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# Understanding Deformable-Gestures Using Paper Prototyping With Children

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## Abstract

**Background/Objectives**: This preliminary study presents the process and outputs from a paper prototyping activity aimed at understanding deformation-based gestures amongst children aged 5-6 years old. **Methods/Statistical Analysis**: This is done by observing them interacting with an artificial deformable object i.e. paper. As a result, we obtained child-defined deformable-gestures that will help with the design and implementation of Organic User Interfaces (OUI) in the future, without considering the current technical level and challenges. A flexible or deformable interface is a type of OUI where when flexible displays are deployed; shape deformation like bending is a key form of input. **Findings:** Upon completing this preliminary study, it is found that children are very much influenced by existing methods like swiping on the screen, pressing on physical buttons and others as compared to using gestures. The results show that the most common gestures are bending upwards and downwards and unfolding. However, there is difference in preference on using paper in real life in portrait format as in this paper it is found that all the children have held their "device" in landscape format. Although the definition and contribution of deformable display is still in its infancy, the use in this study of children of a pre-school age has shown that even at an early stage in their development the children's actions were intuitive. **Application/ Improvements:** To use a more interactive interface and to include more variables to provide a better of the use of the displays in the future. Lastly is to include a larger sample size.

**Keywords:** Children, Deformable, Organic User Interface, Paper Prototyping

## 1. Introduction

Technology has advanced tremendously over several decades with information being processed at incredible speeds. However, when we consider that we can crumple a piece of paper but we cannot bend or fold a computer or tablet there appears to be a gap in the way that we interact with technology and traditional devices. The main limitation is that technology is bounded by its rigid planar surfaces and is not bendable. These interfaces have usability limitations but this is changing with the availability of the concept of an Organic User Interface (OUI). OUIs are currently being described as "the near future space" as far as design is concerned. Examples can be seen in tablet and new generation phones but its potentials are still being explored. In Vertical and Poupyrev[1] summed up what defined OUIs:

- • Input is the same as output - This means the display can be considered as an input device when users start tapping on it.
- • Function matches form - Where the display can take on any form.
- • Form follows flow - The displays can deform and change their shapes.

These three features do apply to OUIs, however other definitions indicate that OUIs have flexible or deformable user interfaces and shape deformation, for example, through bending. As the boundaries of OUIs are forming, this preliminary study focuses on understanding the deformable-gesture to produce possible directions

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for designers and engineers in designing future organic interface.

Paper prototyping is used due to its flexibility and a multitude of ways to bend and fold it where currently such interfaces in digital form are not yet available. Though simple, the concept used encourages creativity from the user groups and it can generate a great deal of feedback, which contributes to the purpose of this study.

Children are less inhibited than adults and are more intuitive, animated and gestured-based. At the age of 5 or 6 years old children are better able to understand instructions whilst still being creative and uninhibited, hence this was the group chosen for the study.

Human gestures have long been studied in the field of HCI aiming to develop gesture based user interfaces alongside with underlying theories. A guessability study was carried out to study user preference on gestures where participants performed gestures to solve twenty-nine tasks[2] Started from year 2010, these deformation-based interactions have been first investigated. However, users were given precise commands and using various materials[3.]

This preliminary study intends to study how the complexity of a physical interface can have an effect on deformation-based interaction[4]. Also, to look at how children perform these deformable-based interactions in their living environment. We begin by conducting a preliminary exploration with the children before implementing any real interface. In this preliminary study, children were observed when using artificial deformable displays of their gestures and behaviors in order to understand how they manipulate deformable displays as input devices. A normal A4 size paper was used as the prototype to find out what will perceive to be an appropriate gesture to use while performing specific commands. Then the commands were given to the children and they are required to perform the gestures as close to how they would perceive normally in real life. Some of the findings include the comparison between the deformation-based gestures amongst the participants grouped by command. Observing the preschoolers' behaviors helped in forming other significant findings as well.

Not many previous experiments have involved users in the design process, which usually occurs during the early stage. They are only needed for evaluation purposes as the experiments mainly focused on technical and technological aspects. Therefore, in order to progress, a user-centered approach was selected automatically.

## 1.1 Deformable Displays

Organic User Interfaces is naturally an intuitive interface armed with its non-planar interface and also its deformable features. Deformable displays cross the boundaries between Extensive research has been carried out attempting to provide users intuitive control by adopting deformation-based gestures with flexible and Organic User Interface. In[5,6] served as an early example and the interaction techniques and device concepts are based on deformation of a handheld device. *Foldable User Interfaces* in[7] looked at interaction techniques that includes folding, flipping, bending and stacking and allows one- and two-handed operations. Flexible displays can provide greater affordances as it has a higher-dimension ability. Another example of an Organic User Interface is Paper Window[8] that allows users to capture the paper affordances in the digital world by simulates digital paper displays by projecting onto a physical sheet of paper. Later, this metaphor was seen in PaperPhone[9] that uses E Ink to bend the interface for common computing actions.

Another hardware prototype that used deformation as input such as in[10] allows complex navigation such as twisting and bending. It was constructed using eight optical bend sensors so it can recognise the wide variety of bending capabilities. Book sheet was developed in[11] based on a similar concept, it adapted the metaphor of turning the pages of a book for browsing content. Book sheet allows users to bend one side of the sheet or the other in order to scroll through digital content such as photos or documents; this is made possible the two thin plastic sheets and bent sensors.

## 1.2 Designing Gestures

Some surface computing prototypes that use system designers to design gestures may not truly reflect of users' behavior although such gestures are appropriate. In[12] first produced the effects of the gestures before asking the users to perform them in order to collect the user-led gestures. All their participants are mainly non-technical. Based on user behavior, their results are able to help designers create better gestures set. According in[13] the effectiveness of the visual system depends on understanding of the object and not just the visual information. Not merely relying on visual information, systems are often based on the understanding of the target object as well.

In[14] has conducted a study to extract deformation-based user gestures by looking at how users interact with several artificial deformable displays. The study considered 31 participants using plastic, paper and elastic cloth. All together 11 commands were given to the participants and every participant was asked to express gestures for thirty-three different settings. According to the result, they realized that users favored coupling of closely related but opposite actions and gestures.

Many of these studies are meant to facilitate users to have intuitive control of their devices and therefore making them more users friendly. Similarly, in[15] proposed an e-book using flexible e-paper to allow the experience of reading a book in real life like flipping and turning pages. Users can turn, flip and leaf through the pages of the e-book. These real life resemblance functions are made possible by the bending degree of the sheet.

### 1.3 Gestures in Children

Some of Kendon's early work did describe an array of gesturing behavior. Like *Sign Language,* they are artificial and highly structured gestural languages. The "piece" sign, for example is considered as artificial but culturally recognized symbols. During speech, very often gestures will come into play unconsciously which these are still categorized as artificial gestures. In[16] has used the Wizard of Oz approach to define child-led gestures with the concept of guessability study. In total, all six children aged six to eight carried out a total of twenty-two tasks. The tasks where gestures were derived from include object manipulation, navigation-based tasks and spatial interaction. Generally, human convey messages to others either through speeches or gestures to emphasize on certain points or emotions[17].

With the growth of the usage of mobiles devices that mainly adopt touch screen technology and iPod by children, in conducted a study specifically to observe the impact of the differences between adult and child in using touch screen. The iPod's input does equals to output and this is one of the features of Organic User Interfaces.

Another new input device *Picture This!*[18] has been incorporated into children's toys for video composition. Children aged from 4 to 10 were observed while playing during the testing stage. The extent of gesture interaction with objects for video editing was monitored to determine how children explore visual perspective in storytelling.

Few studies have been conducted specifically with child gestures; as most interfaces will not distinguish children from adults.

## 2. Research Approach

This preliminary study engaged children ages 5–6 to perform deformable-gestures using a piece of A4 paper by following specific commands given. It intended to explore how these deformable-gestures can be carried out without being influenced by current methods of using an interface. As this study focussed on an imaginary future device, the paper prototyping was used to determine what gestures children carried out based on what was perceived to be logical to them.

## 3. Paper Prototyping

Paper Prototyping is a widely used method in the Human Computer Interaction field in user-centered design processes. This approach enables a better understanding of the gestures performed by the children. In some situations, more than one piece of paper was used to show the sequence of the actions taken. Paper also has the characteristics of a deformable object as it is easily bendable or rolls.

A single piece of blank A4 size paper was used as a "pretend" device. The operation of the "pretend" device using deformable gestures was observed. The paper was intentionally blank to avoid influencing the children.

### 3.1 Participants

They are all together six children participated from a kindergarten for this study. They are three girls and three boys aged 5–6; mean is 66 months and standard deviation is 6.57 months. All of them had some prior experience in using computers and/or tablet computers. Most of their experience of using computer/tablet was through playing games or watching videos under adult supervision. The children were able to use a mouse comfortably and were able to use a touch screen on the tablet.

Parental permission was given to conduct a series of familiarization activities with the children in order for them to become familiar with the researchers and to feel comfortable speaking to them.

### 3.2 Observation

Prior to the study, the children were observed to see how they interact in their own environment. An OUI focus on natural/organic elements so it was important to ensure that the gestures performed during the study were of that nature. The children were observed at their kindergarten while learning and interacting during their classes and outside the classroom during their playtime.

## 4. Procedure

This preliminary study was conducted in a room in the kindergarten after their school time to ensure that the environment was fairly quiet to avoid the children from being distracted. One researcher carried out the study with the assistance of the children's kindergarten teacher to provide a well-known face for the children and to take photographs during the study.

The study was carried out individually with each child. In the room Figure 1, both the child and the researcher are seated facing each other with a table beside them. The teacher was in the room at all times but stood slightly back to avoid interfering with the process.

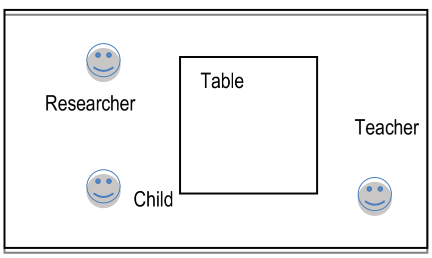



**Figure 1.** The study setting.

### 4.1 Commands

In order to observe the deformable-gestures, several commands were given to the children to operate the "device", in this case, the piece of paper. Some basic commands were selected from existing deformation-based interaction research: 1. on; 2. off; 3. delete; 4. open; 5. close; 6. zoom-in; and 7. zoom-out. Other more complicated commands were not included due to the difficulty in conducting them by using paper. The commands were given to the children verbally during the study and were not revealed before the study took place.

This study is conducted in 4 phases: Investigation, prior study, initial study and follow-up study:

### 4.2 Initial Investigation

An initial investigation was conducted prior to the preliminary study with the intention of finding out how children aged 5-6 years old interact in a typical classroom especially if they often use gestures or not and what kind of gestures do they perform. The 5-6 years old children are typically already started kindergarten. A kindergarten is selected and consensus was obtained from both the parents of the children and the teachers/principle of the kindergarten. They were given a consent form to fill in. Besides observing the children, the teachers were spoken to as well. Three classes were observed as indicated in Table 1.

**Table 1.** Type of classes and number of students

| Types of Classes | No. Of students |
|---|---|
| Mathematics | 9 |
| Mathematics | 6 |
| English | 7 |

Each class is of half an hour long and the researcher has taken notes and picture during the observations. During these classes, typical gestures were observed: Using fingers to count in Mathematics classes, pointing, tapping on the table, putting finger on chin when thinking, waving when excited and when talking to friends, scratching heads when confused or do not understand what the teacher was talking about, shrug the shoulder to indicate they do not understand or not bother and tapping on friend's shoulder to get attention.

The teachers also encouraged the children to use fingers to count in the Mathematics class. They were animated with gestures as well in order to get attention from the children. Typical gestures performed by the teachers are pointing, tapping on the table or the children, putting finger to the lips to indicate to children to be quiet, waving, drawing circle in the air or just drawing in the air.

It is observed and confirmed that children do gesture a lot as well as teachers. Upon discussing with the teachers, it is admitted by them that they often exaggerate their gestures in order to get and to retain the children's attention.

Four parents were spoken to regarding their observation of their children. All four have confirmed that the children do gesture a lot as well as the parents too. It is most apparent when they are doing mathematic homework or when the parents are teaching them at home.

Similarly, 3 teachers were spoken to and all of them confirmed that it is easier to make the children understand the lessons by using gestures. It is evidently and especially true during the Mathematic lessons.

With this initial investigation, it is confirmed that children do perform gestures in natural setting and so do teachers and parents. It is therefore reasonable for the researcher to carry on the investigation in finding out the types of gestures children will perform if they were given a new interface.

### 4.3 Prior Study

Prior to the study, the researcher explained to all the children, in approximately 15 minutes, what they would be doing in the study. The children were shown the A4 blank paper and were asked to hold it. The researcher also had a piece of A4 blank paper in preparation to demonstrate the usage. Several important points were conveyed:

- They were asked to pretend that the piece of A4 blank paper is a make believe "device".
- They were given permission to do what they think is logical/correct with the piece of A4 blank paper.
- It was emphasized strongly that there was no right/wrong way of carrying out any action.

The children were allowed to ask question during this prior session. The researcher then proceeded to demonstrate possible actions. For example, folding (into half), bending or rolling.

### 4.4 Initial Study

During this phase commands were given verbally to the participant and researcher observed and recorded down results. The commands were given one after another.

For example:

- "Let's switch on the device, xx (child's name). How you can switch on the device?"
- "Now how do you switch it off?"
- "Let's say you want to make the picture bigger, how would you do that?"
- "And now you want to make it smaller, how would you do that?"
- "If you want to play a game, how do you "open" the game?"
- "Now you have finished playing, how do you close it?"

During these sessions, some questions were repeated several times before the children finally performed the action. They were not given a choice to skip any command. They were also given a sweet as a treat after the session.

The time taken between the children starting to perform the action after receiving an instruction was measured. An average of 57.5 seconds was recorded.

Only questions related to the commands were given, no other questions/conversations were carried out. This approach allowed the researcher to ignore the gulf of execution and focus on observing unrevised gestures.

### 4.5 Follow-up Study

After the session, the children were gathered again and were asked what they thought of the entire study. They were also able to express their feelings about the actions they took during the study. The researcher spent an average of 10 minutes with each child during this session.

## 5. Results and Discussion

Initially, more than 60% of the children which is 4 out of 6 hesitated in carrying out gestures in fear of destroying the device particularly when considering the act of bending and folding the device. We keep on encouraging them by telling them that it was safe to carry out any gestures which then the boys, especially, were more "daring" and "open up" to perform the gestures. All of the participants were shy at the start of the sessions and were not receptive to engaging in the activity when the researcher was explaining what they would be doing. They found it difficult to determine what they could do with the blank sheet of paper, however, after some warming up time and assurance again that there was no right or wrongs way to carry out a gesture, they eventually started to comfortable to take part. This is similar to finding in where children needed some encouragement before they start performing gestures.

### 5.1 Patterns of Use

It was observed that the right-handed participants mainly used their right hand to manipulate the device. However, when they were unsure, then tended to also use with their left hand. They used their right hand mostly to manipulate the top right corner but sometimes left top corner of the device. Interestingly, all of the children held the device/paper in landscape and tended to put the device/paper down on their laps.

### 5.2 Existing Method

It was noted that as the children had prior experience of using a computer or tablet PC, they were influenced by way in which their existing devices worked. For example, all of them looked for the ON/OFF button for the on/off commands. They preferred to touch the screen and look for buttons to press. All six of the participants tried touching the screen and to look for buttons. Four out of six participants tried to swipe the screen from right to left as they would on a tablet.

## 5.3 Fun Element

All of the children indicated that they had fun playing with the device and this is clearly seen from the way they giggled throughout the experiment.

## 5.4 Types of Deformations

It was observed that the most popular gesture was bending followed by folding and twisting. Only one child performed rolling. None of the children felt comfortable crumpling and tearing the piece of paper in fear of damaging the device Table 2.

**Table 2.** Types of deformation performed and percentage

| Types of Deformations | Performed (N = 6) | Percentage |
|---|---|---|
| Folding | 6 | 100% |
| Bending upwards | 6 | 100% |
| Bending downwards | 6 | 100% |
| Unfolding | 6 | 100% |
| Bending at corner | 2 | 33.3% |
| Folding at corner | 3 | 50% |
| Flip from left-to-right | 4 | 66.6% |
| Flip from right-to-left | 4 | 66.6% |
| Bringing nearer to face | 2 | 33.3% |
| Rolling | 3 | 50% |

## 5.5 Performance

The average time taken as stated above the table to carry out the actions after receiving an instruction was 57.5 seconds. All six children performed better than 57.5 seconds after the second or third instruction as they became more confident using the paper and listening to instructions.

## 5.6 Pairing Commands

The children took less time to carry out the second command when two opposite-but-closely related commands were arranged one after the other. For example, the zoom-in and zoom-out commands are basically the same gestures but with different directions. They tended to bend the paper upwards to zoom-in and bend the paper downwards to zoom-out.

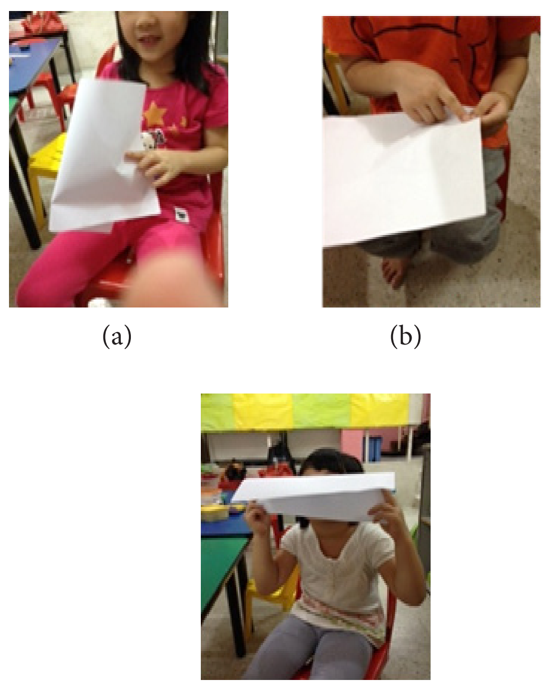
## 5.7 Landscape

The children were given the device horizontally and coincidently all of them have carry out deformation gestures horizontally. This is contrary to the general perception that portrait would be more dominant than landscape as this is how paper is used in real life. This is also not consistent with the outcome of Paper Window where portrait is desired.

## 5.8 Familiarity

The participants tended to apply metaphor actions they were already familiar with. These gestures are therefore naturally intuitive. For example, when asked to turn the device on/off, they all were looking for an imaginary button on the side of the device to press. In fact, they performed the same action for both the "on" and "off" commands.

Figure 2 shows the experiments in progress with the preschoolers. The Figure 2(a) shows the participant folding the device and is performing "close" command, the Figure 2(b) shows the command On/Off is perform where all participants have done the same by pressing on the screen and the Figure 2(c) shows the participant is bringing the device closer to her face indicating the zoom-in command.



(a) (b) (c)

**Figure 2.** Children performing actions; (a) close; (b) On/Off; (c) Zoom-in.

The participants were a little confused with the 'open' and 'close' commands initially. They were not able to deal with the 'close' command, because they were not sure enough to fold or bend the device. They are more familiar with the WIMP-based 'close window' where they click the button to close.

## 6. Limitations and Future Work

We used a piece A4 size paper as an artificial deformable display in this case. It was a blank piece of paper without any information or pictures nor writing on it; in order to avoid any subliminal feedback related to an actual display or to its contents. This lack of interacting capability interface provided us with an opportunity to observe users' initial reactions to the device. This actually fulfilled the intuitiveness we are looking for.

During the action of performing the action, each command may have affected the next command as the previous command may have resulted in the corner of the device to be folded and leaving a mark. In these circumstances the previous command would need to be undone before the participant could carry out the next command.

Overall there were too few variables to provide a better understanding of the use of the displays. Hand-held devices are very much dependent on the context in which they are used, but in this investigation its use was limited by the life experience of the participants and the lack of feedback from the paper 'device' when compared to a physical device.

Besides that, the sample size is not large enough to provide a better understanding of the types of deformable-gestures that a child can perform. It is therefore the intention of the researcher to include at least 20 more children in the next phase.

In this study, no quantitative data was collected other than completion time observations were the main focus of the investigation. Therefore, it is wise that quantitative data is to be included in the future.

## 7. Conclusion

During the initial investigation, it is confirmed that children do often gesture during interaction with friends or learning in the classroom. In certain lesson like Mathematics, the teacher will also encourage them to use fingers to count. This also encourages the researcher to continue to conduct the next phase of experiment.

In this introductory study, we targeted to gain understanding on how deformation-based gestures are performed by children. This is done through observing children ages from 5 to 6 years old interacting with an object. The purpose is so it could aid the future design and implementation of deformable-based interfaces, such as Organic User Interface, through this observation of user-defined. It was observed that the children in the study performed actions based on their previous experiences and the types of interactions that they were accustomed to. This observation is part of the main components of deformable-based gestures, which is consistent with user preference and intuitiveness.

However, there is difference in preference on using paper in real life in portrait format as in this paper, it is found that all the children have held their "device" in landscape format. This is contrast with what Paper Window indicated in their findings.

This study was developed to concentrate on users' input rather than relying on current available technology. Although the definition and contribution of deformable display is still in its infancy, the use in this study of children of a pre-school age has shown that even at an early stage in their development the children's actions were intuitive. Although working with children was a challenge at time the researchers hope to continue their work with children in different age groups to determine if age impact on a child's interaction with a device.

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