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Gesture Interaction Design based on User Preference for the Elastic Handheld Device

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Objective: This study lays its aims at the definition of relevant operation method and function by researching on the value to be brought when applying smart device that can hand carry soft and flexible materials like jelly.

Background: New technology and material play a role in bringing type transformation of interface and change of operation system. Recently, importance has been increased on the study of Organic User Interface (OUI) that conducts research on the value of new method of input and output adopting soft and flexible materials for various instruments.

Method: For fulfillment of the study, 27 kinds of gestures have been defined that are usable in handheld device based on existing studies. Quantitative research of survey was conducted of adult male and female of 20s through 30s and an analysis was done on the function that can be linked to gestures with highest level of satisfaction. In order to analyze needs and hurdles of users for the defined gesture, a focus group interview was conducted aiming at the groups of early adopters and ordinary users.

Results: As a result, it was found that users have much value regarding usability and fun for elastic device and analysis could be conducted on preferred gesture and its linkable functions.

Conclusion: What is most significant with this study is that it sheds new light on the values of a device made of elastic material. Beyond finding and defining the gestures and functions that can be applied to a handheld elastic device, the present study identified the value elements of an elastic device - 'usability and 'fun' -, which users can basically desire from using it.

Application: The data that this study brought forth through preference and satisfaction test with the gestures and associated functions will help commercialize an elastic device in future.

Keywords: Elastic material; Shape changing interfaces; Organic user interface; Interaction design; User-centered design

1. Introduction

Many researchers are seeking for value of new interface beyond traditional input system (Lee et al., 2010). One of the most important trends in HCI area is the conception of OUIs (Holman and Vertegaal, 2008) that can transform and manipulate interface form through adoption of special and various new technologies and materials.

Early studies on shape-changing interface adopting concept of OUIs have suffered difficulties in development due to various technical obstacles (Herkenrath et al., 2008). However, the development of flexible electronics technology (Holman and Vertegaal, 2008) like batteries and bendable circuit boards are now tearing down such technical obstacles. Now is the time for studying values that will bring to future instruments the adoption of flexible and soft materials from the point of view of users beyond the technical research.

This study has its aims at researching on value and method that will be brought when soft and flexible materials are applied to interface from the point of view of users' experience and manipulation. Needs and hurdles will be analyzed that users will have when soft and flexible materials are adopted for the device that they hand carry, finding the most suitable method of use. Studies on various users were conducted by making low fidelity prototype with the most suitable materials with consideration of technically limited points for practical realization in order to perform the study. The study was coupled with normal survey like focus interview and quantitative check method through survey. In-depth opinion was to be researched through qualitative survey above simple preference that users have for elastic device. On the context of various uses, direct observation and opinion collection were conducted on how instruments could be utilized and on what reaction would be shown about the gesture that had been defined in the study. Through quantitative survey, an analysis was tried on the level of preference that users have about the 27 kinds of gestures proposed in the study and on the functions that is linkable to each gesture. Linking the methods between quantitative and qualitative surveys which have been synthetically interpreted from the study results to be effectively utilized for investigation of value and operation method that could be brought when adopting elastic material for handheld device.

2. Related Work

2.1 Elastic display & device

Type, function, and movement of user interface have influence on material of device (Follmer et al., 2012). Examination of prototypes appearing in studies relevant to deformable device can find utilization of various elastic materials like lycra, spandex, fabric, paper, latex, PVC, and etc (Troiano et al., 2014). More flexible and dynamic input interaction can be adopted; like push, grab, prototype, etc. that have not been adoptable to hard instruments for prototype that is applied to elastic material (Watanabe et al., 2008). Early study that adopted elastic material may be represented by Khronos Projector (Cassinelli and Ishikawa, 2005). The screen projected on soft cloth becomes flexible to transform image and react by user's input. Obake (Dand, and Hemsley, 2013) is an example of study in order that users can make more flexible input by coating multi-touch table with elastic material.

Groovepad (Kulik et al., 2012) is an example that has adopted for input pad that users use. As such is the case, examples of study adopting elastic material are being applied for most devices including table (Dand, and Hemsley, 2013), wall display (Paeper et al., 2016; Müller, 2014; Yun et al., 2013), tablet, phone (Follmer et al., 2012), etc. These examples show possibility of utilizing elastic materials for various devices. Also from the standpoint of software, examples vary for virtual 3D modeling (Watanabe et al., 2008), map navigation (Stevenson et al., 2011) and gaming, etc. Study on interface adopting elastic materials now expands to various areas.

2.2 Shape-changing UI

Shape-changing UI may be defined by two types such as flexible display and elastic display (Grunder et al., 2013). This study is conducted on Shape-changing UI that adopts concept of elastic display. Shape-changing UI has much more affordances for users to perform different tasks and can provide experiences about haptic feedback or touch by transforming shape (Coelho and Zigelbaum, 2010). Thus, various methods of input may be applied and relevant feedback also can be expressed in the way other than in existing instruments. Studies on Shape-changing UI are making rapid progress. Classic studies on transforming method and

manipulation for flexible display and foldable display are those on Morephone (Gomes et al., 2013) and FoldMe (Khalilbeigi et al., 2012). Jamming conducted a research on possibility that can be shown when adopting and utilizing flexible materials for various devices including tablet, phone, etc. Case by Bendi (Park et al., 2015) provides users with more familiar sense and experience through adoption of soft materials. Like this, close relation exists between shape-changing UI and elastic material, which make progress through various studies. However, sufficient studies have not been conducted yet on what method of input should systemically be utilized and what sort of function can be linked. This study conducts systemic research on value and manipulation method that elastic device has from the standpoint of user's experience.

It can see that the application of elastic material is extended to a variety of devices through the existing studies. However, the study on the input method for application to mobile device of elastic material has not been performed yet. The research has the differences because its study was done with the users using elastic handheld device's input method which was not performed on the existing research.

3. Interaction Design

In the existing studies regarding elastic material, the possible gestures were defined to be 'push', 'grab', 'squeeze', 'stroke', 'pinch', 'pull', 'tap', and 'expand' (Troiano et al., 2014). In the present study, 27 gestures, which are mainly based on 'touch', 'bending', 'stretching' and 'pinching', were defined as applicable in an elastic handheld device, considering the size and characteristic of a handheld device.

Those 27 gestures mainly based on 'touch', 'bending', and 'stretching & pinching' are shown in Figure 1. For naming them, this study referred to the existing studies and defined them with new names as below.

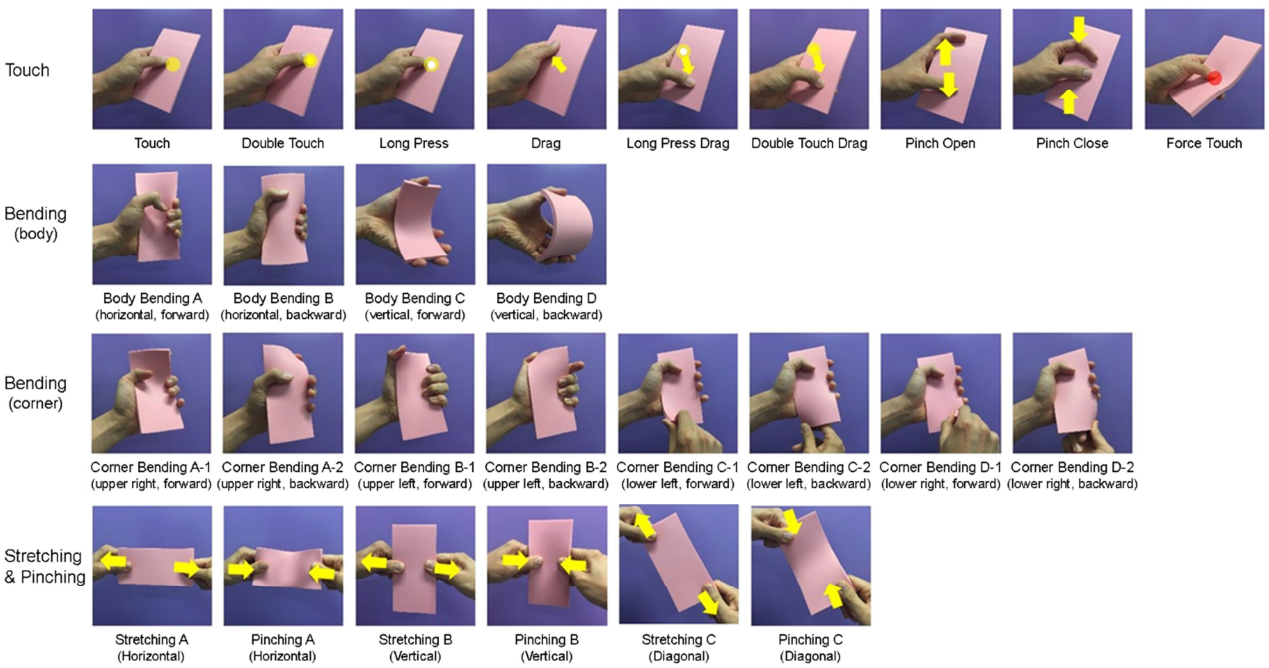


Figure 1. 27 gestures for the elastic handheld device based on 'touch', 'bending' and 'stretching & pinching'

3.1 Touch

The most representative 'touch' input modes are those used in Apple's iOS and Google's Android OS. As for Apple, 8 standard 'touch' gestures are used: 'tap', 'drag', 'flick', 'swipe', 'double tap', 'pinch', 'touch and hold', and 'shake' (Google, 2014). Android OS also allows 8 standard 'touch' input gestures of 'touch', 'long press', 'swipe or drag', 'long press drag', 'double touch', 'double touch drag', 'pinch open', and 'pinch close' (Apple, 2014). This study adopted Android OS 'touch' gesture guideline and added 'force touch (3D touch)' defined by iOS Human Interface Guidelines to the 'touch' input system in consideration of the material property of the device. Elastic material allows more intuitive and proper experience to a user because the shape of the device changes when he performs 'touch' input (Sato et al., 2009). That is, a total of 9 'touch' gestures were defined for this study, including 8 existing 'touch' motions and 'touch force', which was newly added.

3.2 Bending

5 input interactions are defined related to 'bending' of a deformable device: 'bending upward', 'bending downward', 'bending rightside upward', 'bending leftside upward', and 'bending the upper right corner' (Lee et al., 2010). Bending input motion is defined as 'full screen', '1 corner bend', '2 corner bends', and '3 corner bends' (Gomes et al., 2013). Considering the size and the characteristic of a handheld device, this study defined 12 bending gestures: bending a whole body vertically or horizontally (2), forward or backward (2), and each corner forward or backward (8).

3.3 Stretching & pinching

'Stretching and pinching' gestures are possible with an elastic device for its property. As for 'stretching and 'pinching' related gestures, Stretching gestures are defined horizontal stretching (both sides) and horizontal stretching (right side) (Lee et al., 2010). In this study, a total of 6 'stretching' and 'pinching' gestures were defined for the motions of the handheld device: 'horizontally', 'vertically' and 'diagonally' for 'stretching' and 'pinching', respectively.

4. User Research

Both qualitative and quantitative surveys were separately carried out with mobile phone users upon those predefined 27 gestures. In the quantitative survey, the participants were asked of their satisfaction and preferred functions of each input interaction. And their needs and hurdles, which were mainly related to input mode and function, in performing those gestures with the elastic device were asked in the qualitative survey. Both surveys enables integrated understanding and interpretation of the users in terms of input interactions with an elastic.

4.1 Qualitative research

Focus Group Interview shown in Figure 2 (FGI) was conducted to collect the qualitative data on users' opinions upon input interaction with an elastic device. FGI was separately carried out on Group A and B in order to gather more comprehensive and broad opinions on using an elastic device. The profile of groups is shown in Table 1. Based on the technology adoption cycle, Group A were consisted of general users who were slow at adopting new technology, while Group B were consisted of early adopters who had high sensitivity of new technology. By occupation, the users in Group A were mainly engaged in general jobs such as teacher, graduate student, housewife, and pastor. On the other hand, Group B included HCI-related specialists such as professional researcher, graduate students, and undergraduate students.

For practical experience, a prototype of the Elastic Device (3.06 x 6.22 x 0.28 inches) shown in Figure 3 was given to each participant

in FGI. The participants were able to try out various gestures on the prototype and were able to answer questions.

Figure 2. Focus group interview

Table 1. Profile of groups

	Number	Age	Years of using smart phone	Hour of daily use	Interval of switching smart phones
Group A	5 (Male 2, Female 3)	Avg. 34	Avg. 5	Avg. 2.5	Avg. 22.2
Group B	5 (Male 2, Female 3)	Avg. 24.2	Avg. 4.8	Avg. 3.1	Avg. 17.1

Figure 3. The prototype for user research

A total of 7 questions were asked in FGI sessions. The participants were allowed to express their own opinions freely in discussion and thus comprehensive opinions could be collected. Questions that were asked are shown in the Table 2.

Table 2. The question list for FGI

Number	Questions
Q1	Which gesture do you like the most and why?
	What function do you want to be applied to the gesture you liked the most?
Q2	Which gesture do you like the least?

Table 2. The question list for FGI (Continued)

Number	Questions
Q3	What other gestures, apart from what was already given, do you think can be performed?
	What function do you want to be applied to the motion(s) you proposed?
Q4	Which of the gestures, touching, bending and stretching, do you think is the most suitable for the elastic device?
Q5	How much do you think your preference would change if the actual size of the device was bigger or smaller?
Q6	What do you think about the texture of the elastic device and what kind of texture do you want?
Q7	Do you have any intentions of using the elastic device when it is actually available in the market?

4.1.1 Favorite gesture

Favorite gestures are shown in Figure 4 Most of FGI participants in both Group A and B chose the "Body Bending Forward" gesture as the best gesture. They explained that they liked the gesture because it was easy to perform with only one hand and allowed the quickest motion that they could perform when holding a device in the hand. Besides the quickness and convenient usability, some of the users mentioned that they liked the gesture because it was fun. Also, in the case of a participant who answered that the 'Body Bending' gesture was convenient, the device naturally bent forward when he held the device without much thought, which was different from others. The majority of the participants had the opinion that the most adequate function to apply to the "Body Bending" gesture was the locking/unlocking function. They also revealed it would be great if they could use the "Body Bending" gesture to receive calls. This preference can be explained by the fact that the gesture is convenient in using the device immediately when holding it in one hand, especially for locking/unlocking which is the most often used function. Some responded that they best liked "Corner Bending" gesture, which bends the top part of a device forward. They said that it was the most convenient gesture because they needed only a thumb and index finger to perform the top corner bending while holding the device in one hand. They also mentioned that it would be nice to apply such functions of turning on the next song, or turning on and off the lights. As for the bottom corner bending, it requires both hands to use, so the participants did not prefer it. Though very few, there were opinions that input methods like the 'Force Touch' is the most suitable one for the elastic device.

Figure 4. Favorite gestures: body bending (forward), body bending (backward), corner bending (upside)

4.1.2 Least favorite gestures

The least favorite gestures in Figure 5. turned out to be the 'Touch', 'Drag', 'Body Bending', and 'Stretching' gestures. Many of the respondents revealed negative opinions on the 'Touch' gesture. They said it was difficult to apply accurate touch on the elastic device because the device tends to bend and also it feels unstable to hold it in the hand. They stated that it would be very

inconvenient to use a keyboard that often requires a series of touching motions. In addition, it turned out that the feeling of the 'touch' had a great impact on the input interaction. For example, respondents who answered that the 'Drag' gesture was the least favorite stated that they disliked the texture that they felt when performing the gesture. Many participants also disliked the 'Stretching' gesture because they had to use both hands to do so. They didn't like the vertical, horizontal, and diagonal stretching gestures the most because they said it was inconvenient to perform pushing and pulling motion at its vertical stand.

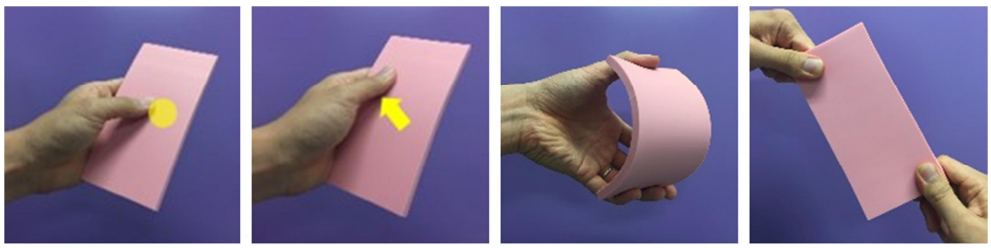


Figure 5. Least favorite gestures: touch, drag, body bending, stretching

4.1.3 Suggested gestures by the participants

Besides the 27 gestures defined in this study, the participants were asked to suggest new gestures shown in Figure 6. Some users suggested a gesture of squeezing the top of the elastic device with the thumb and the index finger. They expressed that the gesture of squeezing both ends of the top could create a fun input interaction in taking a picture. Another suggested gesture was the twisting of the device with both hands to capture a screen. Some other participant suggested a waving gesture like waving a hand fan to be applied to turn pages or change screens while enjoying contents on a device with one hand. Other respondents said that it would be fun to be able to perform a motion like hitting things around with the device or throwing it onto a desk. Though not a new gesture, there were also participants who suggested in repeating a predefined gesture two or three times, which came out of the idea associated with the double-clicking of a mouse or the double-tapping of a touch device.

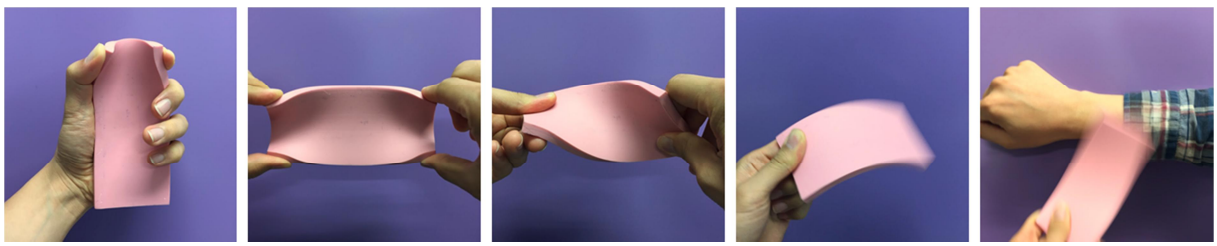


Figure 6. New gestures suggested by the participants

4.1.4 Comparative analysis of touch, bending, and stretching

For the questions about comparing their preference among the input methods (touch, bending, stretching) of the elastic device, most of the participants turned out to be satisfied with the 'Bending' gesture. They said that the 'Bending' gesture most intuitively matches with the elastic device. For this gesture, users stated that they could perform it with one hand and expected a high

usability because it matched most intuitively with the material of the device. There were also many opinions that the 'Touch' gesture was not suitable because the device could move due to it and the feeling wasn't very pleasurable, therefore the existing touch-based method would not be well applied to the new device. Furthermore, the respondents revealed inconvenience for the 'Stretching' device because they had to use both hands and were worried that they might break the device.

4.1.5 Size

In FGI sessions, the prototype, equal to the size of iPhone 6 Plus, was provided as a mockup. The users expressed that they could have performed the pre-defined gestures better if the size was smaller. Many of the participants responded that it would have been much easier and effective to bend and fold the device if the device had been small enough to be handheld. Therefore, majority of the participants revealed that an elastic pad of 9~10 inch could be very inconvenient to use. In the case of a pad, the device is often handheld. Therefore, some users were worried about the display being bent or twisted, which would make it difficult to watch any content. It would be especially difficult to watch anything in mobile spaces like a car or a subway train. Additionally many revealed that a big size elastic device would be inconvenient to use because it requires both hands to hold it. As for the positive side of the input interaction of the elastic device, the participants stated that the 'Bending' input interaction would be nice when an elastic device is used lying on the floor.

4.1.6 Texture

The participants showed two conflicting opinions about the texture of the elastic device. They preferred the jelly-soft texture for the pressing motion while they disliked the texture when rubbing the surface because it felt rough, which is unique to rubber material. They wanted to feel the smoothly coated surface of existing touch-based device for the rubbing motion.

4.1.7 Expectation of commercialized product

There were both positive and negative opinions regarding the use of the elastic device when it is commercialized in the market. Basically, Group B, the early adopters, showed high expectation for the new product, having keen interests in the feeling of the texture feel. They had high intentions of purchasing the device while Group A, the general users, were hesitant. They wanted to buy the device after they confirmed how other users react to the new product. Of the total FGI participants, those who were willing to purchase had positive expectation on its foldable function, lively motion, and new control methods. The participants with negative opinion on the new product stated that they would wait for a while before buying because they thought it was inconvenient to touch and to put it into a pocket. Since there was no significant differences between groups in the other items except for the item of 'Expectation' in the FGI result, the issues presented in the two groups was described.

4.2 Quantitative research

Through a survey, a quantitative research was carried out to analyze the users' preference of input interaction of an elastic device and to associate proper functions to each input interaction. The general profiles of the participants in the survey are in Table 3.

Table 3. Profile of participants

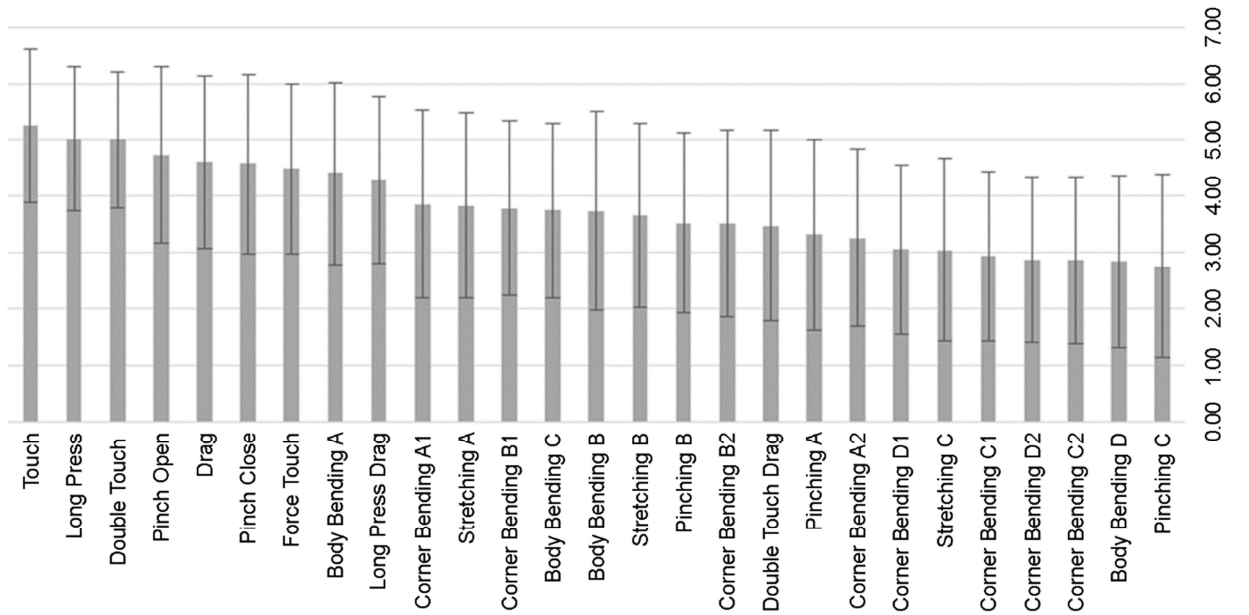
Number	Average age	Average years of using smart phone	Average hour of daily use	Interval of switching smart phones
50 (Male 30, Female 20)	24.2	4.2	2.62	21.19

Users performed 27 gestures with a prototype device, which were predefined in the survey, and their satisfaction of each gesture was measured on 7-point Likert scale.

4.2.1 Satisfaction of gestures

Satisfaction of each gesture was measured and the results are shown in Table 4. The overall satisfaction was 3.79 on average and the standard deviation was 1.55. The participants were most satisfied with the 'touch' gesture, on which most of the existing devices are based, while they showed the highest dissatisfaction of 'pinching C' gesture.

Table 4. Satisfaction of each gesture

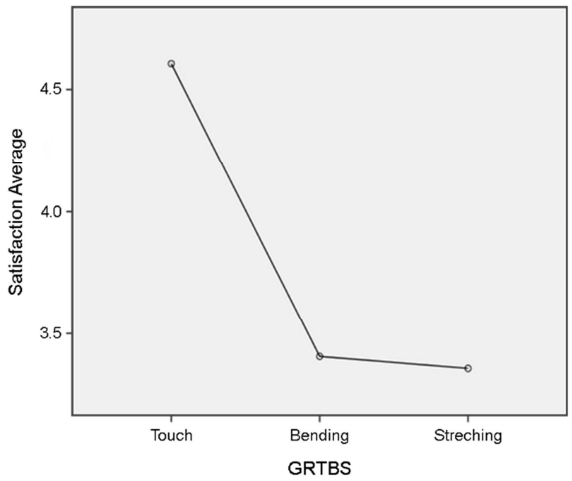


The analysis of one-way ANOVA in Table 5 was carried out in order to ensure more clearly the difference between three types such as Touch, bending and stretching. It can be found that there is a significant difference in at least one group among groups since the significance level is below 0.05 (p-value <0.05) when you view the data of ANOVA analysis. Data analysis was carried out for post hoc test by Scheffe's Method in order to specifically compare the differences between groups.

There is a significant difference as a result of a comparative analysis of the three types through one-way ANOVA and post hoc test. Although there was no significant difference between Bending and Stretching, it was found that there was a significant difference among Touch, Bending, and Stretching. It can be seen that Touch which has the highest existing utilization on input method applied to flexible materials gives high satisfaction to users. When devices are developed with flexible materials, the case of Bending and Stretching deemed to be used as a secondary rather than main input method, and Bending method will be more helpfully utilized than Stretching.

Table 5. Statistic result

	Sum of squares	df	Mean square	*F*	*p*-values
Between	409.751	2	204.876	79.022	.000
Within	3235.627	1248	2.593		
Total	3645.378	1250			



4.2.2 Suitable functions for the new gestures

Along with the satisfaction survey of 27 gestures, functions suitable for each gesture were also recorded. The respondents were asked to check the most suitable functions for each gesture. They were allowed to check more than one function. Table 6 shows the list of 27 predefined functions in this study.

Table 6. Preference of functions for each gestures (multiple selection)

Input methods		Touch									Bending												Stretching					
		T	DT	LP	D	LPD	DTD	PO	PC	FT	BBA	BBB	BBC	BBD	CBA1	CBA2	CBB1	CBB2	CBC1	CBC2	CBD1	CBD2	SA	PA	SB	PB	SC	PC
Locking and power-related functions	Locking	8	10	4	4	1	2	1	1	3	6	2	2	2	2	3	3	1	2	1	3	0	1	4	0	4	2	4
	Unlocking	16	12	7	17	3	5	3	2	4	6	5	4	4	5	1	4	3	1	2	0	2	4	1	3	0	5	1
	Power on	8	11	16	2	2	2	2	0	11	6	7	5	4	5	1	5	2	4	3	2	1	4	0	2	0	3	1
	Power off	5	5	21	1	3	2	0	2	13	14	5	7	5	2	5	2	4	3	2	2	2	1	3	0	3	1	3
	Total	37	38	48	24	9	11	6	5	31	32	19	18	15	14	10	14	10	10	8	7	5	10	8	5	7	11	9
Sound-related functions	Music playing	25	5	4	2	0	0	0	0	0	9	6	1	0	2	1	2	0	1	1	4	2	1	0	2	1	1	1
	Music pausing	23	9	1	0	0	0	0	1	0	10	6	3	2	1	1	3	1	0	0	3	1	1	1	2	1	2	1
	Next music	15	5	4	19	5	5	0	0	1	0	1	3	1	8	3	3	3	5	1	5	2	0	0	3	1	0	0
	Previous music	13	1	4	18	5	4	0	0	1	1	0	1	2	1	2	6	2	2	5	3	5	0	0	1	2	0	1
	Volume up	5	2	5	18	10	6	7	0	3	0	1	2	3	6	3	5	6	7	6	7	6	3	0	4	1	3	0
	Volume down	5	2	4	16	12	6	0	7	3	3	2	3	5	4	4	9	6	7	9	7	6	0	3	0	5	0	3
	Total	86	24	22	73	32	21	7	8	8	23	16	13	13	22	14	28	18	22	22	29	22	5	4	12	11	6	6

Table 6. Preference of functions for each gestures (multiple selection) (Continued)

Input methods		Touch									Bending												Stretching					
		T	DT	LP	D	LPD	DTD	PO	PC	FT	BBA	BBB	BBC	BBD	CBA1	CBA2	CBB1	CBB2	CBC1	CBC2	CBD1	CBD2	SA	PA	SB	PB	SC	PC
Call-related functions	Dialing	13	5	8	3	4	4	0	0	4	2	3	2	1	4	0	1	0	1	0	0	0	1	1	1	0	1	1
	Answering a call	19	6	5	10	2	4	0	0	5	12	10	4	1	6	1	0	1	1	1	2	1	3	1	1	0	2	1
	Hanging up a call	17	7	3	4	1	3	0	2	3	11	7	9	1	2	4	2	1	0	1	0	3	0	2	1	2	1	2
	Confirming a message	18	5	1	6	2	1	1	0	2	4	2	2	2	6	1	0	3	0	0	3	2	1	1	0	1	1	1
	Sending a message	12	1	2	0	3	2	0	0	3	0	1	0	1	2	1	1	0	0	0	1	1	2	1	0	0	0	0
	Total	79	24	19	23	12	14	1	2	17	29	23	17	6	20	7	4	5	2	2	6	7	7	6	3	3	5	5
Image-related functions	Photographing	26	4	2	1	1	0	0	0	2	3	3	1	0	4	2	2	0	0	0	1	1	11	5	5	2	2	1
	Enlarging a picture	4	13	3	3	6	2	45	4	2	0	1	0	1	0	2	1	1	0	0	0	0	23	5	22	5	12	0
	Reducing a picture	2	10	3	3	6	2	12	46	2	1	0	1	1	1	0	1	1	1	2	0	0	3	20	5	21	1	10
	Next picture	9	2	0	22	4	3	2	0	1	0	0	0	0	5	4	6	5	2	1	5	3	1	2	2	1	1	1
	Previous picture	9	1	0	21	3	3	1	0	1	0	0	0	0	2	2	10	7	2	1	2	5	1	1	0	2	1	1
	Screen capturing	5	9	16	0	3	3	2	3	14	5	2	3	2	7	3	1	2	1	0	1	0	11	2	6	3	4	1
	Total	55	39	24	50	23	13	62	53	22	9	6	5	4	19	13	21	16	6	4	9	9	50	35	40	34	21	14
Other functions	Previous page	11	1	0	17	5	2	0	0	0	0	0	0	1	4	3	7	4	5	2	1	1	1	1	0	3	2	3
	Next page	10	3	1	22	4	2	0	0	0	0	0	1	0	6	5	3	3	3	3	3	1	1	1	3	0	3	2
	Add to favorites	4	2	9	2	7	2	0	0	8	3	2	0	1	3	2	2	0	0	1	3	2	2	1	0	0	0	0
	Sharing data	2	2	7	2	14	7	1	0	7	0	3	5	1	2	4	0	1	2	2	1	1	2	3	1	0	5	1
	Deleting data	2	2	7	1	7	11	0	2	5	9	5	4	3	0	2	1	0	2	3	1	3	1	7	0	3	1	2
	Total	29	10	24	44	37	24	1	2	20	12	10	10	6	15	16	13	8	12	11	9	8	7	13	4	6	11	8

Locking and power-related functions

Many users wanted to use touch, double touch, long press, drag, which are used in the existing touch system, to perform locking and power-related functions. There were also a considerable number of users who wanted to use force touch, which has been recently introduced in the latest commercial models. Some users wanted to apply the 'bending' gesture and they preferred more of the 'body bending' gesture in Figure 7.

Figure 7. Unlocking function using body bending forward

Sound-related functions

Many users wanted to apply the existing input interaction modes to the new device in performing sound-related functions. Unlike locking and power-related function, some users wanted to apply the 'bending' gesture to sound-related functions and they preferred the corner bending forward and backward gestures to modulate volume or to move on to the next or previous music.

Call-related functions

The participants showed similar preference of gestures for call-related functions to locking and power-related function. The most preferred gesture to control call-related functions was the 'touch' gesture and was followed by the 'body bending' gesture. Especially, many users wanted to answer and hang up a call by using the 'body bending forward' gesture in Figure 8.

Figure 8. Answering a call using body bending backward

Image-related functions

The users opted for using the touch-based existing modes of changing image size such as the 'pinch open' and 'pinch close' gestures. There were also users who responded that they had like to change image sizes by using the 'stretching' gesture. Here, we could find the usefulness of the 'stretching' gesture, whose satisfaction had turned out to be very low in both quantitative and qualitative researches.

5. Discussion

5.1 Single handed interaction

Single-handed interaction was considered to be the most important factor when the users used a device of elastic material. It was the possibility and convenience of handling it with one hand that they considered as one of the criteria in choosing the most favored gestures with the device. Likewise, the users most preferred the motions possible to operate the device with one hand while performing 'body bending' and 'corner bending' gestures. Moreover, for an elastic device has the shape changing feature, when users bend the elastic device, it makes touch interactions easier to perform using one hand on large smartphones. The shape changing feature is very important for the single handed interaction design of elastic devices.

5.2 Fun

It was 'fun' that most attracted the users when the elastic device was compared with existing devices. While FGI sessions were being carried out, the participants revealed diverse opinions related to 'fun' factor. Even when asked to choose preferred gestures, they responded they had chosen certain gestures because they were fun to do, though they wanted motions easy and quick to play,

too. They also suggested various new gestures when asked to propose a gesture not predefined in the study, showing a strong interest and excitement in the course of interview. The users would hit others with the devices offered as a prototype or throw them onto the desks. They appeared very pleased with finding themselves take pictures with the device whose corners were bent. Therefore, it was known that the elastic device has its value not only of using a new material and providing new input interactions, but also offering 'fun'.

5.3 Preference

The users' preference of the elastic device was various depending on individual taste for it. Not included in the section of study finding, but they were divided mainly into two groups when they encountered the prototype at first: a group with a strong interest in it and the other expressing uncomfortable feeling and complaint. For example, High preference about input method related to touch which has different result of survey from FGI result is interpreted in this context. Additional research is needed applying a variety of sizes and shapes in order to clear the analysis because users have a variety of opinions and preferences about a new future devices.

5.4 Elastic things inspired behavior

We reviewed the data about new gestures suggested by the participants. There was the insight that participants, who conducted their task, got inspired from elastic things. New gestures that were squeezing, twisting, waving and hitting on elastic devices are similar to the movements of using a hand fan, pretzel and whip. If the research about control methods and shapes of elastic things would be conducted, we could find creative interaction methods from there.

6. Future Work

To identify the values of a device applied with elastic material, it is necessary to conduct a study focusing on the 'fun' factors of the device. In this study, the users appeared trying to find 'fun' as the value of the device. Therefore, when a study is conducted to develop 'fun' elements not only in input interaction but also in the overall context such as mobility and storage, we can expect more fruitful results from the study.

In addition, it is necessary to carry out usability evaluation on the prototype made reflecting the findings of this study. Furthermore, it will be needed to conduct the functional tests on the elastic device - from simple functions like locking/uncloaking when performing body bending (forward); moving on music or changing volume while doing corner bending; photographing when bending the four corners of the device.

Additionally, an in-depth study is necessary for the diverse sizes of the device. It will be very interesting to implement size test with a small size (palm-held), a pad size and a large size like a wall display.

7. Conclusion

This study has contributions viewed from the following three points. First, important issues have been deduced relevant to the value that elastic device has and its practical use through studies from a standpoint of user's experience other than technical one. Second, a method of gesture has been defined that is applicable when manipulating the size of a handheld device and gesture method has been found that users mostly prefer. Third, definition of functions that are highly likable to each gesture has enabled practical utilization in manufacturing of such relevant products.

Beyond finding and defining the gestures and functions that can be applied to a handheld elastic device, the present study identified the value elements of an elastic device - 'usability and 'fun' -, which users can basically desire from using it. The data that this study brought forth through preference and satisfaction test with the gestures and associated functions will help commercialize an elastic device in future.

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