A portable application for supporting ABA intervention

Silvia Artoni, Maria Claudia Buzzi, Marina Buzzi, Claudia Fenili, Barbara Leporini, Simona Mencarini and Caterina Senette

Silvia Artoni is based in the Department of Computer Science, University of Pisa, Pisa, Italy.
Maria Claudia Buzzi, Marina Buzzi and Claudia Fenili are based in the IIT (Institute of Informatics and Telematics), CNR (National Research Council), Pisa, Italy.
Barbara Leporini is based in the ISTI, CNR (National Research Council), Pisa, Italy.
Simona Mencarini is based in the Department of Computer Science, University of Pisa, Pisa, Italy.
Caterina Senette is based in the IIT IIT (Institute of Informatics and Telematics), CNR (National Research Council), Pisa, Italy.

Abstract

Purpose – *Applied Behavior Analysis (ABA) is a scientific method for modelling human behavior, successfully applied in the context of Autism. Recording and sharing measurable data (on subjects' performance) between caregivers guarantees consistency of learning programs and allows monitoring the learning enhancements. Data are usually recorded on paper, which requires considerable effort and is subject to error. The purpose of this paper is to describe a portable application developed to support ABA tutors in their work with autistic subjects. It allows gathering data from ABA sessions, giving tutors rapid access to information, also in graphical formats.*

Design/methodology/approach – *The tool was designed via participatory design. Various ABA team members were involved, in order to make the application respond perfectly to their needs. The approach aims to ensure maximum usability, while minimizing errors and ambient interference.*

Findings – *The use of mobile devices (i.e. tablets or smartphones) allows mobility and ease of interaction, enabling efficient data collection and processing. Data plotting allows one to easily interpret gathered data.*

Social implications – *The proposed application, free open source software, can be a valuable aid for supporting the ABA intervention and favor the inclusion of children with autism.*

Originality/value – *Available software to assist tutors during therapy sessions is often proprietary, and research prototypes are not freely available, so paper forms are still widespread. Besides, without attention to usability requirements, assisting tools would be comparable in efficiency with data insertion on paper. Our software was specifically designed following ABA principles and favors efficient data entry allowing natural interaction with touch screen interfaces: drag and drop, taps and gestures. Furthermore, it is shared in the public domain.*

Keywords *Autism, Applied behaviour analysis, Mobile technology, Open source software, Android, Data recording, Monitoring system*

Paper type *Technical paper*

1. Introduction

Applied behavior analysis (ABA) is a scientific approach for modeling human behavior, successfully used in several contexts. ABA-based interventions are applied to people with developmental disabilities, mostly autism spectrum disorders. However, ABA is used in a wide range of areas including industrial safety, education, language acquisition, and medical procedures. It is currently adopted for effective educational training, especially for children with autism, who may have difficulty with traditional learning methodologies (Rosenwasser and Axelrod, 2002; Weiss, 2001).

Autism syndrome falls within the category of pervasive developmental disorders: it is characterized by severely impaired social interaction and communication, often associated with ritualized and stereotyped behaviors. The *Diagnostic and Statistical Manual of Mental Disorders*, DSM-IV TR and International Statistic Classification of Mental and Behavioral Disorders define autism in terms of delayed or abnormal functioning, with onset before three

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years of age, in at least one the following areas: social interaction, social-communicative use of the language, and symbolic or imaginative play (American Psychiatric Association (APA), 2000; World Health Organization, 1992). Some studies shows that 50-80 percent of children with autism also present cognitive delay (Baird *et al.*, 2006; Fombonne, 1999) and that most of these subjects need lifelong professional care (Billstedt *et al.*, 2005). As yet, there are no effective, safe, and accepted medical treatments (Pangborn and Baker, 2005). This suggests the importance of an early diagnosis (by 18-24 months of life) in order to begin immediate psycho-educational intervention.

Over time a variety of psycho-educational interventions asserting positive effects have been proposed (Dawsons and Osterling, 1997; Howlin, 2005; Smith, 1999). Several studies suggest that treatments based on ABA can bring clinically significant improvement to intellectual, social, emotional, and adaptive functioning (Andersen *et al.*, 1987; Howard *et al.*, 2005; Lovaas, 1987; McEachin *et al.*, 1993; Smith *et al.*, 1997; Smith *et al.*, 2000; Weiss, 1999). Many research studies in the last century showed that early and intensive intervention (preschooler six to eight hours/day) leads to great progress in skills and in some cases, to a development equal to peers (APA, 2000; Anderson and Romanczyk, 1999; Lovaas, 1987; Dawsons and Osterling, 1997). In 1973 Lovaas published the first study on the effectiveness of intensive behavioral intervention in children with autism, and then developed the ABA model, validated in a 1987 study. Q1

ABA focusses on socially significant behavior that can be measured and quantified, enabling one to constantly and continuously monitor the behavior of the child and evaluate whether there are improvements, in order to assess whether the procedures adopted are appropriate for that particular child in that specific context.

ABA is an evidence-based approach: it uses strategies and tools with proven efficacy, constantly recording subject actions and behavior, in order to assess and measure subject progress. Eldevik *et al.* carried out a meta-analysis of effects of early intensive behavioral intervention, analyzing measures of change in full-scale intelligence and/or adaptive behavior composites reported in literature by several studies, affirming that “In the absence of other interventions with established efficacy, Early Intensive Behavioral Intervention should be an intervention of choice for children with autism” (Eldevik *et al.*, 2009).

ABA intervention in autism consists of a sequence of programs and trials of increasing difficulty, where the skill to be learned is broken down into small units for easy learning. ABA’s scientific approach relies on measurable data and programs, so data relating to each trial are recorded on a paper form in order to monitor and assess each subject’s progress in the intervention. As mentioned before, early and intensive ABA intervention leads to better results. Various data and information are captured and recorded during the ABA sessions. Usually this information is paper-based and should be exchanged between the ABA team members (usually one consultant, one senior tutor, two to three tutors, the teachers, and the child’s parents). Involvement of the child’s father and mother is fundamental to achieving good results since the program must be followed consistently both at home and at school. This implies that handling paper-based data can require much effort and be prone to error. Supporting tools and systems able to facilitate ABA intervention are certainly encouraged.

This paper is an extension of Artoni *et al.* (2012) in which we described the design of an Android application for supporting tutors in data collection from ABA sessions. The new contribution involves the data analysis and its graphic representation, which facilitates the assessment of the degree of learning of the subject. The targets of our application are ABA members: consultants, (senior) tutors, teachers, and caregivers involved in the child’s education (e.g. parents and relatives). In the following we will refer to these persons as tutors for simplicity’s sake. We believe that a touch-screen mobile device can facilitate data collection and offers simple interaction, at the same time enabling efficient data processing. The small screen size of mobile devices has made it necessary to focus special attention on the design of the user interface (UI) in order to make the application usable and satisfactory. The work proposed herein is part of a study conducted in a Tuscany Regional project exploiting ICT to support the learning process for subjects with autism (ABCD SW[1]). Q2

The paper is organized into five sections. After this introduction, the ABA approach for autism is described and related studies in the field are briefly reported. Next, the focus moves to the design and implementation of the proposed portable application. Last, the paper ends with conclusions and future work.

2. ABA methodology

The ABA approach to autism uses procedures such as augmentative and alternative communication (AAC) and discrete trial training (DTT). AAC provides an alternative method for communicating (usually by images or gestures) used in treating learning disabilities and neurological pathologies. DTT can help children with autism who often do not learn spontaneously (as typically developing children naturally do through imitation, Klin, 1992). Moderato and Copelli (2010) identified many areas of improvement throughout the DTT: attention, motivation, discrimination between relevant stimuli (stimulus control), generalization, cause-effect relationship, observational learning, and communication. DTT is used for teaching and fixing concepts through the procedure of errorless learning; with this technique the subject is immediately provided the help (s)he needs (prompt) to avoid failure (Terrace, 1963). DTT consists of trials of increasing levels of difficulty, repeated several times according to the subject's needs. The skill to be learned is broken down into small units for easy learning and a prompt is given to avoid errors. The prompt is eliminated gradually during the trials.

According to Moderato and Copelli (2010),five parts compose the discrete trial:

(1) Discriminative stimulus: the element that precedes the behavior. Consists of a request by the tutor or an element of the environment that is highlighted.

(2) Prompt: a hint or a suggestion that the tutor provides the child in order to facilitate answers.

(3) Answer (*r*): the behavior that the child performs as a result of the discriminative stimulus.

(4) Reinforcement (*Sr*): the event stimulus that follows the behavior.

(5) Inter-trial interval: a brief pause between consecutive trials.

Basic ABA programs operate using articles of common categories (colors, shapes, numbers, food, vehicles, clothes, animals, etc.) according to the following sequence:

(1) Matching:
   - image with image;
   - word with word (using strings of uppercase letters);
   - image with word; and
   - word with image.

(2) Receptive:
   - image; and
   - word.

(3) Expressive:
   - image.

Each program is executed according to DTT. An article is considered mastered after the subject correctly and independently (without any help) executes the following learning sequence of trials:

(1) Mass trial (MT): basic trial.

(2) Distracter phase: first a neutral (of different category, size, color, etc.) distracter is added to the item on acquisition (MT + Dn); next the same trial is executed with two neutral distracters (MT + 2 Dn). Then a non-neutral distracter (MT + D) and next two non-neutral ones (MT + 2D) are ,respectively, introduced in the trial.

(3) Extended trial: a choice between three items, two previously mastered and the one in acquisition.

(4) Random rotations of three learned (mastered) items.

Usually the tutor decides to make a subject move on to the next program when 80 percent of articles in the category are mastered. Different types of prompts can be provided to help the subject successfully complete the trial (avoiding mistakes), as required by the ABA errorless principle (avoid child errors in the phase of the acquisition of a concept). The generalization process consists in proposing new ways to acquire each mastered item, for instance changing the image representing the object (e.g. the color), the position of the article (e.g. bringing it closer) and/or the discriminative stimulus (e.g. the directive, such as “match” or “combine”).

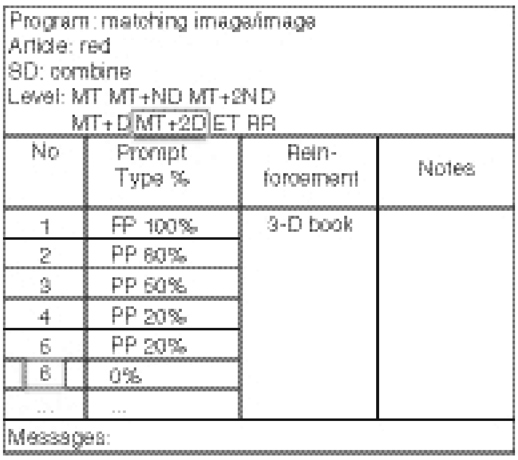
The acquisition of an article requires that the final levels for each program be executed with two different tutors, to ensure that the acquisition is objectively verifiable, disconnected from interpersonal dynamics or mental associations (object-tutor), events that may often have relevant influence. For this, having a device that can reproduce the situation as left in the last session is fundamental for quick completion by the next tutor, reducing errors and rendering unnecessary the exchange of sheets of paper between tutors.

As previously mentioned, the ABA approach requires different tutors to rotate for didactic sessions with the same child, so the ABA team spends considerable time exchanging information on executed programs and trials. In a three-hour session, at least 10 min are spent reading comments on the sessions made by previous tutors and 20 min are spent writing comments on the ongoing session on sheets of paper such as the one in Figure 1. Furthermore, copying data from each session in an Excel file to analyze the subject’s progress is time consuming and prone to error. The proposed application, moving from paper to electronic data, optimizes tutors’ time by allowing rapid access to previous ABA data, providing better time scheduling for the child’s caregivers (tutors, teachers, parents), and allowing them to effectively monitor the child’s progress and, to better define and tune the learning process.

3. Related work

Several studies have confirmed the efficacy of electronic therapy based on AAC. AAC is a technique that provides an alternative method for communicating by increasing the user’s perception, used in learning disabilities and neurological pathologies. Sampath *et al.* proposed a system using AAC for autism that allows bidirectional communication between child and caregivers. Specifically, a gateway on a handheld device was built, allowing conversion between pictures and spoken language, enabling the completion of the communication loop (receptive and expressive) (Sampath *et al.*, 2010).

Figure 1 Paper form for recording trial data


Program: matching image/image
Article: red
SD: combine
Level: MT MT+ND MT+2ND
MT+D MT+2D ET RR

No	Prompt Type %	Rein-forcement	Notes
1	PP 100%	3-D book	
2	PP 80%		
3	PP 60%		
4	PP 20%		
5	PP 20%		
6	0%		
...	...		

Messages:

De Leo and Leroy involved special education teachers in designing SW facilitating communication with children with severe autism, via smartphones (De Leo and Leroy, 2008). The use of a mobile platform offers many advantages: lower cost, greater flexibility, simpler and faster customization, smaller size enabling ubiquity, and a familiar environment (mostly cell phones) for the children. Although many digital products are available for AAC (e.g. GoTalk, Tango, Dynavox, Activity Pad) they are expensive and not very usable or flexible: training is required for set-up and customization, making it difficult for parents to use it at home (Hayes *et al.*, 2010).

A large branch of research on autism is devoted to providing usable tools to assist tutors during therapy sessions and analyze related data. Kientz *et al.* designed and developed two systems for facilitating efficient child monitoring (both progress and behavior): Abaris, the supporting team executing DTT therapy, building indices into videos of therapy sessions, and allowing easy data search; CareLog, for collecting and analyzing behavioral data (problem behaviors). Furthermore, sensors were used to monitor stimming behavior (self-stimulatory movements) in order to understand the cause of an uncomfortable situation (Kientz *et al.*, 2007).

Pino and Kouroupetroglou have offered ITHACA, an open source framework for building adaptable, modular, multilingual, cheap and sustainable component-based AAC products (Pino and Kouroupetroglou, 2010).

However, few details are available concerning the software design and implementation; specific SW is proprietary while research prototypes are not publicly and freely available, so paper forms are still widespread.

Concerning automated systems for collecting data in a healthcare context specifically for observational data, a certain number of tools have been implemented in the last few years thanks to advances in ICT, but unfortunately they are shared primarily through informal networks so are not easily accessible (Kahng and Iwata, 1998). Regarding DTT, Tarbox *et al.* compared a commercial software program for recording the outcome of discrete trials (mTrial) and other subject behavior data on a personal data assistant with traditional pen-and-paper data recording systems, both in terms of the accuracy of gathered data and therapist efficiency in filling out paper or electronic forms by means of a stylus. Results showed equal data accuracy for both formats, but traditional data collection was faster (Tarbox *et al.*, 2010). However, the rapidity of filling out data mainly depends on the software UI and also on the subjective ability and rapidity of the therapist when typing data.

Today modern tablets and smartphones favor data entry efficiency allowing natural interaction with touchscreen interfaces via fingers: drag and drop, taps, and gestures. In the proposed application, trial-related data are rapidly inserted in the UI using different gestures for signaling prompted or independent trials. Furthermore, the availability of electronic data stored in a database makes their processing faster and easier.

4. The proposed portable application

4.1 The user context

The subjects with autismin our study are six children between two and ten years old involved in the ABCD SW project, of which this study is a part. An example of trial data collected by tutors is shown in Figure 1. FP indicates the use of a full prompt to help the child, PP a partial prompt, SD is the discriminative stimulus, and the abbreviations for the levels were presented in Section 2.

4.2 The approach

From the beginning of the project, the application's design has involved senior ABA tutors and psychologists, according to participatory design principles. All members of the design team have participated in ABA sessions for children with autism in order to observe and better understand the natural environment where the application has to run. Among the possible choices for designing interfaces, we chose the participative approach, which guarantees major usability according to the tutor's (the users) needs. The type of data to store, their insertion order, and the controls have been defined with the aid of the person who would use the application, attempting to map as much as possible the procedure followed by tutors when recording data on paper during an ABA session. Participation of the ABA team from the early stages of the project design has helped us build software that is fully ABA compliant.

With this aim, the original data collected was also optimized, integrating new parameters related to the child (e.g. non-collaboration on the part of the child, or problem behavior) or set-up errors (tutor error) that can be useful for co-relating data collected from the ABA sessions with the child antecedent or consequent behaviors.

As previously described, ABA sessions can take place in various environments such as the child's home, school, hospital, or other places (e.g. association headquarters). For this reason, portable and ubiquitous solutions are needed, since the success of ABA intervention relies on its regular and frequent execution.

We selected the Android operating system, which is open source and offers the advantage of Android's developer community, which contributes to improving its functionalities. For deploying the application, we used a tablet device with Android 3.0 O.S. (HoneyComb, optimized for tablets) with display WXGA (1,280 $\times$ 800 pixels; 150 pixels/inch), HD 720p touchscreen, and excellent processing capability (memory up to 32 GB on board and processor speed: 1 GHz dual core). The application is optimized to run with functionalities specifically designed for tablets. The recently released Android version 4.0 brings together smartphone and tablet features, allowing the SW tools to run even on cell phones with a few adjustments for adapting the visual rendering to a smaller screen (including reducing the amount of widgets placed on the UI). When designing for a small touch-screen device offering a virtual keyboard, it is important take into account factors such as the distance between text box and push button to facilitate data entry, font size and color, and contrast level, to ensure readability for all. A path should be found regarding flexible insertion of new elements when selecting items from a pull-down menu in order to make the process more efficient. Furthermore, a usable way to aggregate large quantities of data should be adopted in order to effectively manage the enormous amount of data recorded by the application.

Data entry during an ABA session must be executed very quickly and smoothly so that it is not source of environmental disturbance for the child. Often tutors do not record data in a timely way if circumstances do not permit it (e.g. to avoid breaking the child's rhythm or in the case of problem behaviors) and they must follow mentally, requiring considerable effort. Entering data quickly is also fundamental. To limit writing/editing, both signs and gestures may be implemented, but to be very useful they must be clear and fast. For this the application UI allows tutors to act in a natural way, using gestures to reproduce the signs that they normally used to fill out the paper forms, so the time spent is comparable. Fortunately, touch-screen devices facilitate data entry (compared to mouse-based interactions) reducing coordination efforts to focus on any UI widgets.

As shown in Table 1, the typical form used by a tutor during an ABA program requires detailed data for each trial performed. The tutor frequently has to fill out more than three or four paper sheets for each program, having to rewrite the same information (session, program, and article) several times. Furthermore, for each trial (s)he has to insert the type (indicative, positional, or physic) and percentage of prompt provided to the child, and the type of error occurring if any. In the SW these data are automatically set up by the program according to the previous one inserted/selected. Q3

For each trial, we chose to record the level of prompt used to evoke the answer in order to collect accurate information, increasing the robustness of gathered data (according to Lerman *et al.*, 2011).

4.3 The UI

As previously mentioned, before an ABA intervention the tutor needs to read all the forms from previous sessions carried out by the child with other tutors, in order to choose the best program for the present status of his/her learning. The main interface is designed to enable tutors to record trial data with only a few clicks, from one to max five or six for each trial, depending on how much information must be collected.

When the application is launched, a login page for user authentication appears, since different subjects may be taught to each child. A new account can be created if one is not available. After user authentication, the main page (Figure 2) makes some software functions available including:

(1) selection of a child;

(2) insertion of a new child's account (if not present);

(3) accessing session history (partial or full) in order to monitor a child's progress; and

(4) recording data session.

The tutor selects a child "nickname" from a drop-down menu. This menu is created dynamically using only the nicknames of children associated with the tutor (Figure 2). A new child may be added using the window activated by pressing the New Child Account push button (Figure 2).

Data are recorded locally (in the device) and can be accessed from the application after the login (user and password). Data are managed in an anonymous way since they are associated with a child only by means of the nickname previously chosen by the tutor to indicate the child. No other personal data to identify the child are recorded. There is no sensitive data transiting on the network (since the use of the device is local).

The history button provides a complete overview of past sessions and the child's progress. The tutor can choose/examine the number of previous sessions as well as select the filters to apply, depending on the type of information (s)he is looking for. The tutor can obtain further details by just clicking on the level. An example of the summary is shown in Figure 3. An additional function for showing a child's data in graphic format is provided, in order to make the child's progress and response to the methodology more understandable.

Selecting the recent history button in the main UI, the tutor moves on to the child's recent history page, enabling access to the child's last sessions (details of one trial shown in Figure 3). Then, pressing back button to reach the main page(s) he can jump to the trial evaluation form, the core of the application (Figure 4), by pressing the record session button.

General data such as the ABA program, the article in acquisition, the trial level, and the stimulus provided to the child, are automatically set by the system to those from the last program (even if it has been done in the last session) if the article involved had not been mastered. Of course, all these default values can be changed by the tutor to perform another program or to repeat an executed level if the child needs a refresh. The UI proposes an initial group of eight trials (that can be doubled repetitively) to be filled in with data from each trial: the type and percentage of prompt and additional information as to whether the set-up was smooth or whether an external error occurred (e.g. child distraction, tutor, or set-up error, etc.). If information on an error is added, a text field appears for insertion of any tutor comments.

Figure 2 Main user interface

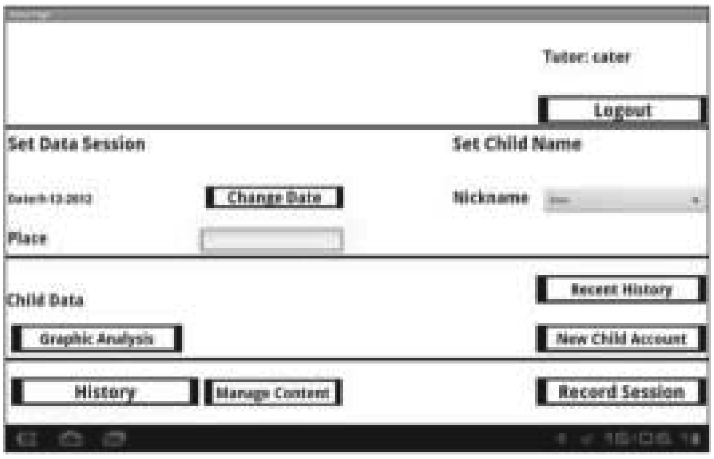


Figure 3 Summary of one trial's data

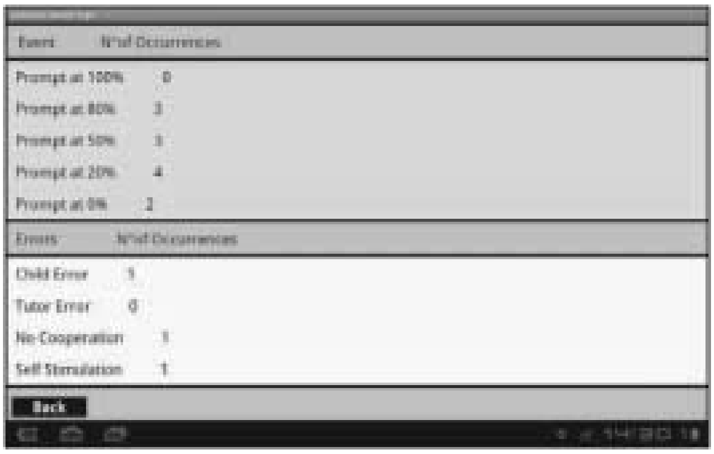


Figure 4 Evaluation activity UI

If more than eight trials are needed for the child to execute a successful independent trial in that combination of program, level, and article, the trial continue button can be pressed to add a new set of eight trials' data (9-16).

The next program and next level buttons allow the tutor to automatically jump to the next program (when an ABA program is completed) or to the next level of the selected program (when the previous level is successfully accomplished), respectively. For each level the same UI is shown, with only a slight difference in background color to help tutors better identify the different levels.

4.4 Managing the content

ABA session data are entered by the tutor on the database using the application. The tutor can also insert new content, such as new categories, new objects for each category, new discriminative stimuli, and new reinforcements (manage content button on the main interface, Figure 5).

4.5 Graphical data analysis

Another important and useful feature offered by the application is the graphical analysis of the data collected. As described above, regular monitoring of a subject's learning progress is a key feature of the ABA methodology. To this end, the team of specialists who deal with the child are

Figure 5 Interface for managing database content

called to continuously analyze the collected data using Excel tables and views as well as manually built graphics.

The tool presented here provides the ability to immediately show data stored in the database in graphical form depending on the type of information considered. This functionality has been implemented using one of the free libraries compatible with Android S.O, AndroidPlot v.5.0.

We implemented different types of queries, designed based on the needs of the tutors who participated in the modeling phases of the software. Specifically, we considered the following queries:

(1) Categories introduced (for a child): this query allows selecting a child and having all the information regarding the categories (s)he worked on, such as date of introduction, number of trials completed for each category and current status. All the data are shown with a table layout.

(2) Articles introduced (for a child): this query allows one to have all the information regarding the articles/categories on which the child has worked, such as date of introduction, number of trials completed for each session and current status related to the type of program. All the data are shown with a table layout.

(3) Articles mastered (for a child): this query allows the graphic rendering of the learning process trend for the selected child in terms of the number of articles mastered during a chosen period of time.

(4) Correct trials (for a child): this query allows the graphic rendering of the learning process trend for the selected child in terms of the number of trials correctly performed during a chosen period of time. As previously mentioned, we consider a trial correct if no prompt has been provided to the child.

(5) Errors (for a child): this query shows the graphic rendering of the learning process trend for the selected child as the percentage of errors that occurred during a chosen period of time. The graphic shows each different type of error performed by the child.

(6) Trials prompted (for a child): this query allows the graphic rendering of the learning process trend for the selected child as the percentage of trials in which the child has received some prompt. The graphic is related to a chosen period of time.

The tutor can access the graphical data analysis functionality using the *GraphicAnalysis* button in the main interface as shown in Figure 2. The first page of the graphical data analysis tool is shown in Figure 6; after the selection of a child (choosing his/her nickname) and the type of query, it is possible to restrict the analysis to a specific period of time choosing a *Start* date and an *End* date.

In the following, as an example we show three types of queries: articles mastered, trials prompted, and errors. Figure 7 shows an example of a query on articles mastered by the child Simo from February to August 2012.

Figure 6 Graphical data analysis, main page

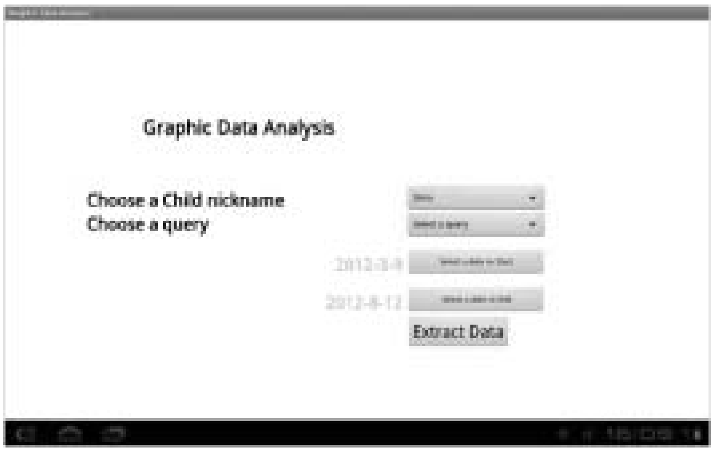
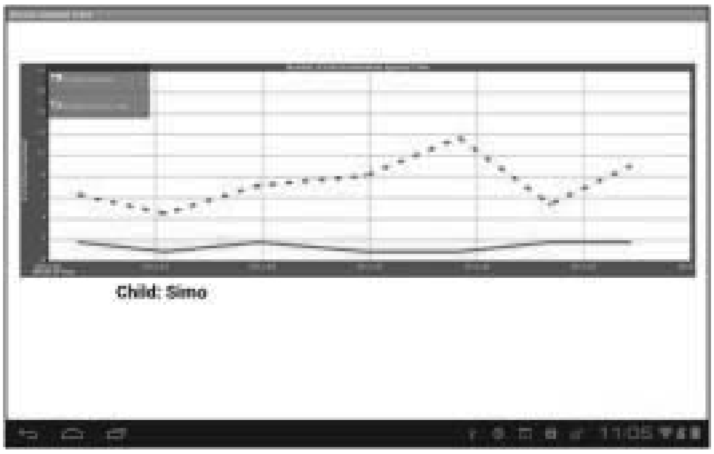


Figure 7 Graphic of articles mastered against time



The two graphics are related to different information: the first one (dashed blue) shows the absolute number of articles mastered against time, the second one (red) shows the number of articles mastered compared to the number of sessions done. The last one is of course more effective for indicating learning improvement or a learning worsening. In this case, for example, the graphic shows that the child seems to be constant in its learning pace. The number of sessions is a very important parameter in such analysis because it can highlight a certain child's need for a high work pace in order to have good results, or vice versa it could show that the child has comparable performance whether working steadily or at a slower pace.

An example of a trials prompted query for the child Simo from February to August 2012 is shown in Figure 8.

The graph shows the amount of trials against time as a percentage in which the child has received some kind of prompt from the tutor distinguished as either prompts at 100 percent (full prompt), meaning trials in which the child needed total help (blue) and prompts variable from 20 to 80 percent grouped in one column (yellow). The last example of query is a type of error occurred for the child Simo from February to August 2012; the results are shown in Figure 9.

The graphic shows three different type of errors: non-cooperative behavior of the child (green), child self-stimulation behavior (red), and errors not well-defined but due to the child (magenta). The blue line shows the total number of errors that occurred in the period under analysis.

Figure 8 Graph of percentage of trials prompted against time

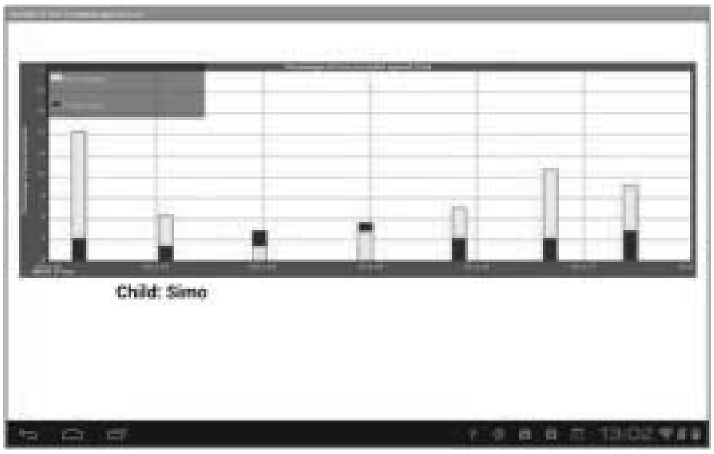
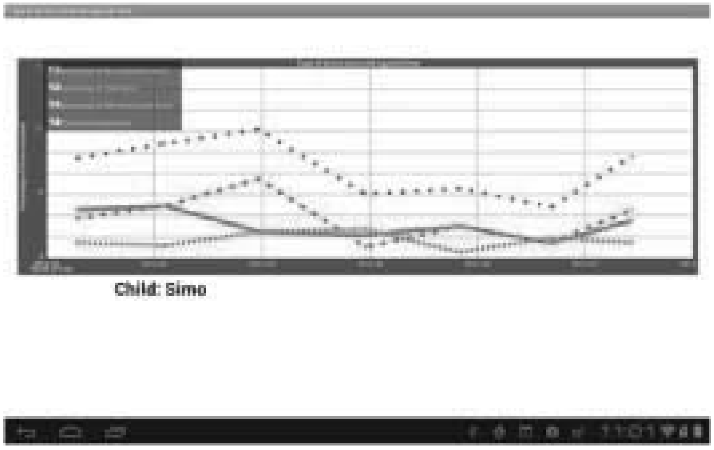


Figure 9 Graphic of percentage of errors that occurred against time



This data allows monitoring the child's behavior and detecting anomalies quickly to rapidly carry out appropriate actions. For instance, in presence of self-injury behavior, a tool such as the ABC (antecedent, behavior, consequence) may help to understand the cause and extinguish it.

5. Conclusion and future work

In this paper we describe an Android-based application for mobile devices aimed at recording data from ABA sessions with subjects with autism. ABA's scientific approach relies on measuring data from each trial in order to monitor and assess the progress of each subject. For each item, the child performs matching, receptive, and expressive programs: each program is executed according to the DTT levels and each trials is repeated several times. For each trial are recorded the percentage of prompt provided, occurrence and type of errors, independent trials, and use of the reinforcement. Considering that in a single 2-hour ABA session 10-20 programs can be carried out, and that intensive intervention needs at least three to five sessions per week, it is easy to imagine the enormous amount of data produced. Usually this information is paper based and should be shared among tutors. The ABA approach requires different tutors who rotate during the didactic sessions with the same child; thus considerable time was spent by the ABA team to exchange information, and this process can be error prone. Furthermore, due to issues of time, usually only a few of the collected data (on paper) are recorded on an electronic spreadsheet and analyzed: e.g. the starting date of an article (item) in the ABA program and the date the article was mastered. However, if these data are not normalized compared to the number of sessions executed, the result is not reliable over time.

The proposed application allows gathering data from ABA sessions; moving from paper to electronic data optimizes tutor time, enabling rapid access to previous data, also in aggregated format, and better time management for the child's team/family (eliminating the need to copy session data). The application is developed for Android-based mobile devices and can be a valuable aid, allowing quick access to information and supporting the data analysis. It was developed in the context of the ABCD SW project, was designed involving two ABA senior tutors, a psychologist, and a pedagogist, as well as a professional ABA consultant and the mother of a child with autism. A mobile platform offers many advantages: it is cheap, flexible, simple to use (touch-screen interaction is quite natural), small-sized so easily transportable, can be used in the home environment at any time, and most of all it can replace most of the paper-based forms usually used by tutors.

Although the usefulness of this application is clear, there could be a potential disadvantage due to the introduction of an external element (a tablet) that might capture the child's attention. For that reason user tests with more children with autism and tutors will be carried out to evaluate the usability (efficiency, effectiveness, and user satisfaction, International Organization for Standardization (ISO) 9241-11, 1998) of the proposed application. Furthermore, the final user test has great importance in determining whether the tutor should be confident using the application in a real environment with the child and whether the time needed to insert data could risk decreasing the child's attention and concentration.

Using software for data acquisition, compared to a sheet of paper, may appear to have less flexibility. The tutor with a sheet of paper might annotate additional subjective elements that in our SW may be entered as a comment (i.e. they are not automatically processed). However, this data are normally lost in the copy from the paper to the electronic spreadsheet because the process occurs over a long period of time. In this sense, the application may ensure greater effectiveness because it allows the insertion and processing of data in real time.

Future studies will include testing new forms for data visualization with libraries that allow more interactivity and customization. At the moment the export of raw data for a more accurate elaboration than the ones provided by the tool is not available. The idea is to equip each query result of the tool with a CSV export function, which can be sent to other devices for processing.

The software is shared in the public domain (under the creative commons license) so that the internet community can promote its rapid improvement.

Note

1. http://abcd.iit.cnr.it/

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About the authors

Silvia Artoni received her Master's Degree from the Faculty of Literature and Philosophy at the University of Pisa in 2004. In the same year she started working as an ABA (Applied Behavior Analysis) tutor under the supervision of Consultant Denise Smith Brunetti and from 2006 under the supervision of Dean Smith (BCBA, UK YAP). Since 2007 she has been working as Senior Tutor. She has also worked at the Infant and Primary School in Lucca as communication assistant for children with autism. She has participated in training courses on ABA and PECS techniques.

Maria Claudia Buzzi earned her Computer Science degree at the University of Pisa in 1995. She has more than 15 years of experience in designing and developing web applications and eGovernment services. In recent years she has been investigating user interface design, with a special focus on usability and accessibility for blind users and for subjects with autism. Technical skills include the coordination of technological and research projects. She follows the activities of the technical groups of W3C (World Wide Web Consortium), and is part of the staff of the W3C Italian Office. Maria Claudia Buzzi is the corresponding author and can be contacted at: Claudia.Buzzi@iit.cnr.it

Marina Buzzi received her Computer Science degree from the University of Pisa in 1991. She has ten years' experience in networking design and internet services. Her research focuses on web usability and IoT. She has devoted extensive study to user interface design, with special attention to usability and accessibility for the blind, and in recent years, for subjects with autism. Technical skills include the coordination of technological and research projects. She follows activities of the technical groups of W3C (World Wide Web Consortium), CMG Italy (Computer Measurement Group) and IETF (Internet Engineering Task Force). She has been a professional member of ACM since 2004 and she follows the activities of the Accessibility and Computing group (SIGACCESS).

Claudia Fenili is a pedagogist with many years of experience in re-education. She has been an ABA (Applied Behavior Analysis) tutor since 2004, a senior ABA tutor since 2007 and ABA consultant since 2009. She has been involved in projects involving the re-education/rehabilitation of children and adults with pervasive developmental disorders.

Barbara Leporini received her Master's degree from the University of Pisa in 1997 and her PhD in Computer Science in 2003. Since beginning her PhD, she has done her research in the field of human-computer interaction. She investigates techniques and methods to make user interfaces accessible and usable to users with special needs. Aside from research, she has taught Computer Science classes and provided technical support at various levels, such as participating in boards and groups working on accessibility and usability aspects for visually-impaired people. She is the president of the Italian Association for the Blind in Tuscany, as well as of the Institute for Research, Training and Rehabilitation (I.Ri.Fo.R.) for the visually-impaired in Tuscany.

Simona Mencarini, Psychologist, has been an ABA (Applied Behavior Analysis) tutor since November 2004, and a senior ABA tutor since February 2009. She was involved in the project of re-education/rehabilitation of children and adults with pervasive developmental disorders. She is currently pursuing her Master's degree in Applied Behavior Analysis "Behavior analysis: theoretical and methodological aspects and applications for autistic disorder".

Caterina Senette received her Master's degree in Biomedical Engineering from the University of Pisa in 2011 and started a PhD program in Computer Science in 2012. She has been a research consultant at the IIT Institute of National Research Council since 2008, where she gained four years of experience in research focusing on accessibility and usability issues for people with special needs, especially blind people. Her main interest is in neuroscience and human computer interaction.