Technology-Enhanced Discriminative Programs for Children with Autism

Silvia Artoni
University of Pisa
Largo Bruno Pontecorvo, 3
56127 Pisa (PI) Italy
+39050 2212772
silviartoni@gmail.com

Maria Claudia Buzzi
IIT - CNR
v. Moruzzi, 1
56124 Pisa (PI) Italy
+390503152632
claudia.buzzi@iit.cnr.it

Marina Buzzi
IIT - CNR
v. Moruzzi, 1
56124 Pisa (PI) Italy
+390503152631
marina.buzzi@iit.cnr.it

Susanna Pelagatti
University of Pisa
Largo Bruno Pontecorvo, 3
56127 Pisa (PI) Italy
+39050 2212772
susanna@di.unipi.it

Caterina Senette
IIT - CNR
v. Moruzzi, 1
56124 Pisa (PI) Italy
+390503158299
caterina.senette@iit.cnr.it

ABSTRACT
Autism impacts a subject's communication, socialization and language abilities with different degrees of severity. Intensive therapy is needed to improve and maintain these abilities over time. Augmentative and Alternative Communication (AAC) enriches communication with images, video or gestures to help children with autism understand a task. Discrete Trial Training (DTT), breaking up a task into small trials of increasing levels of difficulty (structured trials), is used in teaching autistic children. In this paper, we compare the progress of seven autistic children while carrying out both traditional and technology-enhanced Applied Behavior Analysis programs, including matching, receptive and expressive trials. Results show that with ABCD software learning time is reduced, as children in the sample required less time to master new articles and generalize previously mastered skills.

Categories and Subject Descriptors
K.4.2 [**Social Issues**]: *Handicapped persons/special needs.* H.5.2 [**User Interfaces**]: *User-centered design;* I.2.6 [**Learning**]: Knowledge acquisition/Language acquisition

General Terms
Measurement, Performance, Design, Human Factors

Keywords
Technology-enhanced training, Autism, ABA, data analysis

1. Introduction
Low-functioning autistic children experience serious limitations in receptive and expressive communication; this impacts the subject's learning ability and overall behavior. Since learning depends on the child's attention, it is crucial to shape the child's behavior to obtain his/her attention, and to encourage interest and motivation. Discrimination is one of the first programs introduced in pre-school rehabilitation training of children with autism. ABCD SW is a project for designing, implementing and testing software (SW) for teaching children with autism, using Applied Behavior Analysis (ABA). In this paper we describe the results of the project, comparing learning rhythms of the children using both traditional ABA and technology-enhanced approaches. Effectiveness is evaluated in terms of children's learning parameters and accuracy of collected data.

REHAB 2014, May 20-23, Oldenburg, Germany

DOI 10.4108/icst.pervasivehealth.2014.255258

2. Related Work
Several studies have introduced technology-enhanced systems for training autistic children or older subjects in communication, socialization, language and behavior. Kientz et al. designed and developed two systems for facilitating efficient child monitoring: 1) Abaris, supporting Discrete Trial Training, building indexes into videos of therapy sessions and allowing easy data search; 2) CareLog, for collecting and analyzing behavioral data [3]. However, the author's approach follows classic DTT training, but enabling video recording and data monitoring. This introduces complexity and increases the amount of video data on the observed behavior, guaranteeing high accuracy. In contrast, our approach simplifies data gathering by mapping the entire DTT process into electronic devices allowing a rapid evaluation (just pressing a key). Furthermore, to improve accuracy of the data collected, tutors must insert the trial evaluation to activate the new child trial. This allows easy management of the system and offers real-time monitoring of the child's learning trends and behavior.

Until a few years ago, digital products available for augmentative communication (such as GoTalk, Tango, Dynavox, Activity Pad) showed high costs, low usability and low flexibility. Furthermore, training was required for set-up and customization, making it difficult for parents to use them at home [2]. Today's mobile touchscreen devices (tablets, smartphones) are the future of tele-rehabilitation, since they are cheap, flexible, small, easy-to-use and attractive. For instance, Monibi and Hayes implemented a library of virtual cards for autistic children's training activities on a smartphone [4]. Sampath et al. proposed a system using AAC that allows bidirectional communication between child and

caregivers [5]. De Leo and Leroy enabled communication of children via smartphones [1]. To the best of the authors' knowledge, there was no open source free multiplatform software integrating ABA training and learning analytics; for these reasons, we developed ABCD SW [6].

3. ABCD SW

ABCD SW [6] implements matching, receptive and expressive programs, and records learning and behavior data. Tutor and student are co-located using two distinct mobile devices. According to the personalized learning schedule of the child (defined by the ABA consultant), the tutor selects articles and programs, activating trials on the child's device. We chose an iPad for the child console because it showed better responsiveness -- crucial for offering precise and more rapid feedback to children -- to touch and drag compared to other tablets. When necessary, the tutor provides a prompt to the child in order to prevent errors, which are difficult to correct later. Over time, the prompt is progressively decreased until it is no longer needed (fading).

The tutor interface (UI) is shown in figure 1; there is a list of the matching, receptive and expressive programs (the selected ones are indicated in orange), the category and the object on which the child is working (on acquisition). Figure 2 illustrates the child UI.

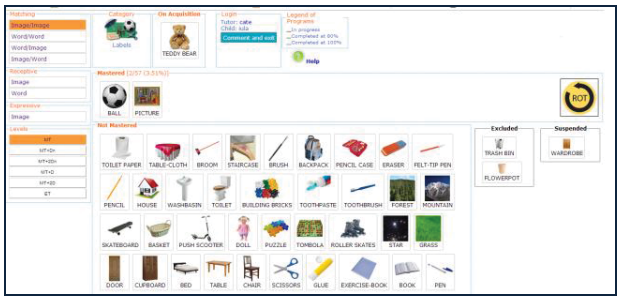

Fig. 1. The tutor's UI: discrimination activity

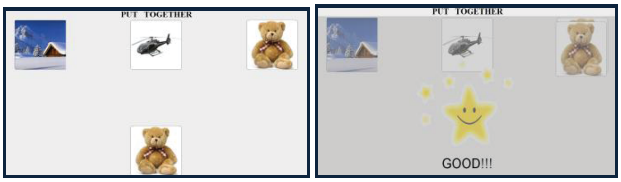

Fig. 2. The child's UI: a matching trial; the reinforcer after a correct trial

The ABCD software, available at abcd.iit.cnr.it, offers several advantages over the traditional method.

Fast trial set-up. The rapid set-up of the trials optimizes therapy time, allowing more training to be carried out than does the traditional one based on plasticized paper cards (or objects) to be arranged manually by the tutor on a table.

Scalability Articles and categories can be easily added via Web interfaces, without changing any code.

Safe learning environment. The child acts in an errorless environment, as required by ABA, since errors are impeded by the software itself (in the matching trial, when in proximity of a target element a similar item is attracted, while a different element is repulsed and goes back to the starting position).

Personalized reinforcers. After any successful trial the child is rewarded immediately by an animated gif. For an independent successful trial the tutor presses the "0" key to activate a personalized electronic reinforcer, as defined in the child's profile (video, animation, game).

Accessible trials. A child's profile defines whether (s)he is receptive and/or expressive or not. Based on this information the software adapts the trial's stimulus and format to the child's abilities (stimulus being the appearance of the article, its physical visual quality; the format is the context of the presentation and the physical response of the child).

A test with seven autistic children (aged 2.5-10 years) was performed during the 2012 school year, with three children starting ABA in conjunction with our user test and four already following behavioral intervention for one or more years. The first 3 months were spent introducing newcomers to applied behavior analysis, to coordinate schools in guaranteeing intensive school and home intervention for at least 25 h per week. In the following we present some considerations on the use of the technology-enhanced sessions compared to the standard ABA sessions.

4. Data analysis

Recording data from an ABA intervention is crucial for the success of the intervention itself, since it allows one to measure, monitor and scientifically check whether the child's performance during sessions leads to learning. The study of data analysis in the ABCD project involved comparing the traditional system of recording session data on paper to the ABCD SW system.

The paper-based model consists of daily data collection forms (for recording session trial data) and a notebook of ABA programs, updated periodically (programs are constantly adapted to children's progress). The daily data collection form contains the recorded data of a single session (categories and work programs, articles, instructions used for trial execution, level of work for each item, number of trials performed in each session and level of prompt), the date and the name of the tutor who carried out the session. The notebook contains a description of the programming designed specifically for the child; i.e., the list of programs and articles to be taught in each program, with dates of the introduction and mastery of each article. When using the paper model, these data are copied from the notebook to an electronic spreadsheet for creating learning graphs, but the process is time-consuming and error-prone. At the end of each session, a comment is written to report any situations relevant for subsequent sessions (greater pleasure in certain reinforcers, a disturbing/distracting event, an exceptionally positive mood, etc.).

ABCD SW was designed to support the ABA intervention including the electronic annotation of session data, previously written on the paper forms, totally retaining its features: 1. type of work: category, program, article, etc.; 2. number and quality of responses, with the recording of each trial and the percentage of prompts used; 3. acquisition of article, with the date of first use and mastery of each; 4. the tutor performing the session and 5. any comments, with a reconstruction of the child's progress that the tutor can access before starting the session. In the electronic system, other data is also collected concerning the child's behavior in order to facilitate data analysis in relation to the subject's behavior, highlighting problems for early intervention.

Accuracy of data collection. Paper documentation is not always accurate, since recording the different types of data requires time and organization. Instead, data collection in the ABCD SW ensures that data are recorded immediately and accurately, and is

always available. When analyzing data collected with the paper-based system, some gaps were found in the recorded data since not all trials were recorded; this did not always allow this study to make an exact comparison between the timing of the articles mastered in the two modalities of work.

Time spent recording data. ABCD SW speeds up data entry compared to the standard paper-based system, describing the qualitative characteristics of each test through keys assigned to the level of prompts and reporting the number of trials performed.

Real-time graphics. The data is available immediately for the creation of real-time graphs to be used by the tutors/relatives who make up the intervention team. Evaluation of the performance by ABA team can thus be rapid and constant, since charts are taken from queries to the database, constantly automatically updated when new trials are executed.

Targeted search. Ease of reading the interfaces and organization of the software for data analysis allows elements to be found quickly and precisely, for example when performing a search for an article via filter; information can include the date of the first and last use and the level of mastery achieved in each program.

Learning time. Data analysis of the two models of information gathering allowed us to compare children's learning times. In sessions recorded on paper, the average time required to master an article is 2-3 days (from 2 to 6 sessions, assuming that children have 1 or 2 sessions per day). Each child has his/her own learning pace, so acquisition time of the items in the same or comparable programs can vary greatly from child to child. In the subjects studied, we considered that on average it took 2 days (from 2 to 4 sessions) for one article to be mastered in a specific program, as shown in Table 1. For the same programs performed with the ABCD SW sessions, in the period examined the average was a little less than 2 days (during tests with the SW the children conducted one session per day, sometimes two, depending on school commitments). All children surveyed had been doing ABA for at least a few months, and some for a few years, so the work on acquisitions by software was conducted more or less parallel to the ABA programming, or as a generalization of previously established skills. It should be pointed out that this mostly concerned the ability to generalize the discrimination of articles presented, since mastery of those articles had previously occurred in the traditional sessions, although with a different stimulus and format.

Table 1. Mastered articles with ABCD SW: average time

Child	Average time to master a single article
E.	1-3 days
Em.	1-2 days
G.	1-3 days
M.	1-3 days
S.	2-3 days
Si.	2-4 days
T.	1-2 days

Table 2. Generalization with ABCD SW: mastered articles

Child	Articles generalized with ABCD SW
E.	75%
Em.	80%
G.	40%
M.	42%
S.	21%
Si.	10%
T.	73%

In all cases studied, acquisition times for articles taught ex novo directly via ABCD SW are shorter for children whose acquisition times are normally longer. For example, the child Si. takes on average 2-4 days (from 4 to 8 sessions) to master an article in the matching programs during standard sessions. The time for mastering new items in the same programs is reduced to 2 days (from 2 to 4 sessions) when teaching via ABCD SW. It is noted that acquisition times are further reduced to 1-2 days (from 2 to 4 sessions) with the increase in acquisitions within the same program, as the teaching process encourages consolidation of the ability to match the proposed elements. Table 3 shows the total number of items mastered by each child from January to June.

Reporting the sessions. To correctly analyze the amount of work proposed to the child in terms of session time and number of items mastered, it is important to verify that the student has maintained on average the number of sessions useful for the development of learning, according to sustainable rhythms designed specifically for each child. ABCD SW offers the possibility of retrieving these data much more quickly than by searching for them in paper records. The automatic reconstruction of the session dates allows charts to be created that analyze the relationship between number of sessions and items mastered, useful for an ABA consultant to verify learning trends (Table 3).

Table 3. Mastered articles for sessions

Child	Total articles mastered	Total sessions	Ratio articles/sessions
E.	203	87	2.3
Em.	225	54	4.2
G.	216	86	2.5
M.	122	40	3
S.	189	112	1.7
Si.	181	91	2
T.	240	112	2.1

Considering the ratio between the total number of mastered items and the total number of sessions undergone in the period of analysis for each child, the result is more than satisfactory. In the analysis of the relationship articles mastered/number of sessions for each child one can read the graphs produced by the SW. As an example, Fig. 3 shows the learning curve of the child Si.

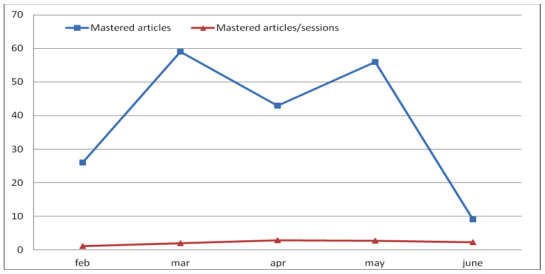

Fig. 3. Total mastered article and ratio mastered article/session

The upper curve, representing the absolute number of mastered articles in all programs, shows a fluctuating trend from February to June, but looking at the line of the ratio of mastered articles per sessions (on average), one can observe that the learning trend was increasing at the beginning and later it becomes almost stable over time. The decline in the month of June simply means that fewer sessions were held and the child spent less time studying with the SW (ending the user test phase). Note that the curve describing the ratio reveals the result of each child's learning more objectively, since it considers the objective quantity of acquisitions achieved in relation to the time of actual work.

Acquisition level. It is also important to consider the level of acquisition achieved in each category of the program proposed to the child. Matching programs are generally simpler to deal with than the receptive and expressive phases. Nearly all the children who participated in the testing phase of ABCD SW completed the matching program in the categories proposed during the period under review. For everyone, part of the sessions was devoted to the receptive phase in more or less detail depending on the child's ability. Some (E., Em., M., T.) reached the expressive stage, while others worked at times in a very selective way with respect to the articles used. Considering that some of the subjects examined are children with severe learning difficulties (low-functioning), it is unsurprising that completing the acquisitions in the various programs can take a long time. The children must go through the acquisition levels proposed by the tutor before gaining access to the next program. The tutor decides whether trials carried out on an article are sufficient to consider the article acquired in that level, and thus can advance the child to a higher level or move to the next program (article mastered).

Using the prompt. It is important to be able to use and check the percentage of prompts given to the child during the exercises in order to understand the level of difficulty proposed and the child's ability to learn during "fading", that is, when the prompt is gradually used less and less. Errorless learning is recommended for ABA intervention: it is better to give a hint to the child to prevent errors, rather than allow him to make a mistake and have to work on eliminating the memory of that error. The prompts serve this purpose: to prevent the occurrence of an error.

Analysis of data verifies that in all subjects studied the percentage of prompts was higher at the beginning of the SW use, i.e., in January and February, to allow the child to have a correct approach with the new work system proposed. Generally, the percentage of prompts tended to decrease rapidly and remained stable in most sessions. For each subject there are periods in which the prompts increase again, usually coinciding with more intense programming and increased levels of difficulty. The possibility of reading data in ABCD SW relating to the use of prompts, described daily, provides a detailed view of the periods/days when the child's work was supported by some aids (different types of prompts). Table 4 shows the percentage of total prompts used in the period January-June for each child.

Table 4. Full prompt used from January-June for each child

Child	Percentage of full prompts
E.	0.96%
Em.	0.46%
G.	2.49%
M.	0.42%
S.	6.08%
Si.	8.96%
T.	1.81%

Overall, the amount of prompts provided during the ABCD SW sessions is comparable to that provided during sessions "at the table". For some children (E., Am, M., T.) it was considerably lower, owing to the high percentages of generalization, since the work on many articles was carried out more easily.

5. CONCLUSION

From analysis of the data collected in the user test, ABCD SW appears to be a useful tool that completes educational ABA intervention in a targeted way. Since it is positive to stimulate the one-to-one relationship of an autistic child with the tutors, parents and teachers, the relationship developed during ABA sessions should be encouraged in order to foster the social and relational skills that are usually deficient in Autism Syndrome. Assuming that the children who approach ABCD SW have already had the opportunity to learn concepts-articles in personalized programs, the SW might be extended with the recognition of articles generalized by working at the computer/tablet. This would allow a more objective assessment of the learning introduced directly through the SW, and facilitate evaluation of the effectiveness of different educational systems.

ABCD SW offers technology-enhanced rehabilitation that performs better than the traditional approach. This scalable and safe tool offers efficiency and efficacy, adapting the discriminative stimulus and format to each child's abilities. This result is in accord with a recent clinical systematic review of behavioral interventions for children with autism, suggesting that ABA may improve some core symptoms compared to special education [7]. ABCD SW integrates analytical tools for scientifically assessing learning progress; the data collection system ensures the recording of many different aspects that are significant from both a quantitative and a qualitative point of view. A statistical analysis of data gathered by the SW, co-related to child abilities measured with standard scales before and after the intervention, is in progress. Future work aims at creating a safe environment where children can progress independently, a self-rehabilitation tool to maintain mastered skills. .

6. REFERENCES

[1] De Leo G., Leroy G. Smartphones to facilitate communication and improve social skills of children with severe autism spectrum disorder: special education teachers as proxies. *In Proceedings of the 7th int. conf. on Interaction design and children* (IDC 08), pp 45-48

[2] Hayes, G.R., Hirano, S., Marcu, G., Monibi, M., Nguyen, D. H. Yeganyan, M. *Interactive visual supports for children with autism, Springer Personal and Ubiquitous Computing* (2010) (18 pp) DOI: 10.1007/s00779-010-0294-8

[3] Kientz, J. A., Hayes, G. R., Westeyn T.L., Starner T., Abowd G. D., *Pervasive Computing and Autism: Assisting Caregivers of Children with Special Needs*, IEEE Pervasive Computing, vol. 6, no. 1, pp. 28-35, Jan.-Mar. 2007

[4] Monibi, M., Hayes G. R. Mocotos: Mobile Communications Tools for Children with Special Needs. *In Proceedings of the 7th int. conf. on Interaction design and children* (IDC 08), (2008) pp.: 121-124

[5] Sampath H, Sivaswamy J, Indurkhya B. *Assistive systems for children with dyslexia and autism*. ACM SIGACCESS Accessibility and Computing, Issue 96, 2010

[6] Buzzi, M. C., Buzzi, M., Rapisarda, B., Senette, C., Tesconi, M. (2013). Teaching Low-Functioning Autistic Children: ABCD SW. *In Proceedings of European Conference on Technology Enhanced Learning* (EC-TEL 2013). Springer Berlin Heidelberg LNCS 8095 (2013) pp.: 43-56.

[7] Ospina, M. B., Seida, J. K., Clark, B., Karkhaneh, M., Hartling, L., Tjosvold, L., Vandermeer, B, Smith, V. (2008). *Behavioural and developmental interventions for autism spectrum disorder: a clinical systematic review*. PloS one, 3(11), e3755.