campaign

The game sessions consisted in completing all the game and were made in the same facilities of the centers where the players attended their regular classes to assure the comfort of the players. In addition, a staff member of the centers always was with the players. The game sessions have been done at the Niu School (Barcelona), Aura Foundation (Barcelona), and the College of Special Education "El Pino de Obregón" (Valladolid). In total, 4 game sessions have been done. During the first of them a usability test have been done with the aim of see how the users interact with the game and to detect deficiencies on user interface. The other 3 sessions have been done by staff members of the center of Valladolid, with the aim of getting more user's recordings to be analyzed later. During game sessions, the role of the trainer (a teacher or speech therapist) is twofold: on the one hand, he/she evaluates the player's recordings and on the other hand, he/she helps players if necessary. The trainer has to sit next to the player. To evaluate the player's recordings, the trainer uses the keyboard of the same computer that the player is using. Besides, to reduce the ambient noise in the recording process, the players use a headset with microphone incorporated (Plantronics USB headset).

25 users have been participated in the game sessions. All of them have a moderate or mild intellectual disability, so they can follow the game in a reliable way. Besides, there are the same number of male than female users and the age range is between 13 and 30 years. Inside these 25 users,

Sentence in Spanish	Sentence in English
¡Hasta luego, tío Pau!	See you later, uncle Pau!
¡Muchas gracias, Juan!	Thank you very much, John!
¡Hola! ¿Tienen lupas? Quería comprar una.	Hello, do you have magnifiers?. I wanted to buy one.
Sí, la necesito.,¿Cuánto vale?	Yes, I need it. How much is it?
¡Hola tío Pau! Ya vuelvo a casa.	Hello uncle Pau! I'll be back home.
Sí, esa es. ¡Hasta luego!	Yes, it is. Bye!
¡Hola, tío Pau! ¿Sabes dónde vive la señora Luna?	Hello uncle Pau! Do you know where Mrs Luna lives?
¡Nos vemos luego, tío Pau!	See you later, uncle Pau!
Has sido muy amable, Juan. Muchas gracias!	You have been very kind, Juan. Thank you very much!
¡Hola! ¿Tienen lupas? Me gustaría comprar una.	Hello, do you have magnifiers?. I would like to buy one.
Sí, necesito una sea como sea. ¿Cuánto vale?	Yes, I really need one. How much is it?
Sí, lo es. Vivo allí desde pequeño. ¡Hasta luego!	Yes, it is. I have lived there since I was a child. Bye!
¡Hola, tío Pau! Tengo que encontrar a la señora Luna ¿Sabes dónde vive?	Hello uncle Pau! I have to find Mrs Luna. Do you know where she lives?

Table 2: Sentences recorded during game sessions

18 have Down syndrome and 7 have intellectual disability without diagnosis of a specific syndrome. As the four game sessions have been performed in different periods of time, not all of the users have done all the game sessions. Some users were not available during the development of some game sessions, so we do not have their recordings. The information of each specific user is shown in Table 1.

One of the purposes of the tool is to collect examples of sentences with different modalities (i.e. declarative, interrogative and exclamatory) produced by people with intellectual disabilities in order to analyze the most common difficulties. The interesting thing is that the intonation patterns should vary depending on the modality. Therefore, the main objective is to check whether people with intellectual disabilities are able to reproduce these patterns adequately (with their variations in rhythm, intensity and tonal range).

Moreover, the combination of different sentences allows us to include inflections that indicate a particular segmentation in oral production. Depending on the context and the speed of elocution, these inflections may correspond to a pause, which implies a silence and, normally, the end of the sentence, or a semi-pause, which implies an intonation change in the same sentence. Thus, the combination of these types of inflection allows us to collect examples with different segmentation and observe whether people with Down syndrome recognize the difference between them. The sentences recorded can be seen in Table 2.

4. Results

4.1. Usability test

After first game session, a short interview was made to the users with the aim of evaluate their opinion about the game. This interview included questions relating of various aspects of the game, such as story, the assistant or the game difficulty.

There is quite a good unanimity with respect to the entertainment and ease aspects of the game. Most of the players believe that the game is funny and easy. The fun aspect is important to improve the motivation. The ease of the game suggests that the difficulty level is adequate. In addition, players with intellectual disabilities believe that the game is lengthy. The reason may be because playing the game requires an effort for them. They need to pay attention during the game in order to solve each of the activities.

There is less consensus on the understanding of the story by players with intellectual disabilities. Regarding the story, these players have serious problems to memorize and understand the absolute context of the story, and they just remember details like the objects they got, some characters they met or some specific scenarios.

In spite of these limitations, a great result is that players completed the game with hardly any distractions. This is important because people with intellectual disabilities have attentional deficits that make difficult doing a same task during a big period of time(Martínez et al., 2011).

Besides of qualitative data that the questionnaire has given, some quantitative data has been recorded automatically during the game sessions. This data can be useful to analyze the user interaction with the game and to implement changes in future version of the video game to improve the user experience. In addition, tests were performed on 10 children aged between 6 and 9 years and on 10 adults. These tests were done with the purpose of comparing the results obtained with the results of the players with intellectual disabilities. As a consequence of this comparison, we observed that game time for people with intellectual disabilities is higher than adults and than children. Besides, people with intellectual disabilities has more errors in activities and need more time to complete these activities.

4.2. Recording analysis

To analyze the prosody of the recordings and to compare them to other recordings that were made by people without intellectual disabilities, some features were extracted from the recordings. These features are similar to others used in other experiments reported in the bibliography (Gonzalez-Ferreras et al., 2012). They concern to frequency: within word F0 range (`f0_range`), difference between maximum and average within word F0 (`f0_maxavg_diff`), difference between average and minimum within word F0 (`f0_minavg_diff`); to energy: within word energy range (`e_range`), difference between maximum and average within word energy (`e_maxavg_diff`), difference between average and minimum within word energy (`e_minavg_diff`);and to duration: number of silences (`num_silences`), silences duration in percent respect to total duration (`silence_percent`), sounding duration in percent respect to total duration (`sounding_percent`).

The information about the corpus generated during the game sessions can be seen in Table 3. This table shows the number of recordings that each user has made as well as the duration of these recordings in seconds. To do the analysis of the prosody we have used only the recordings of the first session. To obtain a similar number of samples between people without intellectual disabilities (Control group) and people with intellectual disabilities (Target group), a series of recordings were made to 20 adult people, 11 men and 9 women.

Table 4 shows the contrast between the two groups of speakers. The most relevant differences correspond with the duration variables num silences and silences percent. As expected, target group speakers use more pauses (2.09 vs 0.88) and the consequence is that the percentage of silences with respect to the percentage of sounding is higher (23.45% vs 12.72%). This result evidences that the users in the target group are less fluent in their turns. On the other hand, there are differences between fundamental frequency but their standard deviation is high. This is because the fundamental frequency depends on the individual and is similar in both types of people. However, energy shows better results to make the difference between both types of people because their standard deviation is lower and depends less on the individual.

In order to make an automatic classification of the recordings, the Weka machine learning toolkit (Escudero-Mancebo et al., 2014) has been used. We made use of the implementations of the classifiers C4.5 decision trees (DT), Multilayer perceptron (MLP) and Support Vector Machine (SVM). We were interested in contrasting the behavior of these three type of classifiers as we observed in (Escudero-Mancebo et al., 2014) that they behave differently in prosodic labeling tasks. As a result, MLP and DT offer the best results with a classification rate superior to 80%.

User	Session 1	Session 2	Session 3	Session 4	Total
U1	8/50				8/50
U2	14/46	16/42	10/20		40/109
U3	12/34				12/34
U4		3/10	7/23	10/59	20/93
U5		12/56			12/56
U6	7/34				7/34
U7	11/93				11/93
U8		13/43	8/29	12/57	33/130
U9		3/14	9/48	11/40	23/103
U10	10/34				10/34
U11	8/24				8/24
U12		9/31	12/49	11/28	32/109
U13	11/44				11/44
U14	9/31	10/28	10/28	12/39	41/127
U15	10/40				10/40
U16	14/55	4/22	10/34	11/48	39/161
U17	13/39	10/30	9/19		32/90
U18	10/38				10/38
U19	7/23	11/29		13/46	31/98
U20		3/9	8/20		11/29
U21	9/46				9/46
U22		11/41	10/40		21/82
U23	13/46	10/38	10/42		33/127
U24	7/37				7/37
U25	8/33				8/33
Total	181/757	115/398	103/357	80/320	479/1832

Table 3: Number of recordings (first number) and duration (second number) in seconds of each session of user recording

	Control group	Target group
f0_range(Hz)	93.1 ± 40.3	94.2 ± 41.5
f0_maxavg_diff(Hz)	54.5 ± 26.5	45.5 ± 22.6
f0_minavg_diff(Hz)	38.7 ± 21.1	48.7 ± 28.8
e_range(dB)	52.3 ± 8.7	52 ± 8.5
e_maxavg_diff(dB)	25.9 ± 4.3	28.5 ± 5.2
e_minavg_diff(dB)	26.4 ± 6.6	23.43 ± 7.52
num_silences(#)	0.88 ± 0.8	2.09 ± 2.3
silences_percent(%)	12.72 ± 12.5	23.45 ± 20.5

Table 4: Average and standard deviation of recording features on people without intellectual disabilities(Control group) and people with intellectual disabilities(Target group)

5. Conclusions and future work

This article has described the use of a video game to record a speech corpus of individuals with intellectual disabilities, in particular, those affected by Down syndrome. This corpus has been analyzed to identify the characteristic prosodic features of these people with the aim of analyze their problems on their communication skills. To do this, their recordings have been compared with other corpus built with people without intellectual disabilities.

To prove the efficacy of this game in relation with this goal, a usability test has been done with some people with intellectual disabilities. This test has been done in their education centers and the results show that the users like playing the video game and the corpus can be recorded without many problems.

In addition, the analysis of the recordings of people with intellectual disabilities has shown that these people have specific features related to prosody. These features are different to other extracted from recordings of people without intellectual disabilities. While the fundamental frequency depends a lot of the individual and is not a discriminatory

feature, the energy and the silences number and duration give more information for classifying a recording inside one or another type. There are very little studies focusing on the acoustic analysis of the voice of people with intellectual disabilities as most studies reported in the state of the art have focused in perception (Kent and Vorperian, 2013). Our results are consistent with state of the art as pauses and disfluences have been identified as the main problem in many studies (Van Borsel and Vandermeulen, 2008). With respect to the prosodic features of F0 and intensity, we find a reference in (Saz et al., 2009) whose authors also observed an anomalous behavior of the intensity in stressed and unstressed vowels.

Although the speech corpus presented in this paper contains recordings which duration is half an hour, nowadays the game is being used in the centers where we made the tests. Therefore, we will improve our speech corpus with new recordings soon.

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