

DIGITAL STORYTELLING FOR PEOPLE WITH INTELLECTUAL DISABILITIES: AN INTERMEDIATE LANGUAGE FOR EXECUTABLE REPRESENTATIONS

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Abstract

Many approaches to the definition of animated story exist, but a good “one size fits all” solution is difficult to adopt and implement. Software for the creation of simple animated stories is often more complex than necessary. Moreover, usually, it is not possible to personalize the functionalities provided by the User Interface to the specific users’ needs. This, in turn, affects the effectiveness of such software. To address these problems, we defined, implemented, and tested a methodology to simplify the process of designing software for animated stories. We defined an Intermediate Language (IL) that abstracts basic concepts useful for the description of a story. The components and concepts of the IL were inspired by the Business Process Model and Notation (BPMN) and the Scratch language. To validate our approach, we applied it to the design and implementation of an app for storytelling. The app we created permits to define the story by means of a simple graphical language; then, a first translation module generates an IL representation; finally, a second translation module produces a Scratch executable file. We tested our app with subjects with intellectual disability. Psychologists supervised the experiments and observed improvements in subjects’ vocal expression, attention level and narration quality.

Keywords: Storytelling, educational software, rehabilitation, Intellectual Disability, Intermediate Language, graphical language, Scratch

1 INTRODUCTION

Digital storytelling is a relatively new form of personal expression and art, evolved over the last decade, which leverages video, music, picture, and narration to create personal short stories about people’s lives, their work, and their experiences, shared with peers and online. One of the main aspects of storytelling is that it permits to “give voice to the voiceless”, and the research demonstrated how important it is in many fields: cultural, educational, and social [1], [2].

Unfortunately, the software for digital storytelling tends to be more complex than necessary for such a simple and general need; this, in turn, makes it difficult to successfully use such application with the purpose of digital storytelling.

Therefore, with this work, we want to address such gap by providing a methodology for designing application for digital storytelling. Given that flexibility is one of the most important features we need, especially considering the different purposes that digital storytelling can have, we designed an Intermediate Language (IL) that abstracts the main “components” needed to design a story: definition of the various phases of a story, selection of custom images for background and characters, recording of voice or sounds, etc.). Such IL is flexible enough and independent from both the specific application user interface and the underlying execution platform. This allows programmers to focus on their specific needs in terms of storytelling, delegating a significant part of the technical details to our solution.

Moreover, employing such abstraction layer permits to easily adapt to new or changed requirements, both from the user interface perspective and from the technological one, so that the time needed to implement such changes can be significantly reduced.

To validate our approach, we also applied it to the design and implementation of an application for storytelling that is intuitive and easy to use even for people with intellectual disabilities. From this point of view, the literature is clear in describing how important and effective storytelling applications can be for people with intellectual disability [3], [4], [5], [6], [7].

The application was tested on the field thanks to the collaboration with educators, volunteers, and people with intellectual disabilities from two voluntary associations (Esagramma - esagramma.net, and Amicinsieme - amicinsiemelipomo.altervista.org). During the experiments, the subjects created stories using their own voices and imagination, under the supervision of educators and psychologists.

The paper is organized as following; Section 2 introduces our approach, Section 3 explains how we applied our approach to digital storytelling, Section 4 shows the experiments we conducted and the results we obtained, Section 5 draws some conclusions.

2 APPROACH

From what described above, it emerges that it would be very useful, in many educational contexts, to have applications that do not necessarily offer complex animations or advanced features, but that allow deep customization of the story and are easy to use.

To be more specific, we think that one of the main features that such tools should provide is flexibility both in terms of different user interfaces that can be offered to the end user (source language) and in terms of the technology used to actually make the stories “executable” on computers (target language). This would allow to accommodate the needs of as many users as possible and make the tools usable in educational paths with different needs.

To obtain such a result, we designed an IL that abstracts the main concepts of a story, being flexible and independent not only from the execution platform (target) but also from the specific application user interface (source).

This should allow programmers to focus on their specific needs in terms of storytelling, delegating a significant part of the technical details to our solution.

To facilitate this process even more from the programmers’ point of view, the IL must be easy to use and understand, and for this reason we considered useful to build its components on top of existing ideas and languages and to provide an example of graphic representation through Business Process Model and Notation (BPMN) that allows to describe the processes in a “human readable” way.

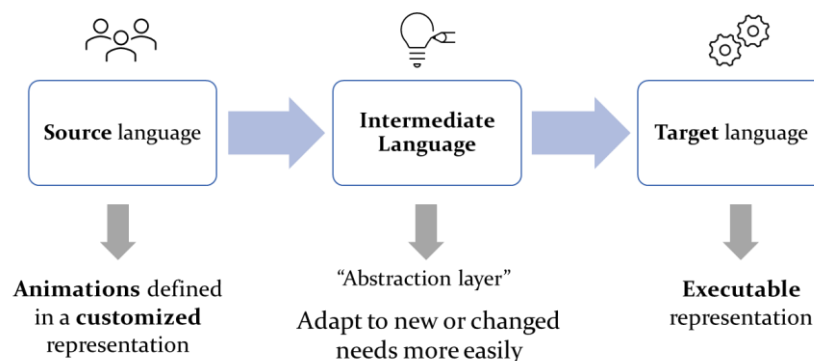


Figure 1 – Translation process and the IL

There are many tools that allow to create and play video, animations, stories, and presentations but, usually, they are either too complex for what the user needs to do, or not powerful enough. Therefore, any programmer who wants to create a simplification or improvement of these tools must create a new visual programming language (source language) [8] based on their needs and then translate it in an existing executable one (target language).

We would like to provide a supporting intermediate model for their work on translation, which can make the translation process easier and clearer, because it is done in smaller steps, and that is flexible and reusable, because in case of changes in the source or target language the programmer can work to modify only one of the two side (see Figure 1). Leveraging our IL-based approach, supporting users with totally different needs is just a matter of designing the appropriate user interface and write another translation module to the IL. At the same time, changing target language just requires writing the appropriate translation module from the IL.

What we need is a language “somewhere in the middle”, that is neither too specific to a given scope (thus being adaptable only to some specific contexts) nor too generic (thus becoming too complex to adapt to different contexts). Moreover, we want a language that allows to represent sequences of actions and events, and to assign each of them to various multimedia objects. For this purpose, (1) we need to understand, collect, and analyse all the concepts that we want to describe with the IL, in the domain of

digital storytelling, and (2) we also need to find an existing language from which to draw inspiration in terms of ideas and concepts, for the creation of an IL able to abstract all the concepts of the domain.

For (1) we took inspiration mainly from the use case we'll describe in Section 4, and from the main concepts of theatre scripts. For (2), after some research, we decided to take inspiration from the BPMN standard, so we reused some concepts and graphical representations for naming the elements of the IL and providing an example of their possible graphical representations.

We also defined our own IL with a syntax and a semantic that should make it simple to use it with different target languages. The syntax definition of the IL is based on the work made in [9], adapted to our needs, as our IL takes inspiration and (some) concepts from BPMN. The definition of formal semantics, for our IL, followed the suggestions and ideas in [10], [11], and was done by means of Petri Nets.

3 DIGITAL STORYTELLING

In this section we will firstly present the case study where we implemented and tested the translation process; then, we will show an example of the translation process, starting from the source language, generating the IL, and finally producing the target language.

3.1 Digital storytelling application

The case study for our work is inspired by the LYV project [12]. LYV is a software for the development of interactive stories created at Politecnico di Milano, with a dual purpose: supporting learning of English as L2, for young people with specific learning disorder, and vocal re-education for children and young people with intellectual disabilities or speech difficulties. Testing LYV, we understood the usefulness of similar software but also realised that LYV was too complex and, even more important, not suitable for a heterogeneous set of users, each one with very different and specific difficulties. Moreover, we realized how difficult it would have been to port LYV to other story "executable" standards. In fact, LYV generated Scratch 2-compatible files but, during the development, Scratch 3 emerged as the new standard; porting was considered too time consuming, however, and thus the project was stuck to the outdated Scratch 2.

For this reason, we decided to create, as a use case, a new application, like LYV but much simpler, which would have permitted to create personalized stories. Moreover, leveraging the IL it would have been much easier to adapt the user interface or the story "executable" standard.

The process we defined for creating the final Scratch 3 "executable" story, starting from the graphical description create by means of the application UI, is showed in Figure 2. The "source language" story is described by means of a simple graphical language; then, such description is translated into the IL; finally, the story is translated into Scratch 3 (the target language.) In the next Sections, we'll describe more in details the story in such three different languages, and the translation process.

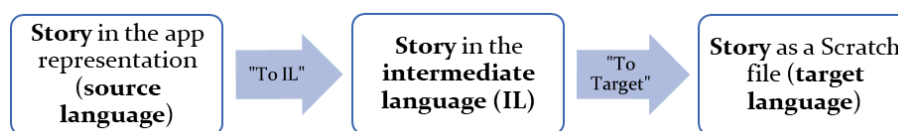


Figure 2 – Case study process

3.1.1 Story

The story, in the UI representation, is a list of scenes. Each scene has a background, two lists of *actors* (characters and objects), the list of *initial settings* (one for each actor), and the list of *blocks* representing actions and sound events happening in the scene. Blocks are the main components of the scene, and their order is based on the "starting time" of the block grouped by subject.

The story in the IL is a project that contains three *pools*: Stage, Actors, and Sound; the pools are divided in *lanes*. The project starts with the *start* event and finish with the *end* event that, by default, are put in the Stage pool, which has the role of managing the whole process; in fact, the Stage pool manages the backgrounds and starts/ends the scenes. The Actors and Sound pools contain the main actions

happening during the story. The starting of a scene is represented by a *message received* event, sent by the Stage, while the ending of the scene is represented by the *middle end* event. The actions are represented with *activities*, an activity is something performed by the actors during the story flow. We have four different kinds of activities: *image setter*, *change costume*, *move* (e.g., glide, hide, turn etc.) and *sound*. In Figure 3 we can see an example of a story in the IL, where there are the three pools: stage, actors (composed by two lanes that correspond to the actors Fairy and Hedgehog) and sound.

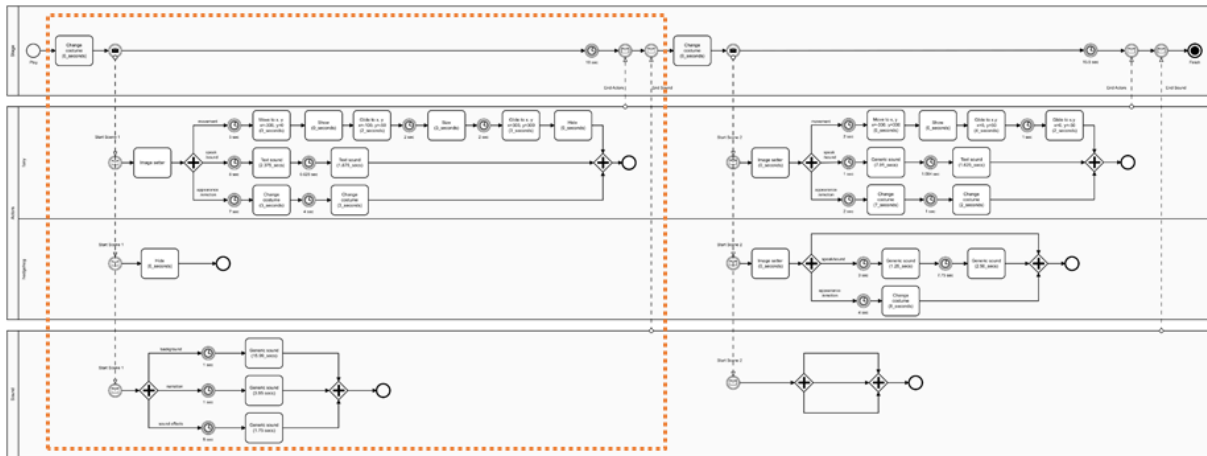


Figure 3 – Example: a story in the IL; the first scene of the story is highlighted

A Scratch 3 file is a ZIP archive, with `.sb3` extension, which contains the story flow encoded as a JSON file, and media contents stored in separate files. In our case the media contents are the images for backgrounds and actors, and the sounds. A Scratch 3 story contains a list of Targets, where a Target is the *stage* (i.e., the background) or a graphical object (a *sprite*). The stage is always the manager of the story, while each Target contains all the information about its actions and sounds, as a list of blocks.

3.1.2 Translation process

In this section we present a practical example of translation from the source language to the target language. For better understanding and for simplicity, we use the graphical representation of the source language and the target language. The IL components are shown here by means of the standard BPMN-defined symbols; note that, *such graphical representation is only provided for explaining how the BPMN directives are used to describe the source language*: during the translation process no graphical BPMN representation is actually generated; instead, the IL is stored in main memory as a collection of objects implementing the various BPMN directives adopted by our IL. In Figure 3 we can see the full story in the IL. For our translation example we will focus only on the first scene.

Application. In Figure 4 we can see the first scene, from the application UI point of view. It has only one character (“Fatina dei Fiori” - Fairy) and there are only three light cyan blocks in the sounds: narration voice, background music, and effect sounds. The character Fairy has three yellow blocks *action* (*enter*, *change size*, and *exit*), two cyan blocks *speak*, one red block *emotion* (“Arrabbiato” - Angry) and one light red block *appearance* (“in volo” - Flying).



Figure 4 – A scene in the app language

Intermediate Language. Figure 5 shows the scene 1 from the “Fairy” point of view. The first *Activity*, after the reception of the message “start scene 1”, is the *Image setter* that set all the initial information about the character in the scene, like position, rotation, and size. After the *Gateway*, the three main flows are managed: the movement flow, the speak/sound flow and the emotion/appearance flow.

Movement flow. We can notice that the app’s yellow block *enter*, which let the character enter the scene, is translated into three different *Activities*: “Move to x,y” (x,y is the point from where the character starts its movement to enter the scene), “show” (before this activity the character is not visible) and “Glide to x,y” (the activity that perform the actual movement until the character reach the final position x,y). Moreover, the app’s *Change size* block is translated into a “Size” *activity*. Finally, the app’s *exit* block is translated into two *Activities*: “glide to x,y” (x,y is the point of the edge where the character finishes is movement and “exits”) and “hide” (the character is no more visible).

Speak/sound flow. The two “Text sound” *activities* correspond to the app’s *Speak* blocks.

Appearance/emotion flow. The app’s *Emotion* and *Appearance* blocks are translated as two “Change costume” *activities*.

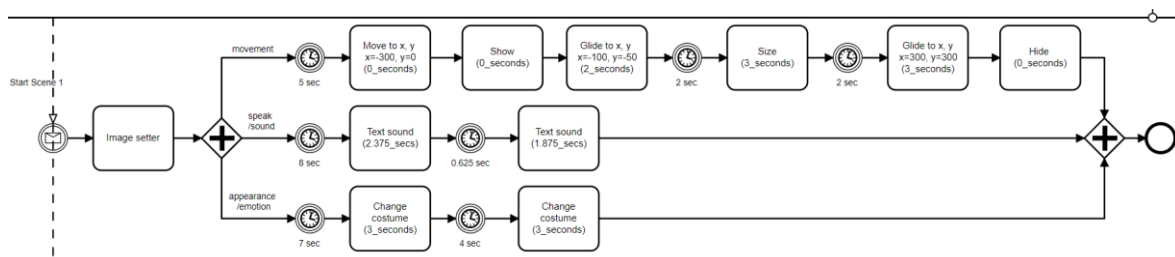


Figure 5 – A scene in the IL: Fairy

Scratch. Figure 6 shows the result of translation in Scratch 3 for scene 1 from Fairy’s point of. Notice that the scene, for Fairy, starts when the message “start Scene 1” is received with the block “When I receive”. After the start of the scene, there are five blocks corresponding to the *Image setter* activity. Finally, the last block of the first stack is a “broadcast”, which sends the message “Gateway scene1” and starts three more stacks corresponding to the three flows created by the *gateway* in the IL. Some activities are directly translated into the corresponding Scratch 3 block, while others need more.

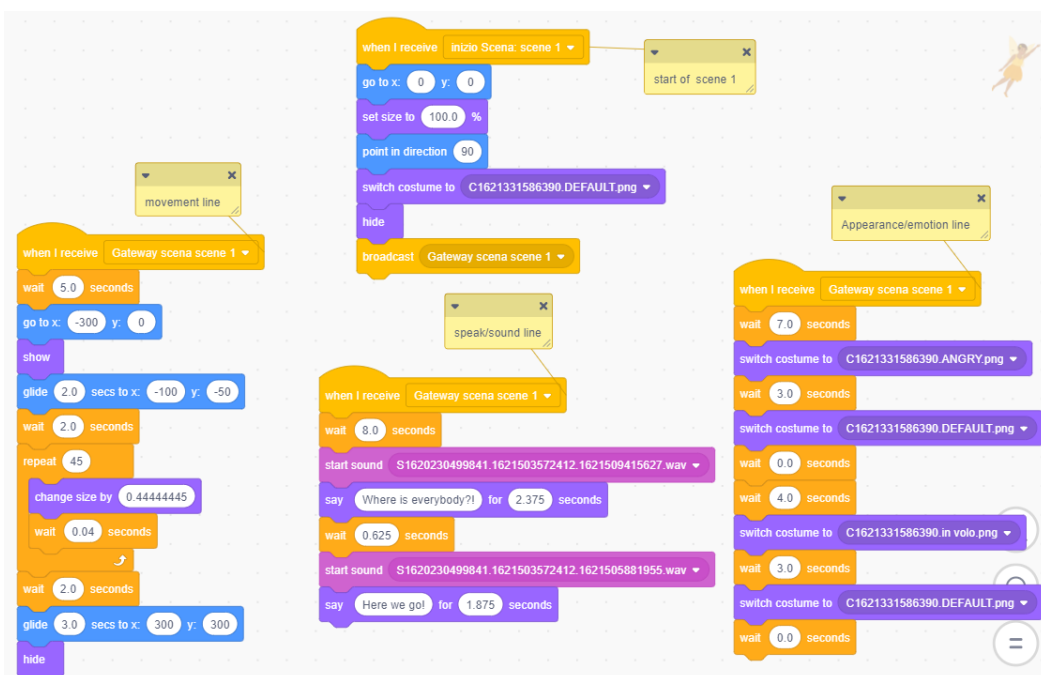


Figure 6 – A scene in the Scratch language: Fairy

As we can notice in Figure 4, in scene 1, the character Hedgehog is not a participant, but it is a character of the story because it is a participant in the scene 2 (see Figure 3). Therefore, in the IL the character has a “hide” activity and the block “hide” is also the only block for Hedgehog in the first scene, as defined in the Scratch 3 language (see Figure 7).



Figure 7 – A scene in the IL language and Scratch language: Hedgehog

3.1.3 User Interface

In this section we will briefly show the user interface of the prototype we created focusing only on the main contents. In Figure 8 we can see a story, composed by a list of three scenes, and the scene details: title, description, list of characters, list of objects, and background.



Figure 8 – App user interface: list of scenes and scene details



Figure 9 – Scene editor interface

The more complex section of the application is the scene editor (see Figure 9). Here the users can interact with a timeline and create the content of the scene, which will be represented by some initial settings and a sequence of blocks.

On the top of the page there is a horizontal pane divided in three parts: (1) The background image with a coordinate plane on it (which helps to find a point x, y); (2) editable details of the selected block, where the fields vary according to the block typology; and (3) the ordered list of the lines of the scene.

The main section of the editor page is the Timeline, divided vertically into seconds, which is composed as follows: a section for each character, a section for each object of the scene, a section for narration, a section for background music, and a section for sound effects (turquoise). The section for the characters or the objects is divided into three lines: (1) the actions (with yellow blocks) within which it is possible to manage movement, rotation, zoom, scene entry/exit of the character/object; (2) dialogs (cyan, only for characters) and sounds (turquoise) to allow the character to speak or to make sounds; and (3) emotions (light red, only for characters) and appearance (soft red) where it is possible to manage the emotion of the character or the look of the character/object.

4 EXPERIMENTS AND RESULTS

To evaluate the effectiveness of the application, experiments lasting a few weeks were planned, involving a group of subjects with intellectual disabilities from two voluntary associations, Esagramma (esagramma.net) and Amicinsieme (amicinsiemelipomo.altervista.org).

For various reasons, mainly due to the COVID-19 restrictions, it was possible to conduct only four sessions: two at Esagramma, in which one hour was dedicated for each of the four participants with moderate/severe intellectual disability, and two at Amicinsieme, where the participants with intellectual disabilities worked together for a total of 4 hours.

Experiment 1	A	M	U	G	Experiment 2	L	E	R
User	Age: 14 Down syndrome	Age: 63 Down syndrome	Age: 30 Severe ID	Age: 20 Moderate ID, autistic traits	User	Age: 49 mild ID	Age: 47 Mild/moderate ID	Age: 52 moderate/severe ID
Experiment	Given: Story and Settings Task: lines & sounds	Given: Settings Task: invents story and lines	Given: N.A. Task: invents story of real life, lines and sounds	Given: Settings Task: invents the story and lines	Experiment	Session 1 (without App): creation of the story and characters Session 2 (with App): creation of the story and lines		
Vocal Expression	↔	↑	↔	↑	Vocal Expression	↑	↔	↑
Narration Quality	N.A.	↑	↑	↑	Narration Quality	↑	↑	↔
Satisfaction	😊	😊	😊	😊	Satisfaction	😊	😊	😊

Figure 10 – Experiments results

In Figure 10 we collected the main results of the two experiments; we will describe them more in details in the next sections.

4.1 Experiment 1

4.1.1 Setting

The experiment was made with the support of a computer and an interactive whiteboard (IWB). The best setting in terms of user experience turned out to be the following: showing the editor on the computer and the player of the scene/story on the IWB, in this way the subjects could see their animated story in a bigger screen while creating it with the editor. Four subjects took part in the experiment:

- A: male, 14 years old, Down syndrome.
- M: female, 63 years old, Down syndrome.
- U: male, 30 years old, severe General Learning Disability.
- G: male, 20 years old, mental retardation and autistic traits.

The purpose of the experiment was to evaluate the application from three aspects: (1) the satisfaction of the subject, (2) the effectiveness it has in helping the subject to improve her/his communication skills, and (3) the application performances and stability.

4.1.2 Results

Subject A. The story of was predefined, but A chose, guided by educators, the lines.

The psychologist decided to set up the experiment based on “The Fox and the Hound” tale. The experiment was based on the ability of the subject to represent the main characters in the scene that he previously studied, to come up with the lines of the dialogue in the scene, record his voice trying to express the emotions of the characters, and to make sounds representing the actions in the scene (for example loud and fast knock on the table for running noise or slow and soft tap on bongo for soft footsteps noise).

The results obtained were satisfying: the use of the application did not bore him as he felt very happy and involved to see the characters move and speak with his voice and sounds. There was a constant evolution of the vocal expression and the emotion expression during registration of the lines, but at the end of the last scene there was a decline in attention and vocal expression because the subject was tired due to the high value of concentration required during the exercise.

Subject M. The story made during this test was invented by the subject.

The subject appeared active and engaged with a good ability to create and follow the storyline. However, she struggled to express herself as she needed assistance for speaking and required a lot of time to tell the story she has decided to perform during the test. Anyway, at the end, she was really satisfied with the story she created. The subject showed significant progress during the experiment as her vocal participation and her narration quality, considerably improved.

Subject U. The story made during this test was invented by the subject in all its aspects, settings, characters, and lines.

During the test, the user appeared to be engaged and eager to create a story where the main characters were people he knew, plus himself. It was not possible to notice a particular evolution within the experiment, as the time available was very limited and problems of concentration and communication were evident. We tried to use a guitar both within the story and by recording the subject playing it, to insert the sound into the story. By imagining some characters known to him in the story, he was more “immersed” in the story and could express himself in a better way. The use of the guitar was key, as it motivated the subject and made him even more happy about the result obtained with his story.

Subject G. The story made during this test was invented by the subject, the characters were chosen based on the preferences of G, the settings were already prepared except the last scene, which was entirely built by him.

In the test phase, the user appeared active and committed, with a good ability to create and follow the storyline. He needed to divide and shorten sentences into two or three words at most, because it was difficult for him to finish a complete sentence without mumbling half of the words. At the end he looked really satisfied with the story he created and animated. The subject showed an evolution during the experiment as his vocal expression and narration significantly improved.

4.2 Experiment 2

4.2.1 Setting

The test was made with the support of a computer and a TV screen. We used the best settings found out in the experiment 1: the editor on the computer and the player on the TV screen.

There were three subjects:

- L: male, 49 years old, mild intellectual disability.
- E: female, 47 years old, mild/moderate intellectual disability.
- R: female, 52 years old, moderate/severe intellectual disability.

The purpose was to evaluate the application from the same three aspects of Experiment 1, but also some others: (1) the satisfaction of the subject with the application, (2) the effectiveness it has in helping the subject to improve her/his communication skills, (3) the application performances and stability, (4)

the possibility to customize the story as much as possible, and (5) the importance and satisfaction to work together in a collaborative learning setting.

4.2.2 Results

Together with the psychologist and the educators, the subjects decided to create a story about the life cycle of flowers. Thus, the first experiment session was focused on the creation of the idea of the story and the description of the main characters. In the first session the characters and the backgrounds for the story were created and added within the application. The new story and the scenes' titles were also created in the application. The second and last session was the main one: using the application to create and animate the full story. At the start of such session, the three subjects chose their roles in the story. E was the "seed", R the "flower fairy", and L was the "elements of nature" (grain of soil, drop of water and ray of sunshine). The three subjects had to interact with each other through the characters of the story.

In the first session, they were not so happy, and one was very bored, but in the second session, thanks to application, they were all so enthusiastic that they all wanted to do more. Because each of them represented a single character, this helped them to empathize more with it, have more fun and gain more stimuli. During this session, we positively noticed how the subjects felt very involved with the process of story creation and took an active role in it, and this is very important to ensure they are willing to engage in such kinds of tasks/activities. As showed in Figure 10, the satisfaction at the end of the experiment was very high for all the subjects; two of them also showed a high improvement on the vocal expression, and two of them showed a high improvement on the narration quality.

4.3 Further results

In Table 1 we collect the most important features of the created application, pointed out by two psychologists and one educator from Esagramma (G. Rubino, C. Pagliardini, C. Bulgheroni) and one psychologist from Amicinsieme (L. Giuntini), who collaborated in the testing phase of the application on the field. At <https://scratch.mit.edu/projects/532749808/> it is possible to see an example of story created with the application during the experiment 2 and then uploaded to the Scratch website.

Table 1 – Application features and benefits

Features	Benefits for persons with intellectual disabilities (user)
The possibility to create a personalized animated story and record user's voice	<i>It creates the opportunity for a cognitive improvement, as the subjects are led to identify with the characters and the story; this is something that many of them cannot do frequently in daily life</i>
Creation of characters and scenes is easy and fast	<i>It permits to the user to maintain a high level of attention and don't get bored</i>
The possibility to decide all the action during the story (movements, sounds and appearances)	<i>It helps the user to observe a continuity in the story and to narrate it in an easy way</i>
The easy way of reviewing the entire scene while creating it	<i>It permits the subject to stay in the context of the story and to see or listen to the changes in real time</i>
The possibility for the users to listen to their voice just recorded while watching the scene evolution	<i>This, within a context, helps them and motivates them in improving their vocal expression and their narration of the scenes</i>
Inserting, in an easy way, new characters, objects and backgrounds (drawings, photos, images, etc.)	<i>It permits to the participant to completely personalize the story and to avoid abstraction (often, for the users, it is very difficult to grasp abstract things)</i>
The possibility to share the created story in an easy and fast way	<i>It helps the user to communicate with others through what they have created and to show it to family and friends (so it helps them to put more effort into it)</i>

5 CONCLUSIONS

Starting from the need of providing tools to simplify the process of building an application targeted at the creation of animated stories, we proposed an IL that abstracts the main concepts useful for the creation of the story/animation, being flexible and independent from both the specific application user interface and the execution model.

To validate that our approach can be successfully applied to a real-world scenario, we employed it in the design and implementation of an application for storytelling that leverages the IL to generate a Scratch 3 file, executable in a standard Scratch 3 player. The IL has been already useful to us, during the development of our application, where it lowered the effort of adding new features to the user interface without modifying the code for Scratch 3 generation. Moreover, we expect that, in the future we, might need to update the application to new Scratch versions, change the target language or add more features to the user interface, and the IL will make such work easier to perform.

With the experiments we conducted, we showed that the application can be useful for people with intellectual disabilities in the following main ways: (1) to improve in communication and verbal expression, (2) to learn to relate more to the world around them, (3) to improve their narration/creativity skills, and (4) to learn to recognize and express emotions in a better way.

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