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Shortages and Challenges in *Augmentative Communication through Tangible Interaction* Using a User-centered Design and Assessment Process

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Abstract: In this article, we present an assessment process on a tangible interaction application oriented to individuals with complex communication needs, called ACoTI, and details about the main results obtained thus far. The process is based on a set of decisions that have been surveyed as key elements for assessing this type of experiences, based on a background review that was carried out. In addition to that, it has taken into account the contribution of key players from the special education field and it is the foundation for the user-centered and evolutionary design of the application. A number of findings and challenges that open up the door to keep contributing to this specific area was presented. For instance, creating an authoring tool that is available for the educators to be able to generate themselves customized activities for their students, considering the specific needs of each of them.

Keywords: Authoring System, Human computer interaction, Tangible Interaction, Augmentative and Alternative Communication, Special Education
Categories: H.5.1, H.5.2, K.3.1

1 Introduction

Tangible interaction-based proposals have received special attention in recent years from designers and educators [O'Malley 04]. Numerous studies acknowledge that the application of tangible interaction (TI) on tabletops has opened huge opportunities in education with children [Marshall 03] [Rizzo 07] [Soler-Adillon 09]. A *tabletop* is a computationally augmented horizontal surface that tracks in real time conventional physical objects and allows a group of users to interact with a computer application [Mazalek 05]. These tangible objects establish a connection between the physical and the digital worlds, and they provide a richer and more natural interaction than traditional Graphic User Interfaces (GUIs) [Ullmer 00]. Tabletops have also fostered the growth of multitouch applications, which share natural interaction with tangible applications.

There are various projects that support the use of tangible interaction or multitouch based on tabletops in educational scenarios. Among the different supporting arguments, the following can be mentioned: increased flexibility, metaphor generation, (re)signification of what is known and familiar through new associations [Price 03], possibility of focusing attention on the task at hand, introduction of an additional channel to transmit information, understanding the world through discovery and participation [Marshall 07], reinforcement of face-to-face interaction and visual contact, accomplishment of hands-on activities, manipulation of physical artifacts [Mateu 13] and encouraging social interaction and collaboration [Rizzo 07], among others. Many of these educational projects include applications that focus specifically on collaboration possibilities [Fernaeus 05] and the development of social skills [Spermon 14] [Gal 16]. All of these aspects have opened the road for using this kind of interactions in the special education scenario. For example, a combination of the visual communication paradigm of Augmentative and Alternative Communication (AAC) with multimedia tangible technology is presented in [Garzotto 10]. [Chen 12] focuses on children with social relation syndromes and proposes the use of games to facilitate collaborative learning in children with autism. Along these same lines, [Silva 13] [Silva 15] present the development of a multitouch collaborative game on tabletop oriented to young people with High-Functioning Autism. Also in [Zancanaro 14] a tabletop touch-based device and a multi-mice desktop version of an application to teach social conversation and social interaction skills to children with High Functioning Autism Spectrum Disorder (HFASD) is presented. StoryTable [Gal 16] [Bauminger 07] allows to create stories and to share experiences, as well as SIDES [Piper 06], which is oriented to the development of teamwork abilities. These authors conceive this type of applications as significant tools for improving social interaction skills and developing expressive language for the target group (they are usually oriented to people with autism). In this sense, Battocchi [Battocchi 10] confirms the validity of using applications on multi-user tabletops as a tool, and focuses on the reciprocal interaction on the tabletop that provides a suitable context for the exchange.

All these previous works have provided the basis for starting our research work. However, we found that these investigations propose different paths to assess TI and multitouch experiences in special education. For instance, some of these works focus on analyzing improvements in relation to the educational goal that they seek, such as analyzing whether students achieve an improvement in social skills and expressive language or their collaboration ability [Piper 06] [Bauminger 07] [Battocchi 10]. Other articles, such as those by [Rizzo 07], [Zarin 11] and [Silva 13], focus on the usability or interaction models of the applications involved. On the other hand, [Chen 12] presents a comparison of articles using tabletops oriented to individuals with ASD (Autism Spectrum Disorder) and how these are assessed. For this comparison, variables such as assessment focus, participants involved (number and age), duration/number of sessions, participant relation setting (working alone, in pairs, etc.), and techniques used to gather data, are considered. However, there are only a handful of studies that analyze the variables and processes to be considered when assessing the use of these innovations in educational scenarios. For instance, the role of instructors during the sessions, the context required for carrying out these sessions, and so forth. [All 16] discusses the same issues for the inclusion of innovations related to the introduction of digital games to educational processes, highlighting the need to making these processes systematic to achieve more conclusive results. In this work, we present an assessment process that is specific for an application involving the use of TI in special education. The process is based on a set of decisions that have been surveyed as key elements for assessing this type of experiences, based on a background review that was carried out and considering the dimensions proposed in [All 16]. We focused on the assessment of ACoTI (Augmentative Communication through Tangible Interaction), which is an application based on TI and is oriented to the special education scenario, but in this case, specifically targeting people with complex communication needs that are starting to use AAC systems. The assessment carried out has uncovered some challenges and needs related to the use of TI in special education scenarios.

The remainder of this article is organized as follows: Section 2 provides detailed related work in relation to the use of TI and/or tabletops in special education scenarios, as well as about assessment methodologies used. It also discusses a number of key issues to consider as a result of the review that was done. Section 3 describes ACoTI and its proposal; Section 4 discusses ACoTI's assessment process, which is carried out in three phases, as well as the results and evolution of the design of the application. Section 5 discusses a number of findings and challenges and Section 6 presents the conclusions of this work and opens up future lines of development.

2 Related Work

To study how educational innovations or interventions involving the use of tabletops in educational scenarios are assessed, more specifically in the context of special education, a survey of various experiences was carried out. Works that focused on the development of communication skills or social skills using tabletops were selected.

People with complex communicational needs [Balandin 02] present various problems related to language functions and, therefore, communication. People with severe speech or language problems rely on Augmentative and Alternative Communication to supplement existing speech or replace speech that is not functional [ASHA, 16]. American Speech-Language-Hearing Association (ASHA) defines: "*AAC as an area of clinical practice that attempts to compensate (either temporarily or permanently) for the impairment and disability patterns of individuals with severe* *expressive communication disorders (i.e., the severely speech-language and writing impaired). AAC incorporates the individual's full communication abilities and may include any existing speech or vocalizations, gestures, manual signs, and aided communication. AAC is truly multimodal, permitting individuals to use every mode possible to communicate*". Therefore, AAC systems are technologies designed for teaching, learning, and using augmentative communication that allow to represent concepts and to carry out communication actions, enabling users to interact and make personal decisions in their social context [Guisen 14].

Some of the works surveyed revolve around experiences carried out with systems based on tangible interaction with tabletops, which are oriented to improving the autonomy, communication and socialization ability for individuals with social relation syndrome and/or individuals with complex communication needs [Chen 12] [Garzotto 10] [Piper 06]. To find out how these experiences are assessed, the work presented in [All 16] was used as reference, given the depth and relevance of the categories proposed in it. Even though this paper is oriented to analyzing how educational interventions through the use of digital games are assessed, the dimensions proposed for the analysis are also relevant for our work. Below, in Section 2.1, some experiences are analyzed to show how assessments are being carried out. Then, in Section 2.2, these experiences are discussed.

2.1 Review of some multitouch and TI experiences in the special education scenario

There are numerous TI experiences with tabletops for children with no specific issues or other needs. For example, in [Spermon 14], Totti collaborative game based on tangible interaction is presented for improving children interaction in a regular science club. A group of 20 children in the ages 10–13 took part in the sessions. Children visited the researchers at Georgia Institute of Technology and participated in groups of four. Each of the following criteria was measured per level of collaboration to determine whether the amount of interaction increased: how much information did each child exchange with other player? How much did each child look at another player? How much did each child look at other players' actions? [Rizzo 07] described The Fire and The Mountain game aimed at exploiting ICT in museums in a non-conventional way, and to experiment/evaluate new forms of technology enhanced learning and social interaction in public spaces. TI was used in a physical space designed to create an emotional relationship with the exhibition subjects. A group of 62 children aging from 8 to 11, participated to validate the design and to identify guidelines for similar museum experiences in the future. Qualitative data analysis methods were applied to verbal and visual data (observer' notes, video recordings, kids' answers). Spermon and Rizzo used film registration of the sessions.

Some additional articles focusing on tabletops and special education are described, but those dealt with multitouch interaction. Particularly, evaluation methodology used in each case is described, using the 4 dimensions proposed in [All 16], based on Cochrane's guidelines [Higgins 08]. These dimensions are: 1. participants involved, 2. How intervention is carried out (this dimension includes contents, format, and duration), 3. Research methods used, and 4. Measurements or indicators used to analyze results.

For example, [Battocchi 10] [Zarin 11] [Silva 13] [Zancanaro 14] [Gal 16] present different multitouch application oriented to improve social interaction, attention coordination and conversation skills. They describe tests and cases of study with reduced groups of children or youngsters (among 5 to 16) with ASD and HFASD. In [Battocchi 10], CPG (Collaborative Puzzle Game) is presented. CPG is a puzzle game developed for the DiamondTouch tabletop to encourage collaboration in children with ASD. It presents a set of interaction rules called Enforced Collaboration (EC): to move a piece, it must be touched and dragged simultaneously by two players. Sessions were carried out to see if EC can potentially be an interaction paradigm, and whether it would encourage collaborative skills. Sixteen children with ASD, aged 8-18 years and their educators were involved. Training sessions (to get familiar with interaction method and to adequate difficult level of the game) were done followed by experimental sessions to compare EC and Free Play (FP) interaction methods. Children completed the puzzles in pairs at locations that were familiar for them with the help of their educators. Previously, the investigators visited the activity centers to get familiar with the children. All interactions that took place during the sessions were recorded in a log. The measurements and indicators considered were mainly quantitative: time to finish the task, total number of moves required, types of moves, number of functional moves (e.g., dragging a piece to the solution area), among others. In [Zarin 11] the Trollskogen tabletop multitouch system is presented with applications intended to enhance and allow for exercise of social communication skills. The design process was divided into 3 phases: first, the design team conducted a contextual study that consisted of visits to a hospital and 3 different schools for students with cognitive disabilities and interviews with users, their teachers, aides, and experts in Down’s syndrome and ASD (observational data in the form of video clips, images, notes was collected). Second, scenario building and iterative prototyping were carried out. Third, the entire system was subject to user exposure, testing, and evaluation. The user group with throughout the design process consisted of 6 children, all of whom were in the age range of 5-8 and have been diagnosed with either ASD and/or Down’s syndrome (an important contribution of this study is the mix of children with different diagnoses). When they tested the system in situ in a classroom, only four micro applications from more than twenty were used. First, the whole group explored the system together, after which the users one at a time, together with their teacher, were encouraged to interact with each micro-application. After each session, they discussed and talked about what happened both with the user as well as with their teachers. A qualitative analysis of observations was carried out. In [Silva 13], 5 children with HFA with ages between 10 and 17 years participated in the sessions. The researcher participated in the role of evaluator of the system and a therapist guide the activity (a total of 8 therapists were involved). A pre-training stage was conducted over a period of 9 days spread over a month. At this stage the functioning of the game was explained to users and they become familiarized with the interaction and manipulation of game elements on a multitouch table. A total of 51 tests were applied during 15 days spread over 6 weeks. Each test lasted between 5 and 15 minutes. Tests were performed at computing room. All sessions were recorded using 3 cameras. The effect of each collaboration pattern on social interactive was evaluated. Quantitative and qualitative analysis was done. Verbal and gestural interaction, types of interactive situations, and interaction intentions were considered as indicators. [Zancanaro 14] presented an application called NoProblem!, aimed at improving social conversation in children with HFASD. The interface of NoProblem! requires 2 children to use it, in addition to that it makes explicit the role of the facilitator and allows for personalization. It uses the DiamondTouch tabletop [Dietz 01] and it allows the ability to recognize multiple touches by different users. The formative evaluation of the proposal was done with 10 children aged 9-13 years, enrolled in special education classes, who participated in a single session. Three questionnaires were used in the evaluation: the Scenario Experience Feedback Questionnaire (to query the children's enjoyment, understanding, ease of use, and other usability issues), the Scenario Learning Feedback Questionnaire (to query how well the children understood and felt about the problem and the solution), and the Intrinsic Motivation Inventory (to query perceived feelings of pressure, enjoyment during the task). Interviews were done and video tapping was applied during the session. Another intervention with NoProblem! was done and explained in detailed in [Bauminger-Zvieli 13]. In [Gal 16] the goal of the study was to examine whether the StoryTable, an intervention paradigm based on a collaborative narrative, multitouch tabletop interface, enhanced social interaction for children with HFASD, and to determine whether the acquired abilities were transferred to behaviors during other tasks. Participants were 14 boys with HFASD, aged 7-12 years who participated in a 3-week, 11-session intervention. Social interactions during two nonintervention tasks were videotaped at three points in time, one prior to the intervention (pre), a second immediately following the intervention (post) and a third three weeks after the intervention (follow-up). The video-recorded files were coded using the Friendship Observation Scale to ascertain the frequencies of positive and negative social interactions and collaborative play. Differences in these behaviors were tested for significance using nonparametric statistical tests.

Other experiences using TI with tabletops oriented to the special educational scenario, are detailed next. Talking papers is a framework in which teachers and therapists can associate conventional paper based elements (e.g., PCS cards) to multimedia resources, and create customized playful interactive spaces to attend specific learning needs of each disabled child [Garzotto 10]. The experience was carried out at a public school with 40 non-disabled students (helping in the activities design), 2 disabled students (who present severe spastic diplegia), their respective specialized educators (guiding the sessions), the researchers (as observers), and children's parents and language therapists as part of the experience assessing process. The intervention was carried out in the regular classroom for 3 months during which students with disabilities performed 3 types of activities to achieve the cognitive, affective and psychomotor goals proposed. Sessions were no longer than 30-45 minutes to account for attention issues. As regards the research methods, observation and video registration were used during the sessions, and discussions and interviews about achievements and difficulties with educators, parents and language therapists, at the end. The measurements and indicators used were mainly qualitative aspects. SIDES (Shared Interfaces to Develop Effective Social Skills) is a tangible cooperative game, using DiamondTouch tabletop, designed to help teenagers with Asperger's Syndrome (AS) in the development of teamwork abilities [Piper 06]. A participatory design approach was used. The participants were: 4 or 5 students with AS in each session, and social skills therapists and parents (designing, monitoring and evaluating the sessions). A pilot test followed by 2 sessions were done at the laboratory (one with rules proposed by therapists and the other with rules proposed by the game). Before starting, they received a tutorial on how to work with the tabletop. Participants' profile (e.g., medical diagnosis) was considered. The implications of design based on group dynamics and their reactions to the activity (considering how the rules were proposed) were analyzed. Observation, notes, logs of interaction with the interface, video registration, a questionnaire and group discussions were used. Finally, a qualitative analysis of the observations and a posterior quantitative analysis (related with tabletop interaction) based on the questionnaire were done. For the analysis of social skills habits, the efficacy of verbal and non-verbal exchanges was considered as a significant indicator of cooperation using a coding scale (Positive, Aggressive, and Non-Responsive) [APAP 13].

2.2 Discussion about the experiences analyzed and key aspects for assessing multitouch and TI experiences oriented to the special education context

In this section, we present a summary of the main issues noted while reviewing background information and a number of aspects that have been considered to be key for assessing interaction experiences using tabletops in the context of special education. No significant differences have been detected in the assessments carried out with multitouch or with tangible interaction. At the same time, more multitouch than tangible interaction tabletops experiences have been found in special education scenario, and most of the works are focused on students with ASD or HFASD.

As a general observation, all reviewed experiences present ad-hoc applications, with some options for modification, but oriented to the specific targets for which they were created and evolved based on a participatory or user-centered design. Also, it is not evident that any standardized assessment procedures have been applied, but there were in fact some common decisions and features among the various experiences that were considered. Thus, in the following paragraphs we will focus on identifying these aspects for each of the dimensions considered in the previous section.

As regards participants (dimension 1), all experiences oriented to special education involved a small number of participants, in agreement with the characteristics that are typical of these students. In [Chen 12], the authors present a comparative table of 5 experiences on tabletop that were oriented to the development of social skills, also showing work in small groups. In this sense, there is a difference with the experiences that are not related to special education scenario, in which, for example, there is a case with 62 children [Rizzo 07].

In all cases, the educators/therapists that are already familiar with the students were part of the experience. In two of these experiences, parents were also involved as a source of information in relation to changes observed, and in one of these experiences their role was also as support for their children. In most of cases, the investigators participated in the sessions through participant observation, and there was a prior familiarization process with the context (visit to the centers [Battocchi 10] [Garzotto 10], observation of student work ways [Silva 13], interviews [Zarin 11], etc.). Also, in the case of the experience presented by [Garzotto 10], the significance of the participation of non-disabled classmates is specially highlighted, in relation to the information they provide and the reinforcement of the link among classmates. It is considered then that, in terms of participants, various types of players from the context of the students should be involved, such as therapists, teachers, and even parents and classmates in some cases (if the children with disabilities attended classes at a conventional school). Additionally, working with small groups of students seems to be appropriate, considering the level of personalization required and the specificity of each task. These considerations have been successfully applied throughout the cases that were reviewed, which is why we believe that they are key aspects to carry out an assessment of this kind.

As regards dimension 2, referring to how the intervention is carried out, it includes session procedure, format, contents and duration. In our review process, it was observed that pilot tests or training sessions are used to analyze the relation between the target audience and the specific technology [Piper 06] [Battocchi 10] [Zarin 11] [Silva 13]. That is, researchers first establish whether the target users are able to work with the technology, what barriers there might be, and the elements to be considered, etc. In addition, pilot tests are carried out in some cases to validate specific dynamics (testing dynamics in absence of the technology). In three of the experiences, there is a participatory or user-centered design, [Piper 06] [Garzotto 10] [Zarin 11], since the target audience is involved (therapists and/or students) in some aspects of the design of the applications. It has also been noted that sessions are always short in duration due to the attention span characteristics of the students. Session contents are oriented to the goals proposed. All of the experiences that were reviewed are focused on analyzing whether educational goals are achieved [Piper 07] [Garzotto 10] [Zarin 11] [Gal 16], and/or on analyzing the usability of the technology at hand together with a set of specific interaction strategies [Battocchi 10] [Silva 13] [Zancanaro 14]. In [All 16], there is a discussion in relation to who should be in charge of leading a session involving educational innovation. The discussion revolves around whether it is the educator or the investigator who should lead this type of projects. According to [All 16], in order to control the correct implementation of the procedure, observation by the researcher would be ideal. In the cases analyzed here, it was observed that experiences were always led by the educators/therapists, and the researchers assumed the role of participant observer. It is important then, that the educators that are guiding the experiences are familiar enough with the innovations that are being studied. As a result of this, it can be concluded that the educators/facilitators/therapists should be involved to a greater degree in the design process of this type of applications.

Finally, it is believed that the link with educators and therapists can be anticipated through pilot tests or by means of participatory design, so that the technology involved, activity dynamics and interaction models are relevant for the target groups. These pilot experiences could also include the participation of some students to analyze barriers, difficulties or preferences. On the other hand, we think that the best option is for sessions to be guided by the educators or therapists of the students involved, since they know the needs of their students and have already built a bond of trust. The researcher should also be involved as participant observer, to carry out the analysis and provide specific guidance on the process.

As regards dimension 3, in relation to the research methods used, from the experiences reviewed it was concluded that techniques such as observation, video records, interaction logs, interviews and surveys, are used. The variables used are relevant to the educational goals and/or the usability aspects to be studied and/or the interaction models involved.

Finally, considering dimension 4, a strong qualitative analysis is observed to establish the scope of the educational goals through the observations, video records and interviews with all the parties involved. The quantitative analysis was used more in relation to issues pertaining to usability and interaction with the applications and tabletops. In this case, measurements such as the time needed to complete a task and the number of interactions performed were used. A combination of quali-quantitative analysis methods is considered to be necessary in this context, in particular when analyzing interaction model efficacy together with the scope of the educational goals.

Multitouch experiences are focused specifically in the patterns or models used in the interaction, analyzing, for example, if they reinforce collaboration or socialization among students. In the TI cases, no specific analysis of the use of the tangible objects have been detected.

Lastly, the work discussed in [All 16] helped us organize our own work in a structured manner following the 4 dimensions presented by them. In the following section, we describe ACoTI, which is an application that incorporates a number of association games oriented to people with complex communication needs. A user-centric methodology was followed, and an assessment process organized into phases was carried out to evolve the application. For the assessment process, several of the aspects discussed in our previous analysis are considered.

3 Tangible Interaction through ACOTI

ACoTI is an application based on tangible interaction on a *tabletop* that consists of a series of association games that allow working with real and virtual objects. The games have been planned to support the language development and communication process in students with complex communication needs [SPAAL 14], in particular, for users of augmentative communication. Augmentative communication is defined as a set of non-vocal codes (linguistic and non-linguistic) that replace or supplement speech and writing, aimed at allowing communicational processes and increasing their fluidity. It is designed to be a resource for those individuals who have difficulty when speaking or using language to express themselves (uttering the actual words) and/or understanding language (processing a code issued in a conventional and arbitrary system of spoken or written signs) [Tamarit 88] [Sotillo 93] [Abadin 10].

The design of ACoTI is the result of research work carried out as part of a joint project between Argentina and Spain. In Argentina, a field survey was carried out at schools with children with complex communication needs to gather information about methodologies used [Guisen 13], and an opportunity for contribution in relation with the acquisition of communication skills for their students by using TI was identified. While this was taking place in Argentina, work was already being developed at a special education institution in Spain, which offered a subsequent workspace to put into practice the assessments presented here.

ACoTI is an application that requires using a tabletop and real objects or miniature toys that are used for the interaction. These have a dual purpose: they can be handled to generate events and actions within ACoTI, and they enable students to experience the representation of the objects in 3D through their different senses.

Tangible interaction supports the abstraction process that is applied to the real object for creating its concept associated to a mental image and an acoustic image, which is the founding instance for language development that in turn enables the development of subsequent stages in the process towards achieving autonomous communication. As the educator/facilitator uses the system for working with different abstract symbols, students are able to conceptualize the real object. Through the different scenarios used by ACoTI in its games, students are encouraged to take possession of the set of pictograms that form their augmentative communication language [Cabello-Luque 12] [Sanz 12] [Sanz 13].

In the next subsection, a brief technical description of the tabletop device is presented and after that, a detailed description of ACoTI's interaction games is provided.

3.1 The tabletop device

The tabletops used with ACoTI are VisionAR [Artola 14] (Figure 1.A) and NIKVision [Marco 09] [Marco 13] (Figure 1.B). Both follow the same model, based on the physical manipulation of traditional toys or real objects (Figure 1.C) over the table surface.

Tangible interaction roots on visual recognition hardware and algorithms. An infrared light USB camera captures video from underneath the table and streams it to the computer station in charge of the visual recognition software (ReacTIVision) [Kaltenbrunner 07]. ReacTIVision tracks the position and orientation of the objects placed on the surface, provided by a printed marker attached to their base (Figure 1.C). Through retroprojection, the tabletop gives image feedback on the table surface supported with a mirror inside the table. The virtual scenario can also be displayed on a monitor (Figure 1.B.). Tangible interaction is achieved by manipulating the objects on the table surface. During play, children move them over the translucent surface of the table, putting their base in contact with the table to enable the camera to see the markers. The operations that the visual recognition software is able to track are the movements over the surface. Children can grab the objects, drag them and rotate them over the surface and so long as the base with the marker remains on the table, the software can track their orientation.

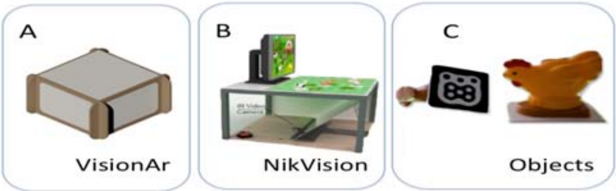

Figure 1: A. Prototype of VisionAR [Artola 14] – B. Prototype of NIKVision tabletop [Marco 09] - C. Physical object with printed marker attached to its base.

3.2 The tangible interaction games

ACoTI is an application conceived as an assistive tool for the abstraction of a real object to its identification in the plane, which is a basic communicational competence for language acquisition. It consists of a series of educational games developed to improve students' communication through association and classification. In the games, a set of virtual elements are presented on the table surface, so that students have to identify which ones are directly related to the physical objects available. The virtual environment (scenario) is composed by a set of virtual elements that belongs to a family of nuclear vocabulary. On the projection on the tabletop, the scenario is shown in an "incomplete" way. The use of different scenarios for the games encourages learning and the incorporation of AAC sign system vocabulary. The objects that have to be associated to their virtual counterparts are suggested either by the outline of the element figure (Figure 2.A), by the pictogram with which its symbolic representation is expressed (Figure 2.B), or by the written word (Figure 2.C). The task of the student is to complete the scenario by associating a physical object (Figure 2.D) with one of the representations on the plane. Each time the child correctly places the object, a feedback is given, through sounds and animations, in order to reflect that the task has been successfully achieved.

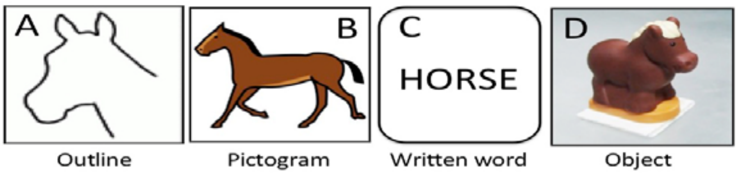

Figure 2: A. Outline of the object (virtual) – B. Pictogram of the object (virtual) – C. Written word of the object (virtual) – D. Physical object manipulated by the student

The manipulation of the physical objects offered by ACoTI and the possibility of adding printed markers to any physical object allow students to "experience" the physical object by perceiving it in all of its aspects and relating it to a 2D representation. Therefore, the identification of the object representation in the user graphical interface (tabletop and monitor or only tabletop), fosters the signification process in the student and gives sense to the physical entity through the construction of its concept and acoustic image. The teacher or therapist can configure the games depending on the level of the progress of the student's language abilities and the corresponding communicational skills to work, but the intervention of a technical professional is required. An *.xlm* file can be edited to change virtual elements, allowing different levels of complexity depending on the degree of abstraction of the real object.

4 Design of the evaluation process of ACoTI

The process to assess ACoTI has been planned taking into account the related work review described in previous sections. This process has also accompanied the iterative design and the evolution of ACoTI, since it initially started as a set of games that gradually grew in number and were improved based on the results obtained in each phase of the assessment. In this sense, ACoTI's design can be considered to be a case of user-centered design as the one used in [Piper 06] [Garzotto 10] [Zarin 11].

Figure 3: Phases of the assessment process carried out for ACoTI

The assessment process was done in 3 phases (Figure 3) that were conceived to consider different previously surveyed key aspects. In particular, educator and therapist involvement was sought (experts in the field of special education) for ACoTI's assessment and iterative design process. The first phase was designed as a pilot test to analyze the proposal of two ACoTI games involving simple and complex association and the cognitive distance within a group of students at a special education school in Spain in relation to those games. During this phase, information was also gathered about the technologies involved and their possibilities and barriers for interaction. In this sense, the guidelines described in Section 2.2 were followed, since two main lines were considered: interaction models and the possibilities offered by the games for the target group, as other reference authors have done before. The second phase took place during a congress where experts on the subject matter were gathered, and it focused on collecting their opinions in relation to the design proposal for ACoTI and what they felt were the possibilities for using the application at various institutions in Argentina and Uruguay. The potential target groups had similar difficulties as those of the group that had been part of the pilot test. In this sense, our goal was to assess possibilities for ACoTI, based on expert opinion, for potentially integrating it to other contexts. This assessment was carried out on an evolved version of ACoTI, obtained after introducing the changes resulting from phase 1. Discussion groups and semi-structured questionnaires were used. In this second phase, an innovation is introduced in relation to the previously reviewed background, since the application is assessed by special education experts and, in many cases, also experts in the integration of digital technologies in this field. Finally, there was a third assessment phase with some of the participants from the second one. This third phase took place in Argentina, and it used one of the games from the first phase and two new ones that were added after the comments given by the experts. This final phase was aimed at encouraging participant-game interaction to analyze playability, configuration needs mentioned in phase 2, and potential for use with their own students. This phase is an extension of the idea presented in Section 2.2 in relation to user-centered design, so that ACoTI can evolve based on the opinion of therapists and specialists, but this time using the games. In the following section, each phase is described in detail, including their goals, participants, intervention methodology, methods used, and measurements and indicators to consider.

4.1 Assessment phase 1. Pilot Test

A pilot test was carried out with students and therapists. It was aimed at finding out, through some games included in ACoTI and other similar applications, at a special education school, the distance between the objectives proposed by the application and the possibility for the target group to actually achieving those objectives. The interaction model proposed and tabletop architecture configuration were also assessed through a study to determine whether it was more appropriate to use only the tabletop surface as display space or if a monitor should be used as well (Figures 1.A and 1.B). The use of the pictograms, the miniature toys, and possible abstraction levels within the games being tested were also analyzed to check if they were appropriate for the target group. Participants were as follows: 8 students from a special education school in Spain and 8 therapists who participated during the initial stages of the interviews for a better analysis of our methodology. Then, some of these therapists were present during the sessions. Participating children (aged 6-11 years) present significant disorders in their communication functions, as well as the processes used to establish a relation with their physical and social environment, and they have difficulty in developing autonomy abilities –in general- in basic learning processes. The games offered by ACoTI could then be of interest to help these students in the abstraction process required for communication, as well as in vocabulary acquisition. Students were screened by school therapists taking into account the goals of the game and student profile. This was done after a number of initial interviews between the investigators and the therapists, during which the proposal was explained to the latter. Assessment sessions were carried out as part of the class activities done by the specific group of students, so that the environment would be as familiar and natural as possible. The therapists were present during the sessions in their usual role for student activities; in this case, the activity was a session to play the games included in ACoTI. In addition to guiding the session, they were asked to observe the barriers that the students found as they interacted with the games and the tabletop. These sessions were carried out in a period of 4 months. During the session, the students played, in pairs, with 2 types of games offered by ACoTI – a simple association game and a complex association one. The therapists guided the sessions and added to the directions provided by ACoTI, providing feedback only when they felt it was necessary. In some of the sessions, the children were able to use both a monitor and the tabletop as display areas, while in others they used only the tabletop. Their behavior was observed in both situations. Sessions were also videotaped.

As regards methodology, observation and subsequent video analysis techniques were used, and logs were generated to determine the cognitive distance between the application proposal and student possibilities. Logs were used to determine the number of successful plays and errors made, as well as the type of errors that were made. The level of attention paid to the display spaces was also recorded, both when the monitor and the tabletop were being used, and when only the tabletop was available. Emotions and attitudes expressed during the sessions were also monitored, based on therapist and investigator observation. Due to the difficulties inherent to identifying emotions in these children, in some cases there was a subsequent conversation with the therapists, who recorded and reported them accordingly. These indicators were used to determine if the proposal brought by ACoTI would allow students achieve their educational goals.

Table 1 summarizes the assessment carried out during the first phase.

Phase 1 - Pilot test	
Goals	• Analyzing the cognitive distance between a group of students at a special education school in Spain and 2 games proposed by ACoTI • Analyzing the interaction with the technology being tested
Participants	• 8 students • 8 therapists
Intervention methodology	• Students work in pairs during the sessions while playing the games in ACoTI. Sessions were guided and observed by therapists. Investigators were participant observers.
Methods	• Initial interviews with therapists. • Participant observation • Video recording • Application logs
Measurements and Indicators	• Level of attention during the game with both two display spaces and just one (number of times the tabletop or the monitor, as applicable, was referred to) • Student attitude during the game • Number of correct answers vs. number of incorrect answers • Types of errors made

Table 1: Summary of phase 1

4.2 Assessment phase 1. Results

When the first evaluation phase was completed, the following results were obtained (Figure 4).

As regards student comprehension, performance and attitude:

- The students performed successfully in association activities such as object/outline in cases of simple association (same number of objects and outlines). They had difficulty in complex association tasks (for instance, when they have a toy whose representation is not shown on the tabletop). This was analyzed through the number of mistakes recorded in ACoTI logs, as well as the observations recorded during and after the sessions through video records.
- Students could relate pictograms with representations on the table. However, they showed preference for using miniature toys for playing the games and controlling the application. An improvement in associations was observed with the use of miniature objects and their connection to pictograms on the tabletop.
- Students were motivated during the sessions, but in some cases they did not know how to continue with the activity, so the therapists had to intervene.
- The therapists stated that more feedback was needed, both visual as auditory, to make the activity fun for the children.

As regards the use of the *tabletop* and tangible interaction:

- It was natural for the students to work with the physical object to interact with the software.
- The process of grabbing an object and placing it on the surface to make an association was natural for the children.
- Using the monitor and the tabletop as visualization devices made it harder for this type of students to focus on the activity. It was observed that just using the horizontal surface as interaction and visualization space yielded better results.

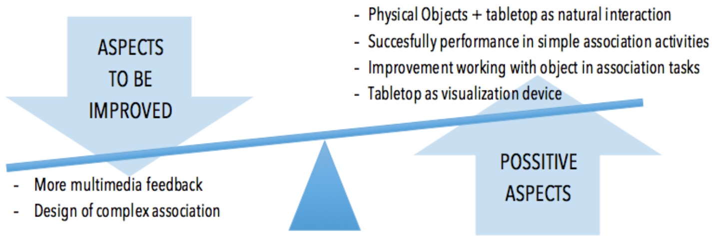

Figure 4: Main Results of phase 1

Phase 1 of our work was focused on the students, and it was possible to work with the games in accordance to the objectives proposed. Based on our observations, students were found to be motivated by the use of tangible 3D objects, but they preferred working on the tabletop without the monitor. Thus, the games were redesigned to follow these guidelines, and phase 2 focused on the opinion of educators and therapists in relation to the redesigned games. In the following section, the evaluation process is detailed and the results obtained in phase 2 are discussed.

4.3 Assessment phase 2. Working with special education specialists

The goal of this second phase was centered on uncovering how ACoTI and its possibilities for use were perceived at various institutions in Argentina and Uruguay. To achieve this, we worked with target groups similar to those that had participated in the pilot test, but now considering different contexts. This is very important, since the project that originated ACoTI is rooted in Spain and Argentina, so we needed to consider different contexts. This aspect was not considered during the bibliographic review carried out. A theoretical evaluation with specialists (4 therapists, 4 educators and 2 specialists in ICT and special need education) of the augmentative communication area was carried out during an international congress on Information and Communication Technologies (ICTs) and disability that was held in Uruguay. The methodology used during this phase was the following: A. Preparing and presenting the materials for the sessions (a video featuring ACoTI, a questionnaire and an introductory presentation); B. Based on the inquiry branches proposed, semi-structured printed out questionnaire was given to 10 specialists from Argentina and Uruguay, which then were divided into 2 groups of 5 specialists each to participate in discussion groups. Discussions were audio-taped for later analysis; C. Analysis of the results and elaboration of an evolution plan for ACoTI.

Initially, participants were shown a video on the possibilities offered by ACoTI, with images of the different games (association through shape, with pictograms and miniature toys), and snippets of the sessions carried out with the students and specialists during the phase 1 of the evaluation. This video was used as a trigger to explain the features of ACoTI. Then, the questionnaire was distributed and participants were given enough time to complete it. The questionnaire and the corresponding answers are detailed in the results section for this phase. Finally, the specialists were divided into 2 groups and they shared opinions, exchanged experiences, and discussed potential uses for systems based on tangible interaction such as ACoTI in educational contexts involving students who are also users of augmentative communication.

As regards measurements and indicators, the answers given by participants to the questionnaire were used. In the case of close-ended questions, the number of times each of the options was selected was considered, while in the case of open-ended questions, the rationale and comments given by each participant were reviewed. The audio tracks recorded during these discussions were also reviewed, and answer categories were created; for example, the proposed scenarios were divided into everyday and occasional, as agreed by the specialists. Several individuals that participated in these sessions later on joined the subsequent phase for evaluating ACoTI, so this second phase was also used to bring ACoTI to interested individuals who work in the special education area. Table 2 presents a summary of the second assessment phase.

Phase 2 - Expert opinion	
Goals	• Analyzing expert views on the possibilities of using ACoTI in various contexts • Enhancing games based on the opinion of the experts
Participants	• 10 special education experts
Intervention methodology	• Session to present the games available in ACoTI with some of the improvements introduced after phase 1 using video and oral explanation. • Individual work of the experts with a questionnaire • Discussion in two groups of 5 experts each.
Methods	• Questionnaires • Group discussion based on proposed discussion lines. • Audio recording
Measurements and Indicators	• Number of answers for each category on the questionnaire • Opinions of the participants For these two, the categories established to group answers were used.

Table 2: Summary of phase 2

4.4 Assessment phase 2. Results

During phase 2 of the evaluation, several results of interest were obtained. The semi-structured questionnaire was responded by 10 participants. The following questions were part of the questionnaire and were also included in the discussion that followed to get deeper insight: A. Could ACoTI games be useful as support to the real object abstraction process up to its identification on the plane?; B. Is the combination of tangible object manipulation with their display on a virtual graphic environment an appropriate strategy to facilitate the future incorporation of communication software (hi-tech alternative augmentative communication system)?; C. Which scenarios and vocabulary do you propose to be developed as part of the games in ACoTI, based on your experience?; D. For which group of students with complex communication needs do you think these games could be useful the most? (as regards the pathology under study and how AAC is used). In Table 3 the main results are summarized.

Phase 2. Results		
	Summary of answers	**Examples**
A	• All of the specialists (10) considered that ACoTI was valid and innovative as assistive technology for the initial phase of language development in individuals with complex communication needs • A tool used by students with complex communication needs should offer, as a requirement, configuration options.	"*The games in ACoTI are clearly designed to support the abstraction process. They are varied, accurate, and situated in scenarios that most people share…I think they could also serve as guidance for the teachers themselves, when they need to create new games to reinforce the learning of a specific set of words, be this for a specific context or specific situations relevant to any given age…*"
B	• All of the specialists agreed on the fact that the use of tangible objects and the association with their graphical representations, facilitates the creation of the corresponding concept, formed by a mental image and an acoustic image. • Seven out of the 10 specialists emphasized the multimedia potential of ICTs as a motivating aspect that is in agreement with the multimodal language that is typical of classroom dynamics in these contexts.	"*When potential AAC users are not motivated to explore the use of digital technology from an early age, the incorporation of communications software may take longer and be more complex and tedious. The combination proposed in ACoTI (handling tangible objects while displaying them in a virtual environment) would be a good start for any age, and especially for younger children.*"
C	• All specialists proposed 3-4 scenarios for using the games included in ACoTI for introducing sets of codes situated in contexts. • These were separated into "everyday" and "occasional" scenarios.	Some of the scenarios proposed are: **Everyday**: family (*mum, dad, brother, sister*), bathroom (*toilet, soap, toothbrush*), Season-related clothes (*summer: T-shirt, shorts; winter: coat, scarf, trousers*); **Occasional:** supermarket (*fruits, dairy, meats, cereals*), park (*sand, trees, play sets, ball*), farm (*animals: cow, pig, horse, duck*)
D	• Individuals with Down Syndrome, cerebral palsy, mental retardation, autism in general were mentioned. However, target individuals should not be considered based on their conditions, but rather in relation to the specific cognitive and motor characteristics of each student.	"*It would be in the interest of the teacher to be able to generate association activities, from the simplest to the most complex, by moving the fiducial marker from one object to another, or by switching the images that create the scenario. Similarly, it would be ideal if the desired feedback could be defined.*"

Table 3: Summary of results of phase 2

After this, several types of potential adaptations that could be used in different cases were proposed. All participants agreed on the importance of testing the experience offered by ACoTI, and focused on the configuration options of the application that will be tackled in the following section.

4.5 Assessment phase 3. Configuration Requirements for the Games in ACoTI

This phase was focused on carrying out a number of evaluation sessions with specialists, special school directors and therapists from the augmentative communication field in Argentina (see Table 4). Based on the results obtained in phase 2, during which the participants considered that it was important for them to be able to create their own TI educational activities, a new evaluation with the participation of 8 specialists, this time in relation to the use of ACoTI, was carried out, aimed at analyzing how to extend ACoTI to meet different needs within the special education field. There were 2 experts in ICTs and special education, 5 therapists/educators, and 1 director of a special education institution. It should be noted that 6 of the participants had already been involved in the evaluation carried out during phase 2. The main goal of this third evaluation stage was going back to the use of ACoTI to dig deeper in relation to the possibilities that should be considered for use in real contexts, and the configuration options that should be provided in each game/educational activity template of a future authoring tool were considered. Before the evaluation sessions, the following actions were carried out: A. Selecting a subset of the games included in ACoTI to test with the specialists; B. Creating a survey to be filled in by the specialists after they tested the games selected; C. Creating a number of questions to kick off a discussion with the specialists after the session. Group discussions/interviews were held after the sessions.

Four sessions were carried out, and during these, the specialists received contextual information. Then, the games selected were introduced. Two of the games had been designed after the two first assessment phases, and both the recommended work scenarios and the feedback received had been taken into account when designing them. The specialists played as end users, using real objects to establish the corresponding associations. The first game presented a scenario and vocabulary on season-related clothes (everyday scenario) and gender (it is called Clothes, weather and gender). The specialists had to use miniature clothing items to dress up two characters (a girl and a boy) that were projected on the tabletop under various weather conditions. They received audio instructions to carry out the objective of dressing the characters appropriately for their gender and the weather. In all the games different audio feedback was provided for each of the two possibilities: correct and wrong. However, this game includes feedback for all the association variables at hand, i.e., if the items of clothing were properly chosen in relation to both gender and the weather projected on the tabletop (Figure 5.A).

The second game uses a supermarket as scenario (Occasional scenario). The game is an association activity that consists in using the tabletop to project an image corresponding to a supermarket, where a person with a shopping cart can be seen (Figure 5.B). The application told players, both visually and by audio, which were the objects that they should add to the cart. Players received a sound and visual feedback every time they did the action correctly, and others when they did it incorrectly. They were instructed to try different variations of this activity: first, the objects were the actual items (an orange, an onion, a carton of milk), and the virtual representations that were shown on the supermarket image projected on the tabletop were photographs of the items; then, the real objects could be used, but their representations on the tabletops were drawings; finally, real objects were used with their corresponding pictograms as virtual objects.

Another game that was available in ACoTI since its creation was also used. This activity consisted in showing the shape of a farm animal over a blue background together with the sound corresponding to the animal (Figure 5.C). The player had to pick, from a set of miniature toys, the animal corresponding to the shape.

Figure 5. A. Clothes, weather and gender association game – B. Supermarket game – C. Animals Association game

Phase 3 - Configuration requirements	
Goals	• Analyzing the interaction of the experts with the games • Defining configuration requirements
Participants	• 2 experts in ICTs and special education, • 5 therapists/educators • 1 director of a special education institution
Intervention methodology	• Sessions for specialists to play with ACoTI. • Surveys • Interview/Group discussion
Methods	• Questionnaire • Video recording • Document to guide the interviews/discussion
Measurements and Indicators	• Number of tasks carried out with consultation vs. number of tasks carried out with consultation/assistance during the game • Configuration aspects to be considered

Table 4: Summary of phase 3

4.6 Assessment phase 3. Results.

The survey presented to the participants asked about which configuration aspects would be needed for ACoTI games to be usable in their contexts. The participants had to choose among various options (shown in Figure 6), and a few additional options were added which were later on discussed as a group or individually through interviews.

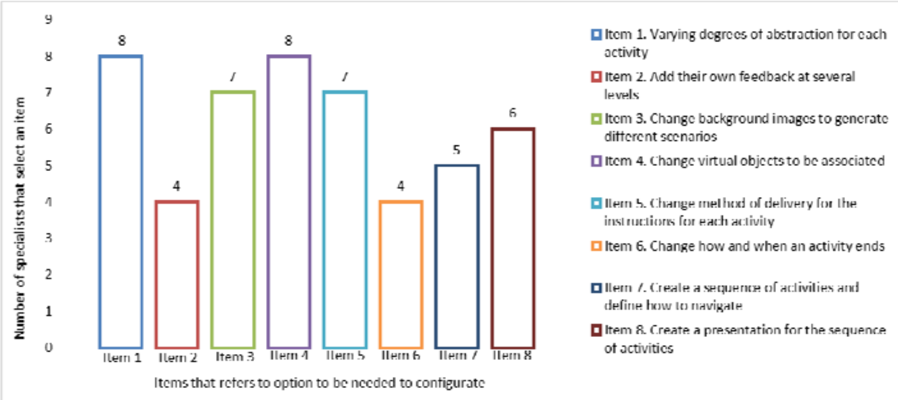

Figure 6: Configuration options required for the activities, chosen by participants

The specialists highlighted various aspects that they consider should be configurable for the activities. Those with the highest agreement rates were:

- Varying degrees of abstraction for each activity depending on the group of participating students (Item 1 in Figure 6). This was subsequently discussed and all the specialists considered that "graphical representations can be used in some cases, while in other cases text representations or pictograms might be more suitable". This aspect should be configurable by educators or therapists in each case.
- Changing the virtual objects to be associated (Item 4 in Figure 6). All of the specialists considered that the virtual objects used for the association activities should be configurable.
- Changing background images to generate different contexts or scenarios (e.g., zoo, supermarket, home, etc.) (Item 3 in Figure 6): this option was also highlighted by 7 of the specialists.
- Adding their own feedback at several levels (Item 2 in Figure 6): four out of the 8 specialists indicated that the therapist or educator should be allowed to add their own audio and/or visual feedback at certain times. One of the specialists considered that "*the types of feedback provided were different for the different activities, since in some of these it was more customized to the type of error, but not in others*". The times suggested for adding this feedback were: after a correct answer, after an incorrect answer, indicating what the error was, and at the end of the activity. Feedback was highlighted during the discussion as a particularly important aspect that should be able to modify it for each activity. In the case of an activity in which there are two variables at play for the association (for instance, the gender and weather activity), the specialists considered that the type of mistake the student made should be identified, i.e., if the clothes are for the wrong gender, for the wrong weather, or both.
- Generating a presentation or contextualization for the sequence of activities (Item 8 in Figure 6): the possibility of creating customized presentations before each activity was assessed, where, for instance, the

educators/specialists could tell a story or show a short video before the activity.

There were other configuration options that were selected to a lesser extent, such as those listed below:

- Changing the method of delivery for the instructions for each activity - audio and/or visual (Item 5 in Figure 6)
- Deciding how and when an activity ends (Item 6 in Figure 6): this would be aimed at being able to show when the activity ends and customizing the ending.
- Linking or creating a sequence of activities and defining how to navigate from one activity to another (item 7 in Figure 6).

On the other hand, these surveys and discussions/interviews yielded other interesting results. As regards scenarios and categories, there were several suggestions during the discussions. For example, that the creation of a repository from where the educators can choose to set up activities could be useful. Some of the scenarios that were mentioned were related to those that had already been proposed during phase 2, but there were also some new ones, such as transportation, hygiene habits, eating habits, and so forth. It was observed that the participants strongly recommended designing association, selection and ordering activities related to the habits or routines of the students. For example, what they should do before going to bed or when they get up in the morning. Most specialists (7 out of 8) stated that it would be beneficial if the games could be played collaboratively or competitively. For instance, sometimes the students can establish the corresponding associations based on their own abilities, but all of them working on the same scenario in order to solve the activity. Some other times, a competition among students could be set up, scoring points based on the correct answers given by each student.

5 Discussion

The entire assessment and successive evolution process for ACoTI, going through the three phases presented here, has allowed us to go deep into the needs and challenges for using TI in special education scenarios, in particular with individuals with complex communication needs. First, we focused on various experiences with ad-hoc activities and games developed with specific educational goals and assessed from various points of view. Our previous review of assessment methods relevant for these experiences has allowed us unveiling some key aspects (presented in Section 2.2) to be considered and detailed in these processes, using the work presented by [All 16] as our foundational stone. After reviewing the assessments, it was observed that, in general, they were based on using the tabletop application in reduced groups of students. Generally speaking, the focus of these assessments is mainly on the students; however, the participation of specialists, parents and classmates, as in [Piper 06], is also valued. Regardless of this, the results obtained revolve around our findings during the process of working with the students. None of the reviewed articles presented results that would allow continuing with the development of this type of activities at the institutions, or that would allow involving special education specialists (educators, facilitators, therapists) in the process. There were various works that involved the use of a tabletop under a multitouch interaction model. These articles have enriched the assessment process presented here, as in the case of [Zarin 11], where assessment phases are proposed and an evolutionary design is used to develop the applications.

Even though during the first phase of ACoTI we worked with students and therapists, similar to other works presented in the bibliography, we conducted two subsequent phases in collaboration with specialists. Our sample was expanded by working with specialists from different countries, which allowed us exploring the possibilities of ACoTI for different contexts and scenarios. For instance, in Argentina, currently used technologies in classroom dynamics (based on the participants involved) are different from those used at the collaborating institution from Spain (in this case, the students are already working with interactive touch boards). However, ACoTI has received positive reviews in both situations. The in-depth work carried out with the specialists allowed us finding challenges that have not been met yet. Among the most significant of these challenges, the following can be mentioned: the need to have more configuration options for the activities/games, the relevance of feedback settings, the abstraction levels used in each activity, the creation of a repository of activities, etc. Some of these issues had already been considered when working with the children during the first phase, such as when it was mentioned that several children had not been able to solve that complex association activities. Thus, it is considered that the need for activity customization becomes a priority for these scenarios. The proposal of having an authoring tool that would allow educators to create these activities themselves is considered to be a still unmet challenge.

Our work both with the specialists and the students clearly showed the motivation that this type of activities can generate, which is in agreement with the findings published in [Batocchi 10] [Garzotto 10]. Additionally, our work with the specialists showed the importance of working with physical objects, scenarios and vocabulary sets, in relation to students' everyday activities and routines as well as depicting occasional tasks. In this sense, after the second phase, new games were designed for ACoTI involving some of the scenarios mentioned by the participants.

6 Conclusions and Future Work

TI and multitouch projects using tabletops have been used in the development of social skills and have opened the road for using this kind of interactions in the special education scenario. This paper focus specifically on TI applications oriented to special education scenario and their assessment processes. Some findings have been highlighted during the literature review: all the experiences analyzed have been presented positive results working, mainly, with ASD and HFASD children, they presented *ad-hoc* applications, some detailed a participatory or user-centered design process and all worked with reduced group of children, and with their therapists and teachers. In various papers related with multitouch applications using tabletops, patterns of interactions have been studied, while in TI applications, the use of the objects has not been considered specifically during the assessment process.

Our work presents the assessment process of ACoTI, based on the literature review, and goes deep in the work with therapists and teachers, who reveals key aspects and some challenges that need to be tackled in this area: the need of having more configuration options in this type of applications in order to create activities for the different educational needs of each children, the importance of the physical objects specifically in ACoTi games related with its goals, the necessity of having scenarios that allow working with student's habits and routines, and the importance of the feedback during the resolution of the activities. These findings and challenges have opened up the door for designing an authoring tool that has been gestating since the second phase of this process, to offer educators the possibility of designing their own tangible interaction-based activities. The tool must consider the configuration aspects that stem from this assessment process. This will allow institutions to use tangible interaction-based activities, which will mean that the experimental phase will be officially over and the technology will become part of their own work methodologies.

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