Extending VITHEA in Order to Improve Children's Linguistic Skills*

Vânia Mendonça
vania.mendonca@tecnico.ulisboa.pt

Instituto Superior Técnico, Porto Salvo, Portugal

Abstract. Autism Spectrum Disorder (ASD) often comprises difficulties in the acquisition of communication and language skills. Several researchers and companies have developed software to help individuals with ASD developing those skills; however, there is a lack of applications in Portuguese that are tailored to the individual needs of each child. In this context, we present VITHEA-Kids, a platform where caregivers can create exercises and customize the interaction between each child and the platform. We also developed a module for the automatic generation of multiple choice exercises, meant to be integrated in VITHEA-Kids. We evaluated this work with caregivers (which provided promising indicators), with a child (ongoing upon thesis delivery) and we also evaluated the generation of incorrect answers in multiple choice exercises (achieving acceptance rates between 61.11% and 92.22%).

Keywords: Autism Spectrum Disorder, children learning, language skills development, automatic generation of content

1 Introduction

Autism Spectrum Disorder (ASD) is characterized by persistent deficits in social communication and interaction, as well as restricted, repetitive behaviors or interests since an early developmental period. Individuals with ASD often face difficulties in communication [2], which could be minimized by therapy. Therapeutic interventions might not be affordable, so the possibility of taking them to other settings or performing them in an affordable way could be helpful.

Given the interest that individuals with ASD display towards computers [6, 15], some authors studied the use of software to teach academic skills to children with ASD [16]. More recently, both companies and researchers have developed educational mobile applications targeting children with impairments, thus easing the practice of verbal skills in diversified settings, with or without assistance. Despite the current large offer of such applications, there are issues left to be addressed: most applications are paid; there is a lack of applications available in Portuguese that take into account each user's characteristics and needs. Considering this situation, we developed a software platform where children with

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ASD can solve exercises to develop or improve linguistic skills regarding Portuguese, having in mind their individual characteristics – VITHEA-Kids. We also developed a module to generate multiple choice exercises.

2 Background

According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) [2], a diagnostic of ASD happens when"persistent deficits in social communication and social interaction" and "restricted, repetitive patterns of behaviour, interests" are present since an early developmental period, causing significant impairment. Often individuals diagnosed with ASD go through therapy in order to improve their communication skills. Most therapies are based in Applied Behaviour Analysis (ABA), a psychology approach where the focus is to modify a certain behavior considering the events that precede (antecedents) and follow (consequences) that behavior. An ABA based therapy comprises the following steps [13]: 1) Identification of the behaviors and the respective antecedents and consequences; 2) Selection of a target behavior as the focus of the treatment; 3) Measurement of the current level of the individual's target behavior (baseline); 4) Implementation of an intervention to improve the target behavior and measurement of this behavior during this process; 5) Assessment of whether the acquired skills were generalized across different settings, people and materials. The most common interventions are the reinforcement based ones, where the manipulated stimulus is something that pleases the individual, i.e., the individual's behavior is rewarded. These include several techniques, such as prompting, which consists in using an antecedent auxiliary stimulus that aims to elicit the desired response. An example of a prompt is to point at an object that the child was told to pick, in order to help the child performing such task [17].

3 Related Work

In this work, we reviewed works concerning the use of technology for children with Autism Spectrum Disorder (ASD) and the use of automatic generation of content in the context of education. Regarding technology for children with ASD, some authors performed surveys regarding aspects such as software features preferred by children with ASD and their caregivers, as well as feedback from users' relationship with technology, namely: previous experiences, main difficulties and reasons to abandon previously adopted technology [3, 6, 15]. The outcome of these surveys indicated that caregivers prioritize communication and social skills. Also, both children and caregivers display interest towards technology; however, caregivers have reported many issues, such as the lack of content customization based on the child's characteristics, among others.

Many researchers and companies have also developed software targeting children with ASD. Some researchers performed studies where they compared the outcome of using software *versus* non-computational solutions, regarding children's language development process, while others focused on evaluating the

impact of a specific set of features. Studies reviewed include Heimann et al [4], Moore and Calvert [12], Hetzroni and Tannous [5], and Massaro and Bosseler [8] and others (see Ramdoss et al [16]). Most of these studies reported progress regarding the children's ability to learn new skills, but the applications utilized in these studies are either discontinued or paid and do not comprise customization options. We have also experimented several applications available in Google Play, and although they exist in a large amount, most of them are only available in English; additionally, many of them are paid (or include paid features) and, as for the free ones, some have several navigation bugs that negatively affect user experience; finally, the possibilities for creating content and the customization options were either limited or none at all. A more detailed analysis of the studies reviewed and applications experimented can be found in the dissertation document [10].

Regarding the use of automatic generation or processing features in the context of education, these can spare teachers and educators time while creating content, be adapted to each student's characteristics, etc. However, we only found one study where automatic generation of content was used in an application for children with ASD [7].

For the automatic generation of content, we analyzed resources and tools that we could use to extract words and images, as well as to assure the correctness of the resulting content. For the task of retrieving words and related images, the only resource that facilitates such task is ImageNet[1], which allows to browse through nested hierarchies of synsets (sets of synonyms) associated with a set of image URLs. As for the correction of the generated content, we experimented TreeTagger [18]: a tool for the Part of Speech (PoS) and lemma annotation of sequences of words that can be used for any language as long as a lexicon and a tagged training corpus are given, which is the case of Portuguese.

4 VITHEA-Kids: A Platform for Children with ASD and Their Caregivers

Recalling the goals defined in Section 1, we developed VITHEA-Kids: a platform where children can solve exercises created by their caregivers. This platform is based on the infrastructure of Virtual Therapist for Aphasia Treatment (VITHEA) [1], an awarded platform aiming to help patients with aphasia to recover their word naming skills by solving exercises in which they should orally reply to a question (e.g. to name the object in an image). VITHEA comprises two modules: the therapist's module, where therapists can create and manage the exercises for the patients to solve and the multimedia resources to be used in those exercises, as well as to manage each patient's information and statistics; the patient's module, where the patients can solve the kind of exercises described above. The exercise instruction and the feedback to the patient's answer are uttered by a talking animated character using a voice synthesizer [14].

[1] `http://image-net.org/`

The patient's answer is validated using automatic speech recognition [9] and it does not have to be an exact match of the correct answers provided by the therapist to be considered correct. When incorrect, the patient can try again for a user-defined number of attempts. However, the correct answer is never provided to the patient, and no helping cues are given during the exercises.

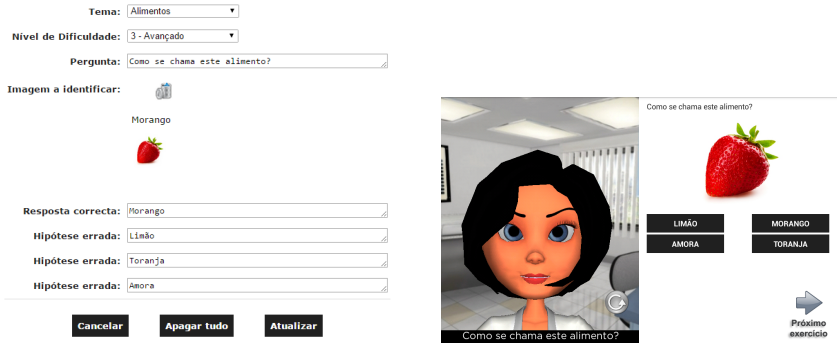
Although VITHEA-Kids is based on the infrastructure of VITHEA, our target users are different and so is the purpose and functionality. One of the differences is that we use multiple choice exercises, since this kind of exercises has been used for children with ASD and might allow to work on skills such as vocabulary acquisition, word-picture association, and generalization. These exercises are composed by a question (e.g, "What is the name of this object?"), an optional image or textual stimulus (e.g, the picture of a fork), and a set of textual or image possible answers, respectively ("Fork", "Spoon", "Cup", "Bowl"), in which only one of the answers is correct (in this case, "Fork"). Each exercise can contain from zero to three distractors, easing the task of creating several exercises with small variations in content and difficulty.

VITHEA-Kids is composed of two modules: the caregiver's module and the child's module, based on VITHEA's therapist's and patient's modules respectively. The caregiver's module allows to create and manage the exercises described above (see Figure 1a), as well as to upload and manage image files to be featured in the exercises, and create and manage child users (whose info differ from VITHEA's patients'). Unlike VITHEA, it also allows for the caregiver to customize the child's module, namely the utterances for the animated character and the reinforcement images to display when the child correctly solves an exercise.

As for the child's module, in each exercise the animated character utters the question, and the exercise area is filled with the stimulus and the possible answers in a random order (see Figure 1b). The child should then tap over the answer they think to be correct. Selecting the correct answer on the first attempt will lead to a reinforcement image. Selecting any other answer will prompt the child to pick the correct answer: the selected distractor disappears, the correct answer is highlighted and the remaining answers are uttered by the animated character. If, after that, the child selects the correct answer, a weaker reinforcement screen is shown. The current exercise can be skipped at any time. When the exercise session ends, information about child's performance is shown. There is also a repeat button to have the animated character repeating her last utterance.

5 Automatic Generation of Exercises

Besides VITHEA-Kids, we also developed a module for automatic generation of exercises, aiming to ease the task of creating exercises, either in VITHEA-Kids or in other contexts. This module generates content for multiple choice exercises of the two variants presented in Section 4, taking as input the exercise topic (e.g, "Emoções" – "Emotions"), a user-provided template for the question generation, composed by an immutable part and a variable whose value depends



(a) Caregiver's module (b) Child's module

Fig. 1: VITHEA-Kids's modules

on the exercise's topic ("Que `<%variavel>` é este?" – "Which `<%variable>` is this?"), information regarding the number of distractors (e.g, "3") and whether the distractors should be related to the given topic (e.g, "true"). The output is an exercise composed by a question/instruction (e.g., "Que emoção é esta?" – "Which emotion is this?"), the correct answer to the question (e.g., "alegria" –"happiness", along with an image of a happy person) and a set of distractors ("tristeza" – "sadness", "raiva" – "anger", and "medo" – "fear"). The words and images are obtained from a hierarchy of synsets similar to ImageNet (recall Section 3).

The exercise generation process comprises three main tasks: 1) Generating the correct answer and the corresponding stimulus, given a certain topic; 2) Generating a question given the exercise's topic, the correct answer generated in 1 and the question template; 3) Generating a set of distractors given the exercise's topic (if relevant), the correct answer and the number of distractors. Generating a correct answer consists in selecting an hyponym of the topic provided (upon being converted to singular). As for the question generation, it involves the following steps (unless the template provided does not include a variable, in which case the template remains unaltered):

1. The template is searched for the variable (a word surrounded by `<%` and `>`);
2. If the variable was found, it is replaced by the word selected within the next steps. Otherwise, the process ends here and the template is returned as the final question;
3. The first hyperonym of the correct answer that contains the topic is selected (if none contains the topic, a random one is selected);
4. The variable is replaced with a word randomly selected from the hyperonyms list obtained in the previous step;
5. The resulting sentence is PoS tagged using TreeTagger;
6. The resulting tagged sentence is checked for inconsistencies regarding number and gender agreement between the variable's replacement and the rest

of the sentence (number and gender information for each word was provided by TreeTagger in the previous step).
7. If an inconsistency is detected, all the words that should agree in gender and/or number with the variable but fail this criterion are corrected using a list of substitutions. Each substitution has the format `regex before after` – if the word to correct matches the regular expression (`regex`), its suffix (`before`) is replaced by the suffix `after`.

In Step 6, we check gender and number agreement for the following patterns: the variable is a noun preceded by a demonstrative determinant; the variable is a noun preceded by an article; the variable is a noun preceded by a demonstrative determinant and a verb; the variable is a noun preceded by an article and a verb; the variable is a noun preceded by a demonstrative determinant, a verb and an interrogative pronoun; the variable is a noun preceded by an article, a verb and an interrogative pronoun; the variable is a noun followed by a demonstrative determinant; the variable is a noun followed by a verb demonstrative determinant.

Regarding the generation of textual distractors, if the distractor should belong to the given topic, it is selected from the leaf hyponyms of the topic. Otherwise, it is selected from all the leaf synsets. The selected distractor cannot be a synonym of the correct answer (i.e., it cannot belong to the same synset) nor match any of the remaining distractors for the current exercise. This process repeats itself for the number of distractors specified. For image distractors, the selected synsets must also include images.

6 Evaluation

We individually evaluated each of the three modules delivered. Regarding VITHEA-Kids, the caregiver's module was evaluated with seven caregivers, including parents and therapists of children with special needs. Participants had to perform 5 tasks and rate them using a scale of 1 to 5 in a questionnaire which also included a set of statements about the overall experience (to be rated using the same scale), and open questions for further observations and suggestions, as well as a question to assess the interest in automatically generated exercises. Most of the tasks were rated with 4 or 5 in terms of how easily/fast they could be performed. All the participants strongly agreed that the platform was easy to browse and makes use of a discourse easy to understand. However, some participants disagreed concerning the clarity of the feedback given in error or confirmation messages. The majority of the participants (6 in 7) found the exercises in VITHEA-Kids useful for their children and would like to use the application again. Furthermore, all the participants were interested in the automatic generation of exercises.

The child's module was evaluated using a Single Subject Design, since each individual with ASD has a unique set of symptoms, characteristics and needs, making it difficult to generalize results across participants. The variant chosen

comprises baseline and intervention phases (recall Section 2), and also a final follow-up phase. The application was tested with a seven year old male child, diagnosed with ASD, who is currently learning how to read, in his classroom, with the help of a therapist. Our goal was to assess whether the child could learn a new word taking advantage of the application's prompting and customized reinforcement. In the baseline phase (using zero distractors), the child never selected the correct answer, so this phase ended after four sessions (the minimum number of sessions required to consider that a stable pattern was observed). In the intervention phase, which overlapped the delivery of this thesis, the child had to solve exercises in which the number of distractors was initially zero and progressively incremented (up to three). This phase ended when the child selected the correct answer during two consecutive sessions, without prompting. In the follow-up phase, prompting and reinforcement were deactivated in order to assess whether the child had learned the target word. Once again, the child selected the correct answer during two consecutive sessions (always using three distractors).

The evaluation of the exercise generation module was focused on the generation of distractors. Thirty participants replied to a questionnaire to generate and rate a set of distractors for each pair of question and correct answer to that question. For each distractor, the participants should indicate whether they think the distractor makes sense in the context of the given input or not (i.e., whether it would be possible to solve an exercise if it was composed of the given question and a set of answers containing the given correct answer and the distractor being evaluated). A total of 180 word distractors and 180 image distractors were generated. Out of the word distractors, 79.44% were marked as making sense, and the average quality rating was 3.75 out of 5 (std dev = 1.41). As for the image distractors, 76.67% were marked as making sense and the average quality rating was 3.82 out of 5 (std dev = 1.44).

7 Conclusions

In this work, we are taking the first steps into addressing the issues presented by the currently available software for individuals with ASD, by presenting a customizable, free of charges platform for the development of linguistic and generalization skills regarding Portuguese, where caregivers can create content having in mind each child of whom they take care. We also present a module that aims to save time to the caregivers by allowing to automatically generate multiple choice exercises. The work described in this thesis originated a publication in 17th International ACM SIGACCESS Conference on Computers & Accessibility – ASSETS 2015[2], under the title: *VITHEA-Kids: a platform for improving language skills of children with Autism Spectrum Disorder* [11].

As for future work, one of our goals is the integration of the exercise generation module in VITHEA-Kids. We also intend to add some features that were

[2] `http://www.sigaccess.org/assets`

suggested by caregivers during evaluation (specially regarding customization) and expand the variety of exercises available. Regarding the automatic generation of exercises, it would be interesting to allow the generation of paraphrases given a question, since it could contribute to improve the child's ability to generalize different formulations of the same question.

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