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Tangicons 3.0: An Educational Non-Competitive Collaborative Game

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ABSTRACT
In this paper we present Tangicons 3.0, an educational game for children between the ages of 6 and 9. Tangicons foster algorithmic construction and reasoning as well as discussions among the players. In contradiction to other collaborative educational games Tangicons intend to avoid competition between children in favor for a strictly collaborative process. Children learn to solve problems together by manipulating physical objects that communicate with each other in order to move virtual characters on a map. This requires a high degree of abstraction. To sustain concentration and motivation, the game also includes playful elements as well as fine and gross motor activity. The focus of the investigation, however, will be the logical-abstract thinking of children. This new version of Tangicons is build with Sifteo cubes as the base technology and a computer for the output on a larger display and sound.

Categories and Subject Descriptors
K.3.1 [**Computers and Education**]: Computer Uses in Education,
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces

General Terms
Design, Experimentation, Human Factors

Keywords
Tangicons, Visual Programming, Tangible Programming, Tangibles, Learning, Tangible User Interface, Ambient Learning Spaces, Educational Game

1. INTRODUCTION
Mark Weiser predicted that the world, in which our children grow up, will increasingly be interspersed with digitally enriched spaces and objects. This world will include digital technology, which recedes into the background [1]. What we perceive, however, will be an increasingly complex programmed, digitally-controlled behavior. Against this background, it seems necessary to support elementary school children in developing logical-abstract thinking skills.

Since 2007 we have been examining reasoning within educational games for young children in kindergarten and elementary school with a learning environment called Tangicons [2]. Tangicons are programming cubes integrated into a game for young children that foster reasoning by laying sequences that program system behavior. They are designed to teach children about abstract manipulation and assist them in constructing cognitive skills as they play. With Tangicons 1.0 and 2.0 children analyze and reprogram a given algorithm, whereas Tangicons 3.0 mainly aim at mental transformation of spatial movement by constructing an algorithm.

For our research it is important that we involve children in the design process of these learning applications. It provided useful insights into the demands of children and how they cope with new tangible interfaces. We thought about the variety of elements to be included in the user interface and its structure.

Especially in the first, but also in the second version of Tangicons children were involved closely in the development from early prototypes onwards. The information that has been collected hereby helped us to build the third version. We were able to rely on many aspects that have been developed before. Therefore we started the new evaluation with a working system.

1.1 Evolution of Tangicons
In our first version, we created non-electronic physical programming cubes together with children in a co-design process. We intended to find out whether children from kindergarten and first grade are able to think in abstract forms and simple algorithms. We intended to introduce them to reasoning, collaborative work and first steps of programming with tangible objects within an educational game, which included cues for gross motor movement. They had to draw conclusions from lights and sounds and had to reprogram the same behavior by creating a sequence of wooden programming cubes in the correct order. We observed that there was great improvement in counting and mapping the abstract events to the programming sequence during play, but the technology created some obstacles (fig. 1).

Figure 1. Tangicons version 1.0

Handling the camera that was used for recognition of the programming sequence was challenging for the young children and the transmission between the computer and the "executing station" was also not very reliable.

The idea came up to integrate the technology into the programming cubes in the second version of Tangicons [3]. We used ATmega8 microcontrollers, accelerometers and radio modules built into the cubes. The station acted as a charging station for the cubes and also included a sound device, colored LEDs and a microprocessor. Additionally, there were two communication modules for wireless transmission of data between the cubes and the station as well as between a PC for reprogramming and the station. In contrast to the first version of Tangicons, there was no camera or infrared connection involved any longer. The aim, the principle and course of the game remained the same. As with the first version of Tangicons the main task was to observe and analyze a sequence of events in order to create the same behavior with the cubes. But the way of programming changed in the second version. The cubes had to be put in order as pairs of two with the same color, first yellow, second orange and third red. The pairs consisted of an argument and a modification cube (fig. 2).

Figure 2. Tangicons version 2.0

Evaluations of this second generation of Tangicons showed that the game flow improved and that children under 5 years went along very well, although there was the new challenge to determine the sequence of pairs of cubes by the color of the cubes.

Unfortunately new problems came up. The technology inside the cubes was quite expensive and fragile and did not withstand the harsh every day-use by children. We looked for something different and found Sifteos [4], good candidates because of their robustness and wireless communication between each other and also with the pc. The interaction with the tangible cubes was somehow different from the version 3.0 with the Sifteos. Symbols on the cubes of version 2.0 could be seen and identified within seconds on each side by rotating the cube. Every possible interaction was clearly obvious to the children. This is not the fact with the Sifteos anymore. There is only one display which content can be changed by clicking, turning or moving, which means that children have to build a more complex mental model of all possible interactions or change the content of the cubes by trial and error. Thus, the gameplay had to be changed significantly as we will explain later (fig. 3).

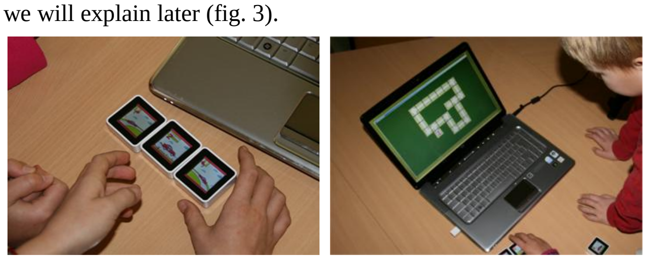

Figure 3: Tangicons version 3.0.
Sifteo cubes (l), grid of the map (r).

1.2 Linking physical and mental activities with Tangicons

Tangicons aims at a mixture of interactive gaming with physical movement. During the educational game with Tangicons, children have to move, even run between their tasks. Although we do not investigate the correlation between motion and learning in this paper, we still would like to underline its importance as it is a vital part of every version of Tangicons. Numerous scientific studies show the positive relationship between movement and the intensity of intellectual abilities in students. Empirical studies of Zimmer [5] show, that versatile motor experiences serve as basis for possible creation of an ideal "cognitive instrument" with better perception and increasing intelligence. Both, fine and gross motor movement, as the two moments of the physical-kinesthetic intelligence, improve concentration and promote learning and cognitive processes, as the research group "Projektgruppe" [6] proved. In a study with children of preschool age Zahner [7] shows that there is an interrelation between motor activity and higher intellectual development. Those who can move better are also more highly productive intellectually. According to Pühse [8] children show more attention in their learning groups if they move while learning. A study by Breithecker [9] has found positive tendencies like increasing satisfaction and joy of learning at school through physical activity during class. In addition Wamser and Leyk [10] show that after brief periods in which students move, they are more concentrated and show better study habits.

While playing Tangicons, concentration on cognitive processes linked to fine motor activity is interrupted for a short time and replaced by gross motor activity. The interrupts are designed on purpose as we want children to communicate and think about their steps upfront and also use the short brakes in order to focus better on their cognitive challenges. Here, the duration of the physical activity is not important. The frequency of these interrupts depends on the behavior of the children. If they communicate and think about upcoming steps while playing, they mostly avoid making mistakes and therefore have to run much less. If they only play by trial and error, they inevitably make more mistakes and therefore have to run more often, which can be perceived as inconvenient. This way the children can decide themselves the balance between natural need for movement and making progress in the game.

In the first two versions of Tangicons [2,3] we aimed at young children between 4 and 6 years and introduced them to abstract thinking and reasoning with the help of simple means. Tangicons 3.0 still uses some of the methods and principles that we worked out with the old versions, but the gameplay had to be redesigned as it aims at older children between 6 and 9 years. We built a game that postulates solving more complicated tasks like mental transformation. Depending on the players, the game can be upgraded with additional complexity for further iterations. It fosters abstract reasoning, collaboration and discussion amongst children, resulting in better teamwork compared to the previous Tangicons.

1.3 Structure of the paper

In this paper we first refer to related work and discuss differences in our approach. This will be followed by a reference to modern theoretical pedagogical approaches and also empirical studies that illustrate the importance of the interweaving of physical and mental activities for learning. Then we describe the educational game Tangicons 3.0. After that the technical implementation is shortly explained, before we present the evaluation section. Finally, we provide conclusions and an outlook on future work.

2. RELATED WORK

There are many good but different educational games that deal with young children in Kindergarten or elementary school. In this paper we want to mention the educational games T-Maze [11], TeleStory [12], and the tangible user interface ARBlocks [13]. We will see that there are significant similarities in the way technology is used or in the plans to support playful construction of knowledge among children of a similar age group. Also we want to point out where the mentioned work of others differs from Tangicons.

2.1 T-Maze

A work called T-Maze by Wang, Zhang, and Wang [11] focused on programming with tangibles. It is developed for children aged 5 to 9. Wooden cubes with TopCodes are optically tracked and the position of each cube interpreted. The goal of programming is to lead an avatar out of a maze, displayed on a screen.

Figure 5. Singular workplace with T-Maze (l), TopCodes on the T-Maze cubes (r).

T-Maze technically follows Tangicons 1.0, using the same basic software developed by Michel Horn [14] by tracking TopCodes on wooden cubes. However, the approach is different from Tangicons 1.0 as arranging the cubes moves an object on a screen instead of the abstract output with blinking lights and sounds in a box. But with Tangicons 3.0 we have a very similar approach regarding the use of an avatar on an external display. The main difference between T-Maze and the Tangicons is that in T-Maze the playing children immediately see what to do with the cubes. Therefore a child will master the movement of the avatar on the screen very fast, handling directions easily by trial and error in real time. With Tangicons the reaction of the system on the handling of abstract symbols is deliberately delayed. It is intended that the children set up a hypothesis together to agree on how the system will respond to the specified code. Also, even if it is not examined further in this paper, we intended to support gross motor skills since we believe alternating cognitive and physical activity helps sustain concentration. By using the Sifteo cubes with integrated technology for Tangicons 3.0 it is still possible to communicate over a longer distance, and thus support gaming in different spatial areas collaboratively.

2.2 TeleStory

With the design of TeleStory by Hunter, Kalanithi, and Merril [12] a language-learning application was developed for pre-school children. TeleStory comprises of interactive characters and objects presented both on Sifteos and additionally on an HD television as part of an animated scene. The large display allows for a richer graphical presentation along with the use of Sifteos and helps to get the attention of the kids while unfolding a narrative. Placing Sifteos next to each other will result in a reaction of the system in real time: a triggered episode of animation with sound will be played for up to 20 seconds on a large screen (fig. 4).

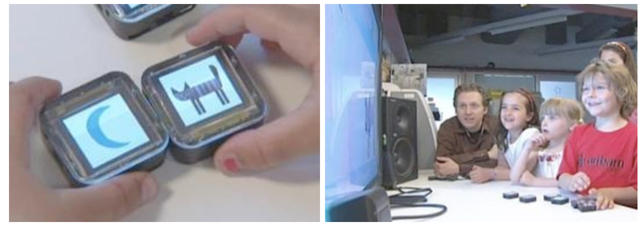

Figure 4. Placing Siftables together and watching an event on the large screen

The interaction between Sifteos and the external display is similar to our Tangicons 3.0 system. Another similarity is the aim to make children understand the connection between manipulated Sifteos and graphical output on an external screen. Differences appear in the real-time response of the TeleStory system and the use of tilt-based selection (using the accelerometer sensor) to select different items on the Sifteos. In contrast to TeleStory we prefer not to use real-time interaction, as mentioned above. Instead of tilt-based selection we chose to use the push function on the Sifteos for selecting different actions. However, we put emphasis on collaboration, which is not explicitly intended by TeleStory and also on movement of our learners, to foster concentration, joy and satisfaction as explained further below.

2.3 ARBlocks

Another recently published work is called ARBlocks [13]. ARBlocks is based on projective augmented reality and tangible user interfaces, aiming at educational activities. The information is displayed by projectors on blocks using a projector calibration technique. The blocks are tracked through a frame marker. Although the technology seems to be rather cost efficient there are strong restrictions to its usage. It is limited to a defined area, whereas the Tangicons can be used in any kind of setting.

Figure 6. Projection on block with frame marker and setting for using ARBlocks

3. THE EDUCATIONAL GAME

The game we invented combines reasoning, communicational aspects and running and addresses haptical, auditive, visual and other senses for fine and gross motor movement of children. Like in former versions of Tangicons, we hold on to the concept of a mixture between problem solving and running.

With several ideas and approaches, we try to bring children together and support communication among each other as our game is played within a group and needs consensus for every step between all involved children. They have to think, argue, and help others in order to make progress. Different from other games, where competition is used to stimulate the workflow and push children to raise their speed, we propagate a non-competitive game where they can work at their own pace. Within this scenario they work not against but with each other as a group and solve problems together. Therefore the educational game satisfies most kids likewise. Slow learners and others are equally esteemed and are not excluded. Non-competitive games foster cooperative learning where students learn to capitalize on one another's resources and skills by asking one another for information, evaluating one another's ideas, monitoring one another's work [15].

In addition Tangicons 3.0 is a turn-based game, where the students can take their time to think about their actions in advance as they determine the speed themselves. Although it can take more time to finish a level, conversation among children is cultivated as they are invited to check each step more often and carefully than in competitive games with time constraints. As the game is not executed in real-time, the children do not immediately see the effect of each Sifteo, and must think aloud about the impact of their doing. This is intended to result in complex and challenging cognitive processes where children are forced to think in an abstract way while planning their actions.

3.1 Aim and intention of the educational game

The actual aim of the game is kept rather simple. Up to four children have to work together in order to guide an avatar through a labyrinth to reach its destination. There are multiple possibilities to solve the problem. The paths can branch and the children have to decide which way is the best, fastest or easiest to go. We constructed the levels in a way that shorter paths have more curves and need more steps than the seemingly longer but straight paths, in order to see how the children react.

The game consists of a Laptop with a roadmap and a set of six Sifteo cubes. Four of the cubes are personal tokens for the children, one for each child. By this, our intention was to motivate all children to take part in the game and integrate in the group as the game cannot continue if one of the tokens is missing. Besides the personal tokens there is one modification token which has influence on the players' tokens and another cube that is used as a "charging station". We will refer specifically to those tokens later on. Depending on preferences and gender the children choose to play either a horse or a sports car. This can be very important in order to address different interests of boys and girls. We wanted to examine whether playing the game with an aversive avatar has negative effect on the motivation of the kids. If a decision is made, a map with the chosen avatar appears on a Laptop in front of the children and each of the four players gets his or her own cube as a personal token. The cubes show either a horse or car in different states. The content of the states can be switched between left curve, right curve or straight forward by pressing on the cube display. This way, the children decide what they want the avatar to do. Left and right means turning on the spot whereas forward moves the e.g. horse one step forward on the grid of the map (fig. 3).

The path of the horse is restricted by the roadside and must be analyzed and split in single steps by the children. In order to reproduce the path by a sequence with the Sifteo cubes, the children require a high degree of abstraction to draw conclusions between the path on the large screen and the cube icons.

The children have to count the number of straights and follow the bending of the curves. Putting the cubes in the correct order is not as easy as it seems. They must be laid out from left to right which is quite abstract as it does not correspond to the road on the map.

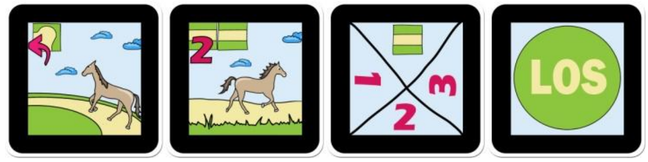

Figure 7: Left curve, 2-steps straight, modifier, executer

Cubes only show left and right curves as well as one kind of straights (fig. 7) but on the map, the corresponding curves and straights can point in every direction (fig. 13 and 16). This requires the children to abstract and map the possible steps from the displayed path to the cubes. This is supposed to be one of the main challenges as it is a difficult task of mental transformation and not easily performed by young children. In addition to the personal Sifteos of the players, there is a modification cube with four arguments on it. One argument shows the corresponding token-state that can be manipulated while the others increase the number of steps from one up to three (fig. 9). This way, the children can perform multiple steps at a time in order to reach the goal. For example if there is a long straight line and a player wants the horse to go three steps with a cube instead of one, he is able to increase the number of steps by holding the modification cube with the desired number next to his other cube. There is also a given restriction concerning the reach of the goal which can be either solved elegantly with the help of the modification or no-operation cube. The avatar is not allowed to exceed the goal and therefore has to be brought in with the exact number of needed steps. Using the modification cube can be done before lining up the four cubes (fig. 9). When all four players have laid their cubes and put them in order, the modification cube converts to an execution button with "LOS" ("GO") written on it (fig. 9). By pushing the button, the programming sequence is executed and transferred to the laptop and the avatar moves along the route.

As we described before, there is another important aspect of the game that inevitably leads to discussion among players. The cubes can only be executed once and have to be "recharged". After the execution, either the horse gets hungry and has to be fed or the car empty and has to be refueled in order to go on. Because the "charging station" is separate from the "programming station", the children are encouraged not to try out different sequences arbitrarily.

3.2 A Tangicons 3.0 game cycle

All four players have to lay down their cubes in a row, then execute their steps and watch the avatar going along the road. After each execution cycle, the avatar is out of energy and has to be "recharged". This workflow has to be repeated until the avatar reaches the goal.

We provide two introductory levels and further levels with increasing difficulty. During the first two levels the children can experience the gameplay and get used to the functions of the Sifteos. After this short training, the children go on to the actual game by playing more complex levels. During the first step they examine the map and by this identify their actual task. Complex maps can have many branches, diverse curves and long straights. It is up to the children, which way they want to go. They can either just plan to the next branch or take a look at the complete map and discuss the further process.

Figure 8: Discussing and correcting

After deciding for a branch, they have to negotiate the order of the players, who wants to start and who is next and then structure their program. It is also possible to reduce the number of steps by using the modification cube, which is done before finishing the program (fig. 9). After all cubes are laid, the children have time to check and discuss whether this is done right or wrong and correct (fig. 8), if necessary, before pushing the "Go" button and executing the program (fig. 9).

Figure 9: Modifying (l) and executing the sequence (r).

After each execution, the players' cubes have to be "charged" again (fig 10, l). Therefore the children run to the "charging station", hold their cube against the "charger" and get back to the programming station (fig.10, r).

Figure 10: Refilling (l) and running (r).

If the avatar does not carry out the expected steps, e.g. going in the wrong but possible direction, the children receive immediate visual feedback. Otherwise, an impossible move leads to negative feedback in the form of sounds (either a stalled engine or a bristling horse). Now they can draw conclusions on their mistakes and try again with a new sequence. The children can think about and discuss as long as they want as there are no time constraints in the game.

3.3 Tangicons 3.0 from a computational point of view

In contrast to previous versions of Tangicons we changed how children have to deal with abstractions in the new version of the game. With Tangicons 1 and 2, children had to deal with abstract sequences and reverse-engineer them with the given tools. Now we choose a pictorial game setting, where we present a concrete problem and give the children abstract tools to solve it. If we look at our game-setting from a programmer's perspective, there is a well-defined problem to be solved with a finite set of functions and a specific way to arrange and execute them. Our game provides the syntax of a small domain-specific language. Each player chooses a function on his or her personal token. The icon on the modifier token tells the player to which functions the given parameters (in our case the numbers 1, 2 and 3) are applicable. After determining the functions and parameters to use, all players collaboratively arrange their tokens in a short programming sequence that has to be four statements long. The concept of the old Tangicons focused on the relation between programming sequences and their output in a very abstract way but also appropriate for children in kindergarten. This was done in order to introduce very young children - starting at the age of 4 - to concepts of reasoning. Our new concept is much closer to programming than the old one and therefore more appropriate to familiarize children starting at the age of 6 with concepts of programming. The semantics of the functional tokens in this approach are easy to understand and thus appropriate for our target group. The technology makes it simple to adapt the concept to advanced scenarios and to increase the level of difficulty for older children.

4. Technical Implementation

Siftables or Sifteo Cubes were developed by David Merrill of the MIT Media Lab [4]. These small 1.5 inch tangible, programmable plastic cubes interact wirelessly between each other and with a computer. They feature a 128x128 pixel graphical colour display that shows animations as well as simple pictures. Accelerometers inside the cubes make it possible to sense whether they are shaken, lifted or tilted by a user and the cubes are able react to this motion. Additionally, with the help of IrDA transceivers, Sifteos register when and on which side other Sifteos are attached, within a distance of 0.4 inches. By this, digital information can be manipulated and exchanged in many ways or shown directly on the displays themselves.

To run games on the Sifteos they have to be connected wirelessly to their Siftrunner execution environment, which works on all three major computing platforms. The Siftrunner is responsible for connecting the cubes, installing games and playback of game sounds, as the Sifteos are not equipped with any internal speakers. Programs for Sifteos are written in C#. The Siftrunner executes the programs and handles all the events sent by the cubes. Events are fired e.g. when a cube is placed next to another or a button is pressed. The program logic can react to these events and for example change the displayed image.

This wireless connection is a huge advantage to the hardware design of our former Tangicon cubes. Not only are Sifteos more robust, but the user experience is more intense, as the visual feedback can be presented instantly and directly. Sifteos are designed to be self-contained, except for the sound output. This means that user input and graphical output generally happens on the cubes. There are no design patterns yet available, which support a graphical user interface that can be displayed somewhere else than on the built-in displays.

To keep the programming code of the Sifteos simple and maintainable, as the provided Sifteo API is rather young and may still change in next versions, we decided to decouple the user input from the rest of our program. As a result, the Tangicons 3.0 architecture consists of two parts: the Siftrunner with its aforementioned functions on one hand and a program written with the Processing environment that handles the external user interface ("the displayed map"), game model ("levels"), and sounds. Both programs are connected via TCP. Every time the Siftrunner receives events that are relevant to the displayed map, a message is sent to the Processing environment. Furthermore this opens up the possibility of using displays that are remote from the Sifteo cubes e.g. a presentation wall, where the controlling PC is out of range for a Bluetooth connection. In everyday-use scenarios in schools it is more likely to run both programs on one computer, most likely a laptop, as resources are limited.

5. METHODS

Two evaluations were carried out in a German primary school. Participants were students from first to third grade.

In the first study 20 children (10 girls and 10 boys) were included. The mean age was 7.5 years and ranged from 6 to 9. All children were enrolled in after school care where the study took place. This evaluation dealt with a quantitative rating of the game's main characteristics. The children were interviewed separately after they had played the game. During the interview a glove puppet looking like a ladybird was employed to accustom the children quickly to the situation (fig. 11). The children were first asked to explain the game they had played to the ladybird. This question served as an icebreaker. Then they were asked what aspects of the game they liked.

Figure 11. Filling out the questionnaire

The second part of the interview was conducted with the help of a questionnaire. Five questions were read aloud and underlined by compatible pictures either by the interviewer or the children. The answers were reported by the children themselves on 5-point Kunin scales. The children were asked the following questions: Was the game difficult or easy to play? How did you like the pictures? How did you like that you had to run during the game? How did you like playing in a group? Finally, children were asked, whether they wanted to play the game again.

In the second field trial we wanted to investigate the progress of the game for a longer time period, because the first evaluation allowed only a very short duration of the game and number of levels. Children were observed while playing and thus some qualitative observations are reported. We were interested in children's reactions to a longer exposure to the game. This came with a limitation of sample size. The field trial took place at the same school with eight children (mean age 8.1 ranging from 7 to 9). Four of these children, two in each group, had also taken part in the first evaluation and thus already knew the game. This was a result of certain organizational restrictions of the school.

6. EVALUATION

Two evaluations were carried out at a German primary school, each with its own focus. The first comprised a quantitative rating of 20 children playing three levels of the game. The aim of our first investigation was an evaluation of some characteristics of the game and an estimation of its difficulty by the children as well as their wish to play the game again. The second field trial allowed some children to play the game for a longer period.

During the first evaluation the children played the game in groups of four children, with three groups containing girls and boys, one group with girls and one with boys only. Each session comprised three trials with increasing degree of difficulty. The game was explained consecutively by a pedagogical educated instructor. The game took place in a group room and the interview was conducted in a pedagogue's office. Two pedagogues familiar with the children attended the sessions in addition to the authors. The children could decide whether they wanted to play a structurally equal game with a car or a horse, with three groups deciding for the car and two for the horse and two groups playing with both horse and car. The children played only three levels of the game with increasing difficulty. The first two levels served as introduction to the game. During the third level the children received help only on demand.

The first two levels (fig. 12) are designed to illustrate the basic game principles. Level one consists of a straight line and can be completed by a sequence of four forward blocks. Level two introduces turns and the use of the modification token. The longer, third level featured a branch forcing the players to decide which way to choose. Both paths differed in length by only one field, but the left could be finished with one sequence whereas the right path needed two (fig. 13).

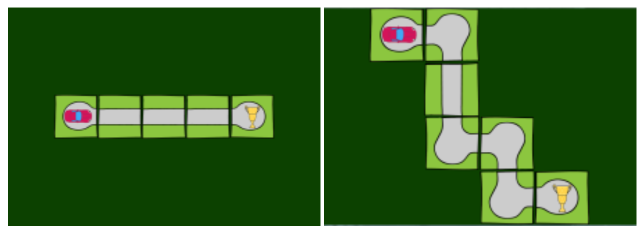

Figure 12. The first two levels

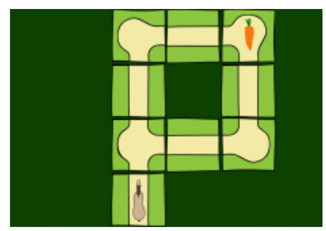

Figure 13. The third level

The first and the third level could be completed by one sequence. The second level requires a minimum of two sequences. The average duration of the game without instruction was 7:38 min. (SD=4:05). At the completion of each level a cup or a carrot was shown followed by applause. The children laughed and seemed to like this small reward (fig. 14, r).

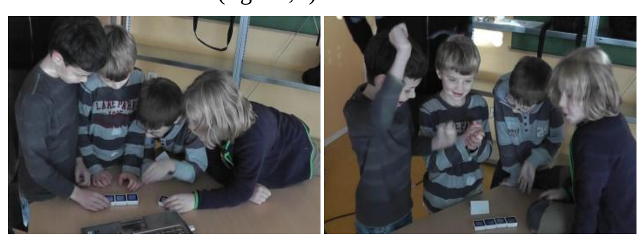

Figure 14. Discussion (l) and completion of levels (r)

After the game, the children filled out the questionnaire. None of the questions revealed significant differences between boys and girls. Figure 15 shows the questions and the respective mean. The results indicate a positive evaluation of the game, because all means differed very significantly from the middle of the scale as one-sample t-tests showed ($t(19)=14.24$, $p < .001$, $t(19)=6.99$, $p < .001$, $t(19)=8.30$, $p < .001$, $t(19)=4.36$, $p < .001$).

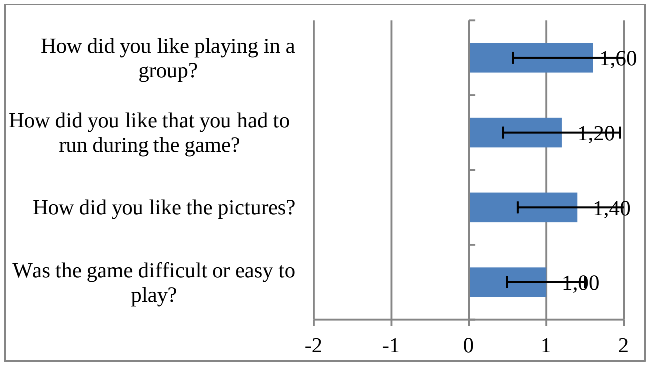

Figure 15. Results of the questionnaire

This indicates that the children liked playing in a group, the extension with running and the pictures. Furthermore, the positive value in the last question shows that children judged the game as rather easy.

Only 3 children (15%) reported that they did not want to play the game again whereas 17 children (85%) explained that they wanted to play the game again. This might be seen as hint that the children accepted and liked the game. Again, no differences emerged between girls and boys ($X^2(1,20)=0.531$, ns).

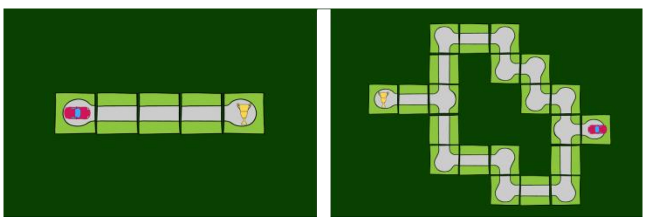

Figure 16. Level one and nine.

During the second field trial, we had two groups of four children playing the game without help after the first three introductory levels. This time, the game was played in the library and recreation room. Cubes and laptop were placed on the floor and the "charging station" was placed on a table at a distance of approximately eight meters. The introduction to the game required around 12 minutes respectively after which the children were asked if they understood the rules. Then they played on their own for 21 and 19 minutes. Both groups completed 6 levels on their own (fig. 16).

The following findings are based on the authors' observations. First of all, we could clearly observe that the game was accompanied by discussion of possible solutions (fig. 14, l). So the children played the game together, nevertheless some children influenced the game more than others. Further, they seemed to differ in their problem solving strategies as some younger children tended to work more with a trial and error strategy.

One of the difficulties of the game was taking the avatar's perspective. Levels increased in complexity by requiring more changes in direction and moving the avatar from top to bottom of the map. The challenging task required the construction of a relationship between the symbols on the Sifteo and the directional movement of the avatar. This mental operation caused problems for some children. Children were observed turning their heads to the side in order to reconstruct the relation between the turn on the map and the cube representing a direction. We also observed that children made mistakes by choosing the wrong direction. Further, this was mentioned by some children when asked about difficulties after the game. The turns are chosen by pressing the Sifteo and have to be arranged so that they conform to the player's perspective and not to the avatar's perspective. The progress of the game in combination with the mistakes might indicate that the difficulty and mental effort required for the game were appropriate for the age group. Finally, we asked children if they wanted to play the game again. One child was unsure and another did not want to play the game again, whereas 6 children (75%) wanted to play the game again. This suggests children generally accepted the game. These observations are first impressions of independent play of the game after a solid introduction and can be used for future adaption.

7. CONCLUSION AND FURTHER WORK

Throughout the evolution of Tangicons we have worked through problems concerning the technology. Cables, infrared connection or fragile parts disturbed the game flow in a way that children sometimes felt annoyed as they were disrupted in their actions. Although this was not a major problem, it contributed to the impression of having an unfinished gameplay. With the use of Siftables, we eliminated these obstacles and could concentrate on the interpersonal interaction between children and gameplay. By this, Tangicons 3.0 has successfully adressed the previous technical challenges and has been designed to elevate the level of programmatic thinking children engage in. Besides skills like counting, reasoning, abstract thinking, communication, team work and collaboration, which the first version already trained, this new version of Tangicons brings children closer to the real complexity and potential of programming. They play a game and naturally get acquainted with functions, parameters and sequences.

Two evaluations were carried out with a different focus. The first showed that the game and its main characteristics were rated positively by the children and that the majority of the children wanted to play the game again. The second field trial allowed a longer duration of the game. We could observe discussions among the children regarding the solution and difficulties with the turns. The latter is ascribed to the increased difficulty of the mental operations. Further children around the age of 9 were not our primary target group and in this single occasion seemed to be less appealed to the game as they seemed not to be challenged enough. For these children our impression was that the game should be extended with additional actions than just moving the horse or sports car to increase its attractiveness.

The versions and evaluations of Tangicons covered a wide age range from 3 to 9 years. A common characteristic of all games is the aspect of physical activity which is supposed to support cognitive activity by sustaining concentration. Thus Tangicons take regard to diverse competences. A variation of the games can be achieved by expanding running with activities as balancing or an obstacle course. This will address gross motor activity and sense of balance in a more challenging way. As the games are partly designed to be non-competitive, the children's motivation to run with a continual speed might decrease. Thus, temporal limits for the running but not for the programming phase will result in improved physical exercise. Further investigations will address the performance of individual children of different ages in greater depth. For such research questions children will play the game alone (contradicting the pedagogical intention) in order to draw conclusions between cognitive abilities and age. This will result in sample sizes that allow statistical analysis and further insights into the applicability to different age groups as well as comparison of group learning versus seperate learning. Another question concerns the importance of the physical activity for the performance. A group comparison will show if there are differences in performance and needed time.

Finally future adaptations of the game can be the subject of evaluation. Future versions may include more complex functions. Starting with different kinds of parameters, for instance applying letters and symbols to functions instead only numbers, and leading to composition of atomic functions to perform advanced tasks. With increasing functionality we may also consider changing the interaction pattern. We might substitute the current function selection via button press by a set of tangible interactions, using the built-in sensors. For example the basic movement functions could be mapped to tilting. Tilting in one direction would activate the respective function: forward, left, right and backward (this toggles the no operation function). Of course these changes in interaction have to be reflected in the user interface on the cubes. To incorporate our game more into school lessons, themes and objectives of the game could be changed.

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