

# Designing Therapeutic Activities Based on Tangible Interaction for Children with Developmental Delay

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**Abstract.** This paper presents a set of activities specially designed for children with developmental delay to be run on vision-based tangible tabletops. This way, the benefits that the combination of tabletop devices and Tangible Interaction offers to the treatment of cognitive problems can reach the children, which is the final aim of the work presented here. Two evaluations with children have been carried out as the result of a collaboration with an occupational therapy center, which has allowed us to detect some usability problems in the developed activities and to extract some conclusions that are also presented in this work.

**Keywords:** Tabletop · Developmental delay · Children with special needs · Activities · Tangible Interaction · Therapy

## 1 Introduction

Developmental disabilities are a group of related chronic disorders of early onset estimated to affect 5 % to 10 % of children [6]. The developmental delay is a subset of developmental disabilities defined as a significant delay in two or more of the most common developmental domains (gross/fine motor, speech/language, cognition, social/personal, activities of daily living) whose main problem is that there is not a specific method to cure it, so any treatment plan will have to take every child's uniqueness into account and it will be designed to focus on the child's individual needs.

Regarding this matter, our group (the AffectiveLab at the University of Zaragoza, Spain) has developed NIKVision, a vision-based tangible tabletop device designed for very young children and children with special needs [1] in which the interaction is carried out by positioning objects on the tabletop surface (Tangible Interaction), allowing children to play with the computer manipulating conventional toys. NIKVision has been tested in nurseries, schools and special education schools, proving its usefulness when working with this kind of children [5].

Based on our experience over the past years when working with children with special needs, the objective of the work presented here has been to develop tangible tabletop activities for the NIKVision tabletop specially designed for children with developmental problems.

This paper is organized as follows. Section 2 describes the state of the art. Section 3 presents the methodology used to develop the activities. In Sect. 4 the evaluation of the activities is presented. Finally, Sect. 5 is given to the conclusions and future work.

## 2 State of the Art: Tangible Interfaces and Tabletops for Children with Developmental Delay

In this section several examples of the use of tangible interfaces and tabletops to work with children with developmental delays are analyzed, in order to determine how our work can contribute to this field.

On the one hand, regarding some works that make use of tangible interfaces, *LinguaBytes* [3] is a research programme which aims to develop an interactive and adaptive educational environment that stimulates the language and communicative skills of multiple handicapped children aged 1–4 years. Two tools have been developed during that project: *E-scope* and *KLEED*.

*E-scope* is a tangible device aimed to children with language and communication developmental problems. The prototype consists of a wooden ring-shaped toy with sensors and actuators, a computer with a wireless station and a screen. Using *E-scope* the children can listen to stories or play educational games by rolling the *E-scope* over different pictures that trigger different stories.

*KLEED* is a modular system consisting of exercise mats that can be connected to a central console. In this case, the child interacts with the device by placing physical tagged objects over the mats in order to listen to interactive stories or to realize exercises.

Also, Hunter et al. [4] have developed activities to teach children aged 4–7 years spatial concepts and sentence construction by using *Siftables*, hybrid tangible-graphical user interface devices that allow wireless communication and that can detect other devices of the same kind. Two main activities can be done with these devices: ‘*Make a Riddle*’ and ‘*TeleStory*’.

In ‘*Make a Riddle*’ the child has to use three *Siftables* to create a sentence that will update an image in a fourth *Siftable*. Not all the combinations have an associated image. That way, the child will feel more motivated to create different combinations in order to obtain an image.

In ‘*TeleStory*’ the child can influence the story of a cat and a dog that are traveling. In this case the child uses the *Siftables* to change the elements of the story: for example, if the child uses a *Siftable* that is displaying a sun, the scene of the story will become daytime.

Finally, the *Interactive Fruit Panel* [2] is a tangible interface designed to help children with communication problems connect real objects (in this case fruits) with their graphical representation. In addition to their communication skills, the activity also makes the children work out their concentration and memory.

On the other hand, the only work that uses a tabletop to work developmental problems is [8], where the authors use *Reactable*, a tangible tabletop that allows the creation of music pieces, to work with autistic children, in order to offer them an alternative means of communication. The interaction with *Reactable* is usually carried out by using special objects but it also allows a direct interaction.

Analyzing the examples above it can be concluded that although there are several works that use tangible interfaces to work with children with developmental problems, the use of tabletops in this field is not very widespread. Besides, the works that make use of tangible tabletops usually focus on working just a definite developmental delay, without offering the possibility of working with children with different problems.

Therefore, the objective of this work was to create a set of tangible tabletop activities that could be useful for children who suffer from a varied range of developmental problems.

### 3 Developing Tangible Therapeutic Activities

The process had two differentiated parts: the establishment of the therapeutic goals that our activities had to fulfill in order to be useful for different children (analytic stage) and the creation of the activities (executive stage).

#### 3.1 Establishing the Goals

We made contact with the center ENMOvimientoTO, an Occupational Therapy Center (OTC) specialized in the early identification of delays and disorders in children aged 0–16 years.

The main objective of this OTC is to help these children carry out their daily activities, and since NIKVision had previously proven to be useful with children with special needs [5] the therapists of the center were interested in seeing whether it could help this kind of children as well.

Thanks to the documentation and advice of the OTC therapists, we were able to establish some therapeutic goals that had to be achieved by the activities that we were going to design. In order to decide on these goals, we took into account the possibilities offered by the combination of the NIKVision tabletop and the Tangible Interaction. Furthermore, from the great variety of disabilities of the children visiting the OTC, we had to choose the most common ones, since our objective was to develop activities that could help most of the children.

#### 3.2 Development of Activities

The executive stage comprises two stages as well.

In the first instance, once we chose the therapeutic aspects to work with we started designing the activities. Then, we created simple concepts of the new activities and asked the OTs for their opinion. Finally, once we were sure that the activities fulfilled the necessary requirements for the children visiting the OTC, we implemented them.

The activities that were developed as a result of this interchange were:

- Bees: this activity helps to exercise visual attention.
- Fishing: this activity helps to practise coordination and fine motor skills.

- **Twister:** this activity helps to make use of bilateral coordination. In order to realize this activity, the children have to be able to tell apart their left hand from their right hand.

In the second place, a fourth activity had to be developed after the first evaluation session since we discovered that the ‘Twister’ activity was too complicated for most of the children, as it will be explained in the Sect. 4:

- **Plumber:** this activity helps to practise bilateral coordination but in this case the children do not need to tell apart their right hand from their left hand.

Following all the activities are explained in detail.

**Bees.** In this activity, the tabletop surface shows an animation of a tree full of hives with several bees flying around. The animation also shows a beekeeper standing under the tree. After some seconds, the bees stop flying and each one of them disappears into a different hive. Among the bees, there is only one that carries honey (see Fig. 1 Left).



**Fig. 1.** Bees activity. Left: Background-animation shown on the tabletop surface. Right: Physical honey pot toy to interact with the tabletop.

The activity is completed when the child places a honey pot toy (see Fig. 1 Right) under the hive where the bee with honey disappeared.

In order to give feedback to the child, we use the beekeeper character and different sounds:

- If the child places the honey pot toy under a wrong hive, the beekeeper will show a sad expression and a sound saying that there is no honey in the hive will be reproduced.
- If the child places the honey pot toy under the correct hive, an animation of honey falling out of the hive will appear, the beekeeper will begin to jump for joy and a sound saying that the honey has been collected will play.

**Fishing.** In this activity, the tabletop surface shows an animation of a pond with a pier where a cat is standing. Also, next to the cat there are shapes of the fishes that the cat likes (see Fig. 2 Left).



**Fig. 2.** Fishing activity. Left: Background-animation shown on the tabletop surface. Top-Bottom Right: Physical rod and fish toys to interact with the tabletop.

In this case, two different sets of objects are used: fishing rods of different length (see Fig. 2 Top-Right) and fish toys of different shapes and colors that are placed on the tabletop surface (see Fig. 2 Bottom-Right). To complete the activity, the child has to use one of the rods to catch the fish that have the same shape and color as the ones next to the cat and place them on the pier.

In order to give feedback to the child, we use the cat character and different sounds:

- If the child places the wrong fish on the pier, the cat will show a sad expression and a sound saying that the cat does not like that fish will be heard.
- If the child places the correct fish on the pier, the cat will start to applaud and a sound saying that the cat likes that fish will play.

**Twister.** This activity is a tabletop version of the original Twister game. The surface of the tabletop shows a twister roulette and four rectangular areas of different colors where the child has to place his hands (see Fig. 3 Left).



**Fig. 3.** Twister activity (multiplayer). Left: Background-animation shown on the tabletop surface. Right: Physical gloves to interact with the tabletop.

The objects used in this activity are gloves that the child has to wear on his left and right hands (see Fig. 3 Right), and a peculiarity of this activity is that the child has to keep his hands still on the colored areas until new instructions appear on the screen. The activity can be played individually or cooperatively.

In this case, we simply use audio feedback instead of using a character to tell the child if he has placed his hand on the correct area or not.

**Plumber.** In this activity, the tabletop surface shows an animation of a pipe composed of segments of different colors. Some of those colored segments present water leaks of the same color. The animation also shows a plumber standing under the pipe (see Fig. 4 Left).



**Fig. 4.** Plumber activity (multiplayer). Left: Background-animation shown on the tabletop surface. Right: Physical gloves to interact with the tabletop. (Color figure online)

The objects used in this activity are gloves of different colors that the child has to wear on his left and right hands (see Fig. 4 Right). The variety of the colors of the pipe segments, water and gloves depends on the number of children playing:

- If just one child is playing, the pipe will only have blue and red segments and just the blue and red gloves will be used.
- If two children are playing, the pipe will have blue, red, yellow and green segments and every child will wear different gloves: one child will wear the blue and red gloves and the other child will wear the yellow and green gloves.

To complete the activity, the child has to place his gloved hands over the segments of the pipe that have water leaks.

In order to give feedback to the children, we use the plumber character and different sounds:

- If a child places his hand over a segment whose color is not the same as the color of the glove, the plumber will show a sad expression and a sound saying that the color is not the same will be played.
- If the child places his hand over a segment whose color is the same as the color of the glove, the plumber will dance with happiness and a sound saying that the water leak is fixed will be reproduced.

## 4 Evaluation

When a first prototype of the first three activities was implemented, a NIKVision tabletop was installed in the OTC and an evaluation with the children was planned in order to detect usability problems in the developed activities.

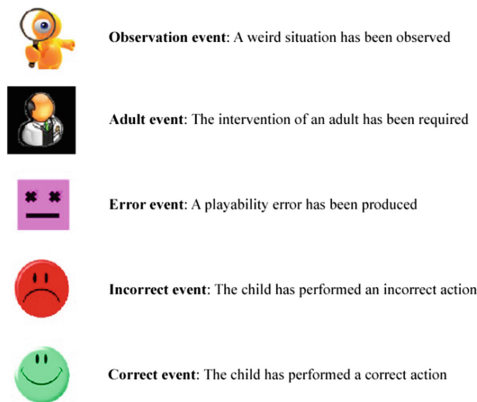
### 4.1 Methodology

The evaluation was carried out for a week with the participation of a total of ten children who had several developmental issues like visual attention, coordination, fine motor skills and bilateral coordination.

During the evaluation, the children tested all the activities mentioned in the previous section except the ‘Plumber’ activity (which was developed as a result of the first evaluation as it will be commented further on) allowing us to detect some aspects of the activities that had to be corrected.

In order to locate usability problems we used a video analysis usability method consisting of a simplification of DEVAN [7], so that all the sessions with the children were video recorded for that purpose.

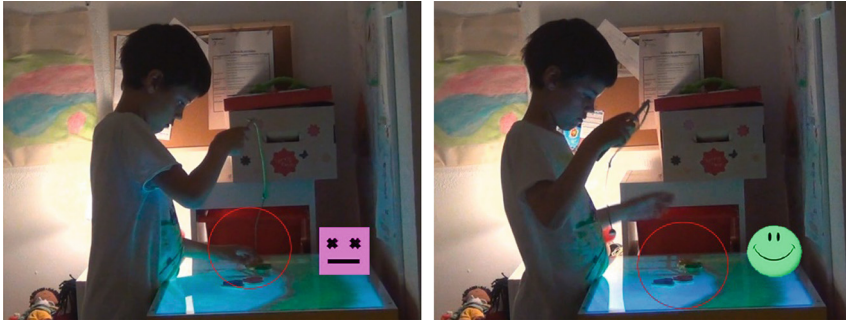
After the evaluation, a usability expert reviewed the videos and labeled them using five categories of usability events (see Fig. 5.). If an event happened in more than 50 % of the cases, it was considered a “critical point”, meaning that a correction in the game had to be made in order to prevent that event from appearing again. Otherwise, the event could be considered an “isolated case” and be ignored.



**Fig. 5.** Events we take into account while the children play

In the Fig. 6 an example of labeling is shown.

Since some usability errors were found in the developed activities, we carried out a second evaluation session for another week with the same ten children when a second version of the activities was available.



**Fig. 6.** Example of labeling a video. Left: the child uses his two hands to grab the rod instead of using just one hand (error event). Right: The child is able to complete the task (correct event).

### 4.2 First Session

Regarding the first evaluation session, Table 1 shows the critical points that were found when the children tested the developed activities.

**Table 1.** Critical points of the activities

Activity	Times	Event	Explanation
Bees	7	Error	While the bee is still flying, the child begins to move the honey pot toy over all the hives, so that he is able to complete the activity without paying attention to the bee
	6	Error	After an incorrect action, the child chooses the correct hive but the wrong sound that was reproduced with the first incorrect action keeps playing, confusing the child
	5	Adult	Instead of putting the honey pot toy under the hive, the child places it over the hive
Fishing	7	Error	The child does not return the fish to the water once the task is completed, so when the next task begins there are already some fish placed on the pier that can make the audio feedback play even when the child has not done anything yet
Twister	8	Error	The child does not know that he has to keep his hands still on the tabletop during all the activity

As shown in the table, in the “Bees” activity there were three critical points that had to be fixed:

The first critical point was resolved by deactivating all the areas in which the child can place the honey pot while the animation of the flying bees is being reproduced. That way, even if the child tries to guess the correct hive by probing all of them he does not get any kind of response and consequently he is forced to pay attention to the bee in order to see what hive is the correct one.



In order to solve the second critical point, it was decided to give priority to the correct feedback. That way, the moment the child performs a correct action the other sounds that could still be playing stop and just the correct sound remains, eliminating the possibility of confusing the child with contradictory feedback.

Lastly, regarding the third critical point we considered to modify the game so that the child could place the honey pot over the hive instead of under it. However, during the evaluation we also observed that some children immediately realized what they had done wrong when seeing the animation of the honey falling from the hive, so in the end it was decided not to change the game.

Also, the evaluation showed that most of the children could complete the activity without problems. Therefore, we decided to increase its level of difficulty for the next evaluation by adding more distractors to the animation (more bees that carry no honey) and by increasing the speed of the bees.

The ‘Fishing’ activity had just one critical point that could be easily fixed by adding an intermediate task in which the child has to return the fish to the water. That way, the possibility of a task being affected by the fish that the child has placed in the previous task disappeared.

Finally, the ‘Twister’ activity had just a critical point but in this case it was rather difficult to fix it because even when children were told to keep their hands still, they usually forgot to do so and removed them from the tabletop. Also, most of the children found difficult to tell apart their left and right hands even when the gloves that they were wearing had the indication on them. After studying the problem we concluded that to fix those problems would imply to change the ‘Twister’ activity completely, so it was decided to design another activity that could supply the ‘Twister’ problems. As a result, the ‘Plumber’ activity appeared, as it was mentioned in the Sect. 3.2.

### 4.3 Second Session

Once the critical points mentioned in the Table 1 were fixed and the new ‘Plumber’ activity was created, we carried out the second evaluation session for another week.

We tested again all the previous activities and the ‘Plumber’ activity with the same ten children who had participated in the first evaluation.

This time, no critical points were found in any activity so it was concluded that the second version of the activities was definitive.

## 5 Conclusions and Future Work

After analyzing several examples that make use of tangible interfaces and tabletops to work with children with developmental delay, we have created a set of four tangible activities that can help children with different developmental issues.

Thanks to the collaboration with the Center ENMOVimienTO we have been able to test the developed activities with a total of ten children. Also, the first evaluation session that was carried out allowed us to detect some usability problems in the first version of the activities that could be fixed for the second session.

After that second evaluation, the therapists of the center confirmed the utility of the activities, since the children had felt very motivated to use them.

In the very next future, we intend to keep working on the developed activities and to create new ones that cover a wider range of developmental issues so they could be useful for more children.

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