UNIVERSITÀ DI PISA

Scuola di Dottorato in Ingegneria “Leonardo da Vinci”

Corso di Dottorato di Ricerca in
INGEGNERIA DELL’INFORMAZIONE

Tesi di Dottorato di Ricerca

Technology-enhanced Programs for Children with Autism: implementing Applied Behavior Analysis Intervention on Mobile Devices

Caterina Senette

Anno 2015

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Autore:

Caterina Senette ______________________________

Relatori:

Prof. Luca Fanucci ______________________________

Dott.ssa. Marina Buzzi ______________________________

Dott.ssa. Maria Claudia Buzzi ______________________________

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To my father.

Sommario

I disturbi dello Spettro Autistico (ASD) appartengono alla classe dei disturbi pervasivi dello sviluppo caratterizzati dalla presenza di difficoltà nella comunicazione e nella sfera sociale. Molti studi nell'ultimo secolo mostrano che l'intervento precoce e intensivo (4-6 ore al giorno in età prescolare) favorisce progressi importanti e in alcuni casi porta ad acquisire abilità paragonabili a quelle presenti negli individui normo-tipici. Dal momento che i metodi di insegnamento tradizionali sono raramente efficaci nelle sindromi ASD, vengono adottati nuovi approcci allo scopo di sfruttare meglio le abilità presenti nel soggetto. Fra questi, l'intervento precoce basato su ABA (Applied Behaviour Analysis) offre ai soggetti con autismo la possibilità di apprendere in maniera strutturata in base alle caratteristiche dell'individuo. Nell'ambito delle strategie di intervento non tradizionali trovano posto le applicazioni hardware e software per l'apprendimento assistito che si sono dimostrate efficaci grazie alla intrinseca distanza fra dispositivo e bambino che non richiede il coinvolgimento emotivo di quest'ultimo. Nonostante la varietà nell'offerta dei software didattici, raramente questi rispettano i principi dell'ABA e quando accade il risultato è rappresentato spesso da software commerciali con costi aggiuntivi per le famiglie. Inoltre non esistono ancora protocolli formali per testare il software didattico esistente in letteratura dedicato a soggetti con autismo e ancora molto poco è stato fatto nell'ambito dell'interazione uomo macchina nel caso in cui l'utilizzatore sia un soggetto autistico.

In questa tesi viene descritta la progettazione, lo sviluppo e il test di una suite di strumenti software conformi alle specifiche ABA, disegnati per supportare i bambini e i tutor nel percorso di apprendimento. Lo strumento principale, ABCD SW, è un software didattico open source adattivo e basato su Comunicazione Aumentativa Alternativa (AAC) e Discrete Trial Training (DTT). Il software permette al bambino di eseguire gli esercizi ABA registrando automaticamente tutti i dati di sessione mentre il tutor integra le informazioni registrando la valutazione di ogni singola prova. Fra gli altri, è stato integrato uno strumento addizionale per l'analisi dei dati che offre al tutor la possibilità di monitorare nel tempo l'apprendimento e le performance del bambino. Viene discussa inoltre l'efficacia dell'intervento ABA precoce grazie ai risultati ottenuti da uno studio pilota con 7 bambini con autismo coinvolti in un percorso di apprendimento comprendente sessioni di analisi comportamentale ABA tradizionali e sessioni con il supporto del software ABCD. Per la valutazione di efficacia sono stati usati due approcci: 1) una valutazione soggettiva tramite i riscontri ottenuti mediante un questionario online somministrato alle persone (insegnanti, genitori, tutor, etc.) che hanno lavorato con i bambini; 2) una valutazione oggettiva basata sui dati di performance ottenuti nelle sessioni con utilizzo del software correlati con le valutazioni delle abilità personali e sociali effettuate da uno psicologo in tempi antecedenti e successivi al test. I risultati mostrano che i bambini manifestano miglioramenti significativi nella sfera della comunicazione ($p< 0.05$). Ognuno dei membri del team ABA ha rilevato inoltre miglioramenti anche nella socializzazione e nel comportamento. Lo studio pilota suggerisce quindi l'efficacia dell'intervento ABA mediato dal software attraverso l'uso dell'iPad, strumento che è risultato molto gradito dai bambini.

Abstract

Autism Spectrum Disorder (ASD) is a pervasive developmental disorder characterized by difficulties in communication and social integration. Many research studies provide evidence that early and intensive intervention (preschool age 4-6 hours/day) leads to great progress in skills, and in some cases brings the child to a developmental level equal to his/her peers. Since traditional educational methods are rarely effective in ASD, new teaching approaches aimed at better exploiting the subject's abilities are currently adopted. Among these, early intervention based on Applied Behavior Analysis (ABA) offers children with autism the possibility of learning in an accessible structured way, adapting pace, format and feedback to the subject's abilities.

Considering technology-enhanced learning, several studies have shown the effectiveness of computer-assisted programs for special education of autistic children due to the intrinsic 'distance' between the PC and the child that does not require emotional involvement (a computer does not require interpretation of emotion) allowing the repeatability of answers (reducing anxiety). Although there is a great availability of educational software programs, few of them apply ABA principles. Most of them are commercial products having additional costs for families. Moreover, there are still no formal protocols for testing the learning software for autistic subjects and further studies are necessary in the field of human-computer interaction when the interaction is performed by an individual with autism.

In this thesis, I describe the design and implementation of a set of software tools that comprise ABCD SW (Autistic Behavior & Computer-based Didactic SoftWare), an ABA compliant application, designed to support children and tutors in a 1-to-1 learning process. ABCD SW is an open-source adaptive software based on Augmentative and Alternative Communication (AAC) and Discrete Trial Training (DTT), specifically developed for an early intervention (2-6 years old). The software allows children to perform ABA trials, automatically storing all data of the sessions. The tutor must integrate the evaluation data (prompt provided, behavior) by pressing just one key. A learning analytic tool extracts data, offering real-time monitoring of children's learning for assessing at a glance progress or problems experienced by each child. The effectiveness of ABA intervention supported by ABCD SW has been tested via a pilot study with seven autistic children. The efficacy was evaluated through two data sources: 1) subjective feedback collected through an online survey proposed to the ABA team of the children involved in the user test; 2) an objective assessment based on learning analytics trends highlighted by the ABCD software correlated with the children's evaluations. These evaluations were made by a psychologist before and after the user test, through Vineland adaptive behavior scales for measuring personal and social skills. Results show that children manifested improvement in communication, especially in the expressive communication sub-category ($p < 0.05$). Furthermore, the ABA team observed that children improved in communication, socialization and behavior. The pilot study suggests effectiveness of rehabilitation of autistic children using this ABA technology-enhanced intervention.

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1. INTRODUCTION AND RELATED WORK

Autism Spectrum Disorder (ASD) is a pervasive developmental disorder characterized by difficulties in communication and social integration, and by the presence of behavioral problems, although symptoms vary significantly from child to child. 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 3 years of age, in at least one the following areas: 1) social interaction, 2) social-communicative use of the language, 3) symbolic or imaginative play [1]. Some studies shows that 50-80% of autistic children also present cognitive delay [9,30] and most of them need lifelong professional care [14]. As yet, there are no effective, safe and accepted medical treatments [71]. This suggests the importance of an early diagnosis (by 18-24 months of life) in order to immediately begin a psycho-educational intervention. Many research studies have indeed shown that early and intensive intervention (preschool age, 6-8 hours/day) leads to great progress in skills, and in some cases to development equal to peers [1,3,56,25].
Since traditional educational strategies are rarely effective in ASD, new teaching approaches aimed at better exploiting the subject's abilities are currently adopted. [25,42,98].

Applied Behavioral Analysis (ABA) is a scientific approach that can bring clinically significant improvement to intellectual, social, emotional, and adaptive functioning [2,41,56,60,100,97,107]. 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. Recently, 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” [28].

ABA focuses on socially significant behavior that can be measured and quantified, enabling one to constantly and continuously monitor the behavior of the child and assess whether the procedures adopted are appropriate for that particular child in that specific context. It provides one-to-one teaching via trials of increasing difficulty according to Discrete Trial Training (DTT) where the skill to be learned is broken down into small units for easy learning, and makes extensive use of Augmentative and Alternative Communication (AAC). The child’s progress is constantly monitored by collecting data from the child's performance.
Usually this data is paper-based and exchanged between the ABA team members (typically 1 consultant, 1 senior tutor, 2-3 tutors, the teachers and the child’s parents or other caregivers). Involvement of the child’s parents is fundamental to achieving good results since the program must be followed consistently both at home and at school. However, handling paper-based data can require much effort and be prone to error.

Despite technological advances in educational applications, usable systems to facilitate and support ABA intervention in a holistic approach including learning and monitoring (data collection and analysis) are still needed.
Concerning technology-enhanced learning, research on the potential of CAI (Computer Assisted Instruction) in autism began in the 1970s. Results show that associated learning scenarios are easier for people with autism thanks to the emotional distance between a computer and the user, which can reduce anxiety and problematic behaviors [101]. In recent years, many programs for autism have been developed, but only a few are specifically designed to support ABA intervention. A team from NUI Galway has created a web engine that could be helpful for developers of applications based on ABA principles, but unfortunately, this proposal relies on proprietary technology with considerable development costs [49]. Furthermore, nearly all the software currently available is commercial and thus not economically feasible for all families of autistic children. A 2006 study by Whalen et al. based on the use of software designed on ABA principles showed that the use of CAI improves social and communication skills by reducing inappropriate behavior [109]. Another study showed that computer instruction is more effective when combined with the physical presence of the tutor rather than when used alone [85]. In accord with these results, our study favors a platform where tutor and child work together while using two separate devices to interact with the same application.
Since a chance to learn is directly linked to the possibility of communicating, in recent years much effort has been made to develop tools that facilitate communication by means of technology based on Augmentative and Alternative Communication (AAC). Recent research has confirmed the benefit of electronic intervention based on AAC. Hirano et al. [40] designed and implemented a visual scheduling system (vSked) for planning and organizing children’s activities in the classroom in a visual way. In addition to increased efficiency for caregivers, they also observed improvements in student-student and student-teacher communication. Monibi and Hayes have conducted comparative studies on current existing applications in order to classify the characteristics in terms of requirements and constraints, proposing different approaches for future communication tools. Their prototype tool, MOTOCOS, has been proposed to overcome the limitations of existing tools [64].

According to teachers and experts, the available digital tools (e.g., Tango[1], Activity Pad[2], DynaVox[3]) still require expertise and training, showing little usability and flexibility. Recently, a qualitative study in 2010 focused on several available technologies (vSked, Motocos, SensaCam Microsoft[4]), identifying their main limitation as the inability to document and monitor over time any progress in the learning process. Considering these findings, the authors then redesigned these applications as needed and defined new guidelines to combine the advantages of analog devices with the potential of ubiquitous computing solutions [38,40]. Conversely, the ABA approach considers evaluating a subject's progress crucial to defining future learning programs.
Research in this field is currently focusing on using mobile devices. There are several interesting studies [26,101] specifically focused on communication and language but to the author's knowledge, these applications do not also monitor learning trends, one of the main goal of ABA.

Monitoring systems for checking the child's progress is a key component of ABA intervention. In recent years, systems for monitoring children with autism have attracted research attention. However, most of them are specifically designed to observe subjects' behavior and not to monitor their learning trends. For instance, Leroy [54] created a digital library of data related to appropriate and inappropriate behavior of children with autism in different social settings during the therapy, which includes video recordings. Decision trees and association rules provided more detailed insight into high and low levels of appropriate and inappropriate behavior.
DDtrac is a software for educational programs of children with autism, and supports the collection and analysis of data for documenting the progress of children with autism [23]. DDtrac supports both quantitative (numeric) and qualitative autism data collection. The quantitative data that can be collected include instructional data, social data and behavior data. The Kellar Instructional Handheld data (KIHd) System [92] is a real-time data collection tool for gathering instructional data about students diagnosed with autism. The software presents a database-driven handheld-based data collection and analysis system.
However, both software programs, DDtrac and KIHd, require manual input of data from the therapists in order to analyze them. By contrast, our software automatically records and stores most of the data, such as programs, levels, categories, articles, progressive number of trials, errors and time elapsed between the trials as well as the child's response. Tutors complete the evaluation of the exercise by simply pressing a key on the keyboard (to insert the type, full or partial -- and percentage of prompt provided, i.e., 100, 80, 50, 20 or 0). In this way, data can be homogeneously analyzed through the data analysis tool presented here.
Another tool is ABPathfinder (http://www.abpathfinder.com/) a cloud-based software program that improves the efficiency and effectiveness of ABA therapy by reducing paperwork and improving data outcomes. All the complex processes of

[1] http://www.tango.me/
[2] http://www.activitypad.com/
[3] http://uk.dynavoxtech.com/default.aspx
[4] http://research.microsoft.com/en-us/um/cambridge/projects/sensecam

ABA therapy, including data collection and charts, are specifically created for this therapy. Unfortunately, ABPathfinder is a commercial product that presents additional expenses for the family of an autistic child, already burdened with the cost of the behavioral intervention.
Recently Tarbox et al. have compared the use of a PDA (Personal Digital Assistant) for collecting behavior data with traditional pen-and-paper data recording. Their conclusions were that data accuracy is equal for both formats, but traditional data collection was faster [102]. However, we claim that rapidity mainly relies on the software features and usability of user interfaces (UIs) as well as on the subjective user's ability to insert data. The use of gestures would make the process more natural. In addition, having electronic data enhances the evaluation and assessment phases.
Lastly, scientists have applied data mining techniques in order to analyze large sets of stored ABA data. In Freeman [32] the relation between physiological events, environmental factors, and the occurrence of problem behaviors are analyzed using the data mining system LERS (Learning from Examples based on Rough Sets.

The work proposed herein summarizes the study conducted during a Tuscany Region project exploiting ICT to support the learning process of children with autism (ABCD SW[5]). The goal of the project was to implement software tools to support ABA intervention in children with low-functioning autism. Three main related tools have been created for: (1) a didactic software supporting the ABA 1-to-1 intervention that consists of simply programs (match, touch, order, etc.) for article discrimination and logical sequences, to be executed in progress through trials of increasing degrees of difficulty; (2) a learning analytic tool, and (3) a work-alone tool for empowering children in self-executing mastered programs, in order to maintain mastered skills over time. An additional tool, available only for Android mobile devices, has been created for favoring data collection in classical ABA intervention.

Usually, the child's work is carried out in 2-3 h sessions where different programs are executed. Each session can be performed in class or at home involving teachers, therapists and parents (for enabling a coherent learning process). Intensive, coherent and early ABA intervention (at least 25-30 h /week) facilitates the child's learning [29,83,84,108].

In this context we realized the didactic software **ABCD SW** (1), a web-based application for teaching low-functioning autistic children [5,6,16,17]. The system relies on ABA principles, Augmentative and Alternative Communication and Discrete Trial Training. Since learning about simple articles such as common everyday objects can be very difficult for low-functioning children at pre-school age, the didactic software implements discriminative programs to teach basic skills – colors, foods, animals, numbers, letters, places, relatives, human body parts, etc. – in order to stimulate receptive and expressive language. ABCD software is customizable: non-receptive and non-verbal children are supported by labels (words) and it is possible to define the most appropriate multimedia reinforcements. The software relies on a Web architecture: using a laptop, the tutor defines the

[5] http://abcd.iit.cnr.it/

exercises dynamically activated on the child's screen. The child interacts with the software through a touchscreen tablet since tactile interaction is more natural and easily used by 3- to 6-year-old children; however, the child could use any device provided with an Internet browser able to support JavaScript and HTML5.

After the child has gotten used to the software programs and has mastered a certain number of proposed skills, he/she can reiterate the consolidated programs using a safe (errorless) **work-alone** environment that completes ABCD SW (3). This additional tool, designed for refresher sessions, is usable by children without adult control. This allows the child to maintain mastered programs over time (since low-functioning children might lose them if not continuously refreshed) while promoting his/her autonomy

The learning analytic tool of ABCD SW (2) allows conversion of raw data into easy-to-use graphics and tables, showing the child's learning progress. Graphics regarding each children' progress are available via Web interface to therapists and parents for facilitating decisions on how to best direct the educational program and make the learning process more effective. The learning analytics software is implemented by merging two data sources: 1) computer-recorded data (events performed by children, such as pointing, drag-and-drop, touch zone, elapsed time for accomplishing the task, etc.) and 2) data annotation of therapists/caregivers, necessary for specifying whether a prompt is given (type, %) and registering additional useful notes.

Thesis Organization

The thesis is organized into six sections. After this introduction, ABA intervention for autism is detailed in Chapter 2. Next, the focus moves to the design and implementation of the proposed tools. Chapter 3 introduces ABCD SW and the learning analytic tool for data analysis. Chapter 4 is devoted to the pilot test conducted to evaluate and assess the effectiveness of these two integrated software programs. Chapter 5 introduces the work-alone Web Tool for children's safe independent playing, to maintain skills already learned in the ABA intervention. Chapter 6 illustrates a complementary software tool designed for Android mobile devices, enabling tutor and caregivers to collect data when dealing with traditional ABA sessions (not assisted by computer). Last, the thesis ends with conclusions and future work.

2. AUTISM AND ABA

2.1 Autism

The clinical syndrome falls under the category of Pervasive Developmental Disorders along with Asperger's Syndrome, Rett syndrome and childhood disintegrative disorder. Concerning the overall prevalence of autism, the CDC's Autism and Developmental Disabilities Monitoring (ADDM) Network estimated in 2010 that about 1 in 68 children aged 8 years (14.7 per 1,000) in USA has been identified with autism spectrum disorder (ASD) [19]. Criteria are definitely improved today compared to the past; it predominantly affects males at a ratio of 1:4, and almost always occurs within the first 3 years of life.

The symptoms of Autistic Syndrome include behaviors that are the consequence of severe changes in the functional areas of the brain responsible for:

- communication
- social interaction
- stereotyped behavior.

The severity of symptoms in autism widely vary from individual to individual and in most cases tend to improve with age, especially if mental retardation is mild or absent, if there is verbal language, and if a valid treatment is adopted early. Autism may also be associated with other disorders, and there are different degrees of autism among them.

Among different possible treatment approaches, behavioral science considers autism a specific disorder, characterized by a combination of anomalous behavior upward or downward. The anomalous behavior upward include aggression, self-stimulation, and echolalia in language, while the downward includes deficiency in communication and social interaction and deficits in the play role. According to behavioral scientists, there is a specific correlation of these behaviors with the environment. This correlation can be identified and treated according to the assumption that each behavior can be modified changing the environment.

2.2 ABA Intervention

Behavior analysis and its relationship with environmental stimuli was founded in the early 1900s. In 1903 Ivan Pavlov, Russian physiologist, Nobel Prize for medicine in 1904, presented his data on conditioned reflexes showing that environmental stimuli can induce physiological and behavioral changes[69].

In the 1950s the American psychologist BF Skinner presented his theory on the importance of reinforcement (satisfaction, immediate reward) in determining behavior, learning and, ultimately, psychological development [95,96].

In 1968, Baer, Wolf and Risley, University of Kansas, coined the term Applied Behavior Analysis (ABA) to indicate the intervention of behavioral psychology formalized by Skinner’s principles in socially significant human behavior, particularly in the case of developmental disabilities, mental retardation and aberrant behaviors associated with autism. [7]

Behavior analysis is just one method of Natural Science. ABA, an offshoot, involves the use of analytical methods and results with the aim of significantly changing socially important behaviors, and autism is just one of the many contexts in which it has been applied successfully.

Since the 1960s, many researchers have documented the effectiveness of ABA principles and methods to improve a wide range of important skills and reduce behavior problems in people with autism [83,84,104,105,108]. Like other interventions, ABA adopts programs that enhance the level of communication: augmentative and alternative communication, training of verbal behavior, communication with images and more.

Currently, authentic ABA programming for people with autism often brings together several widely validated methods in an extended but highly individualized program. For each student, the skill to be promoted and the behavior problems to reduce are clearly defined and measured by direct observation, with independent examinations carried out by different observers trained for this purpose. The treatment is chosen for each individual, using as a guide data collected during an initial assessment aimed at evaluating skills in different fields (learning ability, communication, social, academic, personal care, mobility, fun and games, etc.). All the competences to acquire are then divided into smaller components according to an ascending order, from simple to complex. The overall goal is to help each subject develop skills that in the long term could allow him to be more independent, autonomous and satisfied. To strengthen existing skills and build up those that have not yet developed, a wide variety of analytical procedures are used. This variety allows multiple opportunities to learn and practice skills at any time of day, with massive positive reinforcement. One way to organize learning opportunities is to offer the student a series of tests, each consisting of:

- an instruction from the tutor
- an opportunity to answer for the student
- feedback from the tutor depending on the student's response.

The iteration of these structures represent discrete trial training (DTT). Some researchers affirm that abuse of DTT procedures could tend to produce skills that are not transferable (generalizable) from the classroom to daily life [89,90]. For this reason, today ABA programs mix discrete trial procedures with a variety of other methods, including the sequences of primary education (known as teaching random procedures), task analysis, and connections to teach skills that involve sequences of actions. There is a strong attention to making learning fun and on involving the student in positive social interactions.

In a real ABA program, procedures are clearly specified: the instructions, the stimuli (prompts) and reinforcements (rewards, materials and everything else that is used to develop each skill) are strictly adapted to the specific student. There is a written plan or a set of instructions to teach for each learning goal, and the behavior analyst, responsible for the intervention, encourages all other team members to constantly implement these plans. It is particularly important for parents to be educated to implement the procedures outside the formal sessions of treatment, in different contexts (home, playground, community), in order to increase the generalization ability of the acquired concepts. The so-called problem behaviors (such as stereotyped behavior, self-injury, aggressive and unstable attitude) are not explicitly reinforced while appropriate alternative behaviors are intentionally rewarded.

The student's progress is measured frequently. Data are presented in graphs to provide a visual image of what is going on with each ability or problem behavior during treatment. The data are regularly analyzed by the analyst's behavior so that student's errors can be identified at the beginning of the educational training and the methods immediately adapted if progress is not satisfactory.

2.3 Structured Learning

There is a great deal of evidence on the effectiveness of behavioral intervention in autistic syndrome if intensive and continuous treatment starts at preschool age [29]. In practice:

- early (starts before 5 years of age)
- intensive (not less than 20 h per week)
- continuous (not less than 2 years)

For behavior modification, the ABA approach uses a series of steps in order to make it more functional [31]:

1. Consider each problematic behavior
2. Observe the behavior
3. Identify the basic level of the behavior in accordance with the quantitative parameters (frequency, duration, intensity)
4. Define the behavior or goal/goals to be achieved
5. Subdivide the ultimate goal into sub-goals
6. Teach small steps through direct instruction and/or incidental teaching (situations that arise in real life)
7. Apply the principle of learning without errors ("errorless learning"), using techniques to help (prompt) and progressively reduce the amount of prompts over time
8. Reinforce the successes or the approximations to the correct answer
9. Alternate different activities, more or less complex
10. Generalize
11. Evaluate the results.

The principle of errorless learning is a cornerstone of ABA because it is very difficult to correct an error previously stored.
As mentioned earlier, the DTT consists of a sequence of elementary trials repeated several times according to the needs of the child. The work is organized in programs in order to teach the child basic concepts such as discrimination between objects (article) of different categories such as colors, shapes, numbers, or letters.
According to DTT, the process of mastering one article in a specific ABA program (for example, matching image/image colors) goes through a sequence of levels with increasing degrees of difficulty (steps 1-9 described below). Each time a program is mastered (based on objective data recorded on paper by the therapist, i.e., 80% of articles in the category are mastered), the tutor may move on to the next level.

The sequence of the DTT is listed below:

Mass Trial: basic trial that ensures the success of the child with the article in acquisition status in a custom program.
Mass Trial with one neutral distractor: trial that involves an item completely unrelated to the category for color, shape, similarity of name in order to determine whether the child is able to discriminate the target item.
Mass Trial with two neutral distractors
Mass Trial with NON neutral distractor: distractors belong to the same category, or may be similar in color, shape, similarity of name, etc.
Mass Trial with two NON neutral distractors
First extended trial: a trial that proposes a choice between three elements: the article in acquisition and 2 others selected from the items already mastered in the

same category. In the first two tests the item under test remains in the usual position. If the child makes a mistake, he/she has to repeat the test with the same elements in the same position.
Second extended trial: similar to the previous one but performed by a different therapist (this is a sort of generalization).
Random Rotation: three elements of the same category, one of which is the article in acquisition status and two chosen randomly from the set of existing ones within the same category.
Rotation Block: a rotation of two elements activated when the child works with the second article in a certain category for each program, not having a third mastered element available with which to perform the rotation; you can also do it after a random rotation if the child is wrong and the therapist wants to start the exercise again but not from scratch.
The generalization process consists in offering new ways to master the previously learned article, for example by changing the stimulus (color image using a pattern or template instead of a picture, and then making an abstraction), changing the position of an article, and/or the discriminative stimulus (ie the instruction that is given to the child). Within each path of learning, different types of aid (prompt) can be offered to the child according to its learning needs, in order to help him successfully carry out every test without errors, as required by the ABA principle.

Basic programs covered by the ABA intervention include:

Matching: Image / Image; Word / Word; Image / Word; Word / Image

Receptive: Image; Word

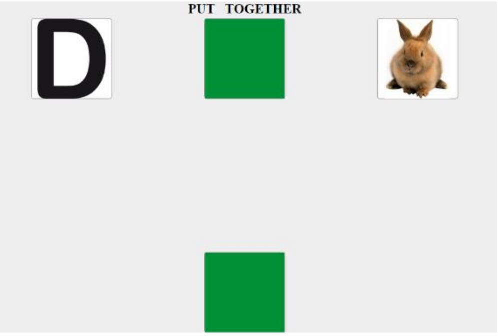
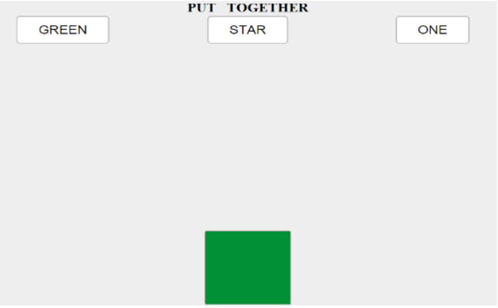
Expressive: to enhance the communication, oral if possible, or in another form.

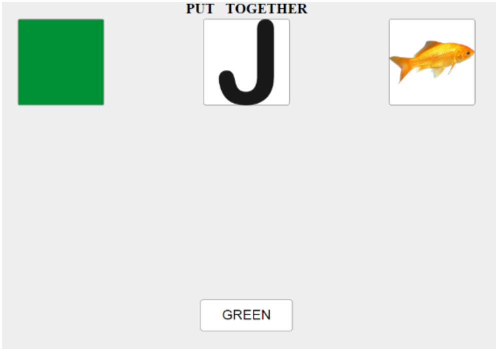
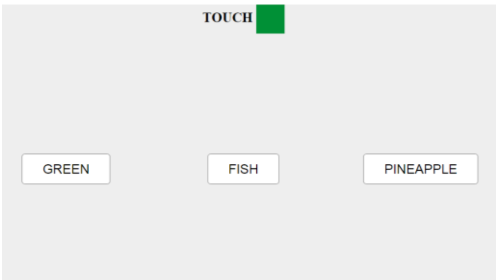
An example: If the goal is to learn the category of COLORS

To illustrate the ABA methodology, suppose that the category COLORS contains a set of twenty colors. Each item represented with an image is proposed in a cardboard square on a white background with a design that takes up about three quarters of its surface. Words are rectangles proportional to the length, written in uppercase letters. The cards of the items are a double pair having equal elements. There are then forty square cards with images of colors and 40 rectangular cards with the words corresponding to the colors.

The matching program for the COLORS category has four sub-programs: matching Image/Image, Word/Word, Image/Word and Word/Image COLORS (Table 2.1). The receptive program has two sub-programs: receptive word and receptive image. With the expressive program, the individual should achieve ability in order to communicate verbally or through labels.

Table 2.1. Programs, discriminative stimulus and child's response

ABA PROGRAM	SDs	Child's Response
A – MATCHING: Image/Image	"Put together"	Move the image to the same image 
Word/Word		Move the text label to the same text label (GREEN over GREEN) 
Image/Word		Match the image with the corresponding text label 

Word/Image		Match text label with the corresponding image 
B - RECEPTIVE Image	“Touch color_name”	Touch green image 
Word		Touch GREEN 

C – EXPRESSIVE	“What is it”?	Say the color (green) if the child is verbal Touch the textual label (GREEN), if the child is non-verbal 

3. ABCD SW SYSTEM

3.1 ABCD SW

The idea of ABCD SW Project is to map ABA principles implementing a specific SW program suitable for therapists and children with DSA syndrome, using modules designed to enhance children's cognitive processes, language development and social skills. The project mainly aims to create didactic computer-based exercises in order to render ABA intervention more effective and efficient. We focus on teaching young children (2-6 years old). In fact, according to recent studies [3,20], early intervention in children affected by autism disorder is more effective for learning and developing social abilities. To simplify child-computer interaction and allow a modality "similar" to the physical ABA therapy, we chose to use touch-screen devices and vocal synthesis to announce the commands of the learning modules (exercises). The language required is simple and minimal (short sentences without articles, e.g., touch apple, match yellow). However, caregivers may also speak in order to integrate text commands in the best way to stimulate the child.

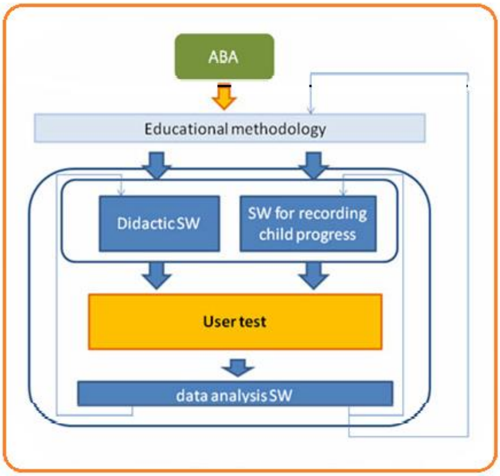


Fig. 3.1. Scheme of the ABA eLearning Environment for child with autism

As shown in Fig. 3.1, the three main SW components of this learning environment are:

Didactic SW, i.e., modules for learning categories of articles in which each program (match, touch, order, etc.) is executed thanks to levels of increasing degrees of difficulty. The workflow done by the child is based on the concept of a session that represents a single instance of intervention that could include data of different programs. Each session can be performed in class or at home involving teachers, therapists and parents and allowing a coherent learning process.

Monitoring SW to control the child's progress is a key component of the methodology. This module merges two data sources: 1) computer-recorded data (events made by children, such as pointing, drag-and-drop, touch zone, elapsed time for accomplishing the task, etc.) and 2) data annotation of therapists/caregivers, necessary for specifying whether a prompt is given (type, %) and to register additional notes. Additionally, the presence of changes in programs (e.g., moving to a previous difficulty level) are also reported by the tutors/therapists to highlight the child's weaknesses.

Data analysis SW allows conversion of raw data into easy-to-use graphics and tables, showing the child's learning progress. Graphics regarding a child's progress are available via Web interface to therapists and parents to allow decisions on how to best direct the educational program and make the learning process more effective.

The project covered all these aspects as a whole and not as separate components.

3.1.1 Participatory Design

In order to better fit the primary idea of the project and the single requirements listed by the end users, we choose the participatory design involving all the ABA team members in the system design. Participatory design with therapists and caregivers is essential for reaching reliable results. An ABA team usually consists of tutors, teachers, and, very important, the child's parents/family members to guarantee consistency in the behavioral approach both at home and school. Our multidisciplinary team comprises software analysts, designers and developers, two psychologists, six ABA tutors, one ABA consultant and two parents of children with autism. For each child more than one tutor is necessary in order to ensure that the child's learning is not dependent on a specific person.
Examples of applied participatory design for software development are presented in [36,64] and [66].
We interviewed the therapists and the parents, watched videos of therapy sessions, and we were also present at ABA sessions with different children and therapists. Some of the subjects under therapy have no trouble in presence of external viewers, so it was possible to observe their teaching session at a certain distance. Usually ABA intervention needs a very basic environment free of distraction and usually consisting of a small table, two sets of equipment for the child and the tutor, and variable work material depending on the type of program

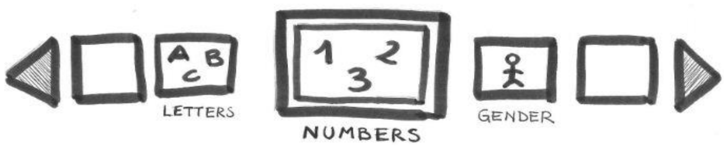
to perform. The tutor sits facing the child and arranges the material on the table announcing the command to the child.
The teacher decides which program to propose from among the following:

1. **matching:** image to image, image to word, word to image, word to word
2. **receptive** program (e.g., using the command: “Touch apple”)
3. **expressive** program (e.g., using the command: “What is this?”)

Depending on the choice made, the teacher presents the child with the material (usually hand-made colored square cards), organized in categories. In addition to cards, real elements such as plastic objects, dishes, fruit or other elements may be used. The child executes the request either independently or in response to a therapist’s prompt. A reinforcement, such as a game or something else particularly pleasing, may be given to the child after a sequence of correct trials to encourage him/her in his work.
In ABA, each program is implemented using a sequence of trials of increasing degrees of difficulty:

1. **Mass Trial:** basic trials (there are only a couple of the same items, and the child needs to match them), ensuring children’s success on acquisition
2. **Distracter phase:** first, a neutral distracter is added to the item on acquisition, next two neutral ones. Then one non-neutral distracter is added, and next, two non-neutral ones.
3. **Extended Trials:** a choice between 3 items; 2 of them must be mastered and the third on acquisition
4. **Random Rotations** of learned items. If the program is just at the beginning and 3 items have not been mastered, it is possible to work on a rotation of the 2 items mastered in that program (Block Rotation).
5. **Generalization:** consists in proposing new ways of acquiring each mastered item, to verify if the child is able to recognize the item in the real world.

Within this sequence of learning, different types of prompts may be provided to help the child complete the trial successfully, according to their learning needs and implementing the principle of errorless learning (errors in the acquiring phase could be very difficult to correct.
In order to avoid influencing the imagination of therapists regarding the user interfaces (UI) of the didactic software, we asked them to picture how they imagine it, without showing them our personal ideas. Fig. 3.2 shows three examples of organization they proposed.



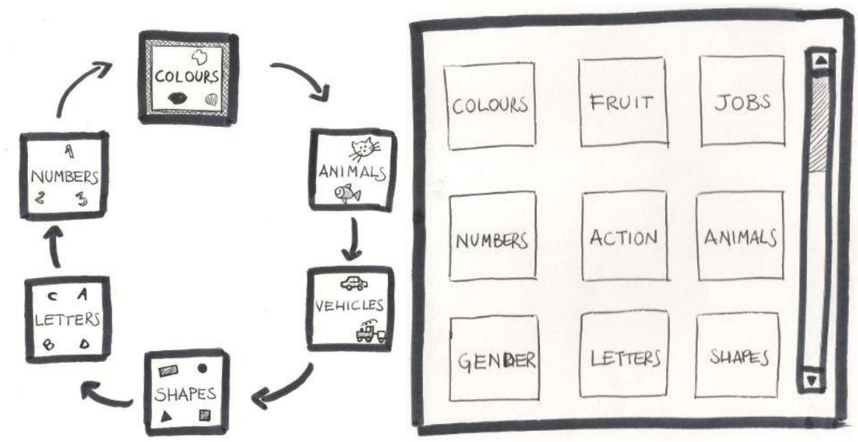


Fig. 3.2. The UIs proposed by therapists: carousel (up), circular icons (bottom left), square icons (bottom right)

Starting from the top one, there is a carousel for selecting the category on which to work), a circle of icons, and icons (arranged in a square) with a search function. As previously mentioned, the complexity of Discrete Trial Training and teaching by levels increase the complexity of the UI (Fig.3.3).

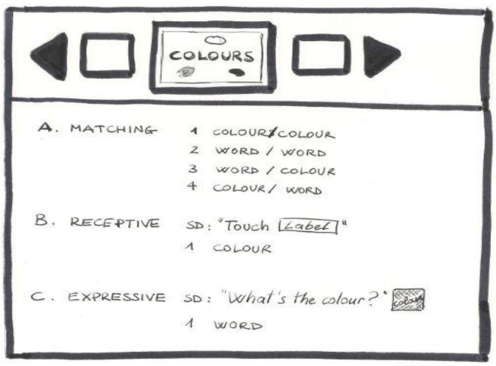


Fig. 3.3 Programs (matching, receptive or expressive) for the selected category (color)

The generalization applicable to the software is obviously limited compared to what happens during a typical ABA session without the computer. Within the software modules the generalization is carried out changing:

- the Discriminative Stimulus (i.e. the therapist's command)
- the position of items on the screen
- the stimulus, i.e., the visual features of items (photo, drawing, outline, sketch).

As a result of the analysis phase based on participatory design, ABCD SW must be:

- Comprehensible: to this aim, the software is based on Augmentative and Alternative Communication, so it uses images (also animated) and labels.

- Errorless: the software tries to avoid a child's error.

And it must allow:
- Learning by increasing levels of difficulty. This requirement has been satisfied implementing the Discrete Trial Training defined in the ABA, including mass trials, trials with one or two (neutral and not) distracters, extended trials and rotations.
- Monitoring children's progress. ABCD SW records data on the trials regarding performance and evaluation. This point is central and focal to the ABA since it allows the interventions and progress to be measurable, favoring the set-up of the teaching strategy according to results. Data needs to be collected and transformed into graphic form to highlight the progress or weaknesses of the child and allow directing the therapy as needed.

From a point of view not closely linked to learning process, ABCD SW has good influence on the automation of the three phases typical of ABA intervention, facilitating and speeding up the tutor's work:

1. Trial set-up, allowing easy addition of items and categories by using a content management system (CMS)
2. Configuration and control of the flow of the educational programs assigned to the child according to the ABA sequence
3. Evaluation of each trial executed.

Obviously, computer-based therapy should complement traditional face-to-face ABA therapy and not used as an exclusive approach for promoting learning mainly because:
- A computer does not involve the child's physical social interaction directly; in fact, it allows easier interaction for children with DSA because it does not require social skills. However, computers can teach behavioral schema that could be helpful in social interaction.
- ABA requires a long period of daily therapy, around 4-6 h per day. However, too much time spent at a monitor could damage the child's eyesight.

Therefore, a crucial aspect in the design phase is attention to a UI that should avoid any possible visual auto-stimulation for the child; thus an interface with all icons fixed in view might be preferable to carousel solutions, activated via mouse or touch. One interesting option is to customize the UI according to a child's abilities (low- and high-functioning children) and if possible, their preferences.
According to the ISO usability definition [44], didactic software should guarantee efficacy, efficiency, and user satisfaction. Other fundamental design criteria were:
- *Modularity and scalability*, allowing easy addition of new modules, items (to acquire) and programs
- *Customization*, to better adapt to each child's needs and abilities
- *Multilinguality*, to favor the adoption of the SW in other countries
- *Openness,* to guarantee interoperability
- *Robustness*, for solid error handling
- *Adaptability,* because each child has personal abilities that can be very different, so the SW must meet the specific communication abilities (receptive

or expressive) and temporary needs if the therapist decides to skip or reiterate a learning route.

- *Guarantee of privacy and security:* all data must be kept anonymous (access via nickname) and secured with the appropriate technologies (login, certificates, etc.), and specific views only on the related child data would be created for each person accessing the software.

3.1.2 The Role of Images

Sight is one of the main channels through which we learn. Gardner, in his theory of multiple intelligences, emphasizes the crucial role of what he calls visual-spatial intelligence. [33]. For many autistic subjects, the visual system is even more active because it somehow compensates for deficits in verbal and sorting sequences. Some studies prove that the method of "learning through seeing" is usually the most effective also for children with autism [38,79] because use of the visual channel has been shown to reduce the symptoms associated with cognitive, communication and social disabilities.
Therefore, material supplied to the children during the therapy sessions is mostly visual and must fulfil the requirements of clarity, simplicity and precision in communication. Images must be clearly legible, large, well-defined, on a neutral background, and in a central position on the page; the windows are minimal (minimal number of elements, no background images, etc.) since any other element can be a distraction. Images chosen for the exercises display different degrees of abstraction: from those closest in appearance to the real objects (represented by photographs) to the most abstract (represented by objects' silhouettes), passing through intermediate stages of more or less abstract drawings. The trials usually start with a photo of the real object (e.g., an apple) and progress towards the abstraction: a color photo, a black and white version, a realistic drawing, a stylized one, and finally a black silhouette of the object. Different apples with different colors is another possible generalization. Images are the stimuli provided to the child in the trial, whereas an example of abstraction is shown in Fig. 3.4.

Fig. 3.4. Abstraction of the stimulus of the trial: color photos, b/w photo and silhouette (category food, article apple)

Furthermore, for each object we can have various sequences of abstractions: considering colors, for instance we might have a colored square, then a stylized colored square (strokes), color spots, the tip of a brush full of color, etc. (see Fig. 3.5). The reason is that the child needs to learn to recognize an object in its various representations.

Fig. 3.5. Abstraction of the stimulus of the trial: drawings (category colors, article red)

3.1.3 The Architecture

ABCD SW is a dynamic Rich Internet Application based on distributed Web architecture, with two devices -- a laptop for the tutor and a touchscreen tablet for the child -- connected via Internet. No physical connection between the devices is required, making interaction more natural and suitable for autistic children, eliminating the possibility that they may be attracted to plug in/out cables. (Fig. 3.6)

Fig. 3.6. ABCD SW environment: Tutor and Child's devices running the same session

In order to verify the best kind of touchscreen devices to use with ABCD SW, we tested two different large touchscreen monitors and five types of touchscreen tablets, actively involving the children in the testing phase. The use of big touchscreen monitors was quickly discarded because they are not very sensitive, so they do not provide ready feedback to the child's actions. This fact could cause serious difficulties and delays in the child's learning, especially due to the consequent frustration with the lack of feedback, crucial for autistic subjects. In addition, the use of large monitors required USB cables to connect them with a PC. Since autistic children are often attracted by cables, their presence could be a distraction; or worse, the cables could be used improperly by the children, causing safety issues. Conversely, a touchscreen tablet does not require cables and has a very sensitive touch screen. Another advantage is the system's portability, which makes it possible to perform an ABA session anywhere, anytime.

If a touchscreen tablet is not available, the tutor and the child can share the same computer; child interaction is possible with mouse or touch pad but this solution is less natural for a child than the touch one. In order to share the same PC, the tutor can choose to activate this variant before the session's start.
Specifically, ABCD SW is a PHP, AJAX and HTML5 Web application that relies on the Drupal CMS and the MySQL database. The use of the content management system enhances data management, offering native scalability and support for internationalization. All the software's functions are implemented using jQuery and JSON libraries, which enables creation of abstractions for low-level interaction and animation, advanced effects and high-level widgets. The AJAX technology, handling calls to the server, allows the efficient and easy exchange of data, thus the HTML5 client user interfaces are constantly updated (see Fig. 3.7). Images extracted from the database are dynamically inscribed in rectangles and carefully designed to be simple. to avoid student distraction.
For drawing objects in the Web browser, the JavaScript Library Raphaël using SVG (Scalable Vector Graphics) has been adopted. As Raphaël uses the SVG W3C Recommendation and VML as a base for creating graphics, each graphical element is a DOM object, so it is possible to attach JavaScript event handlers or use indexes to modify its features. The library allows easy positioning of the image on the "canvas" and provides methods for animating the element, enabling its movement when needed. The use of SVG makes it possible to adapt the canvas to different screen sizes respecting the relative distance between displayed items, avoiding any confusion for the child. When interacting through ABCD SW, Google Chrome or Mozilla Firefox should be used since they better support HTML5 functionalities.

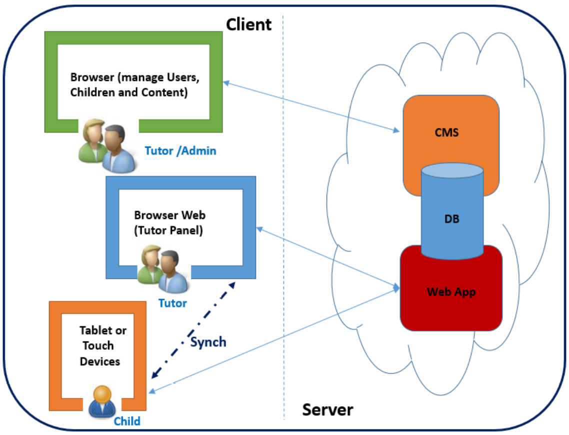


Fig. 3.7. The Architecture

The application relies on a relational database built with MySQL. Its dynamic behavior is highly dependent on this data structure, especially for the continuous real-time monitoring and updating of statistics on the child's performance during each trial.

The use of a CMS also offered us some advantages for database organization; in fact, all the data relating to the software's configuration (categories, articles, etc.), being typically static content, were inserted through interfaces easily built using Drupal. The structure of the database is then realized by Drupal itself. Upwards of this basic CMS structure composed of many tables, we added tables for the automation of the ABA workflow.

3.1.4 The Tutor's User Interface

After a previous registration phase, to access the didactic software the tutor has to login and select the child's nickname -- several children can be followed by the same tutor and a single child can have more than one tutor. A particular administration UI is available for the tutor or parents to add one or more children, specifying in the configuration's file their ability (receptive/not, expressive/not) for making the software adapt to their needs. After login and selection of the child's nickname, a summary presents data on the previous trials/sessions performed by the child with the software. If needed, the tutor can read information on the recent trials performed by other tutors. Reading the history of previous sessions is extremely valuable for setting up the current work. In traditionally performed ABA sessions, access to this information involves reading an enormous amount of data and notes recorded on paper, requiring time and effort. To aid tutors in this operation, we created an interface, immediately visible after the login phase, which provides data about previous sessions with different levels of detail. The page shows an ordered list of links labeled with the date and name of the tutor who performed the session. (Fig. 3.8)

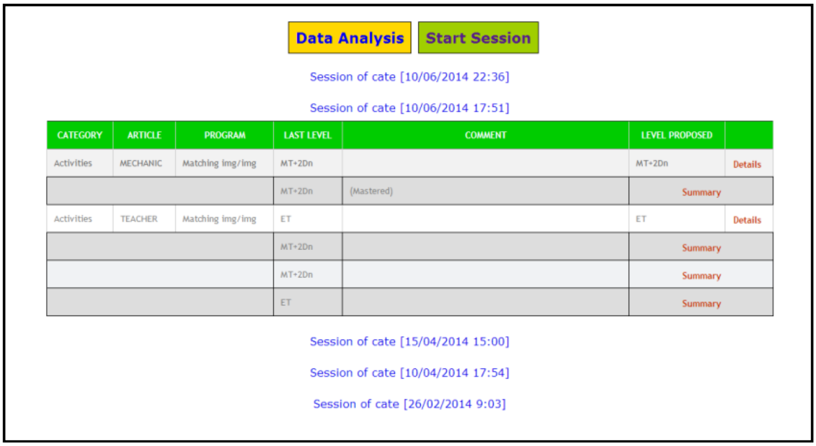
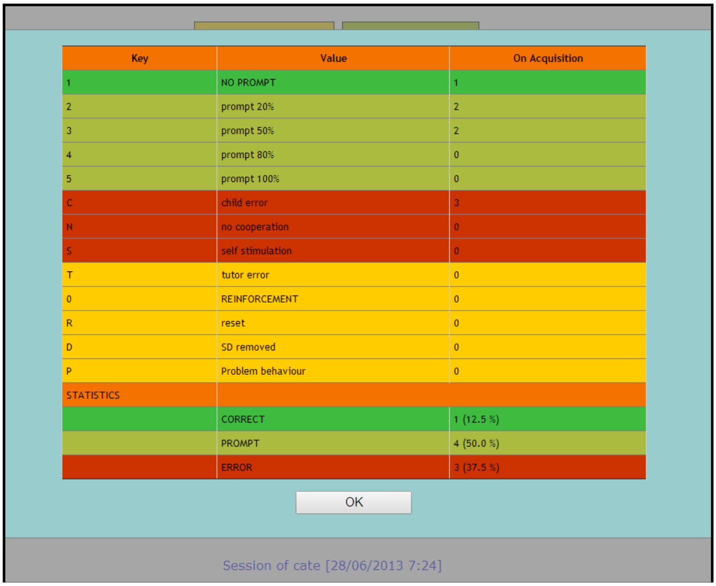


Fig. 3.8. The history of previous sessions

Clicking on a link shows data related to programs performed in that session; a second click on each level summarizes the statistics related to the single trial (Fig. 3.9).



Key	Value	On Acquisition
1	NO PROMPT	1
2	prompt 20%	2
3	prompt 50%	2
4	prompt 80%	0
5	prompt 100%	0
C	child error	3
N	no cooperation	0
S	self stimulation	0
T	tutor error	0
0	REINFORCEMENT	0
R	reset	0
D	SD removed	0
P	Problem behaviour	0
STATISTICS		
	CORRECT	1 (12.5 %)
	PROMPT	4 (50.0 %)
	ERROR	3 (37.5 %)

Fig. 3.9. The Summary of data related to one of the previous sessions

To start a new session, tutor presses a push button that activates a dedicated environment (Fig. 3.10). If the child has already used the software, the system proposes the configuration of the last exercise performed, i.e., the last combination of program, category, level and article on which the child has worked so that the exercise can be continued where it left off. All the articles of the category are visible as images grouped by the current learning status (mastered, not mastered, on acquisition, excluded, suspended), allowing the tutor to easily keep this information. The UI is interactive and allows drag-and-drop of the articles so they can change the status rapidly, except for the mastered one that can be defined only after fulfilling the ABA rules. The software encourages tutors to follow ABA rules by proposing the correct trial sequence, but it is also flexible, allowing the tutor to modify the order if needed. Pushing the level button (visible on Fig. 3.10) activates the trial on the child's device. At the end of each trial, the tutor may decide to continue on the same level or change class or program level in accordance with the methodological rules. At the end of a technology-enhanced ABA session using ABCD SW, the tutor can leave comments and subjective impressions about the session in order to have useful notes for his future work with that child or to communicate information to the other tutors. After this step, he/she ends the session.

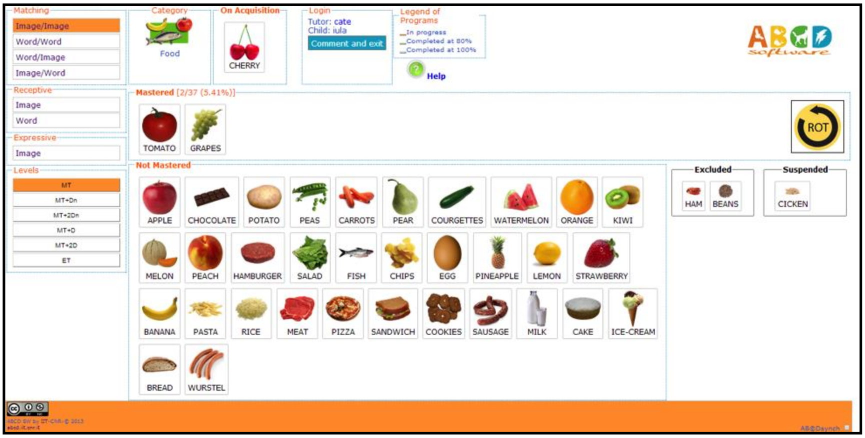


Fig. 3.10. The Tutor User Interface for setting the trial

3.1.5 The Child's User Interface

Using his/her laptop, the tutor defines the program and level of the ABA exercises to run. The proposed exercise is then dynamically activated on the screen of the child's tablet.

The number of elements (pictures or textual labels) on the screen depends on the program and on the level selected. The layout is dynamically arranged on the screen based on this number. The UI on the screen is organized to make the task clear to the child, avoiding confusion. For example, in matching programs, the target element is placed at the bottom, closer to the child, and it is the only element of the UI that can be moved. This configuration is consistent with the typical arrangement of the materials on the table in a traditional ABA session. According to the ABA principle of errorless learning, if the child tries to match the target element with an incorrect item, the target is rejected and returns to the initial position; otherwise, if the match is correct the target element is attracted by the correct article, thanks to a region of attraction placed around it. All actions -- dragging, touching-matching -- performed by the child are recorded in the database in real-time and instantly visible on the tutor's panel (described later), so the tutor can monitor what is happening on the child's screen obtaining a summary of the trial performance in the current level. In case of Matching programs, since the software does not allow incorrect matching, the system records each child's attempt to match an incorrect item as a child's error.

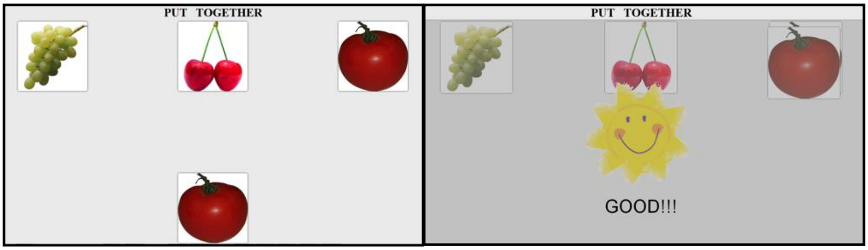
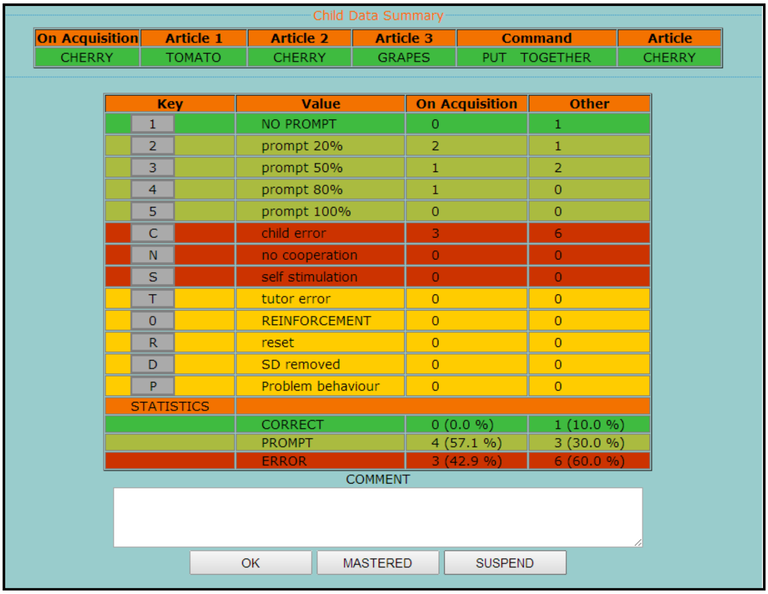


Fig. 3.11 The child's UI: matching trial with two distracters; feedback after a correct trial on the right

The Child's environment is set up according to the child's profile. In Fig. 3.11, the system proposes a trial for which the child has to match the *tomato* target at the bottom with the correspondent at the top. Since the child is non-receptive, i.e., does not respond to vocal instruction, the canvas supports the child by proposing the command as a label on top of the screen. This kind of aid is generally consistent even when the child is not yet able to read because when working with non-receptive subjects, the tutor normally utilized labels with the written command (e.g., 'put together' as in Fig. 3.11). Due to the intensive repetition of the exercises, the child learns the labels associated with commands although considering the label as an image. According to the importance of reinforcing a correct behavior, each correct trial is rewarded with a small customizable animated gif that appears on the screen (Fig. 3.11, right).

At the same time, when the child's screen is triggered, the tutor UI is overlapped with a second UI containing a control panel with real time data of the exercise that helps the tutor evaluate each trial. The evaluation is made by pressing one key for recording information on the prompt provided (if any) or errors (Fig.3.12b). This UI reports information on the trial displayed on the child's device -- first row in the upper part of Fig. 3.12a -- and the real-time summary of statistics regarding the child's performance in the current trial. This is extremely helpful for the tutor, who can obtain an overall view of the exercises. There are the sums of trials for level of prompt provided: 0, 20%, 50%, 80%, 100%. The child's behaviors are recorded (error, non-collaboration, self-stimulation), as well as any tutor errors. If the child does the exercise independently without prompts, or if the tutor considers the child has done the best he/she could do, an interactive reinforcement such as a video, animation, etc., can be activated on the child's user interface.

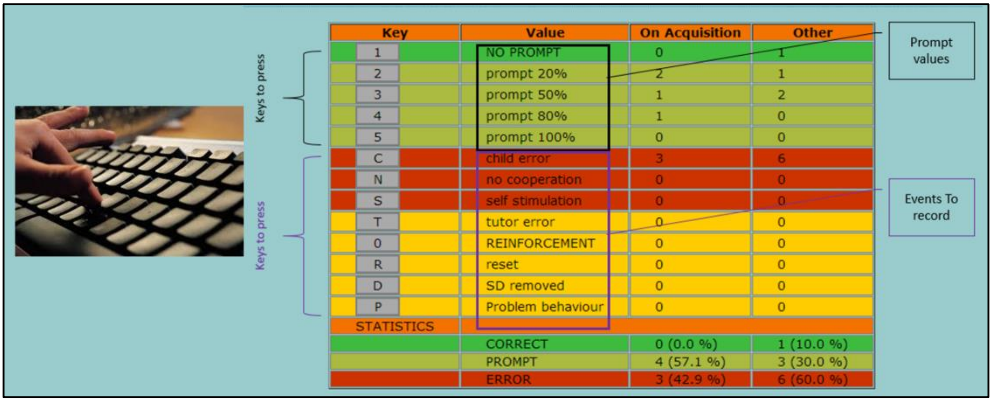
If the proposed selection of an object in the trial is not suitable for the child, it is possible to activate the reset of the child's user interface. The last three rows of this UI provide the tutor with a summary of the child's performance on the exercise of this level/program, with the total number and percentage of correct, incorrect and prompted trials.



On Acquisition	Article 1	Article 2	Article 3	Command	Article
CHERRY	TOMATO	CHERRY	GRAPES	PUT TOGETHER	CHERRY

Key	Value	On Acquisition	Other
1	NO PROMPT	0	1
2	prompt 20%	2	1
3	prompt 50%	1	2
4	prompt 80%	1	0
5	prompt 100%	0	0
C	child error	3	6
N	no cooperation	0	0
S	self stimulation	0	0
T	tutor error	0	0
0	REINFORCEMENT	0	0
R	reset	0	0
D	SD removed	0	0
P	Problem behaviour	0	0
STATISTICS			
	CORRECT	0 (0.0 %)	1 (10.0 %)
	PROMPT	4 (57.1 %)	3 (30.0 %)
	ERROR	3 (42.9 %)	6 (60.0 %)

Fig. 3.12. The tutor control panel



Key	Value	On Acquisition	Other
1	NO PROMPT	0	1
2	prompt 20%	2	1
3	prompt 50%	1	2
4	prompt 80%	1	0
5	prompt 100%	0	0
C	child error	3	6
N	no cooperation	0	0
S	self stimulation	0	0
T	tutor error	0	0
0	REINFORCEMENT	0	0
R	reset	0	0
D	SD removed	0	0
P	Problem behaviour	0	0
STATISTICS			
	CORRECT	0 (0.0 %)	1 (10.0 %)
	PROMPT	4 (57.1 %)	3 (30.0 %)
	ERROR	3 (42.9 %)	6 (60.0 %)

Fig. 3.12a. Focus on Evaluation made by the tutor

3.1.6 Synchronization between the Child and the Tutor UIs

The ABCD SW architecture considers the devices involved as autonomous and independent. This independence is guaranteed while making full use of their Internet connectivity. The communication modality between the devices is created using the database as a common channel. Each event from the tutor's or the child's device is saved on the channel, and every second the two terminals are synchronized with new data (if present). Specifically, the mechanism has been implemented with multiple jQuery's AJAX call to the server based on AJAX long

poll technique. With long polling, the client requests information to the server but if the server does not have any information available for the client, it does not send an empty response. Instead, the server holds the request and waits for information to become available (or for a suitable timeout event), after which a complete response is finally sent to the client. This mechanism reduces the amount of data that needs to be sent; moreover, multiple requests can be sent to the server by the same UI client and each one is processed independently from others.
An alternative to the server-client conversation could have been the use of HTML 5 sockets but when the tool has been implemented the specifications of this technology do not seemed to be sufficiently stable. The effect of this implementation can be seen in the tutor control panel (Fig. 3.12, upper section), the interface from which the tutor can see all information regarding what is happening on the child's screen.
In order to guarantee the synchronization capability, the crucial point is the definition of sessions: each session has multiple programs, each program has multiple levels and each levels include several trials. Each trial is univocally associated with a child with a certain ID and to a tutor with another ID. Different users can simultaneously access the web application with different devices connected to the same internet network or to different networks without interference because the channel that connects tutor and child is made by unique identifiers and a specific token.

3.1.7 Content Management with CMS

As previously mentioned, ABCD SW is a web application designed to be customizable. The implementation of this feature for allowing the user (tutor or caregiver) to control the software settings has been implemented using a CMS (Fig. 3.13).

Fig. 3.13. The tutor-admin UI

The use of a CMS permits managing the application's content independently from the code, allowing end users to add/modify them in a user-friendly way.

Furthermore, CMS is crucial for effectively managing the enormous amount of data collected through the software. Drupal allows abstracting the physical database using PHP Data Objects, thus making it unnecessary for a programmer to write SQL queries. The entire framework of the software was built with a large use of data views to facilitate the presentation of content to the users.

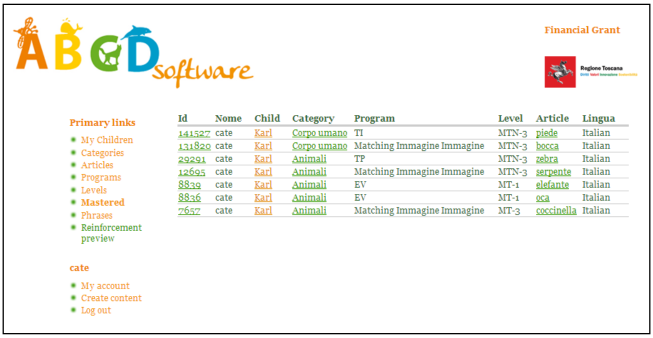


Fig. 3.14. The articles mastered View

Specifically, using that view, a tutor can:

1) manage children associated with him/her by choosing for them different levels of software customization
2) manage content such as articles, categories
3) view all the programs completed by the child and the related articles mastered as shown in Fig. 3.14
4) create personal content for the categories: Places and Familiar
5) propose possible future content to be introduced in the software, to become available for all users (Fig. 3.15).

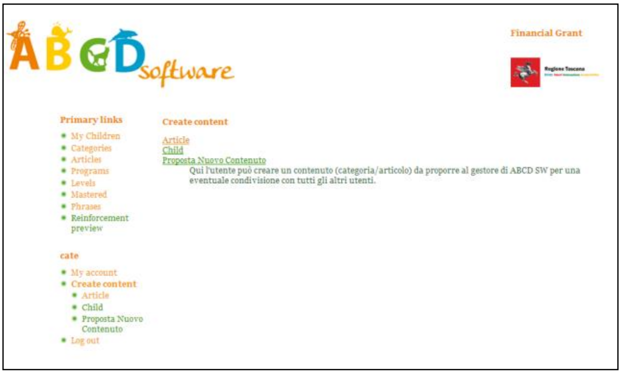


Fig. 3.15. The “Create Content” Page

3.1.8 Multilingual Features

Also due to the CMS support, the software is multilingual: all texts of the user interfaces, labels for articles or categories, and commands for the exercises (discriminative stimuli) can easily be shown in different languages with no changes to the software code.
Drupal CMS could automatically manage multiple versions of the same website in different languages using the mechanism of additional modules and Content Construction Kit (CCKs). However, considering that in our case the Drupal framework has to serve another web application (ABCD SW), the translation engine of the CMS has proved to be somewhat inefficient. The solution has been to create an array of key value pairs in which each label having the same key has been assigned a value dependent on the value of the parameter “language” (Fig. 3.16). This parameter is set in the child's profile and allows instantiating the software UIs with key-value pairs of the array expressed in the selected language.

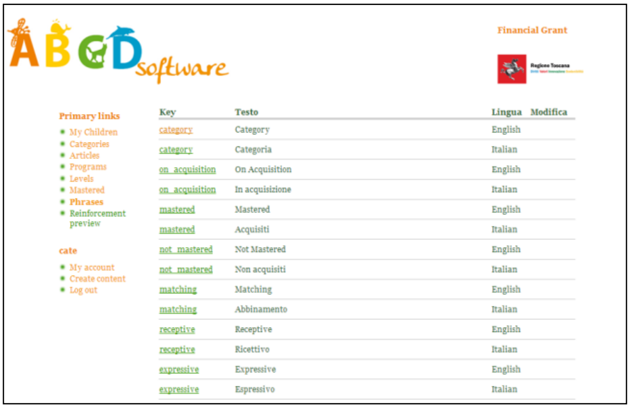


Fig. 3.16. Summary of texts used by software in different languages

To realize ABCD SW as a multilingual application, all that is needed then is to define multiple series of this key-value pairs, one for each language. For this purpose, we have provided users who desired a different language version of the software with a web interface to insert the translation of the software text content. After a check by the software administrators to avoid weak quality or inappropriate content, the translation proposed is integrated and then published in ABCD SW.

3.2 TOOL for Data Retrieval

3.2.1 Introduction

In this section of the thesis, I describe a learning analytic tool integrated in the ABCD SW, which allows ABA users (tutors and parents) to visualize information about the learning trends of children executing the software – the enhanced intervention previously illustrated [10].

Why is this tool necessary? ABA intervention aims to modify behavior starting from the antecedent and consequent analysis of any situation in which the child with autism shows inappropriate conduct. Therefore, it is very important to collect data regarding behavior. Literature offers several data collection systems for monitoring children's behavior. Leroy [54] presented a digital library of data related to appropriate and inappropriate behavior of children with autism in different social settings during the therapy, which includes video recordings. Decision trees and association rules provided more detailed insight into high and low levels of appropriate and inappropriate behavior. However, it is less frequent to find implementations of systems for monitoring learning trends of autistic children. Among these systems, we mention DDtrac [23], software for educational programs in autism. It supports the collection and analysis of quantitative (instructional data, social data and behavior data) and qualitative data, for documenting the progress of children.

Another contribution is offered by the Kellar Instructional Handheld data (KIHd) System [92], a real-time data collection tool for gathering instructional data about students diagnosed with autism. The software presents a database-driven handheld-based data collection and analysis system.

Those examples, DDtrac and KIHd, require manual input of data from the therapists. Conversely, our software automatically records and stores most data, such as programs, levels, categories, articles, progressive number of trials, errors and time elapsed between the trials as well as the child's response. In addition, tutors complete the evaluation of the exercise by simply pressing a key on the keyboard (to insert the type, full or partial -- and percentage of prompt provided, or to record inappropriate behavior). In this way, data can be analyzed homogeneously.

Concerning automation in collection and analysis of data, there is ABPathfinder (http://www.abpathfinder.com/), a cloud-based software program that improves the efficiency and effectiveness of ABA therapy by reducing paperwork and improving data outcomes. Unfortunately, ABPathfinder is a commercial product with additional costs for the family of an autistic child, already burdened with the cost of the behavioral intervention.

Of course, pros and cons derived from digital collection and analysis of data resulting from behavioral intervention could be carefully considered. Recently Tarbox et al. compared the use of a PDA (Personal Digital Assistant) for collecting behavior data with traditional pen-and-paper data recording. Their conclusions were that data accuracy is equal for both formats, but traditional data collection was faster [102]. However, we claim that rapidity mainly relies on the software features and the usability of user interfaces as well as on the subjective user's

ability to insert data. Using gestures would make the process more natural. In addition, having electronic data enhances the evaluation and assessment phases.
A further advantage of having digital data of ABA intervention is the possibility of combining different data sources to have large amounts of information that could be helpful in epidemiological investigation. Where large sets of stored ABA data are available, the same can analyzed with data mining techniques. In Freeman [32] the relation between physiological events, environmental factors, and the occurrence of problem behaviors are analyzed using the data mining system called LERS (Learning from Examples based on Rough Sets).

3.2.2 The proposed Tool

A didactic session of about 2.5 h can produce a large amount of data since the trials are very short. The behavioral data types used in our analysis mainly refer to an event sampling, i.e., how many times the behavior occurs in a defined range of time. The possible behaviors are related to the learning: articles and categories mastered, successful trials, errors and prompts. The learning analytic tool we have developed in ABCD SW elaborates data gathered by the software and shows it through graphs and charts to make it quicker and easier for tutors to monitor and evaluate a child's progress, and consequently, if needed modify the objectives of the ABA programs to improve learning and/or behavior outcomes.
The tool supports tutors in data analysis, automatically aggregating and extracting data according to the preferred view and displaying it in an intuitive rendering. The tool is a web-based application implemented in PHP and JavaScript that relies on an SQL database for extracting session data. The implementation makes use of the jQuery framework.
The application is embedded in the didactic software environment for the tutor's benefit, making it easy to analyze a particular section of data before starting a didactic session, offering a quick look at the child's learning trends. This possibility is also helpful for assessing the materials before the session starts.
The learning analytic tool also helps the consultant who coordinates the ABA intervention to prepare reports before team meetings and assess future refinements. To efficiently analyze the data collected, different functions could be developed to provide data views, according to the expertise and the needs of users (educators). Thus, we decided to base the functions' design on what tutors usually look for when analyzing the child's data of the ABA sessions, traditionally recorded on paper.
During the learning activities, tutors are mainly interested in collecting data that could reveal a positive/negative learning trend and increased/decreased occurrence of problematic behaviors. Periodically tutors need to assess the intervention based on the current status of the child. They need to analyze the following data type: 1) period of time it took to acquire a certain article, thus knowing the dates of its introduction and mastery; 2) number of articles mastered in a certain period; 3) occurrence of problem behaviors and 4) quantitative/qualitative evaluation of use of tutor's prompt during the exercises. The ABA-based didactic software records all this data related to the children's trials. Therefore, the proposed learning analytic tool provides a basic set of queries that tutors usually need and that are arduous to implement manually. However, if the pre-defined

queries implemented are insufficient, it is possible to save raw data from the database to refine the view and the analysis as preferred.

The tool supports multiple types of charts in order to show the child's progress. Stacked bar, multi-line and single-line charts are used to show the results of different queries. To implement these charts we used Highcharts, a library written in JavaScript that offers intuitive and interactive charts to web sites or web applications. This library is supported by the most recent versions of browsers, including Safari. Highcharts allows users to interact with charts providing access to the information according to levels of increasing/decreasing complexity, i.e., obtaining detailed or overall information. For example, if there is more than one data series, the user can click on one of them to hide or unhide it, selecting what to highlight. Indeed, when 'on mouse over' events above the charts occur, a tooltip text with information is shown on each point and series following the movement of the mouse over the graph. Another interesting feature is that by zooming in (in the X or Y dimensions) on a chart, it is possible to closely examine a particular portion of the data related to a short period of time.

Two buttons on the upper right of each chart allow the user to manage data shown by the tool, for instance to produce reports. One button automatically provides a print version of the chart; the other button handles data saving in various formats: PDF file, image PNG or JPEG, or SVG representation.

Finally, we implemented an additional JavaScript function that allows users to automatically export and download all the data extracted by the learning analytic tool into CSV format. This feature permits further elaboration processes not provided by the tool.

To access the learning analytic tool, the tutor typically logs in as usual. After login, s/he can decide to access the didactic software or the learning analytic tool by pressing a button on the UI. In this way, the data analysis tool shows only data related to the child selected in the login phase. The first page allows the tutor to choose from among six different predefined queries. For each query, the user can set a time interval by specifying the start and the end date of interest. The queries are described in detail in the following:

1. Articles: Allows looking for information about articles used in the didactic session during a selected time interval and detailed in a monthly resolution. A filter permit to easily look for a single item in a category, for all the articles in that category or for all the articles without category distinction. Results are shown in table format. For each article, the table reports the number of trials performed on each article and the ABA programs in which the article has been totally or partially mastered. Clicking one of the articles opens a pop-up with more detailed information, such as the date of the first and last use. A button allows downloading data selected in a CSV file.

2. Categories: Shows a table with the list of categories used in the didactic software sessions executed in the selected time interval, detailed in a monthly resolution. A filter allows looking for data regarding a single category or for global data concerning all the categories used. Clicking one of the categories produces a pop-up with more detailed information, such as the date of the first and last use of the category and the list of the articles used. A button allows downloading the data selected in a CSV file.

3. Articles Mastered: This query reports the number of articles mastered by the child, the number of sessions performed and their ratio. The query results are

created in tabular and graphic formats. In Fig. 3.17 the upper line (blue) shows the number of articles mastered vs time, and the lower one (red) represents the number of articles mastered compared to the number of sessions completed. The number of sessions is an important parameter in such an analysis since it can highlight a child's greater or lesser need in terms of frequency of work (session hours) in order to obtain good results. The chart can be dynamically modified to highlight specific information, selecting only the line of interest.
As previously mentioned, for all the graphs on the upper right side of the chart two buttons are available (see Fig. 3.17): the first for the print version of the chart, and the second for exporting/downloading it as a PDF file, a PNG or JPEG image or an SVG vector image. It is also possible to download all the data extracted by the query into CSV format.

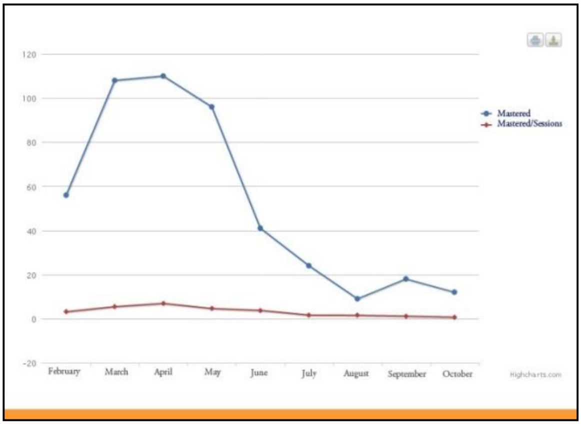


Fig. 3.17. Graph of number of articles mastered vs time

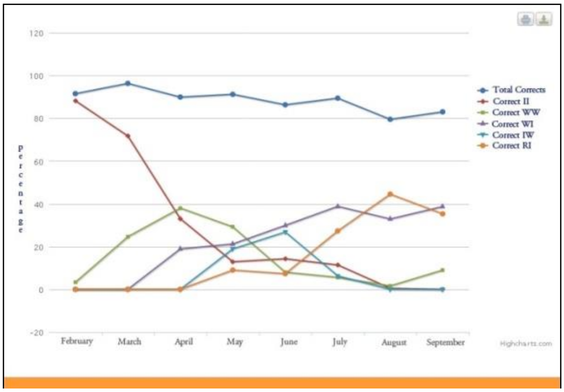


Fig. 3.18. Graph of correct trials vs time

4. Successful trials: The query returns the percentage of correct independent trials performed by the child (without prompt) through ABCD SW. If needed, the tutor can access an additional table available through a pop-up menu with the list of the articles used in each trial. Information is shown as a textual table and as a chart. An example of the chart produced by this type of query is shown in Fig. 3.18: the acronyms refer to matching (M) and receptive (R) programs indicating whether combinations of Images (I) and Words (W) are used, as described in paragraph 3.1.1 of this chapter. It is possible to print or download the chart in a different format, and to download raw data in CSV format. The chart can be dynamically modified to highlight specific information selecting only the line of interest.

5. Error types: The query provides the percentage of different kinds of errors (i.e., error performing the exercise, auto-stimulation, no collaboration). It is possible to obtain information on which article was under acquisition when the child made a specific error, at which level, and so on (Fig. 3.19). The chart is interactive and allows highlighting specific information. It is possible to print or download the chart in a different format, and to download raw data through a CSV file.

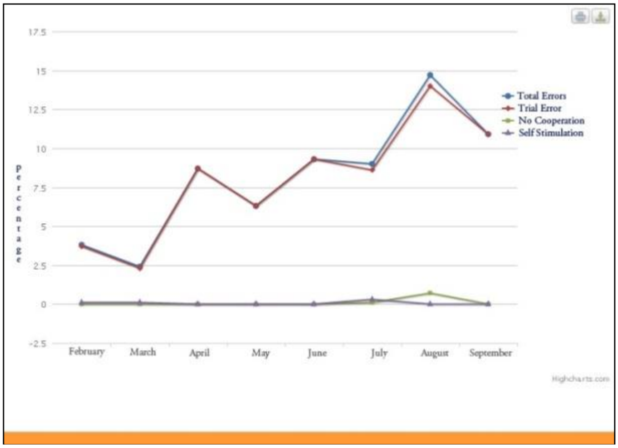


Fig. 3.19. Graph of error types vs time

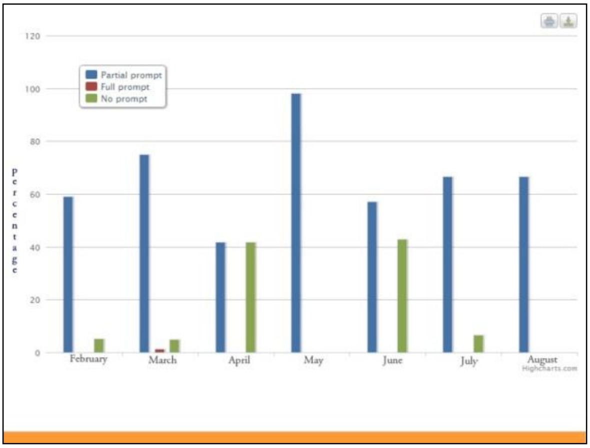


Fig. 3.20. Graph of prompts provided vs time

6. Prompts provided to the child: The query returns the percentage of occurrence of different levels of prompts, aggregated by relevance, i.e., Full prompt, Partial prompt and No prompt. Recall that the didactic software allows easy recording of prompt levels by pressing a key on the keyboard; keys from 1 to 5 are associated with percentages from 0% to 100%. All the data information is shown as a textual table and as a chart; an example of outcome is shown in Fig. 3.20. The chart is the result of grouping the prompts by the three above mentioned classes. If a more detailed view is desired, this query provides information (in table format) about the articles for which one or more prompts have been needed. For this type of query, a daily view of the use of prompts is also available, if required. As for the previous queries, it is possible to dynamically modify the chart to highlight specific information, print or download it in different format, and to download raw data in CSV format.
The tool can also be used outside the didactic software environment, although the database exploited is certainly the one collected by that software. This can be useful for offering an overview of the learning results to different subjects involved -- also indirectly -- in the intervention. In this case, after the login phase, it offers a look at the data of all the children associated with the logged-in tutor, since a specific child was not selected. In this way, it is possible to process the data of all the children together, in order to obtain information extended to the whole working group.

Results from an online questionnaire for evaluating this learning analytic tool showed that it was well-appreciated. The 12 ABA professionals that used it in conjunction with ABCD SW said it reduced the effort of manually retrieving the large amount of data produced in ABA sessions: each tutor is able to view the child's performance in real time, useful at the beginning of each intervention (to rapidly see previous progress) as well as for child assessment.
Thanks to the online questionnaire, we collected suggestions from the users that permitted us to improve the tool's usability as well as the efficiency of information retrieval performed.

4. THE PILOT TEST

4.1. Approach

A test with seven autistic children (aged 2.5-10 years) was performed during the 2012 school year. The main aim of this test was to refine the ABCD SW, enhance its functions, improve the user interfaces and mainly evaluate the effectiveness of behavioral intervention mediated by the software. Children were recruited by LASA (Lucca Associazione Sindromi Autistiche), a no-profit association of autistic caregivers promoting ABA for the care of autistic children, which contacted parents and set up specific agreements with the children's families. Three children started ABA in conjunction with our user test and four had previously followed a behavioral intervention, generally for 1 or more years. The first 3 months were spent introducing newcomers to applied behavior analysis and to coordinate schools in order to guarantee an intensive school and home intervention of at least 25 h per week.

4.2. Data Analysis

Data analysis in the project was conducted comparing the ABCD SW system to the traditional system in which data sessions are recorded on a paper-based model [4]. The paper-based model consists of daily data collection forms (for recording session trial data) and a notebook of ABA programs, periodically updated (programs are constantly adapted to children's progress).
The daily data collection form contains 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 plan specifically designed 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 dates are also copied in an electronic spreadsheet for building learning graphs.

At the end of each session, a comment is written to report situations that could be relevant for subsequent sessions (greater pleasure shown for certain reinforcements, a disturbing/distracting event to avoid, a specific difficulty, an exceptionally positive mood, something that compromised the success of the work, etc.).

ABCD SW was designed to support the ABA intervention in its execution and to allow the electronic annotation of session data, trying to reduce the use of paper forms. All the traditional paper form features are retained: 1. type of work: category, program, article, etc.; 2. number and quality of responses, recording data of each trial and the percentage of prompts used; 3. acquisition of articles, with the date of first use and mastery of each; 4. the tutor performing the session and 5. any useful comments for depicting a reconstruction of the child's progress that the following tutor can access before starting the session. In the electronic system, data on the child's behavior is also collected in order to facilitate data analysis and highlight problems for early intervention. In the following, some differences between the paper-based collection of data and the automatic one provided by ABCD SW will be discussed.

Accuracy of data collection. Paper documentation is not always accurate, since recording the different types of data requires time and organization and since it is often not a real-time activity, it suffers from human errors. In addition, datasheets are peculiar and not useful without human mediation [58]. Sometimes when analyzing data collected with the paper-based system gaps were found asììsince not all trials were recorded, thus preventing an exact comparison between the timing of the articles mastered in the two work modalities -- standard and through ABCD SW. Instead, data collection in the ABCD SW ensures that data are recorded automatically and accurately, and are always available and accessible.

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 carried out for each program.

Real-time graphics. Data is available immediately for the creation of real-time graphs to be used by the ABA team. Evaluation of the performance can thus be rapid and constant, since charts are taken from the database, constantly and automatically updated when new trials are executed.

Targeted search. Software interfaces conveniently designed for data analysis allow elements to be found quickly and precisely, e.g., when searching 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 time required for mastering an article is 2-3 days on average (from 2 to 6 sessions, assuming that children have 1 or 2 sessions per day). Each child has his/her own learning pace, so timing of the acquisition 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 4.1. For the same programs performed with the ABCD SW sessions, in the period examined the average was a little less than 2 days x article (consider that during tests with the SW the children generally conducted 1 session per day, sometimes 2, depending on school commitments). All children surveyed had been doing ABA for at least a few months, and some of them for a few years, so the program proposed via software was conducted in parallel to their ABA plans, or as a generalization of previously established skills. In this last case, ABCD SW was used as a way 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 4.1**. Mastered articles with ABCD SW: average time*

Child	Average time to master a single article
1	1-3 days
2	1-2 days
3.	1-3 days
4	1-3 days
5.	2-3 days
6	2-4 days
7	1-2 days

***Table 4.2**. Generalization with ABCD SW: mastered articles*

Child	Articles generalized with ABCD SW
1	75%
2	80%
3.	40%
4	42%
5.	21%
6	10%
7	73%

In all cases studied, acquisition times for articles not previously introduced through the traditional sessions and taught directly via ABCD SW are shorter than the standard ABA ones.

For example, child 6 takes on average 2-4 days (from 4 to 8 sessions) to master an article in the matching programs during the standard sessions. The time for mastering new items in the same programs is reduced to 2 days (from 2 to 4 sessions) with teaching via ABCD SW. We noted that acquisition times are further reduced to 1-2 days (from 2 to 4 sessions) proportionally to the number of articles mastered in the same program, probably because the procedure of teaching encourages the consolidation of the ability to match elements. Table 4.3 shows the total number of items mastered by each child during the period January-June.

Reporting the sessions. To correctly analyze the amount of work proposed to the children in terms of session time and number of items mastered, it is important to verify that each student has maintained on average the number of sessions useful for the development of learning, according to their specific sustainable rhythms. The automatic reconstruction of the session dates using ABCD SW allows creation of charts for analyzing the relationship between number of sessions and items mastered, useful for an ABA consultant to verify learning trends (Table 4.3).

Table 4.3. *Mastered articles for sessions*

Child	Total articles mastered	Total sessions	Ratio articles/sessions
1	203	87	2.3
2	225	54	4.2
3	216	86	2.5
4	122	40	3
5	189	112	1.7
6	181	91	2
7	240	112	2.1

Considering the ratio between the total number of mastered items and the total number of sessions undergone in the user test period for each child, the result is more than satisfactory. For example, I will analyze the learning curve of child 6, as shown in the mastery curve of the graphs produced by ABCD SW (Fig. 4.1).

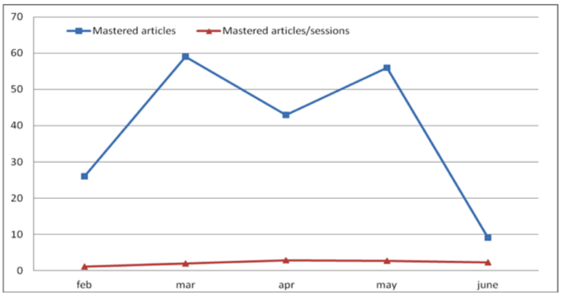


Fig. 4.1. Total mastered article and ratio mastered article/session

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), it is possible observe that the learning trend was increasing at the beginning and later it is almost stable over time. The decline in the month of June simply means that fewer sessions were held (due to school ending) and the child spent less time studying with the SW (ending also the user test phase). 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 a 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 have 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, depending on the child's ability. Some children (1, 2, 4, 7) reached the expressive stage, while others worked only a few 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 at that level and to advance the child to a higher level, or to move to the next program (article mastered).

Using the prompt. 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, having to work hard to remove that error from memory. The prompts are needed for this purpose: to prevent the occurrence of an error. Moreover, the use of prompts needs to be gradually reduced (fading phase), so it is important to be able to check the percentage of prompts provided to the child during the exercises in order to understand the level of difficulty proposed and when/how to introduce "fading".
Analysis of data confirms that in all subjects studied the percentage of prompts was higher at the beginning of the SW use (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 provides a detailed view of the periods/days when the child's work was supported by some aids (different types of prompts). The following table shows the percentage of total prompts used in the period January-June for each child:

Table 4.4. *Full prompt*

Child	Percentage of full prompts
1	0.96%
2	0.46%
3	2.49%
4	0.42%
5	6.08%
6	8.96%
7	1.81%

Overall, the amount of prompts provided during the ABCD SW sessions is comparable to that provided during traditional sessions. For some children (1, 2, 4 and 7) it was considerably lower, owing to high percentages of generalization, since the work on many articles was carried out more easily.

4.3 Discussion

Analyzing 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 a child with autism with the tutors, parents and teachers, the relationship developed during ABA sessions should be encouraged 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. This would allow a more objective assessment of learning directly introduced through the SW to better evaluate the effectiveness of different educational systems.

ABCD SW offers technology-enhanced rehabilitation that performs better than the traditional approach. The software, scalable and safe, offers efficiency and efficacy, adapting the discriminative stimulus and format to the child’s abilities. This result is in accord with a recent clinical systematic review of behavioral interventions for children with autism, which suggests that ABA may improve some core symptoms compared to special education [70]. 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.

4.4. Software Assessment

In order to verify these preliminary findings, we conducted a further evaluation using subjective (qualitative) and objective (quantitative) methods [11].

4.4.1 A Subjective evaluation

An online survey has been designed and implemented using GoogleDocs. The URL of the questionnaire has been sent to the ABA team following the participants in the user test.

The questionnaire was composed of two parts aimed at evaluating the classic ABA intervention and the technology-enhanced one using ABCD SW. The purpose of the questionnaire was to evaluate the effectiveness of behavioral intervention mediated by the software in terms of skills and progress achieved by the child as well as the degree of satisfaction of both children and caregivers who followed the child during the training. The results were represented as frequency distributions.

As shown in Fig. 4.2, we collected 47 questionnaires; among these 70% were ABA professionals with specific training (tutors, senior tutors and consultants), the others were parents and teachers.

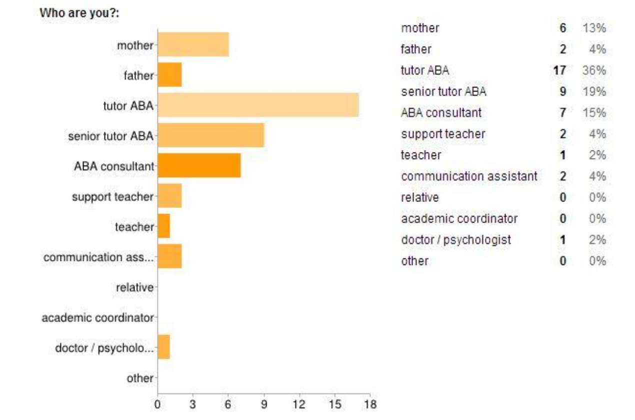


Fig.4.2. Distribution of Survey Participants

Almost the entire sample of users (91%) was satisfied with being part of the project; three persons attributed their low satisfaction to the particular and complex situation of their child (Fig. 4.3).

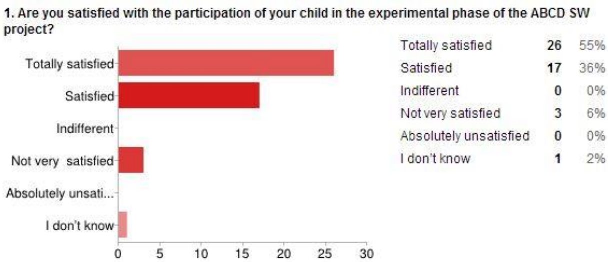


Fig.4.3. Participant's satisfaction

Regarding children's progress observed by participants during the intensive ABA intervention, 98% of the users declared that their children showed progress in different abilities, 72% observed significant improvements, arising from the enlargement of the working environment and the exposure to different situations (Fig. 4.4).

Fig. 4.4 Children's progress

Since the ABA team involved in the project was able to guarantee an intensive intervention (at least 25 h per week) each child was engaged in structured learning of more sustained work than usual. More than half the participants observed positive changes in the children and high pleasure in executing assigned tasks, and in general a good degree of collaboration from all the children (Fig. 4.5).

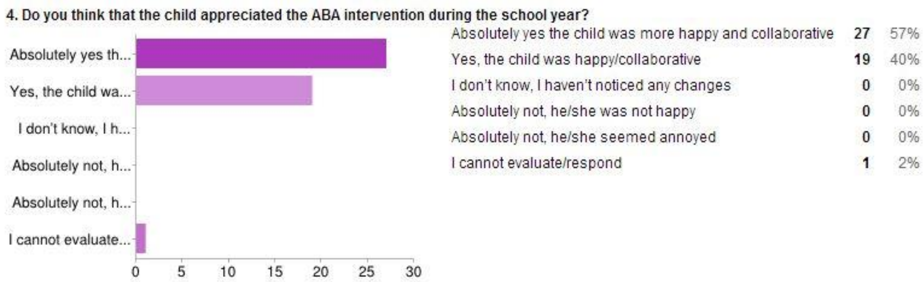


Fig. 4.5. Liking of the ABA intervention by the children

Significant improvements in the child's communication were observed by 60% of participants. The use of AAC and PECS aims to favor any kind of communication (visual, gestural, spoken). Globally, 98% of the sample declared that children increased the number of communication intents (Fig. 4.6).

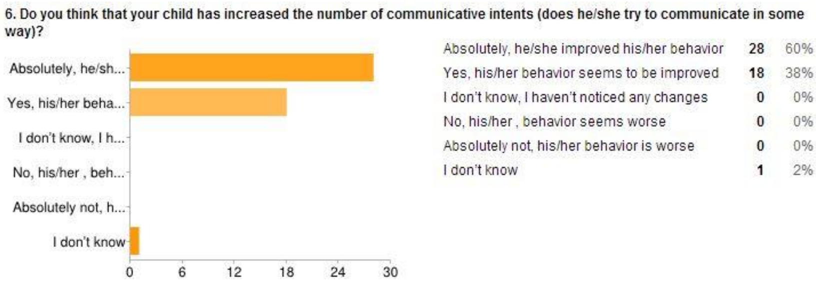


Fig. 4.6. Improving communication

The primary goal of any behavioral intervention is the modification of a child's responses to environmental stimuli in favor of a more frequent occurrence of correct behaviors, appropriate to the context. Asked about that, 97% of the sample answered that correct behaviors seemed to increase in frequency for their children (Fig. 4.7).

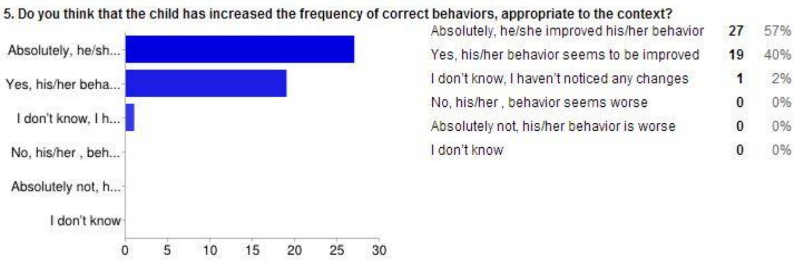


Fig. 4.7. Frequency of correct behaviors

Unfortunately, increasing the number of correct behaviors does not necessarily mean decreasing problem behaviors. ABCD SW was considered useful in this respect as well. Indeed, concerning frequency of problem behavior, responses showed that for the children presenting problem behaviors at the beginning of the intervention (6 out 7 children), their frequency decreased over the year (38 users noticed a decrease in that type of attitude, as shown in Fig. 4.8).

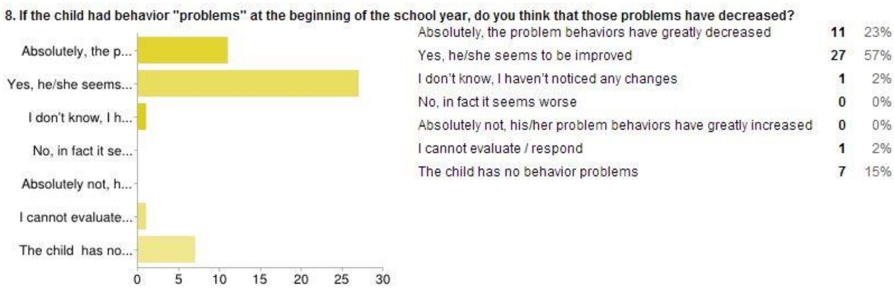


Fig. 4.8. Decrease in problem behaviors

Among different types of problematic behaviors, we also analyzed the perception of users regarding the occurrence of stereotypies and self-stimulations, typical autistic behaviors. A total of 66% of users observed that children had reduced self-stimulation during the intensive ABA intervention (Fig. 4.9).

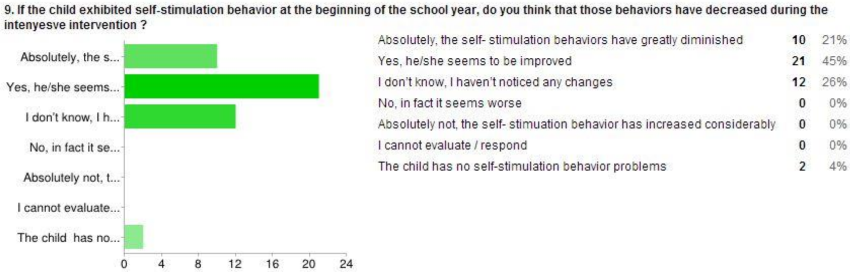


Fig. 4.9. Occurrence of self-stimulation behavior

The increased frequency of correct behaviors observed by participants might be in some relation with greater communication and comprehension of the surrounding environment, which could induce greater cooperativeness of the children. The subjective evaluation showed that 91% of the subjects interviewed think that children were more collaborative during intervention than at the beginning of school (Fig. 4.10).

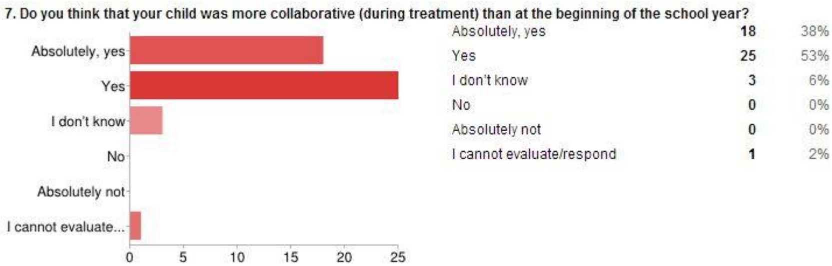


Fig. 4.10. Children's cooperativeness

Moreover, ABA intervention also seems to be a good way to improve social attitudes. A great percentage of users (91%) think that their child expressed more sociability during intervention respect to the previous period (Fig. 4.11).

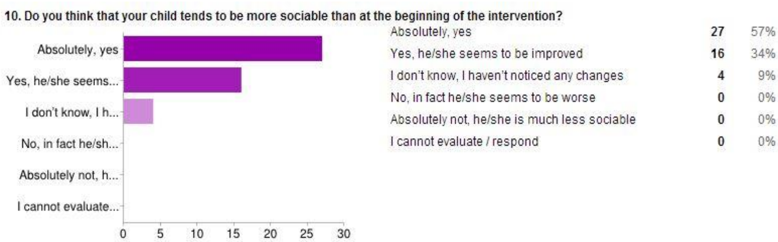


Fig. 4.11. Social skills of children using SW

For the second part of the questionnaire we collected fewer answers (33 users instead of 48), since parents and consultants might not have worked with ABCD SW. Tutors took the touchscreen tablet away after the ABA sessions, not leaving it to the family for educational reasons: the tablet might be given to the child as a free play object and possibly inappropriately used for self-stimulation. Furthermore, if not used for a short time, children experience a desire to work with it and they are stimulated to have appropriate behavior because working with the touchscreen tablet operates as a positive reinforcement.

Children greatly appreciated the use of the tablet (iPad), as shown in Fig. 4.12: more than 50% appreciate the tool. One of the children, who was unable to focus attention on using a computer or watching TV before the user test, showed great interest in and increased attention to using the tablet as a personal learning environment, probably due to easy touch interaction and clear images, available in a reduced screen adequate for his little hands. When we bought the tablets, we also purchased an associate protective insurance coverage in case children threw the device on the floor. Instead, they all take care of their tablets, not manifesting any aggressive behaviors with them.

Fig.4.12. Children liking the software

Concerning usability of the software – effectiveness, efficiency and user satisfaction – participants expressed positive evaluations.

4.4.2 An Objective Evaluation

Table 4.5 displays some of the information about the ABA strategies that the ABCD SW provided as data storage and analytics that enable accurate tracking and precise monitoring of the learning path. The results are presented as medium values of the participants' learning path.

***Table 4.5**: Medium value of learning path indicators in matching programs for the entire user group*

	Image Image		Receptive Image	
	Average	SD	Average	SD
Sessions	97	60.43	7	3.1
Introduced articles	316	82.6	43	14
Mastered articles	133	89.7	8	2
Introduced categories	13	0.9	2	0.5

As shown in Table 4.5, in order to evaluate the entire child sample we focused on two of the six programs implemented by ABCD SW: matching program (Image/Image) and receptive program. Although all the children did the same training in terms of hours spent with the SW, each of them worked differently contributing to this analysis with a non-homogeneous number of observations. For example, some children need to work in many sessions of short duration, with an intermediate pause, other children work better without interruptions. During the pilot test only two programs were completed at 80% by all the children; the other programs were started in some cases or not explored at all in other cases. The matching program and specifically Image/Image is introduced to all the children at the beginning of the intervention because it is the simplest and requires only basic expertise. If the child is unable to work with words (due to age or ability) all matching programs involving text are temporally bypassed and the student moves to the Receptive program based on images. Thus the matching image/image and the receptive with images programs are used the most. With these first programs, the tutor was able to verify that:

- Each child had become familiar with the tablet and with the new work environment; familiarization is more successful if done starting from the basic program, more immediate and intuitive.

- The child has learned the concepts proposed to him with the traditional ABA mode and he/she is able to generalize them via the abstraction introduced by the software. With respect to this use of the software as a means of generalization, we verify a greater number of trials made on the upper levels of a single program; it means that for many items we started directly with the mass trial with one non-neutral distracter. Only if an item was introduced for the first time (or not actually learned), did the tutor propose the full work flow starting from the easier levels of difficulty: Mass Trial, Mass Trial with one neutral distracter, etc.

In about 6 months (January-June 2012), each child did an average of 97 sessions. The high SD (Standard Deviation) indicate that children did not work uniformly, as previously mentioned. However, the number of sessions per se does not help us if we do not connect them with the results in terms of concepts introduced and mastered. Each child had 316 items introduced, about 3 items per session, considering that the child works with one article at a time and moves to the next one only if he performed all the levels for that article. About one-third of the articles proposed were mastered. Both the SD values of the proposed articles and the articles mastered are high for the usual reason that children worked in different ways (number of articles introduced) and achieved non-homogeneous results (number of articles mastered) due to the different children's profiles with respect to the syndrome.
The average number of categories introduced (13 for image/image and 2 for receptive image with SD of 0.9 and 0.5 respectively) is homogeneous between the children; it means that all children worked more or less with the same number of categories. Comparing data regarding sessions done and articles introduced, it would seem that those who worked more (greater number of sessions and articles

introduced) did so within the same category. This is possible because of some large categories such as *Labels (*including a large number of items not otherwise classifiable).
Considering the other matching programs involving words, carried out by only two children, as an example, Table 4.6 shows the results obtained by one of them.

Table 4.6*: Number of sessions, introduced and mastered articles and introduced categories in the other Matching programs of one child (not included in Table 4.5).*

	Word Word	Word Image	Image Word
	(n)	(n)	(n)
Sessions	66	18	9
Introduced articles	151	115	48
Mastered articles	95	28	11
Introduced categories	8	5	3

Overall VABS-II data were aggregated and analyzed. Statistics for changes from T0–T1 on measures showed significant differences ($P < 0.05$) on Communication dimension (from a scoring of 101.0 SD = 50.4 to a score of 118.5 SD = 55.6) and in the Expressive subscale (from a value of 57.7 SD = 33.6 to 69.3 SD = 37.7) (Table 4.7).

Table 4.7*: Pre-Post intervention Vineland Adaptive Behavior Scale/Subscale mean scores*

Pre- Post-intervention Vineland Adaptive Behaviour Scale/Subscale Scores						
	Time 1		*Time 2*			
	Mean	*SD*	*Mean*	*SD*	*p-value t-test*	*p-value Wilcoxon-test*
Communication	101,0	50,4	118,5	55,6	< 0,05	< 0,05
Receptive	30,7	6,4	32,7	3,7	ns	ns
Expressive	57,7	33,6	69,3	37,7	<0,05	<0,05
Written	12,83	15,39	16,50	17,4	ns	ns
Daily Living Skills	129,7	56,4	136,2	45,7	ns	ns
Personal	99,8	28,2	104,0	18,7	ns	ns
Domestic	15,7	15,7	16,7	12,7	ns	ns
Community	14,17	15,98	15,50	16,7	ns	ns
Socialization	93,5	41,7	99,7	47,5	ns	ns
Interpersonal Relationships	37,7	20,0	37,8	20,2	ns	ns
Play & Leisure Time	37,3	16,4	39,7	18,0	ns	ns
Coping Skills	18,5	9,5	22,2	14,3	ns	ns
Motor Skills	116,3	26,2	123,5	14,3	ns	ns
Fine	41,8	18,5	48,0	10,1	ns	ns
Gross	74,3	9,4	72,2	8,4	ns	ns

4.4.3 Discussion

For each child the mastery time was shortened using the technology-enhanced intervention compared to the classic one, also since the setting and evaluation times are notably reduced with automatic procedures [4]. For the same reasons, children had more learning opportunities in terms of categories and articles introduced during computer-enhanced sessions, and this greater effort required was well-accepted.
Concerning statistic indexes, our study highlights that participants achieved improved communication skills in general, and specifically in expressive communication (for the two children who have reached this program in the test period). This is in line with previous findings. A meta-analysis of scientific literature (until 2007) conducted by Ospina et al. provides some evidence of improvement in adaptive behavior, communication, interaction, comprehensive language, daily living skills, expressive language, overall intellectual functioning and socialization when delivering behavioral treatments [70]. This benefit increases with increased intensity of the intervention [80]. However, authors question the validity of these findings since there are few studies, with few participants over a short time period.

4.4.4 Lesson learned and study limitations

During the entire project, we addressed many challenges. The most demanding in terms of economic and time effort was to coordinate the intensive intervention at home and at school, which required making agreements with the children's schools, and training teachers and parents in ABA methodology. In countries such as Italy where the educational program does not support this kind of intervention, it is recommended to set up these agreements as early as possible.

A crucial factor for the most successful behavioral intervention is the close collaboration of parents. In our test period the involvement, although good, was not completely adequate for the protocol's needs. For future work, we suggest providing a specific program of parent training beforehand.

There is a vast amount of data stored in each child session; this quantity requires further indicators to be defined in order to verify whether any statistical significance occurs on these data. On the other hand, different data could probably be recorded to allow correlation analysis between apparently different parameters. For example, in the case of occurrence of a problem behavior it could also be useful to record the duration of that behavior, not only its occurrence. In that way, we could see whether that duration increases or decreases with time and correlate this information with delays in the learning process of a certain concept that was in acquisition during the occurrence of that problem behavior.

This study presents some limitations. First of all there is the small size and the non-homogeneity of the sample; this is due to the difficulty of enrolling low-functioning children with similar functional and behavioral profiles. The sample in this study was not selected by the researchers. In common with any research based on informed consent, participation is self-selected and a certain level of sample bias therefore cannot be excluded. An Association of parents performed the enrollment of the study population and of the tutors. This led to an informal selection, not only based on the functional profile (low). A more rigorous selection of participants enrolled by medical staff taking into account age and homogeneous competences, along with the selection of a matched control group using a randomized controlled design for assessing the effects of the technology-enhanced ABA intervention, will guarantee results of higher value.

Another limitation is that the work carried out by one child is quite different from that executed by another (from only one/two programs to the expressive program). Each autistic individual is unique and has specific abilities, so the progress and the learning trends are very subjective and could depend on external factors such as family involvement, health conditions, chance factors, etc. Thus, our findings are not representative of the population with autism in preschool age. Certain types of behavior may have been overexpressed or otherwise not expressed in our sample. This makes it impossible to generalize these results. In addition, some measurement bias could have been introduced. Moreover it would be important to take into account what kind of treatment (if any) in a public or private health structure the child and/or family are undergoing.

We also need to consider that training with software was conducted by ABA tutors who are part of the project and expert in the correct use of the software, but we cannot exclude the possibility of sessions not being properly conducted (such as change of level or program at the wrong time with respect to the need of the child). Thus, our pilot study did not report on treatment fidelity. Other sources of bias could have produced contamination between different intervention conditions and ability to generalize from the findings.

However, it is equally important to evaluate progress child by child since this can provide indications for future research. In our test all children progressed steadily during the school year while a certain decrease in their performance was suddenly noticed after the school closed and support of the project for intensive intervention stopped (at the end of the school, before mid-June). In addition to the promising results of ABA intervention that derive from the systematic literature review and from the meta-analysis in this field, data concerning maintenance and generalization indicated some limitations to their effectiveness. Several studies have in fact focused on a systematic integration of social interventions within a comprehensive and long-term context of high-quality ABA support for all developmental needs. Well-designed outcome studies (and long-term outcome studies) in this field would help fulfil the need for models involving effective education for pre-schoolers with ASD.

4.5. Software Improvements during pilot test

During the entire project, including the user test, the software was tested and improved to better adhere to the tutors' needs and make the teaching methodology that implements ABA principles on electronic devices more usable.
Several adjustments and new functions were implemented during the pilot test. First, we realized that mastery of an article (the goal of the ABA programs) is not a definitive process. Sometimes it happens that a child appears to be unfamiliar with

an article previously considered mastered, so the work on this article must be repeated. For that reason, we added the status ‘suspended’ to the previous defined “acquisition” and “mastered”. Furthermore, we modified the flow among the status: a mastered article can return to acquisition status when required. Similarly, if an article appears to cause behavioral problems or seems to be very difficult for the child, tutors could decide to diversify the work, temporarily bypassing the obstacle. The implemented solution is to allow the tutor to put an article in the “suspended” status permitting a later re-approach (Fig. 3.10 in Chapter 3). In addition, the tutor can decide a priori to exclude one or more articles if he/she considers them not suitable for a specific child, putting them in the ‘excluded’ status (Fig. 3.10 in Chapter 3).

Another tutor’s request concerned the possibility of adding comments as a final step during a session. Writing comments in the software (or manually) requires time and attention, not always available when working with ASD children because for instance, the child may initiate self-stimulation or other problem behavior requiring the tutor’s attention. Therefore, we implemented the possibility of inserting/updating this data after the session, protecting the integrity and consistency of global data.

The software favors easy configuration of the most suitable child UI because it proposes the single trial of different levels/programs according to adaptability rules. For instance, a different canvas for the child’s screen is proposed according to the child’s characteristics, since the command can be presented or not depending on whether the child is non-receptive or receptive. However, especially in the case of the program “Receptive word”, an image of the target article appears near the stimulus (Fig. 4.13). Some children need this kind of discriminative stimulus as a little prompt so the tutor can control its appearance or disappearance by pressing a key.

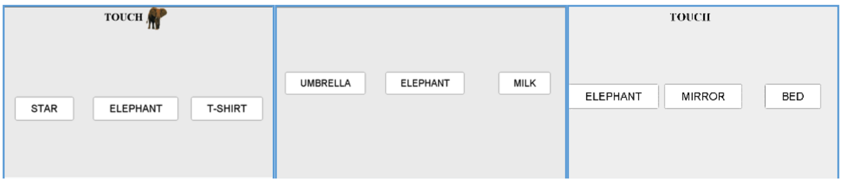


Fig. 4.13 Example of software customization: different UI for Receptive program

Another phenomenon observed during the pilot test was that children often show some problems in fine motility when dragging an element on the touchscreen display. Specifically, if they started with a basic level of the exercise that requires dragging an element in a unique trajectory (from center bottom to center top) they were often unable to experiment the other trajectories required in the following levels. To tackle that problem, from the first level of difficulty the software now assigns random screen positions to the target element so children are forced to experiment and train different wrist movements. Concerning personalization of software, a new level of customization introduced was the possibility of loading personal items in the *Places* (of the house, school and other familiar places) and *Family* categories that obviously contain different images for each child. In this case, tutors and parents can add content (images) to the database, associating

them with his/her child thanks to a user interface designed for this purpose. The association with the child user profile will make this content invisible to the other users.
Summarizing, the main characteristics of the ABCD SW customizations depending on a child's abilities are as follows.
Customizable features:

- Personalization of multimedia reinforcements (child configuration file)
- Personalization of the categories Relatives and Places (UI for items upload)
- Exclusion or suspension of problematic items (drag & drop in the tutor UI)
- Fading of the visual support for the trial ('D' Key)
- Reset of a trial if inadequate for the child ('R' key)
- Child age < 5 years: Matching programs only with words are removed from the tutor UI (child configuration file)
- If the child is Non-Receptive, the command is shown as a word in the trials (child configuration file)
- If the child is Non-Expressive, and thus cannot answer vocally, the UI shows three words from among which the child will choose the right one (child configuration file).

Regarding the general features of the software, the recovery session mechanism has been introduced to resolve the problem of an unintentionally interrupted session. ABCD SW works using the concept of PHP sessions, it means that each time a user accesses the application there is a time interval after which, if the user is inactive, the session is interrupted. Generally, a traditional ABA session must be carried out without interruption except in cases of occurrence of a problem behavior that forces the tutor to diversify the intervention trying to extinguish that incorrect behavior. In that case, the event occurred can be recorded in the database and the session completed. Nevertheless, the test phase with real users revealed that some users sometimes opened a session suspending it for hours even without having problem behavior ongoing, or it happened that the web browser crashed. These events could cause different problems in the correct closure of sessions. To face those anomalies, the software has been improved introducing the possibility to recover a session. Specifically, looking for the ID of each session and introducing another field for tracking the status of sessions, when a tutor accesses the software a query controls if incorrectly closed sessions are present in the database, and if necessary offers the user the opportunity to complete (conclude) or to continue the interrupted session (see Fig. 4.14).

Fig. 4.14 Example of Recovery Session alert message

5. WEB TOOL FOR REVISION SESSIONS

5.1 Background

ABCD SW differs from other available free software designed for teaching children with autism, since it is designed as an ABA rehabilitation tool so the child uses the application only in a 1-to-1 setting, with a tutor/caregiver. Generally, free apps for kids can be used without an adult's presence. As described above, in ABCD SW two separate environments coexist: one for the tutor and one for the child, communicating through a common database on a remote server. The application's flow, in ABCD SW, is automated but partly controlled by the tutor/parent. In such a context, the unique environment for the child is the tablet where the exercise takes place. The child's environment UI is carefully designed to reproduce only the selected task mapping exactly how it happens in traditional sessions *at the table*. The child is left alone during the trial's execution because the interface is safe and free from distracting elements while in the background the tutor monitors what is being proposed to the child and, using his laptop, inserts the evaluation data without interfering with the child's interaction, if a prompt is not necessary.
Working with ABCD SW, at a given level in the learning path, it might be useful to allow the child to go over the previously acquired articles, possibly without the presence of the tutor/caregiver. In low-functioning children with autism, mastered items are unstable: if not continuously refreshed over time they may be lost. To this end, we designed an additional web tool, integrated and complementing ABCD SW, where the child can work and do the exercises in complete autonomy. In the following paragraphs, a brief description of the application ABCD-self is presented.

5.2 The Approach

In ABA programming, teaching is done level by level and the order of programs and levels within them is crucial. The revision phase is conceived as *rotation*, or *rotations block*. According to the ABA definitions, we have a **Random Rotation**

when the trial includes three elements of the same category, one of which is the article in the acquisition status and two are chosen randomly from the set of alredy mastered ones within the same category. A **Rotation Block** is a rotation of two elements; it is the only possible when the child works with a second article in a category, not having a third element mastered available for the random rotation. It is also possible to do it after a random rotation with child errors if the tutor wants to restart the exercice but not from scratch.
Consequently, the type of exercise that the child can do during the revision belongs only to these two categories (random rotation and rotation block) within already done/mastered programs and articles.
The revision phase allows the children to reinforce the mastered concepts and provides them the opportunity to manage themselves during a work session. Self-management, however, creates new scenarios of behavior not easily predictable, which need to be verified by further test.

5.3 The Tool

The application design has required some attention regarding several aspects. First, we choose to deploy a Web application in accordance with the nature of all the tools developed within the ABCD SW project. However, that choice led to some difficulties in the implementation phases. By its nature, a Web application must be available anywhere and on any device, requiring a cross-browser programming difficult to optimize when working with different mobile devices like Android tablets and iOS iPad. Each browser has a different behavior with the current Internet technologies such as HTML 5, jQuery, Raphaël, etc. We consider that children who had worked on ABCD SW through a touchscreen tablet (specifically an iPad), would probably also like to use the same device for the revision tool both because they are familiar with it and it has served to motivate and reinforce them, as reported in Chapter 4 of this thesis. Therefore, we focused on the limitations and specifications of this particular device, the iPad, among the mobile world.

5.3.1 The UIs

Safe Environment

To provide a safe environment in a Web application has a precise meaning: to enable the child to move around within the application and never outside. Therefore, we decided to offer the Web application as a native desktop application. To this purpose, it was necessary to provide the interfaces in full screen version without any navigation element, preventing the child from intentionally or unintentionally changing the URLs of the application. Indeed, a low-functioning child with autism would be almost certainly distracted by the typical navigation elements of a web page, such as the forward/backward buttons, which probably could tempt the child to activate them repeatedly. We have designed it so that the UIs cannot stimulate the children to distraction or auto-stimulation, and it is impossible for the child to close the application and move alone out into the web unsupervised. In the case of desktop browsers such as Chrome, Internet Explorer and Mozilla Firefox, to make a web application navigable as if it were native is sufficient to enable full screen mode. For browsers designed for mobile devices, things are a bit more complicated and it is not enough to recreate the full screen mode via JavaScript but we need to use other strategies. Specifically, among possible solutions we chose to:

- Take advantage of the Safari mode '*Add to Home Screen Tab'* in full screen to access the first page of the application.
- Insert appropriate tags on each page for compatibility with mobile devices.
- Conveniently, use of the *iframe* element to call the individual application pages hosting them inside a page container. In this way, the browser does not report redirection to different pages and has no other windows that would cause the exit from the full-screen mode and the return of navigation keys elements.

Application's Flow

The application's flow is partially decided by code and partially left to the choice of the child as described in the following. At this step of the design process, we asked ourselves about the need to give the child the opportunity to make a choice. Is the child able to make a choice? In 1998 Moes [63] investigated how providing choice opportunities to children with autism impacts their performance during teacher-assigned homework activities. The author's findings supported the use of the child choice as a teaching strategy to improve the academic performance of children with autism during curricular activities. The study showed, in fact, that providing students with opportunities to make choices about the order of task completion or regarding the stimulus materials, improved participants' accuracy, productivity, interest and reduced their problem behaviors. It is worth noting that the target of the above-mentioned study was a group of high-functioning children with autism. Our application instead is intended to be used specifically by low-functioning preschool children. Nevertheless, literature shows that low-functioning children who use software for kids are familiar with software tasks where they have to choose levels, programs and so on. Obviously, the options that the child must choose should be clear, understandable and easily activated. The best way to be clear and easy-to-use for children is once again to exploit visual and vocal channels. All the active elements are therefore images and whenever there is a possibility the child might be confused, the software UI also activates a vocal feedback to help the child understand what the App is asking him.
After the *Login* phase the child can access the tool. The first user interface shows the programs list with all the programs for which there is at least one category in which the child has mastered at least two items. This ensures that it is possible do at least the *Rotation Block,* one of the two levels of revision previously described.
For each program, we propose a demo to help the child become familiar with the task required. In fact, although the child has already worked enough with a specific program in previous sessions with the tutor, he/she may still be confused by the new way of working, requiring a minimal effort in its generalization ability. The demo is activated at the first click on the program icon if the child needs it, and thus presumably if almost one of the following conditions is verified: 1) the child has already done the program in standalone mode less than 5 times; 2) a certain time

interval (settable, by default 1 week) had passed from the last time he/she did the program.
A second click on the same program icon moves the user to the list of categories to choose. As mentioned before, the software makes only available those categories that contain at least two mastered items. Clicking on the selected category activates the trial.
The interface provided is well known to the child, because it is the same UI proposed by ABCD SW. The number of elements (pictures or textual labels) on the screen depends on the program/level inside a specific program. The layout is dynamically managed arranging the number of elements on the specific dimension of the screen in order to make the task clear to the child, avoiding confusion. Similarly to traditional ABA sessions and ABCD SW, in matching programs the target element is placed at the bottom, closer to the child, and it is the only element of the UI that can be moved. To avoid any errors, respecting the ABA principle of errorless learning, if the child tries to match the target element with an incorrect item, the target is rejected and returns to the initial position; otherwise, if the match is correct the target element is attracted by the correct article, thanks to a region of attraction placed around it. According to the importance of reinforcing a correct behavior, each correct trial is rewarded with a little and customizable animated gif that appears on the screen.

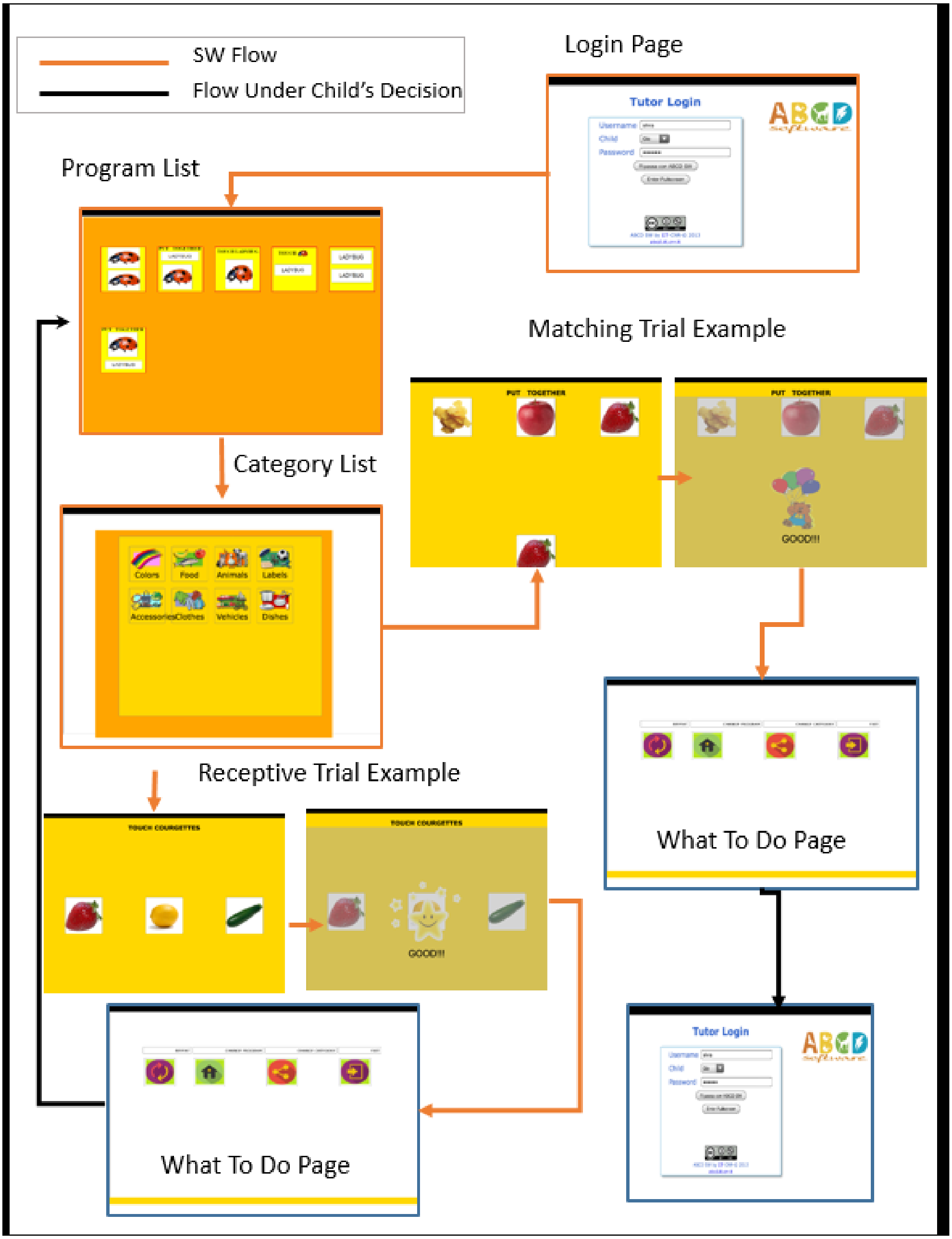


Fig. 5.1 UIs and typical work flow of the tool for revision.

The software offers the child a prefixed number of exercises (ten), and the screen is updated dynamically whenever the exercise is done correctly. According to the type of program proposed, the number of elements depicted on the screen can be at maximum four: three element and one target. It can happen that the child does the exercise wrong intentionally to activate for fun the rejection movement or in a compulsive way. To prevent the interruption of the program's flow, we fixed a maximum of ten errors in the same exercise/arrangement on the screen. Reached this maximum, the software proposes a new arrangement. At the end of the proposed set of exercises, the program presents to the child an UI for choosing the next work to do. Four images used as buttons allow the child to: 1) continue to work on the same program/category 2) change the program 3) change the category or 4) exit the application. (Fig. 5.1)

Environment suitable for children

Unlike ABCD SW, which is an environment used by the tutor where the child interacts only with one interface, the tool for the revision is completely dedicated to the child. This substantial difference needs further investigations in the field of applications dedicated to favor learning of children with autism in order to establish which specific design features promote learning and could allow us to derive good criteria for their realization. In a study conducted by Lahm [51] examining software features used in commercial programs for kids, results showed that children with disabilities, including autism, prefer program with high interaction requirements, animation, sounds and voice features. In another study, Putnam and Chong [77] collected several data from an online survey about software and use of technology among people with autism. Using open-ended questions the authors collected many suggestions for improvements in software and hardware design: responders suggest considering sensory integration issues, portability of products, easy to use and possibility to have voice activation. The 19% of responders specifically requested that software be designed with fun in mind, it means that learning experience cold be better appreciate if similar to games. In order to satisfy these requirements interfaces have been thought to be simple but eye-catching. The colors, fonts and pictures are designed to capture the interest of the child in the right way and to not cause information overload or wrong and excessive stimuli. For the same reason, all the *animation elements* and the page-loading effect being part of some windows have a speed that does not cause excitement in those kids too sensitive to changes in visual signal. On the other hand, whereas the privileged mode of interaction is the touch mode, we needed to realize the interfaces preventing the child to trigger events such as zooming in/out, elastic bounce, over-scrolling, and the other effects equipping modern browsers, with the aim to guarantee a pleasant and effective navigation experience. Furthermore, those events, if activated repeatedly, could trigger problem behaviors patterns leading the child to self-stimulate neglecting the task.

The environment should be permissive, not prohibitive: the child should navigate encountering only elements that can be activated, without interface widgets that are restricted or not allowed, in order to reduce the frustration provoked each time a user tries to select an element (button, link etc.) that cannot be activated.

Even in this context, the personalization of the tasks with respect to the child's profile, has a great relevance; if the child is non-receptive, i.e., does not respond to vocal instruction, the canvas supports the child by proposing the command as a label on top of the screen. Vocal feedback is provided in different situations. When the child needs to choose to move from one UI to another, a vocal command is announced to help the child understand what the interface is asking him/her.

Moreover, during the exercise the correct answers are rewarded by a vocal message such as: <<”Good!!”>> while the wrong responses have a <<“No!”>> as a negative feedback. The expressive program is done with labels (although the child is verbal) because at the moment there are some difficulties implementing a voice recognition system in a web page for mobile browsers with the maximum reliability. However, in our context speech can be unclear even in verbal children and could cause wrong software feedback, which is not allowed for comprehensible reasons.

5.3.2 Data Collection

The tool described herein is able to record data of child’s interaction. Specifically, data recorded refers general information about sessions like the time when the child opens a session, and information related to the programs/categories on which the child works. For each trial is also recorded the items involved, randomly extracted by software, since in the rotations levels there is no item to master. Regarding to the child's interaction with the screen, each correct trial is recorded together with any attempt to make an error -- the explicit error is not allowed to the child in accordance with the ABA *Errorless* principle as repeatedly mentioned in this document.

Considering the exercises were held autonomously, tutor does not insert any evaluation and he/she does not report any behavior problem. Of course, the child will never be left completely alone, and the presence of the tutor/parent who assists him without actively participate has the aim to eventually remedy to unexpected events.

Since data are stored in the same database supporting ABCD SW it is possible to take advantage of the tool for data extraction and analysis in order to get quick information and summary of the child’s performance. The available data are of two types: correct trial and incorrect trials; therefore, the information automatically provided are:

1. Ratio number of correct trials/ number of sessions, versus time
2. Ratio number of incorrect trials/ number of sessions ,versus time
3. Possible recurrent error on a certain article
4. Data regarding general child’s interaction with the Web tool for revision

This information is obtainable thanks to three queries implemented.

The first query implemented allows evaluating the number of correct trials illustrating through both a chart and a table the percentage of correct trials done versus time differentiates by program. (Fig. 5.2 – Left and Fig. 5.3)

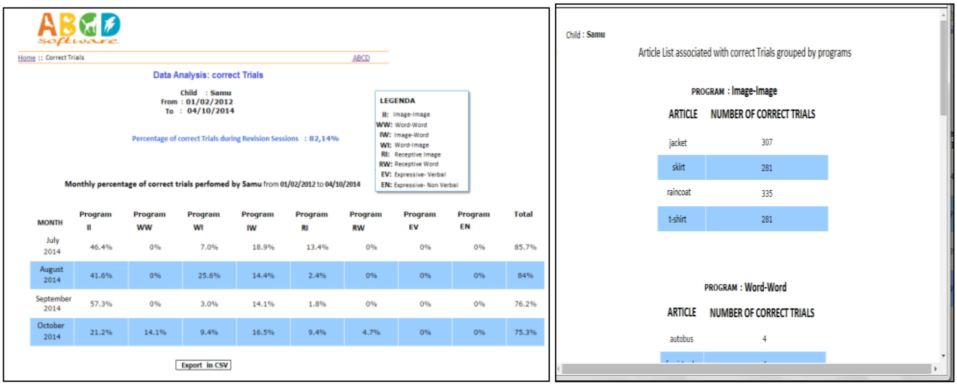


Fig. 5.2. Left: Number of correct trials vs time (table). Right: Number of correct trial per articles (additional pop up).

In addition, another pop-up of the query page shows the number of correct proof for each article involved in the trial. (Fig. 5.2 - Right)

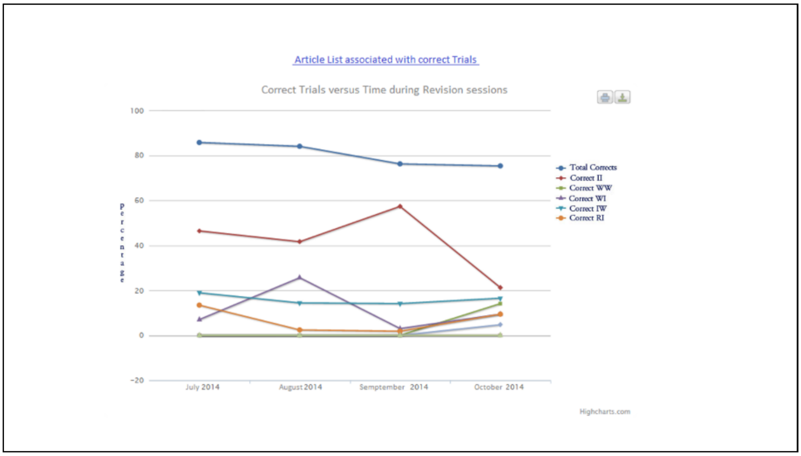


Fig. 5.3. Number of correct trials vs time (graph)

The second query allows evaluating the number of incorrect trials illustrating in a chart and in a table format the percentage of errors occurred versus time. Even in this case, another internal pop-up shows the number of errors for each article involved in the trial allowing the tutor to be informed in case of recurrent errors on the same element. As shown in Fig. 5.4 - Left and Fig. 5.5.

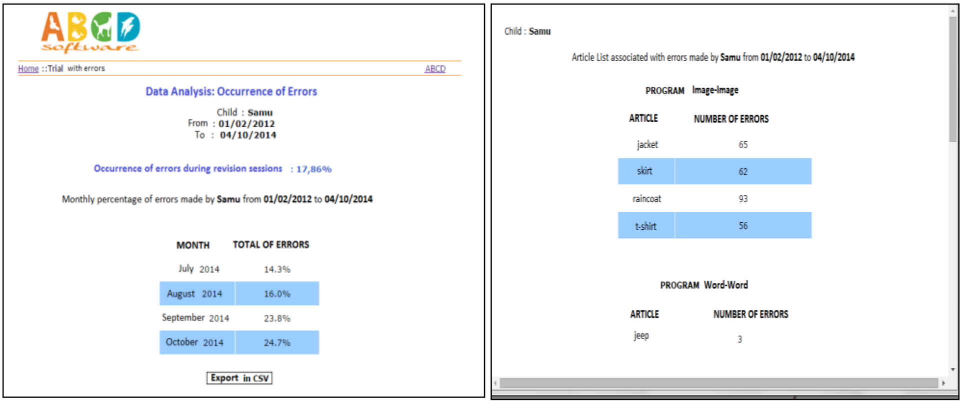


Fig. 5.4. Left: Number of incorrect trials vs time (table). Right: Number of incorrect trial per articles (additional pop up).

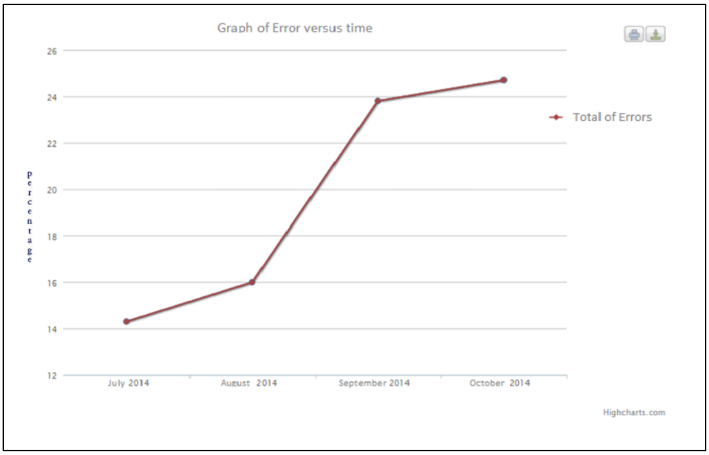


Fig. 5.5. Number of incorrect trials vs time (graph)

Data extracted by the third query concerns the child's interaction with the tool, inspecting how the child move around the interfaces. It allows knowing information such as:

- Average time spent for a session, eventually pointing out the presence of negative or positive time peaks that could reveal, if associate with other data, a problem occurred during the session.

- The number of time the child changes a program or a category.

- Average time to run a single trial, eventually pointing out the presence of negative or positive time peaks that could reflect hesitation in doing the exercise or excessive swiftness especially if the exercise is done incorrectly. (Fig. 5.6)

Home :: Session Data ABCD

Session's Data during Revision Work

Child: **Samu**
From : **01/02/2012**
To : **16/12/2014**

Child: **Samu**

	VALUE
Total number of Revision Sessions	87
Average time per session	14 min
Minimum value of time per session	7 min
Date of session associated with the minimum value	Sessione di silvia [02/08/2014 22:48]
Maximum value of time per session	20 min
Date of session associated with the maximum value	Sessione di silvia [15/12/2014 14:34]
Average number of "*change program*" per session	7
Average number of "*change category*" per session	4
Average number of "*repeat*" per session	2
Average time to perform a set of 10 exercises	3 min

Fig. 5.6. Data resulting from interaction with the revision tool (table).

The tutor can then, remotely (temporally and physically) monitor child's work and take appropriate action if necessary. To facilitate the prompt intervention of the tutor, the application periodically checks the child's performance in terms of correct and incorrect trials and, if necessary, it informs the tutor about multiple errors occurred in a number greater than a fixed threshold, especially if they are done when working on the same item. At the end of the session, if the condition above mentioned is true, an e-mail message is automatically sent to the tutor e-mail address (registered in the profile). In addition, when tutor logs in ABCD SW to start a session or to analyze data, a window alert reports what happened during the revision sessions, pointing out potential irregular events.

5.4 Discussion

The software module described in this chapter has not yet been tested with real users. It represents an interesting attempt to investigate the field of Self-Learning for children with autism. Arising from a well-known environment, ABCD SW, it will probably be easy to use for children. Conversely, it is not easy to predict the behavior of the child left alone in front of this application that guides and 'communicates' with him/her, offering a certain degree of autonomy.

6. ANDROID TOOL FOR DATA COLLECTION

6.1 Background

Safety guidelines suggest to limit to two (maximum three) hours per day of computer-assisted therapy (for problems of eyestrain and socialization of the subject, also depending on age), thus the use of the tablet has to be alternated to the classic ABA intervention performed on a table or in a natural setting. As previously described, ABA sessions can take place in different places such as the child's home, school, hospital or other places (e.g., association headquarters) to enable the process of generalization, i.e. children have to learn without be dependent from the context (tutor or environment). For this reason, portable and ubiquitous solutions are needed, since the success of ABA intervention relies on its regular and frequent execution. Moreover, with traditional sessions there is a problem to collect and combine the data. In this case, collection and processing of data can be done through the use of a tablet, with the obvious advantages of ubiquity.

In the following we describe an Android application that aims to help tutors in their daily effort of collecting data during traditional ABA sessions [6-91].

6.2 The Approach

All members of the design team have participated in ABA sessions in order to observe and better understand the natural environment where the application had to run. In order to guarantee major usability we chose the participative approach, so we design all the software interfaces according to the tutor's (the users) needs. Participation of the ABA team from the early stages of the project design has helped us build software that is fully ABA compliant. The type of data to store, their insertion order, and the controls have been defined with the aid of the person who will use the application, attempting to map as much as possible the procedure followed by tutors when recording data on paper during a traditional session on the mobile device.

Program: matching image/image
Article: APPLE
SD: Combine
Level: **MT MT+ND MT+2ND MT+D MT+2D ET RR**

N.	**Prompt** Type %	**Reinforcement**	**Notes**
1	FP 100%	Icecream	
2	FP 100%		
3	PP 80%		
4	PP 80%		
5	PP 50%		
6	0%		
...	...		

Messages: …

Fig. 6.1. Paper form for recording trial data

We selected the Android operating system, because it 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. (Honey Comb, optimized for Tablets) with display WXGA (1280x 800 pixels; 150 pixels/inch), HD 720p touch-screen and excellent processing capability (memory up to 32 GB on board and Processor speed: 1GHz Dual Core). The application is optimized to run with functionalities specifically designed for tablets. The 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 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 keep them in mind, requiring considerable effort. To limit writing/editing, both signs and gestures may be implemented, but to be very useful they must be clear and fast.

As shown in Fig. 6.1, the typical form used by a tutor during a traditional 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 application described here these data are automatically set up by the program according to the previous one inserted/selected, but they can manually modified.
According to Learman et al. [53], for each trial, we record the level of prompt used to evoke the answer in order to collect accurate information, increasing the robustness of gathered data. Thanks to the possibility that computerization offers to improve the quantity of information gathered, the original data collected was also optimized, integrating new parameters related to the child (e.g., child no-collaboration, or problem behavior) or set-up errors (tutor error) that can be useful for correlating data collected from the ABA sessions with the child antecedent or consequent behaviors.

6.3 UIs for data collection

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 (Fig. 6.2) 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
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 (Fig. 6.2). A new child may be added using the window activated by pressing the New Child Account push button (Fig. 6.2).

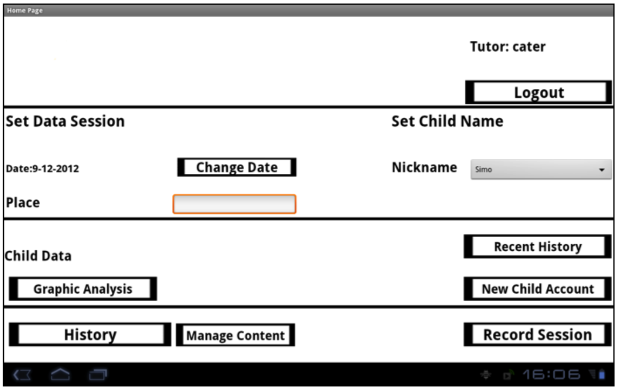


Fig. 6.2. Main user interface

The database, SQLite version 3.0, is local to the application. It is represented by a single file with a maximum capacity of about 4 Tb and it works with appropriate Java classes, both standard and customized. Data are managed in an anonymous way and accessed after the login (user and password) phase. They are associated with a child only by means of its nickname previously selected by the tutor. According ethical and privacy guidelines no personal data to identify the child are recorded. Moreover there is no sensitive data transiting on the network (since the use of the device is local).

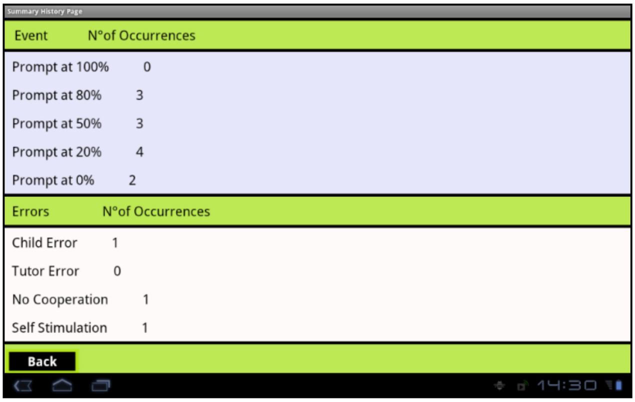


Fig. 6.3. Summary of one trial's data

As previously mentioned, before an ABA intervention the tutor needs to read all the information from previous sessions carried out by the child with other tutors, in order to choose the best program for the current learning progress.

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 Fig. 6.3. 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 user interface, the tutor moves on to the child's Recent History page, enabling access to the child's last sessions (details of one trial is shown in Fig. 6.3). Then, pressing *back button* to reach the main page (s)he can jump to the *Trial Evaluation Form*, the core of the application, (Fig. 6.4) by pressing the *Record Session* button.

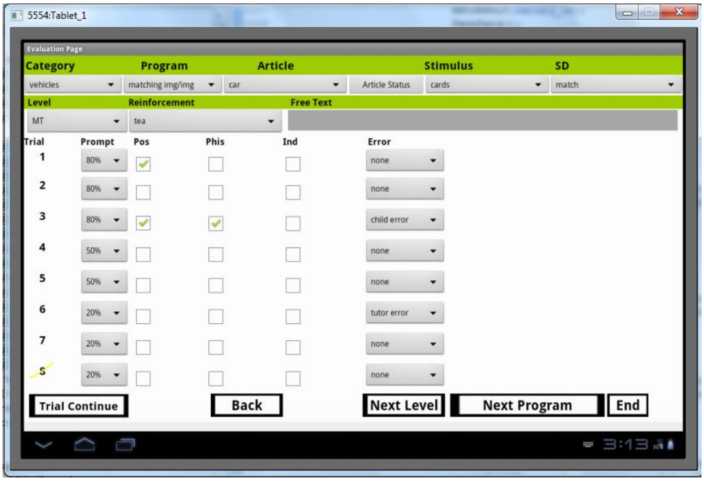


Fig. 6.4. Evaluation Activity UI

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. 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 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 work on mastered article, if the child needs a refresh. 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. Specifically to indicate the number of trials needed to the child for an exercise (the number of repetition of a specific matching for instance) before doing it independently, tutor uses a gesture above the numeric label, from one to eight, as shown in Fig. 6.5.

Fig. 6.5. Examples of Gestures frequently used by tutor

Android provides a widget of type *android.gesture* that represents a transparent control dedicated to gestural input type and which can be placed on top of other controls or contain them. In our case, the insertion of the widget has covered the label (number) which identifies the executed trial, in accord to MVC philosophy, in the xml file while methods useful for its management have been implemented in java class code. Signs for gesture were decided during design phase according to those more commonly used by tutors and they are inserted in a library to be used at runtime by the application. Due to the large density of controls in the interface have been chosen gestures like those in Fig. 6.5 that are faster than the circle, initially candidate, which requires relatively long time to be drawn. Of course, this choice can be easily changed.

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.

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.

6.4 UIs for 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 intervention. To this end, the team of specialists who deal with the child are 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 providing child-related data:

1. **Categories introduced**: this query allows selecting a child to have all the information regarding the categories (s)he worked on, such as date of introduction of the program, number of trials completed for each category and current status. All data are shown with a table layout.
2. **Articles introduced**: 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**: 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 selected time range.
4. **Correct Trials**: 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 time range. As previously mentioned, we consider a trial correct if NO prompt has been provided to the child.
5. **Errors**: query shows the graphic rendering of the learning process trend for the selected child as the percentage of errors that occurred during a selected time range. The graphic shows each different type of error occurred.
6. **Trials prompted**: 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 selected time range.

The tutor can access the Graphical Data Analysis functionality using the *GraphicAnalysis* button in the main interface as shown in Fig. 6.2. The first page of the Graphical Data Analysis tool is shown in Fig. 6.5; 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 selecting a *Start* date and an *End* date.

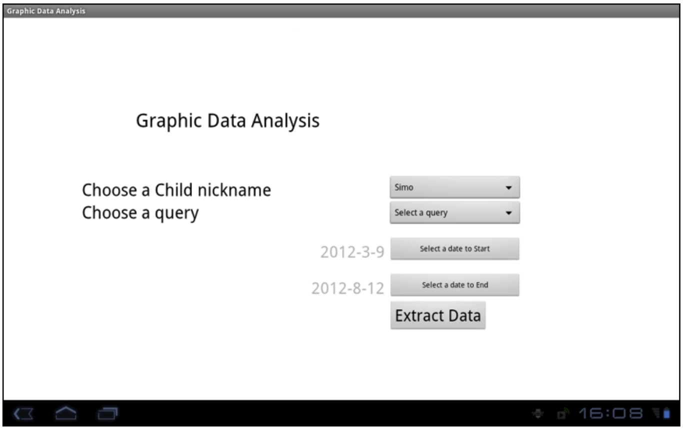


Fig. 6.6. Graphical Data Analysis, main page

In the following, as an example we show three types of queries: Articles mastered, Trials prompted, and Errors. Fig. 6.6 shows an example of a query on *articles mastered* by the child Simo from February to August 2012.

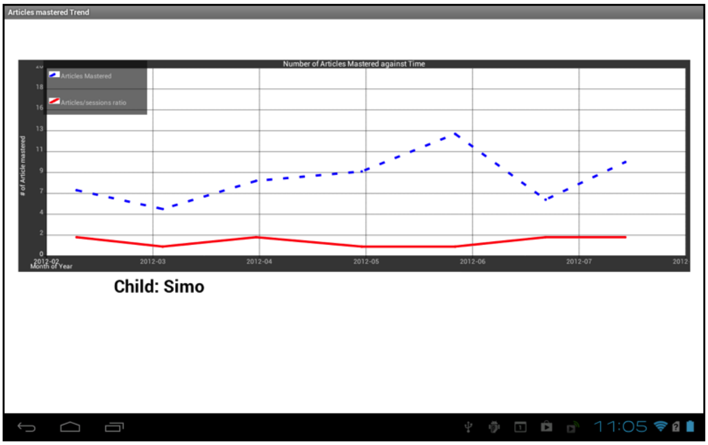


Fig. 6.7. Graphic of Articles mastered against time

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 performed. 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 Fig. 6.8:

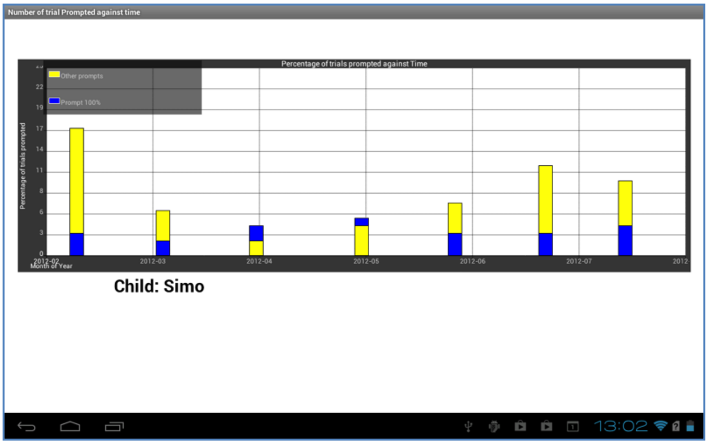


Fig. 6.8. Graph of percentage of trials prompted against time

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% (full prompt), meaning trials in which the child needed total help (blue) and prompts variable from 20% to 80% 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 Fig. 6.9.

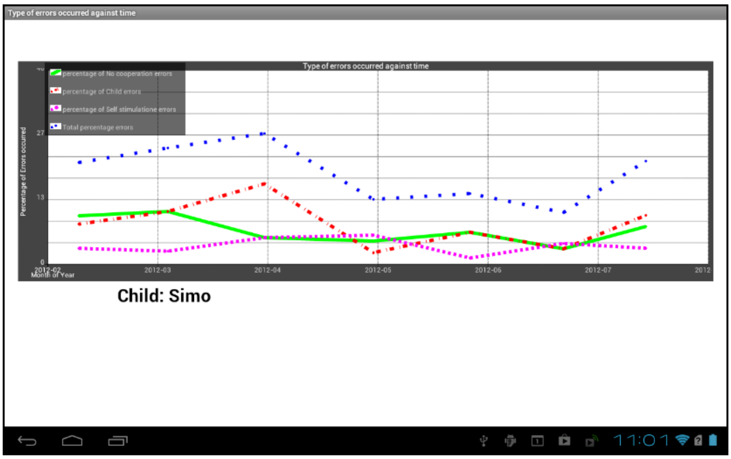


Fig. 6.9. Graphic of percentage of errors that occurred against time

The graphic shows three different type of errors: a) non-cooperative behavior of the child (green), b) child self- stimulation behavior (red), c) child errors (magenta). The blue line shows the total number of errors that occurred in the period under analysis.

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 plan a strategy to extinguish it.

6.5 UIs for Content Management

ABA session data are entered by the tutor on the database using the application. The tutor can also inserts new content, such as new categories, new objects for each category, new discriminative stimuli and new reinforcements triggering the suitable page from *Manage Content* button on the main interface, Fig. 6.2. The resulting interface is visible in Fig. 6.10.

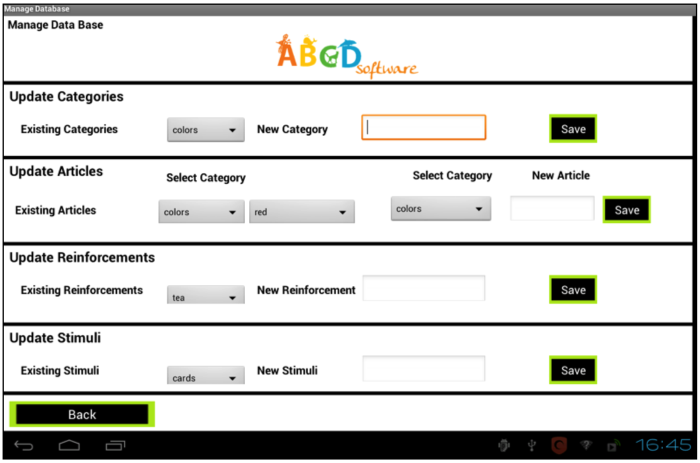


Fig. 6.10. Interface for managing database content

6.6 Discussion

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 designed involving two ABA senior tutors, a psychologist, and a pedagogic, 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, [44]) 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 work environment with the child and whether the time needed to insert data may impact on the child's attention and concentration.
Using software for data collection, 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 is normally lost in the copy from the paper to the electronic spreadsheet because the process occurs over a long 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 enable the export of query results in a CSV format, which can be sent to other devices for processing.

7. CONCLUSION

Accessible education for children with learning disabilities is still a great challenge and should be one of the main priorities of our society in order to promote autonomy, allowing them to benefit from learning opportunities and be further integrated into society. With accessibility in mind we can provide more options and greater flexibility in learning as well as respond to different needs and limitations of end users, even by simply allowing them to learn in their preferred style [43].

In this thesis, I discussed the design and architecture of a suite of applications implemented in the context of a Tuscany Regional project for exploiting ICT to support the learning process of autistic subjects. The didactic software ABCD SW, based on ABA, AAC and DTT and created for teaching low-functioning autistic children at preschool age, is the main application. This software is a Web-based application for ABA intervention that supports tutors and caregivers by automating the trial set-up and sequence, and enabling the evaluation of trials executed by the child. In this way: 1) the sequence of trials can be proposed more or less rapidly, according the subject's learning pace. 2) Data gathering is accurate since tutors are forced to provide an evaluation in order to continue the intervention. 3) The population of categories is scalable -- a web interface allows uploading new items in the category -- since no change to the code is required to add new elements.

Furthermore, the software is multilingual: all the texts of the user interfaces, the labels for articles or categories, and the commands of the exercise can easily be made available in different languages (with no changes to the software code, only the translation of these items is required).

A test with seven autistic children (aged 2.5-10 years) was performed during the 2012 school year. The main aim of the test was to refine the software, enhance its functions, improve the user interfaces and, of course, evaluate the effectiveness of technology-enhanced behavioral intervention. Children were recruited by LASA (Lucca Associazione Sindromi Autistiche), an association promoting ABA for the care of autistic children that contacted parents and set up specific agreements with the children's families.

From the 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 to foster 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. This would allow a more objective assessment of the learning path introduced directly through the SW, and an evaluation of the different educational systems in terms of effectiveness.
Overall, ABCD SW seems to be a technology-enhanced rehabilitation that performs better than the traditional approach. The software, scalable and safe, offers efficiency and efficacy, adapting the discriminative stimulus and format to a 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 [70]

We also did a statistical analysis of data gathered by ABCD SW correlating child abilities and skills, measured before and after the intervention using specific Vineland scales, in order to verify these preliminary findings. Results showed that the intensive intervention has benefited all participants. Children have manifested improvement in communication and in particular the expressive communication sub-dimension was improved ($p < 0.05$). Moreover, all parents, caregivers and the ABA team evaluated that children improved in communication, socialization and behaviors.

In conjunction with ABCD SW, we created a learning analytic tool to help tutors in their daily work. Since ABA intervention relies on the systematic collection of data in which the environmental variables involved in a specific behaviour are carefully annotated, it means that its efficacy is steadily monitored by analysing this data. The learning analytic tool favours the monitoring phase by automatically extracting, aggregating and visualizing the children’s progress, based on data from the didactic software sessions. A set of predefined queries was implemented for retrieving the most relevant information on a child’s performance over time. Data are rendered through charts and graphs, allowing the user to further explore them in an interactive modality. In this way, the application provides tutors with accurate real-time monitoring of children’s learning and behavior, allowing them to more accurately tune and personalize the intervention.

The learning analytic tool was designed involving all members of an ABA team in order to better respond to their needs when performing data extraction and pre/post- processing.
Results from an online questionnaire showed that this tool was well-appreciated by 12 ABA professionals who used it in conjunction with ABCD SW. Reasons for the appreciation are related to the reduced effort needed to manually retrieve the large amount of data produced in ABA sessions: each tutor is able to view the child’s performance in real time, useful both at the beginning of each intervention (to rapidly view previous progress) and for child assessment.

Since in low-functioning children with autism, mastered items are unstable (if not continuously refreshed over time they may be lost), we also created a safe environment where children can work independently, a sort of self-rehabilitation tool to maintain mastered skills. We designed the tool as a Web application but it is usable as a native desktop application. All the interfaces are offered in full screen version, without any navigation element so the child cannot (intentionally or unintentionally) change the application. The tool is able to record data concerning the child's performance and the child's interaction: correct/incorrect trials, UIs visited and so on. Data can be analyzed and rendered in a graphical view by the learning analytic tool. Since the tool has been only recently completed to verify the potential usefulness of this application and evaluate how the child would respond to the opportunity of working alone, we plan to perform a user test in collaboration with the ABA team and school, hoping it would open new scenarios for research in the field of autonomous learning, even for autistic children.

Besides the web tools, considering that children should work intensively during ABA interventions but not always using the technology-enhanced programs, we realized an Android-based application aimed at recording data from traditional ABA sessions. Considering that in a single 2-h ABA session 10-20 programs can be carried out, and that intensive intervention requires at least 3-5 sessions per week, it is easy to imagine the enormous amount of data produced. Usually this information is paper-based and should be shared between tutors/caregivers. The ABA approach requires in fact that different tutors rotate during the intervention sessions with the child, in order to ensure that her/his learning is not dependent on a specific person. The ABA team spent considerable time exchanging this information (recorded on paper), and this process can be error-prone. 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 data analysis. 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.

Our software tools are Web-based (and an Android app) so they are fully suitable for use with mobile devices anywhere, anytime to promote learning. Furthermore, the entire suite of this tool is open source and free, relieving families of additional costs for software (http://abcd.iit.cnr.it/). Free software has more chance of being used by many people who can benefit of it. Open source software can benefit from contributions from the developers' community, which could help us implement new functionalities to cover different ABA programs.

Future Works

In future studies it would be extremely interesting to investigate the true potential of the children with autism. At the moment, ABA intervention requires one-to-one interaction with specialized personnel and is very expensive, so it is limited to a few daily sessions. This is a restriction that might not completely exploit the actual learning abilities of the children. The creation of a controlled environment that allows children to progress in the hierarchical levels alone without the supervision of a tutor, once a degree of success is reached, might be an interesting field to be investigate. The children's controlled zone implemented in the ABCD SW is the first step toward maintaining the errorless principle while trying to better exploit the learning abilities of low-functioning autistic children. New studies are needed to investigate this potential as well as explore new strategies, even when not strictly ABA-compliant, for teaching autistic children. Specifically, we plan to build new software that relaxes the ABA constraints (1-to-1 intervention), to better exploit the potential of the Internet to collect anonymized data from a larger number of users. This should overcome the main limitations that currently afflict this study: the small size sample, the difficulty applying criteria for participant selection, and the lack of a control group.

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