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Variables that Influence Emotional Interaction between Human and Personified Flexible Devices

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Abstract

Alongside with the research and development on flexible displays, personification design is considered as one of the most prospective philosophy of design in terms of emotional interaction because people unconsciously tend to feel pleasured from things that are similar to themselves. Herein, using the personification design of the flexible display, this paper proposes that the degree of angle, the speed, and repetition of the movement of the personified flexible device influence the emotional interaction between human and flexible devices. For the study, the prototype is videoed and survey is conducted on 22 participants. As a result, according to the statistical analysis, speed plays the most significant role on emotional interaction between human and personified flexible devices, repetition and angle following after it in the respective order. This emotional interactive personified display is prospected to have various usages, applicable in notification and entertaining function.

Keywords*: deformable display, personalization, personification, human computer interaction, user experience*

1. Introduction

There has been increasing interest on flexible displays, experiencing significant technological development and studies on user interaction (UI) and user experience (UX). Regardless of this development, there are still limitations to introduce of these products on the market, due to the uncertainties on how people will accept them. Herein this paper suggest that personification is on the light of the design philosophy of the flexible display, and finds that different variables, such as degree of angle, speed and repetition of the movement should be considered on personification design of the flexible displays.

2. Literature Review

2.1. Researches on Deformable Displays

There has been increasing researches on deformable displays in the recent decades. Deformable displays, such as foldable display, bendable display and rollable display have been introduced by multinational corporations, such as LG, Samsung and Sony, and there has been various researches on user interfaces and experience [1-3, 5, 8, 11, 14-15, 18]. For instance, Lee *et al.* finds that there are numerous ways to change the user interfaces of deformation display, through folding, bending, twisting, swinging, rolling, flipping, crumpling, curving, zero-crossing and corner-bending [19]. Ramakers *et al.* [17] present a deformable device that can be physically transformed into different features, allowing users to interact with the device in various ways. Pederson *et al.* [4] have explores how different parameters of shape change influence upon user experience. Among researches which studies on the application of the usage of the deformable devices, such as in music,

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game and art [6, 20], Park *et al.* [21] present Bendi, a deformable device that provide tactile and visual response to the user, delivering emotion interaction with the user.

2.2. Personification Design of Display

There are two main methods on personification; indirect characterization and direct characterization. Indirect characterization refers to personification that indirectly describe the character through the way they move or talk. On the other hand, direct characterization is instantly recognizable personification which can be intuitively identified, through its outer look and direct implementation about its identity. Between two methods of personification, this study uses direct characterization for personifying the devices, particularly focusing on visual information that the displays provide through its movement.

As for a previous research, the study on what form should the flexible display should be applied in the future is conducted. Here, it is argued that the personification should be applied for the future deformable display design since people tend to be unconsciously attracted to things that are similar or familiar to themselves [12-13]. Indeed, using the personification, it has been found out that it is possible to standardize the emotion of personified devices, which is applicable to use on notification function [13]. The factors that influence upon the personification has also been studied, finding that people tend to express their emotion on the flexible display by reflecting their facial expression, body movement or their abstract expression of their mind. Factors that influence the emotion of the personified display include angle, speed and repetitiveness.

2.3. Researches on Emotional Interaction

Although it has not been applied on the deformable display, Bailenson *et al.* [10] studied how haptic display enhance emotional interaction using Six Basic Emotions. Six Basic Emotions is the emotion model where Ekman contend that happy, sad, anger, fear, disgust and surprise is the preliminary emotion in terms of human culture and facial expression [16].

Circumplex Model of Emotion is another kind of emotion model coined by Russell [7], where the emotions are distributed by the level of arousal and pleasantness. Pederson *et al.* [4] on the other hand contend that although there are not significant linkages, there is existence of emotional interaction between flexible display and human according to the Circumplex Model of Emotion.

In this study, we aim to use both Six Basic Emotions and Circumplex Model of Emotion for the research. Six Basic Emotion is used to determine ‘six basic motions’ to conduct the user study, and Circumplex Model of Emotion is used to analyze how these six basic motions alter by changing variables.

3. Methodology

3.1. Overview Process of the Study

To outline the overall research process, the study mainly consists of 4 main stages (see Figure 1). First, 6 movements which represents each emotion of Six Basic Emotion is selected via the pilot study. On the next stage, the prototype that express those emotions is created, and multiples of these movements are videoed, changing a single variable of angle, speed and repetitiveness. After videoing these prototype, the user study is held, asking how the level of arousal and pleasantness change in the Circumplex model of emotion when each variables are altered, and interview which asks their application usages which consider hedonic and pragmatic quality is also conducted.

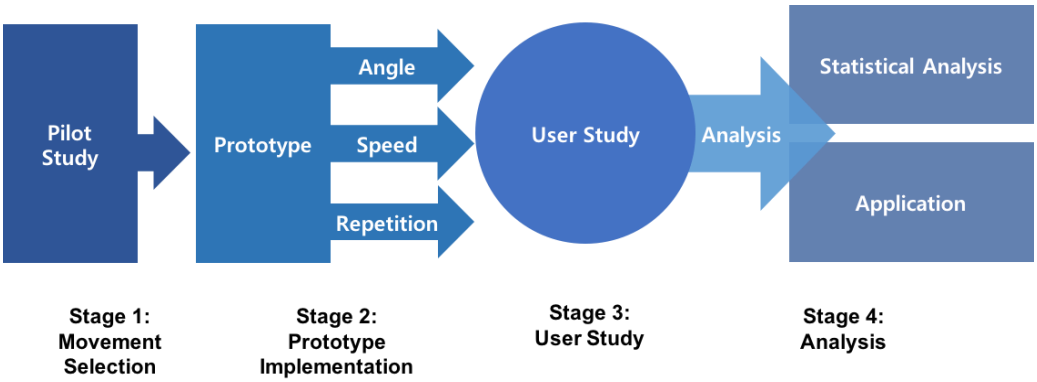


Figure 1. Overview Process of the Study

3.2. Pilot Study

Before conducting the study which find which factor influence upon the emotional interaction between the users and the devices, the pilot study is conducted on 10 participants [12]. In the pilot study, clear plastic film that is cut and drawn into the size of iPhone 6 is given to the participants and asked them to freely personify the devices based on 6 basic emotions of Paul Ekman; happiness, sadness, anger, fear, disgust and surprise. As they freely shape the plastic film to express the emotion, how they personify the devices accordance with the emotion, and which variables influence upon the emotional interaction is asked through the interview.

As a result of the pilot study, it has been found out that the most participants tend to personify the devices through their experience or the memory of the body movement when they feel such emotion. It has found out that the participants tend to perceive rectangular-shaped device as a body, and use the top corners as its arm, bottom corners as its legs to personify the devices.

On personalization of personified flexible devices, degree of angle, speed and repetition of the movement, and positioning of the devices is pointed out as the key variables which influence upon the emotional interaction between the user and the devices. Here, we take angle, speed and repetition as the variable. Other factors are taken into consideration for the further study.

3.3. Prototype Implementation

In order to find how the emotional interaction between the user and the device may change by differentiating a single variable, the linear actuating prototype is created and videoed to test on the participants.

The prototype consists of two parts, the actuator on the below that implement the deformable movement, and the deformable display that will represent as a future personified deformable display (see Table 1).

Using this prototype, total 24 movements were videoed. The first 6 movements functioned as an independent variable that expressed emotions from Paul Ekman's Six Basic Emotion, happy, sad, angry, disgusted, feared and surprised. The other 18 movements acted as the ones that test 3 variables that influence the emotional interaction, angle, speed and repetition.

The prototype is created, microcontroller which activates the linear actuator. The linear actuator allows the display on the top to change its shape by moving the actuator upwards and downwards (see Table 2).

The main components of the prototype are linear actuator, switch, controller, selector, power cord, and most importantly, 9 linear actuators. In order to activate the movement

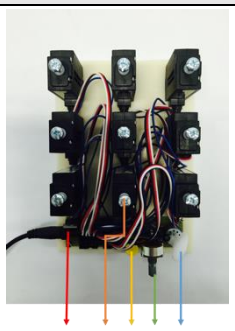
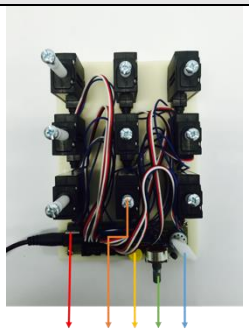
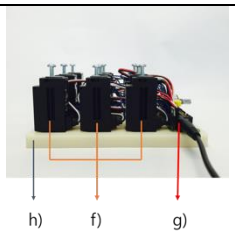
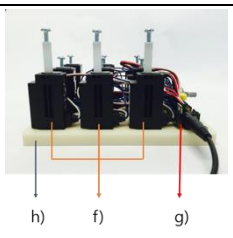
through the linear actuator, the selector selects which linear actuator should be moved, and controller determines how much should it be moved. All of those movements could be initiated only when the power and the switch is turned on. The 3D printed block on the below supports and connects all those major components, acting as a base of the prototype.

Table 1. Initial Design of the Prototype

View	Prototype
Side View	When deactivated 
	When activated 

They are composed by: a) linear actuator, b) flexible material

Table 2. The Prototype from the Top View and the Side View

View	Prototype	
	Deactivated	Activated
Top View		
Side View		

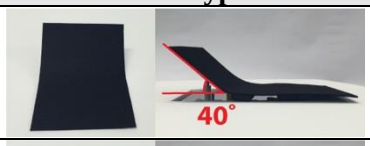
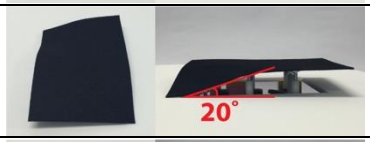
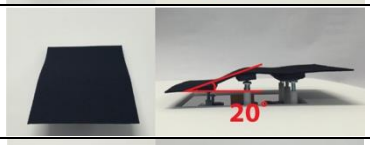
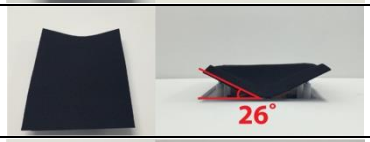
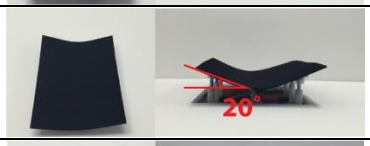
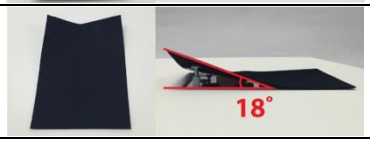
The Components Include: c) Switch, d) Controller, e) selector, f) linear actuator, g) power cord and h) 3D printed base block

3.4. Video

To test the user experience of the personified flexible device, the movement of the prototype is videoed. User study is conducted using video regardless of the construction of the prototype because of the sound that the prototype makes when it changes its shape. In the beginning, both methods on showing the real prototype and showing the video underwent the study. However, the prototype made mechanic sound, and it severely increased the emotion towards the flexible device into the negative feeling. Since the

sound plays crucial role on emotional, video recorded prototype is tested upon the users, providing only visual information to the users.

Table 4. Samples of the Video that Tests Angle.

Emotion	Prototype
Disgust	
Happy	
Angry	
Surprised	
Feared	
Sad	

Here, for the research, 4 main variables are videoed, naming the original version of the movement of the device as the 'independent' since the video act as an independent variable with no variables changed. Then, three other videos are titled as 'Angle', 'Speed' and 'Repetition'. Each titles are named with the variants that would be altered. The following are how those variables were changed in order to conduct the study:

- Angle is tested via showing the grid that shows the difference from the side view (see Table 4). In order to show the clear difference on the angle, the side view with the grid is shown to the participants. The difference on angle between the independent variable and the angle are 10 (±2) degrees.
- Speed is altered using the tool in the Final Cut Pro X. According to the instructor, the device moves in 20mm/s. Using the Final Cut Pro X, the speed is increased through fastening the original video 4 times faster, moving in 80mm/s compares to independent variable that moves in original speed, 20mm/s.
- Compared to the independent variable that moves three times, repetition is measured by showing the device that moves single time only.

Between each scene, participants had time to rest so that the video that they are watching is not influenced by the previous video that they have previously watched. The amount of time gap given between each videos is 30 seconds since according to Todd *et al.*, the capacity limit of visual short-term memory usually does not last more than 30 seconds [9]

3.5. User Study

Using the videos, 'Independent', 'Angle', 'Speed' and 'Repetition', the survey is conducted to find the emotional interaction between human and display.

The first part of the survey consists of the questions that asks for the demographics of the participants, such as their age and gender. The second part is comprised of the questions that asks participants' familiarity on displays, through asking how many devices that they commonly use, how long do they use the devices on daily basis, how frequently do they replace their smartphone, and what is their expected satisfaction on the upcoming flexible displays based on 7 point Likert Scale.

On the third part, each videos, 'Independent', 'Angle', 'Speed' and 'Repetition', is shown and asked the participants to plot which emotion in the the Circumplex Model of Emotion do they think each motions are representing. By comparing scattered point that the participants have plotted how each variable influence the level of arousal and pleasure is measured.

After the survey, in-depth interview is conducted with the actual prototype so that the participants can freely share their opinions and thoughts on deformable flexible display.

4. Result and Conclusion

4.1. Participants

For the study total 22 participants volunteered to conduct the survey. The total user study lasted for 50-60 minutes on each participants, taking 30 minutes to watch the video, and 20-30 minutes to conduct the interview. At the end of the interview, gifts are given to each of the participants.

The average age of the participants are 21 years old, which gender proportion is counted as 16 males and 6 females. On average, participants use 3 devices for 8 hours on daily basis, and the smartphone replacement rate is about 23.5months. This statistic shows that the participants over all are not too behind the current technology. These participants rated 4.18 on their satisfaction on future flexible display on 7-point Likert scale. The detailed information of the demographic and familiarity on technology is described on the Table 5.

Table 5. Detailed Information of the Participants

Part	Question	Average	SD
Part 1	Age (years)	20.73	4.13
	Gender	16 Male, 6 Female	
Part 2	Number of Devices (ea)	3.09	1.06
	Daily Usage (hr/d)	7.63	4.13
	Smartphone Replacement (months)	23.52	11.54
	Expected Satisfaction (7-point Likert Scale)	4.18	1.65

4.2. Emotional Change in Circumplex Model of Emotion

The result of the survey reflects how the participants perceive each motions in relation to the emotion that is outlined in the Circumplex Model of Emotion. Since six motions are tested on each variable, on independent, angle, speed and repetition, the data per each participant, and 22 volunteers participated on this research, total 132 answers are collected for each variable (see Table 6.)

For the analysis, all the data categorized into 4 categories accordance to the four quadrants of the Circumplex Model of Emotion; pleasant-aroused, pleasant-mild, unpleasant-mild, and unpleasant-aroused. For example, excited is categorized into pleasant-aroused category since it is placed on the quadrant where x-axis is pleasant and y-axis is aroused. Using this categorized result, the comparative statistical analysis, paired t-test is conducted to find if the emotional change occurred between each variables (see Table 7).

Table 6. Result of the Survey

Variable	Category				Total
	Pleasant-Aroused	Pleasant-Mild	Unpleasant-Mild	Unpleasant-Aroused	
Independent	29	40	27	36	132
Angle	51	25	15	41	132
Speed	62	18	8	44	132
Repetition	13	48	57	14	132
Total	155	131	107	135	528

Table 7. Paired t-test with Independent Variable

Variable against Independent	Chi square value	Degree of freedom	p-value
Angle	13.265[a]	3	.004
Speed	31.426[a]	3	.000
Repetition	27.217[a]	3	.000

Through the result of the hypothesis testing, the difference between independent variable and other altered variables, angle speed and repetition, is considered to be statistically significant, rating lower than .05 on p-value.

- H0(null hypothesis): there is no significant difference between two groups
- H1(alternative hypothesis): there is significant difference between two groups

As a result, although all of the results are rated to be highly significant, the speed is considered as the variable which mostly influence the emotional interaction of the personified flexible devices, rating 0.00000069 on it p-value. Repetition, rated as the next influential variable which alters the emotional interaction rated as 0.0000053 on its p-value, and lastly, angle rated as 0.0041 on its p-value of its paired t-test.

4.2.1. Angle

Through the interview, it has been found out that 75% of the participants consciously agree that change in angle of the deformable display influence the level of arousal. As the degree of angle decrease, participants perceived the device to feel pleasant. Anger was the only emotion where the participants increased its arousal instead of increasing pleasantness.

Some participants argued that the degree of angle may be not as much different as the speed. This is because when the device moves at the smaller degree with other variables to be constant, the amount of time that it reaches its maximum height is reduced.

4.2.2. Speed

The study also finds that there is positive relationship between speed and the level of arousal of the personified flexible display. When the device moves four times faster than the independent variable, participants in general experienced increase in the level of arousal. Through the interview, the participants used the term 'the greater intensity of emotion', 'more lively feeling' or 'being hurried' to express the increase in the level of arousal.

Indeed, compared to independent variables where 49.2% of the participants perceive the videoed motions to be aroused quadrants, when the speed fastened, 80.3% of the participants are in aroused upper quadrants of Circumplex Model of Emotion.

4.2.3. Repetition

Likewise, there is also a positive relationship between the level of arousal and repetitive movements. About 49.2% of the participants saw the devices to be on the mild quadrants when the device moved three times in the independent variable video. Contrastingly, it has been appeared that 79.5% of the participants agreed that the device that moved single time to be mild.

4.3. Reflection of Emotion

In the interview, the participants commented that their current state of emotion plays large influence on how they perceive the motions are. For instance, three of the participants mentioned that the motion that the motion that express happiness may seem pleasant because they are feeling pleasant at the moment. If they are currently feeling frustrated, the motion might seem like it is pattering.

4.4. Application Usage

4.4.1. Notification Function

Fifteen out of twenty-two participants commented that the personified flexible devices would be effective to be used as a notification function. They commonly said that the deformable display can be very useful when a user has to put the device in 'mute' mode. It would be more effective than vibration, because first, it would not make noise that bother the others, and second, the user would be able to recognize the movement when the device is attached to the body because it moves in a greater scope than vibration.

Five of the participants in particular was interested in this function, providing specific application situation for notification. They said that it would be faster to decide if they would like to pick up the phone or not depends on the movement of the devices. For instance, if it express anger, they would be able to instantly recognize that they the phone call is from a person that they would not want to pick up, and would be able to ignore it without touching the phone.

4.4.2. Entertainment

Participants had high demand to use the flexible devices on the entertainment purpose in general. Indeed, one of the participant believes that this does not have any functional use cases, but would be able to use it when she feels bored. She said that it would be funny to see how the device reacts upon how she touches it or plays game.

4.4.3. Locking the Motion

Half of the participants commented that the deformable displays have to have 'locking' system, locking the physical motion at the deformed state. It would have very low

pragmatic quality if it deforms whenever they use it. One of the participant had high expectancy on deformable display, commenting that the deformable display would allow the users to use both flat and curved display if they are able to lock the hardware motion of the display. Overall, in order to enhance the pragmatic quality of the emotionally interactive deformable display, the motion locking system is necessary.

4.4.4. Personalization

Participants mentioned that emotionally interactive personified deformable display fits with the current social trend over the world, personalization. Indeed, personalization of smart digital device has become one of the key factors for changing users, and demand for it is expected to increase over time. Since the era of industrialization, quantitative production of the manufactured products increased people's will to differentiate themselves from the others. As screen-based technology has already widely spread in our society, the demand for other interaction method has augmented. This personified flexible device can be one of the ways that can fulfill these demands because it allows users to express their individualized emotion through its hardware.

5. Conclusion

Throughout this study, we created the prototype and tested how angle, speed and repetitive movement of flexible display influence the emotional interaction between the device and the user. As a result, the speed plays the most significant role on how the participants, repetition and angle influencing after in the respective order. Speed and repetition have positive relationship with the level of arousal, and angle on the other hand has negative relationship with the level of arousal.

Through the in-depth interview, the application of the device is also discussed, finding that the device can be used as notification function, and entertaining purposes. To improve the pragmatic quality, the device should also have a locking system which permit the device to keep its deformed state while using the phone.

As a limitation of the study, this study does not take the current emotional status of the participant into consideration. For the future work, how the interaction with the flexible device reflect the emotional status can be researched. As for the future work, we also aim to make a prototype that can test the application usage of this personified devices, finding the efficient way to apply it in the real life. Cross-cultural study on how people from different backgrounds perceive different personified flexible devices can also be held.

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