

Designing and Testing a Tangible Interface Prototype

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ABSTRACT

This paper describes the design and testing of a research Tangible User Interface (TUI) prototype for children. Some theoretical background is given on the evaluation methodology for children's products and designing TUI for children. The prototype is described and an exploratory initial study that investigated its usefulness is outlined. The authors found that the prototype went some way towards meeting the requirements but that it also needed some modifications for future use. The paper concludes with some reflections on the design of research prototypes and some recommendations for further studies in this area. The authors propose that a modified prototype can be used for evaluating the usability of a range of child-centered evaluation methods in future studies.

Author Keywords

Experimental prototypes, Evaluation designs, Children, Tangible interface, Validity, Usability

ACM Classification Keywords

K.3.1 [Computers and Education]: Computer Uses in Education – Collaborative learning, Computer-assisted instruction (CAI)

K.8.0 [Personal Computing]: General – Games

INTRODUCTION

As the Interaction Design and Children (IDC) series has developed and as greater emphasis across academia has been placed on the different needs of children in the design and evaluation of products, so there has been an increase in studies that have examined how useful different evaluation methods are with children, and how appropriate different evaluation methods are for different contexts.

There have been empirical studies of Usability Testing Methods (UTMs) [1, 4, 8] involving using techniques like Think Aloud (TA) protocol [5], Constructive Interaction [9], Cooperative Evaluation [10], Peer-Tutoring [7] and Problem Identification Picture Cards (PIPC) method [2].

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Our large research project, of which this study is a part, is focused on the use of various tangible user interface (TUI) prototypes to determine how useful several user based evaluation methods might be for children using tangible technology. In this work, one focus is on producing results that are not dependent on a particular software / hardware configuration.

Designing Tangible Applications

Ulmer and Ishii [16] define TUIs as being systems that use physical artifacts as representations and controls for digital information. They provide several features (characteristics) by which tangible interfaces differ [16]. A subset of these is outlined in the following section.

Binding. In a tangible interface there is a binding between the objects and the digital information. This binding can be *static* or *dynamic*.

Objects. A major feature of tangible interfaces is in the way that the physical objects interact. These interactions are facilitated by *spatiality, relations or connections*.

Embodiment. This refers to the extent to which the tangible interface is embodied. In a *fully embodied* system, the output and the input are in the same physical space. *Nearby embodiment* is defined to be that where the output is very close to the input. A third type of embodiment is *environmental*.

Metaphor. The physical artifacts that make up a tangible interface are generally representative of something; however, the extent to which the user of the interface is informed of this representation varies.

Tangible Applications for Children

There have been many studies [12] that have described tangible interfaces for children. Several key studies are briefly discussed here.

One of the earliest tangible interfaces for children was TICLE [15]. Created in 1999, this was a desktop environment which used a physical *tangram*¹ consisting of seven pieces on a projected desktop. Using spatiality and

¹ Tangram is a Chinese puzzle, and a type of dissection puzzle. A tangram consists of 7 pieces, called tans, which fit together to form a shape of some sort.

connectedness, the physical pieces were represented on a computer screen (environmental embodiment). The game pieces were statically bound to the information.

Snark [6, 13] uses a room-based interface with handheld devices. It has also been played outdoors and is one of only a few tangible interfaces that have been developed into different aspects. In the room-based version, the binding is predominantly static, the game uses spatial and relational interactivity, and the embodiment appears to be local and environmental. Without playing the game, it should be noted that classifying the interactivity and the characteristics of any TUI is prone to some errors of interpretation.

A different sort of interface is Ec(h)o [17]. This is a tangible cube that is used on museum visits. With verb metaphors and probably nearby embodiment, Ec(h)o is a spatial interface that is statically bound and it is supported by a handheld device intended for use in wide spaces.

A TUI that appears to have some dynamic binding is Tangible Flags [3] and is also intended for use in open spaces. This TUI uses abstract metaphors and spatial interactions to encourage children in information gathering in a physical space. These few studies highlight the diversity of TUIs.

THE DESIGN OF AN EVALUATION PROTOTYPE

Considering several of the dimensions of tangible interfaces, a prototype tangible game was required to potentially meet the following:

- Could a single game be designed to be played in different tangible interfaces (incorporating different characteristics of tangible interfaces)?
- With different instances of one game, would children have a reasonably consistent experience?

To begin to answer these questions, the researchers decided to focus on the two tangible dimensions of tabletop and room-based, and to design and build a working application and test it for consistency. Thus, a game was designed to be played across both dimensions of interaction, with both involving a screen displayed feedback. The simple principle behind the game in both versions is to interact with the interface to find eight correct items amongst sixteen shuffled pieces. In this case the items are images of food. In both versions of the game children can play alone, in pairs or in teams. The child or team to gather the most food items wins the game. Two prototypes were created, one for the tabletop and one for the room. Both implementations were coded in Visual Basic® and used the Phidgets® technology.

Tabletop

16 wooden bricks are placed in the squared slots of a 4 x 4 grid on a board. Light sensors are placed below the board in correspondence to eight of the squares, which have little holes to let the light pass through. These eight squares have

a picture of food on them (Figure 1), whilst the remaining 8 squares are labelled with "Oops! Try again!" on top. When a brick is lifted up, if a correct one is selected, the light through the hole will activate the sensor. When bricks are selected, by picking them up the representation of the brick is displayed both on the grid (in the squares) and on an adjacent computer screen where the corresponding picture appears. This allows for relatively close embodiment.



Figure 1 - The tabletop interface

On discovering a food picture, the child keeps the brick and the picture remains on the screen. If it is an "Oops!" one, the child will put the brick back in its square and it will be the next child's turn. This version of the game could be played without the screen, which supports the notion of meaning away from the technology [16].

Room-based

In this version of the game, the eight food items are "hidden" in 10cm x 10cm x 2cm blocks of wood. The blocks are tagged with RFID tags and are read using a reader that is situated close to a SmartBoard® where the outputs from the game are displayed. 16 blocks are used altogether, which are shuffled and placed in a large cardboard chest (in the version used in this study, the cardboard box also contained Christmas decorations to add engagement). Eight blocks correspond to food items and eight blocks are blank. When a food item is discovered, the item is displayed on the SmartBoard®, in all other cases the "Oops, try again!" writing appears on the screen.

In playing the game, children take turns, either individually or in teams. The first child/team picks up a block and brings it to the reader. If the block represents a food item, the physical block is kept and the child/team places it into their collecting basket. If the piece is wrong it can be returned to the chest or removed (in the user study the wrong pieces were removed).

This game is less embodied than the tabletop version and the interaction is relational rather than spatial. There is again no metaphor, the coloured wrappings on the blocks have no meaning, however, as with the tabletop version, noun metaphors could be added to the blocks.

TESTING THE PROTOTYPES

Having designed and implemented the two interfaces to behave differently but provide a single game experience,

the first requirement, *could a single game be designed to be played in different tangible interfaces?* was met. To test the second question, *with different instances of one game, would children have a reasonably consistent experience?* A user test was needed.

The user test took place over two days in the University PlayLab of the ChiCI Group. On the first day, a group of Year 1 children (aged 5 to 6) from a single class at a local state primary school took part. On the second day, an older group of Year 4 children (aged 8 to 9) from the same school participated. The children came to the study voluntarily. In the user test, as well as looking for a consistent game experience, the researchers were interested to find:

- Were the two tangible versions of the game playable?
- How did play differ across the two games, and how could this be related back to the characteristics of the games?
- Did one version of the game appear significantly easier to succeed at than the other?

Method

The children came to the game in small groups (4 or 6). These groups were typically semi-friendship groups in that each child in the set had a friend along. The children played while they were observed and videoed and, after playing, they completed a short questionnaire of preferences [14].

Results

In total, 43 children played the games: 25 older (aged 8 to 9) children and 18 younger (aged 5 to 6) children. Every child coming to the games was able to play immediately once the rules had been explained. No child opted out of playing. The children liked the games, they came to the game area with high levels of curiosity and interest and they remained engaged with the games during the play. Based on the results of the after play questionnaires, there was no clear winner as regards preferences. However, by engaging with the children as they filled in the questionnaires, and from the comments made during play, it seemed highly likely that the preferences indicated by the children were influenced by whether they had won or not, the specific game, and by their play mates, i.e. whether they were playing with their own mates, playing individually, or playing in a randomly created team.

The older children played the games faster than the younger ones and typically had multiple turns.

Tabletop

The tabletop game was immediately more attractive to the children than the Room-based game. It had more affordance [11] and many children just dived in and started lifting the bricks. Figure 3 shows children playing at the Tabletop.

During play, in general, the children only looked at the computer screen when they got a piece of food; this was to double check that the food had been credited to them (i.e. appeared on the screen).



Figure 2 - Children playing the Tabletop game

Room-based

When children approached this game (see figure 3), they seemed more hesitant as it was not clear what they should do. After having the game introduced to them, the children quickly grasped the concept. Because of the lack of affordance, the game appeared to be slightly harder to start but was more engaging in terms of unpredictability. This unpredictability made the game harder to win and some found the game “funny” as they enjoyed putting their hands in the box and mixing around with the blocks and the leftover Christmas decorations. On realising what was happening, one child placed a Christmas bauble on the RFID reader to see what happened (nothing did!).



Figure 3 - Children playing the Room-based game

Observations of the children playing confirmed that the two interfaces were easily playable. Some important similarities and differences were noted that would influence the further development of the prototype. These are summarized here:

Engagement. The engagement in both interfaces was high, even after multiple attempts.

Collaboration. The games required and encouraged collaboration. This had a side effect of creating a blame culture as well as a support culture. In both games there appeared to be a similar amount of talking and discussion and it was good to see how pairs of children collaborated to improve their chances of success.

Unpredictability. For children taking a second turn at a game, the unpredictability made the Room-based game more challenging than the tabletop game. In the Tabletop game, the physical mapping remained unvaried, so that the only way to introduce some variability was to rotate the board. This would be easy to modify in future versions of the game.

Learning during play. The tangibility of the interface reduced the need for instructions. The tabletop game became easier the longer it was played as the children were able to memorize where the empty spaces were. In the physical game this was not possible and so, to balance the game play across the games, a decision was made to take away the empty blocks once they had been 'found out'.

DISCUSSION

This work has raised more questions than it has answered. Challenges that remain for the work include the designing of other tangible characteristics, the levelling of the game experience, and then, when all that has been resolved, the evaluation study of the evaluation methods. It is probably not possible to include all the characteristics of tangible interfaces in two or three prototypes.

Levelling the game experience will require more user studies as it is only by watching the games being played that discrepancies in engagement and complexity can be discerned.

Future work will include the implementation of extra functionality for the prototypes (i.e. add behaviour to the bricks on the table top). Alongside this, future, more structured user studies will allow for a focus on distinct evaluation aspects.

Another possible direction would be to exploit the educational potential of the game by introducing specific contexts and adding relevant related contents.

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