DEVELOPMENT AND EVALUATION OF A COMPUTER GAME FOR TEACHING VOCABULARY TO CHILDREN WITH AUTISM

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Abstract: Autism is a global development disorder that affects children's ability to communicate, to establish relationships and to respond appropriately to the environment. Within Computer Science, the area of Human-Computer Interaction (HCI) can assist in building high quality tools that can help the development of children with autism. This work aims to analyze the impact of a computer game developed exclusively to help children with autism in vocabulary acquisition. The results obtained so far show that children were able to effectively learn new words. Evidence of generalization and retention has been shown.

1 INTRODUCTION

Autism was first identified by (Kanner, 1943). He described a group of seriously injured children who had certain common characteristics. The most noticeable was the inability to relate to people. Since then, autism has been a subject of research in different areas within universities.

According to the 10th International Statistical Classification of Diseases and Related Health Problems of 1992 (ICD-10), autism is considered a Pervasive Developmental Disorder, which would present a pattern of abnormal development and/or impairment, manifested before the age of three. The abnormal function of the child's skills can be related to three areas: social interaction, communication and imagination (Figure 1). This triad represents a broader view of the autistic spectrum and forms the basis for current diagnostic criteria, as described in the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV). The diagnostic criteria expressed in the DSM-IV Autistic Disorder are consistent with the criteria in the ICD-10 for Infantile Autism, both listed under the general heading of Pervasive Developmental Disorder. The DSM-IV includes a diagnostic category of 'Autistic Disorder' in the section titled Pervasive Developmental Disorders. The diagnostic criteria for the DSM-IV and the ICD-10 for autism are almost identical, although in the ICD-10 it is known as 'Childhood Autism'. For a diagnosis of autism, at least two symptoms of impairment in social interaction, one symptom of impairment in communication, and one symptom of restricted and repetitive behavior must be present. These characteristics should be evident until the age of three, although diagnosis is usually done later.

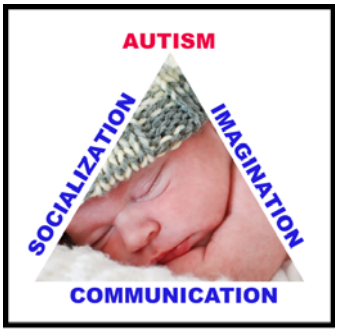

Figure 1: Autistic triad.

According to the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders Revised (APA, 2000) this developmental disorder affects 1:100 children, with higher incidence in males (3:1, against 4:1 in female children). In Brazil, epidemiological studies of the disorder have not been done, but based on statistical studies conducted in other countries (Fombonne, 2010), it is estimated that in Brazil there are 500,000 people under twenty years old with this disorder. And approximately

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115,000 of these are children aged 0 to 4 years. Although incurable, it is possible to ameliorate the developmental delay caused by the disorder. This is possible through early detection of the disorder coupled with specialized treatments (Schopler et al., 1995). Ideally, treatment should begin preferably even before three years of age (Robins et al., 2001; Wetherby et al., 2004).

Treatment should be performed by a multidisciplinary team consisting of professionals from different areas of health. In addition, other approaches are commonly used in treatment, such as therapeutic horseback riding, music therapy, speech therapy, swimming, contact with animals and, recently, interventions using the computer.

Computers are considered promising tools to assist people with autism. Some of the early researches showed positive results in using the computer to treat people with autism dates back to 1973 (Colby, 1973). Currently there are several works that explore the use of computers to support the development of people with autism. There are jobs in the area of virtual reality (Charitos et al., 2000; Kerr, 2002; Parsons and Mitchell, 2002), robotics (Dautenhahn, 1999), face recognition (Baron-Cohen and Golan, 2006), cooperative games (Piper, 2006), and several others that use the technology for this purpose.

One of the main factors that motivate the use of computers to treat these people is that with computers you can create controlled environments that are interesting and without distractions. These features are considered important for success in treating people with autism (Dautenhahn, 2000; Putnam and Chong, 2008).

The aim of this work is to develop and evaluate a computer game created specifically to teach vocabulary to children with autism aged 5 to 10 years old.

2 THE VOCABULARY GAME

The process of language comprehension and acquisition is complex. A person must have many skills to be able to understand and comprehend the meaning of the spoken words. This means understanding the meaning and having the ability to process the sounds of the spoken word. This process is the basis of the language use in communication. The acquisition of vocabulary is an important component in this process (Gupta and Macwhinney, 1997). Studies show that the breadth and depth of vocabulary knowledge is related to the ability of good reading (Stanovich, 1986; Wood, 2001), and also to academic success (Vermeer, 2001).

2.1 Game Characteristics

In designing software for children with autism it is especially important that the interface should be designed in a socially responsible way. Although children with autism are a diverse group, there are characteristics commonly found in autism (NAS, 2004) which were considered in the design of this game. The following items summarize the design decisions (DD) related to certain characteristics:

- They are likely to prefer predictable, structured and controlled procedures and environments and, possibly as a consequence, they are often attracted to inanimate objects, machines and computers. DD: A computer version of a paper-based vocabulary game is developed.
- They may have difficulty with remote object references (proto-imperative pointing), and may have difficulty understanding the use of a mouse. DD: The game is presented using a touch sensitive screen, allowing direct manipulation using a finger. The possible answers in the lower part of the screen can be draggable, giving a strong analogy with the physical world. Mouse or touchpad can also be used.
- They are generally highly visual. DD: Figures can be used throughout the whole training.
- They tend to focus on particular details and prefer local than global integration (Happé, 1997). Consequently, a child with autism might focus exclusively on some apparently irrelevant details, e.g. great interest might be taken in the experimenter's glasses, or a program can be used not for its primary purpose, but just for the pleasure of the accompanying noises. DD: Screen design is kept very simple with no complex features.
- They may be highly sensitive to noise, finding intolerable noise, which is barely perceptible or unremarkable to others (Bogdashina, 2003). DD: Sound features can be turned off.
- They may have problems with manual dexterity. DD: A simple docking function aids the final placement of the child's chosen answer.
- They may find failure very debilitating (Jordan and Powell, 1995). DD: There is no penalty for a wrong answer. The accompanying adult may encourage another attempt if appropriate to the

particular child at the time.

Challenges, needs, and skills vary by age of a child and severity of their diagnosis, and each case of autism is unique. So, the game can be personalized for each child. It is possible to change its options and adapt them over time. Goals can be set for each child, individually.

2.1.1 Game Procedure

The game is based on matching-to-sample procedure, which is a form of conditional discrimination.

The basic operations in the matching-to-sample task are: first, the sample stimulus and an array of choice stimuli are presented; second, the participant responds by selecting a stimulus from the array which he/she believes that corresponds to the sample stimulus; third, informative feedback is given as to whether the correct choice was made.

The essential components of the task consist of the sample stimulus followed by a set of choice stimuli, which includes a stimulus that corresponds to the sample. Based on some rule or relationship, the participant should respond by choosing the correct one.

In the actual application, the sample and choice stimuli are linguistic stimuli. Although the sample and choice stimuli have a correspondence, they may vary widely in terms of their actual properties. For example, a very simple task may be matching picture to picture, while a more complex one would consist of matching a word to picture. Table I shows all the existing possibilities of matching in the game. The game proceeds in the following the sequence:

- The stimulus item and the array of choice items are presented on the screen.
- The child is (verbally) asked to locate the identical item using the touch screen, mouse or touchpad.
- If the child chooses the correct response, there is a display congratulating him/her. Otherwise, the incorrect item wiggles, as if saying “No, not me”.
- The trial is repeated until the child reach criterion.

2.1.2 Game Training Cycle

The game training is based on a Discrete Trial Training (DTT) cycle. DTT is the primary teaching method for a number of the behaviourally based interventions used in teaching children with autism.

Table 1: Matching-to-Sample Possibilities.

	
Sample stimulus is a word and the choice stimuli are a set of pictures	Sample stimulus is a picture and the choice stimuli are a set of pictures
	
Sample stimulus is a picture and the choice stimuli are a set of words	Sample stimulus is a word + picture and the choice stimuli are a set of pictures
	
Sample stimulus is a word + picture and the choice stimuli are a set of words	Sample stimulus is a word and the choice stimuli are a set of words

Children with autism often face many deficits and difficulties in learning (Schopler et al., 1995). Discrete-trial training can help to compensate for these difficulties.

A discrete trial is a single cycle of a behavior based instruction routine. A particular trial may be repeated several times in succession, several times a day, over several days (or even longer) until the skill is mastered. There are four parts, and an optional fifth, to a discrete trial.

- **Discriminative stimulus** (S^D) - The instruction or environmental cue to which the teacher would like the child to respond.
- **Prompting stimulus** (S^P) - A prompt or cue from the teacher to help the child respond correctly (*optional*).

- **Response** (R) - The skill or behavior that is the target of the instruction, or a portion thereof.
- **Reinforcing stimulus** (S^R) - A reward designed to motivate the child to respond and respond correctly.
- **Inter-trial interval** (ITI) – A brief pause between consecutive trials.

The parts of the discrete trial are often represented symbolically in the following format, adopted in the remainder of this work:

$$S^D \rightarrow R \rightarrow S^R \rightarrow ITI$$
$$(S^P)$$

Essentially, this illustrates the order of a discrete trial. First there is the teacher's instruction (S^D). If the teacher thinks the child may need some help responding correctly, she will give him/her a little prompt, cue, or model to help him/her out (S^P). Then, either with help or without, the child gives some response to the instruction (R). If the child responds incorrectly, the teacher might correct him/her, and then give him/her another chance. If the child responds correctly, or close to correctly, the teacher might give him/her some reward or praise to encourage him/her (S^R). After that sequence is completed, the teacher might want to pause for a little while before continuing, to let the child know that they have completed one cycle and have moved on to the next (ITI).

The game followed the same idea behind DTT. Initially, the main character makes a request (S^D). If there is delay in response time, the character reinforces the request (S^R). A guess (S^P) can be customized to be presented sometimes during the game. When a correct response occurs (R), the character congratulates the child and an animation appears.

2.2 Game Goals

Research on treatments to help children with autism should include the retention and generalization of behaviors (Schreibman and Ingersoll, 2005). Behaviors refer to any skill or knowledge gained by an individual during treatment. Learning new words is a behavior that can be taught and measured. Retention and generalization can occur separately for a behavior; however, it is desirable to ensure that both occur (Bregman et al., 2005). This investigation measured the retention and generalization of learned material after a period of time.

2.2.1 Retention

Retention is the ability to remember over a period of time (Smith, 1994). Retention of a new word would entail remembering the word after a period of time with no exposure or training in that word.

There is little value to learning skills that are forgotten (Powers, 2005). Time spent teaching skills that are not maintained is time wasted. If the skill was worth teaching in the first place, the skill should be either automatically maintained by the child in the natural environment or it should be learned so well that it is easily remembered when necessary. Retention could include periodic review or practice of material so that it is remembered.

2.2.2 Generalization

Generalization is the ability of an individual to demonstrate a behavior outside the treatment environment (Bregman et al., 2005). Behaviors that are generalized can be used with different stimuli, people, and situations. Generalization of new words would be evident by the ability to recognize a word in a different form, such as other pictures or objects, which represent the word that was previously taught by the computer. Other aspects of generalization include the use of a new word that is spoken by a different person or used in a different setting. New knowledge must be transferred to different materials and environments to be useful. Words learned on the computer should be useable in the real world. This investigation evaluated the ability of the participant to generalize his learning from the computer game to objects and flash cards.

3 METHODOLOGY

3.1 Participants

The criteria for selection of participants included prior diagnosis of autism, availability of family, and a trained professional to mediate the search. To date, this research involved three children aged five to nine years. The vocabulary known by the children was verified using receptive tests for identification of approximately ten among 105 significant figures. In the receptive tests, children were only asked to point at the correct word, and they did not need to say it aloud.

3.2 Ethical Issues

The research was carefully designed to maximize student learning and avoid subjecting them to situations of discomfort. Their parents have carefully read and signed the consent form.

3.3 Procedure

The study consisted of four phases: pre-tests, pre-training, training and post-tests.

3.3.1 Pre-Tests

This phase consisted in the identification of words unknown to the child. 105 words were used in the same size cutouts of small-format cards.

The words represented by the figures correspond to nouns of different categories: fruit, transportation, animals, insects, furniture, electronics, cooking, music, tools, buildings, food, clothing, hygiene, and school.

The pictures were displayed in pairs and the child was asked to receptively indicate (*i.e.*, to just point at) one of the figures through requests such as: "Show me the apple." The criterion to consider the word correct was the hit of at least three consecutive times in which the same word was shown alongside different sets of figures. Three consecutive errors indicated otherwise. Since it was just a pre-test, there were no scheduled consequences for hit and miss and no help or correction procedure was used during this phase.

This phase was considered finished when approximately ten words were identified as unknown to the child.

3.3.2 Pre-Training

Before starting the training, participants were taught to use the proposed game. At this stage the participant used only the known vocabulary. The criterion for completion of this phase was to hit five times the target word.

3.3.3 Training

At this stage, children trained words that were unknown as first identified in the pre-test phase. The training included ten sessions. Generally, sessions took fifteen to thirty minutes each.

To teach new words, we use both an identity and an arbitrary model. In the identity model, both the word to be learned and the array of stimuli are in the same type of representation, i.e., both images or both words. In the arbitrary model, there is a combination of words and images.

The game issued for each hit a compliment for the participant to keep performing the activities until the end of the training; these interventions were contingent on successes. There were no programmed consequences for error situations.

The criterion for completion of the task was to correctly answer at least five consecutive attempts involving the same word without an error. While the criterion was not reached, the word was not switched.

3.3.4 Post-Tests

At this stage, we verified if the retention of the taught words, *i.e.*, the extent to which these words were remembered over time.

(Biemiller and Boote, 2006) tested retention after two periods of non-exposure treatment, 2 weeks and 6 weeks. In their study, the retention period was 4 weeks.

For our assessment, we used the same figures and procedures of the pre-tests. Generalization tests also occurred during this phase. We followed the same procedure as the pre-tests, including physical objects.

The game only required a receptive response, not an expressive one. The generalization from receptive to expressive is not guaranteed with children with disabilities (Biemiller and Boote, 2006). Thus, the participant was tested to determine if the words that he could select receptively in the game could also be labeled expressively.

To determine whether generalization occurred also in a significant way, we conducted tests in which a picture was presented to the child and requests were made or questions like “What is it?” were posed. The child should say the name of what was presented. Objects were also used in this way.

4 RESULTS

The evaluation assessed the extent to which developed the game contributed to the acquisition, retention, and generalization of vocabulary, as well as a subjective evaluation of each child's response to the program. Data were captured and analyzed in two distinct moments of the study: training sessions and post-tests. The results obtained so far show that children were able to significantly learn some vocabulary, with retention of about 94% of new words after 30 days. Table II provides the individual

performance of each child. As can be seen in the table, children were also able to generalize the acquired knowledge (M = 0.94, SD = 0.10).

The three participating children seemed to enjoy working with the game. They came for the evaluation sessions requesting the "squirrel", which is the game's main character. We have also observed that the praises fired by the main character made the children happy.

Table 2: Number of trained words, total number of words retained and generalized after a period of training and total training time for each participating child after 10 sessions.

Child	Trained	Retained	Generalized	Training Time
A	9	9	9	0:53:30
B	12	12	12	1:08:28
C	11	9	9	1:05:15
Total	32	30	30	3:07:13
Average	10.67	10.00	10.00	1:02:24
SD	1.53	1.73	1.73	0:07:53

5 CONCLUSIONS

The evaluation of the known vocabulary is an indicator of cognitive development. Acquiring words means not only to be able to speak, but also understand the spoken word and look it up in memory. There is always a need for individuals to use their cognitive ability to understand and interact to the world. Moreover, without a large repertoire of words, it is difficult for children to create new conceptual categories (Bee, 2003). Therefore, this study aimed to analyze the impact of a computer program developed exclusively to help children with autism in vocabulary acquisition.

The computer program developed for this research combined visuals, sound effects, incentives, and reinforcements. Preliminary results showed that children could learn at least two nouns at each session. Generalization and retention tests also showed that children were able to recall the nouns trained and to apply the acquired knowledge in novel situations. In addition, they were highly motivated to interact with the computer.

This study is limited by the small sample and by the potential variance in responses by children with autism. Additional research should be conducted to examine more children with autism with different abilities. The effects of computer instruction, the use of collaborative as well as individual computer activities, and the specific visual and auditory production techniques that promote interest and learning should also be examined.

In conclusion, we hope that this work can contribute to and promote other projects in the area of information technology in special education, especially in the education of children with autism.

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