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Master's Thesis
Academic Year 2021

Emolleia – Wearable Kinetic Flower Display for Expressing Emotions

Keio University
Graduate School of Media Design

Yifan Zhuang

A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
Master of Media Design

Yifan Zhuang

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Abstract of Master's Thesis of Academic Year 2021

Emolleia – Wearable Kinetic Flower Display for Expressing Emotions

Category: Design

Summary

We explore how what we wear (our clothes and wearable accessories) can be more expressive and represent our mood in the moment. In this paper, we present Emolleia, an open, wearable kinetic display in form of three 3D printed flowers that can based on wearer & onlooker's facial expression, dynamically perform 8 pre-defined animations. Users can define their own animated motions. We describe the prototype design and hardware considerations. We also evaluate the expressiveness of the prototype in user survey (n=50), mapping 8 pre-defined animated motions to the reported, user-perceived valence, arousal and dominance. Several animated motions show significant responses for perceived valence and arousal, presenting evidence that Emolleia can be effective in communicating feelings. By conducting conversation study with Emolleia, we explored how facial tracking technology with wearable computer can be used to enhance social interaction and encourage people express themselves more.

Keywords:

wearable display, aethetic wearables, emotion, interactive design, fashion

Keio University Graduate School of Media Design

Yifan Zhuang

Contents

Acknowledgements **vii**

1 Introduction **1**
1.1. Background 1
1.2. Socialization & Non-verbal Communication 1
1.3. Proposal 2
1.4. Research Question 3
1.5. Contribution 3
1.6. Thesis Structure 4

2 Related Works **5**
2.1. Wearable Devices 5
2.2. Wearables with emotion expressing 5
2.3. Emotion & Color 6
2.4. Fashion with technology 7
2.5. Flower Design Reflect Emotion 8

3 Emolleia **9**
3.1. Concept and Final Design 9
3.2. Design Process 11
3.2.1 Sketch 13
3.2.2 Prototyping 13
3.2.3 System Description 17
3.3. Pre-study 21
3.3.1 Design Research 21
3.3.2 Pilot Survey 23
3.3.3 Result 23

3.3.4 Pilot Study 24

4 Evaluation **27**
4.1. Study 1: Emotion Elicitation 27
4.1.1 Participants 28
4.1.2 Study Protocol 28
4.1.3 Results 29
4.1.4 Discussion 31
4.2. Exhibition 34
4.3. User study 2: Conversation Use Case 38
4.3.1 Participants 38
4.3.2 Study Protocol 38
4.3.3 Results 41
4.3.4 Discussion 42

5 Conclusion **43**
5.1. Finding 43
5.2. Limitation 43
5.3. Future Work 44

References **46**

Appendices **53**
A. Questionnaires 53

List of Figures

1.1 Emolleia 4

3.1 Model wearing Emolleia around shoulder 9
3.2 The interpretation sketch of how Emolleia react to surround people according to their facial expression 10
3.3 The soft of user define animation 12
3.4 The first Emolleia design sketch 12
3.5 The Emolleia design sketch - profile 13
3.6 The Emolleia design sketch - front 14
3.7 Test prototype & 3D modeling images 14
3.8 Emolleia sketch SMA ver. 15
3.9 The 3d model of petal 17
3.10 The 3d model of Emolleia support 17
3.11 Final prototype of emolleia 18
3.12 System description of M5STACK 19
3.13 Overview of the assembly of Emolleia 20
3.14 A color wheel to help categorize intensities of eight primary emotions-anger,fear,sadness,disgust,surprise,curiosity, acceptance and joy [1] 21
3.15 Beetle color change observing sketch 22
3.16 Implementation explanation of prototype used in pilot study . . 24
3.17 Pilot study set up 1 25
3.18 Pilot study set up 2 25

4.1 The-Self-Assessment-Manikin-SAM-Measure-Scales-valence-arousal-and-dominance-pole 27
4.2 The Emolleia motion used in Animation Study 28
4.3 Replies of where people would like to wear the device 30

4.4 Replies of Who would you be willing to use this product under the company? 30
4.5 The mean value of Emolleia's arousal 32
4.6 The mean value of Emolleia's valence 32
4.7 Eight Motions mapped to valence-arousal coordinate axes based on average SAM scores from survey results 33
4.8 Poster of Emolleia in KMD forum 2021 35
4.9 Description of facial recognition system 36
4.10 Emolleia interactive process step interpretation 36
4.11 Exhibition - KMD forum 2021 37
4.12 Face recognition process flow diagram 39
4.13 Conversation use case set up 40

List of Tables

4.1 Descriptive statistics of SAM scores over eight types of motions. Figure. 4.1 illustrates differences among eight animated motions. 31
4.2 Emolleia's Motion & Color Design 38

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Chapter 1
Introduction

1.1. Background

Every morning, after we wake up, part of our morning routine is to pick what clothes and accessories to wear. Sometimes these choices are affected by our mood in the moment; how we feel after getting up, what sound is playing on the radio. Sometimes, we dress to impress, picking our favourite outfit in which we feel confident, relaxed or beautiful, and communicating these feelings to the people we meet.

Clothes and accessories are part of our self-expression, yet usually we can just change how we look and adjust it to our feelings a couple of times a day by putting on different clothing items.

There are already quite a few explorations on utilizing garments or accessories to assist self expression, social interaction, or conversation efficiency. Researchers and designers have started realizing instead of a simple decoration, garment can actually be functional as an extension of our body, as an advanced communication method to augment or even perform non-verbal communication as eye contact, facial expressions, gestures, posture, and body language. [2]

1.2. Socialization & Non-verbal Communication

Take a moment to imagine on this beautiful blue planet, there are roughly 7.6 billion people living together on the same land, connected tightly as an organization which every internal individual has been more or less affected by one and another during million years. We have been constantly interacting with other human being spontaneously or reluctantly under this gigantic social system, by communicating through verbal or non-verbal methods. Socializing, has already

become one indispensable part of our daily life.

Although undeniably we are heading to the united society in very high speed, there are still some incredible people were unable to openly express themselves very well under social context or a conversation due to variety reasons.

Some studies pointed out that non-verbal communication can convey more information than verbal communication. [3] Some scholars state that most people trust forms of nonverbal communication over verbal communication. [2]Ray Birdwhistell concludes that nonverbal communication accounts for 60–70 percent of human communication. [4]

For example, shy people always find it hard to tell surrounding individuals to keep distance when they prefer to be alone, or let others know they are willing to socialize but lack of courage to ask.

Zimbardo (1977) proposed that there are two types of shy individuals; (1) shy introverts who prefer to be alone and lack social skills and, (2) shy extroverts who desire to interact with others, but lack social skills and experience internal distress and cognitive distortions about social situations. [5]

The motivation of this project is to assists people who has difficulty on expressing their emotions to show their acceptance and rejection in a gentle way.

1.3. Proposal

In our research, we explore how to create more expressive clothes and accessories that are able to instantaneously reflect our feelings. We work on integrating wearable computing in our clothes to dynamically show mood changes and represent how we feel in the moment. We focus on wearable accessories and clothes that can change and reflect the intentions, moods, and feelings of the wearer. The target user of this device is people who has difficulty to express themselves in social conditions.

In this thesis, we present Emolleia, a wearable kinetic display in form of three 3D printed flowers that equipped a facial tracking camera which can detect your presence and recognize your facial expression. As you approach, Emolleia can dynamically perform eight animations at different speeds according to wearer & onlooker's facial expression. Users can define their own animated motions.

The kinetic display is the result of several design iterations trying to capture the movements of flower ensembles.

1.4. Research Question

The aim of this study is to explore more possibilities utilizing wearables to assist on emotion expressing, ultimately enhance our conversation efficiency or even social life. Here is three research questions we would like to raise:

Research Question 1 Are wearables able to express people's emotion?

Research Question 2 Does affective wearables make participants to be more aware of other people's emotions?

Research Question 3 Will participants who relatively express their opinions less than others be motivated to speak out their thought, and will participants who relatively talk more than others realize that those who talk less have something to say and offer them a chance to speak out?

1.5. Contribution

The contributions of this paper are as follows:

1. We present the concept, design and prototype implementation of Emolleia, a kinetic display consisting of three flowers (the 3D model, components and software will be open-sourced).

2. We conducted a user survey with 50 participants to elicit potential use and application cases.

3. In the emotion elicitation study with the same participants, we evaluated 8 designed animated motions of Emolleia regarding their perceived emotional qualities using the self-assessment Manikin [6].Several animated motions show significant differences for perceived valence and arousal.

4. In the user study 2 conversation use case, we picked and mapped 5 emotion-correlated animations on Emolleia then conducted an experiment with 6 participants to observe how wearables enhance people social interaction and self expression.

Figure 1.1 Emolleia

1.6. Thesis Structure

This thesis is divided into 5 chapters. Chapter 1 is an introduction to this project. Chapter 2 presents related works, chapter 3 focused on describing the design concept, process and implementation of Emolleia, chapter 4 explains the two user studies and analyses experiment results, chapter 5 concludes with the findings, limitation and future work.

Chapter 2
Related Works

To understand the design concept Emollia, we first explore related works in the fields of wearables. Here we specifically focus on emotion expression, emotion & color, fashion and technology, also the flower design with emotion.

2.1. Wearable Devices

According to Susan Elizabeth Ryan, the term 'wearable technology' or WT applies to work that is functional in application and potentially commercial in distribution or experimental and conceptual in nature to aid the awareness of embodiment. [7]

There's a long line of research in wearable computing and in human computer interaction fields targeting the recognition, visualization, and evocation of emotions [8–12].

Springlets, expressive, non-vibrating mechano-tactile interfaces on the skin. Embedded with shape memory alloy springs,it's a thin and flexible stickers to be worn on various body location which provided a new interactive experience in tactile social communication, physical guidance, health interfaces, navigation, and virtual reality gaming. [13]

2.2. Wearables with emotion expressing

Researchers link garments, clothes and accessories to how we are perceiving us and actively use these effects for communication and therapy [14]. Garment is one of the most intimate things that we interact with in our daily lives. Garments are used to hide, reveal, and distort the self that we present to the world. [15] There are several works using wearables to display and communicate emotional

feedback in with kinetic using tactile sensations [13, 16].

There are variety of researches which using wearables to assist on self-expressing and explore new possibilities on social interacting have been conducted.

Rain Ashford presented one emotive wearables which will reflect wearer's EEG data on pendant, to show if this person is paying attention or concentrating on what is going on around them, or is relaxed and not focusing or concentrating. [17]

The Awe Goosebumps uses the inflatable silicone to externalize and amplify feelings of goosebumps [12]

Under COVID-19 pandemic, there are also some works presents a stepping stone towards productizable solutions for smart face masks that potentially increase the acceptability of face mask wear in public which display the emoji on the mask. [18]

Fashion makers and designers are also rethinking their trade and incorporate wearables in their designs [19]. There is an emerging area of 3D printed, computer generated fashion individualized for the user [20]. They utilize often the connections between shapes, forms and emotions [21]. Vasquez et al. present wearable, expressive accessories combining biodegradable materials with electronics [22].These works however are often not dynamic and cannot change while the user is wearing them. Most work in the wearable garment and accessories space focuses on utility and use cases (e.g. detecting wetness) [23–26]. Vasquez et al. present wearable, expressive accessories combining biodegradable materials with electronics [22].

2.3. Emotion & Color

Color is an important design element that can meet a variety of human needs. [27] Color is also an important aspect of our efforts to create personal spaces to our own liking. Moreover, color choices can have important social consequences as our choices are part of our presentation to others, and thus these choices may influence how others perceive us. [28]

Many studies have shown that cultural background, age, gender, personality do have strong affect on people's interpretation and choice towards color. [29] Social introversion and neuroticism may be associated with the preference for dark and cold colours (in this case grey, brown, and black). Similarly to these

colours, introvert personalities tend to withdraw from the external environment. [30] Studies indicate that there is a common preference for white in Asian areas. White with its associative image of being clean, pure, harmonious, refreshing, beautiful, cheer, gentle and natural is preferred in Asian regions. [29]

Many studies have shown that color is associated with emotional expression. In the Color - Emotion Association case study conducted by Banu Manav shows, Pink and yellow color samples were associated with dynamism, cheerfulness, and enjoyment. Green elicited a high number of responses, including the feelings of excitement, relaxation and vividness, confidence and purity. Blue was associated with calmness, being peaceful and cold. [27]

In 1980's Robert Plutchik [31] divided emotions into eight main categories. Half of these emotions are positive emotions, and the other half are negative ones.

Studies have also been conducted on novel method of expressing emotions for a robot by dynamically changing the color luminosity of its body. [32]

2.4. Fashion with technology

Researchers and designers are not satisfied with placing wearables only in Engineering or Human Computer Interaction side. There are quite some experimental fashion garments been created with both aesthetic outlook and ingenious interaction.

We are inspired by the following research works and their vision follow closely. Berzowska et al. present first prototypes of kinetic electronic garments focusing on self-expression [15]. Berglund et al. present a controllable, dynamic changing costume and extend this concept towards kinetic dynamics [33]. Jarusriboonchai et al. show a transforming dress that dynamically reveal and conceal areas of skin [34]. They also explore the design space of wearables for intimate communication [35]. The designed artifacts focus on wrist bands, earbuds etc. and are complimentary to the research presented here. We are not aware of any works presenting an open-source, wearable, kinetic display to express feelings.

INTIMACY 2.0 which created by Daan Roosegaarde, is the dress made of smart fabrics which become clear when electrified by a quickening heartbeat. [36] Smoke dress is the garment being activated by proximity sensors. When someone steps

into the personal space of the wearer, the dress creates a veil of smoke which can be smell and taste by people around it. [37] [38] Dobbelstein et al. present a wearable olfactory display allowing users to receive multiple computer generated scents related to notifications, reminders or other kinds of digital data [39]

Iridescence is an interactive collar, equipped with a facial tracking camera which will flip the colors and start to make patterns, in response to the movement of onlookers and their facial expressions. [40]

The ability to communicate things experienced through our other senses, such as smell, taste, and touch, has not been developed until recent years. [12]

2.5. Flower Design Reflect Emotion

Flowers are also often used as a way to express emotions. Bernhaupt et al. included flowers in a game as a feedback mechanism on how much the user is smiling while playing a game [41]. Urui et al. use flower displays for memorials to express mourning and remembrance [42].

Chapter 3
Emolleia

3.1. Concept and Final Design

Emolleia is a 3D printed emotive wearable which will recognize and respond to your facial expression. As you approach, Emolleia will dynamically perform happy, sad, surprise, neutral, disgust five emotions to correspondingly interact with you.

Figure 3.1 Model wearing Emolleia around shoulder

Three blooming transparent flowers shape garment can be wearing around the shoulder. With a web camera turned on, the onlooker's facial expression will be detected and categorized, according to the facial expression, the Emolleia will

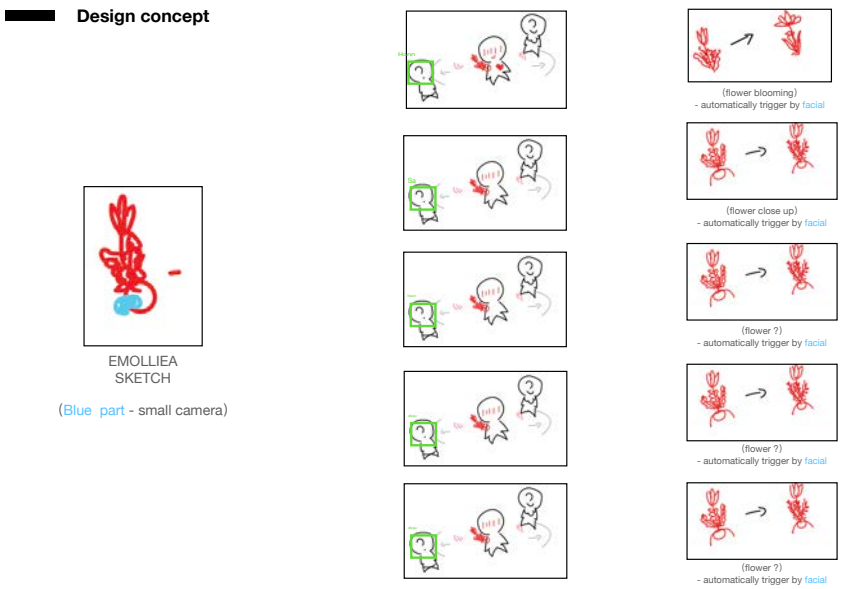

Figure 3.2 The interpretation sketch of how Emolleia react to surround people according to their facial expression

perform five pre-definded correlated motion.

Our initial intention was to design a simple accessory to express wearers mood in a given situation. We sought to explore more possibilities that people can do to express their emotion through not only facial or body language, but also non-verbal language and wearable computer. We especially wanted to target the upper body and shoulder region, as it's visible also in video calls and so far not so many accessories are worn on the shoulders. After consulting the related works and several focus group discussions, we settled on a flower design.

The application ideas from experts ranged from signaling the willingness/reluctance for social interactions, over allowing interest matching in a party setting (flowers would represent the approximate match to the person you are closest to) to using the flowers as a socially acceptable shutter for a video camera (easy to see if it recording or not).

We sought to explore more possibilities that people can do to express their emotion through not only facial or body language, but also non-verbal language and wearable devices.

Each of three flower has been equipped LED light unit inside in order to perform color change to express emotion.

We also provide users a software to let them monitor and customize the flower's motion and color of connected device (see Figure. 3.3). Users can set the motion triggered either by the groove sensor/buttons or interactive commands via serial communication such as Bluetooth and Wifi. The signal lines for each servo motor and RGB LED (NeoPixel compatible) are connected to the M5stack, and the power supply is 5[V] from an external power source such as a mobile battery. 3.3

3.2. Design Process

We conducted several pilot studies, first using one flower to seethe animated motions. After expert feedback (2 designers, 4 wear-able computing researchers) we found that the expressiveness of a single flower was limiting and decided to add 2 more to represent movement patterns.

We also constructed a soft which allow wearer define there own animations. The soft is still under testing process. 3.3

Figure 3.3 The soft of user define animation

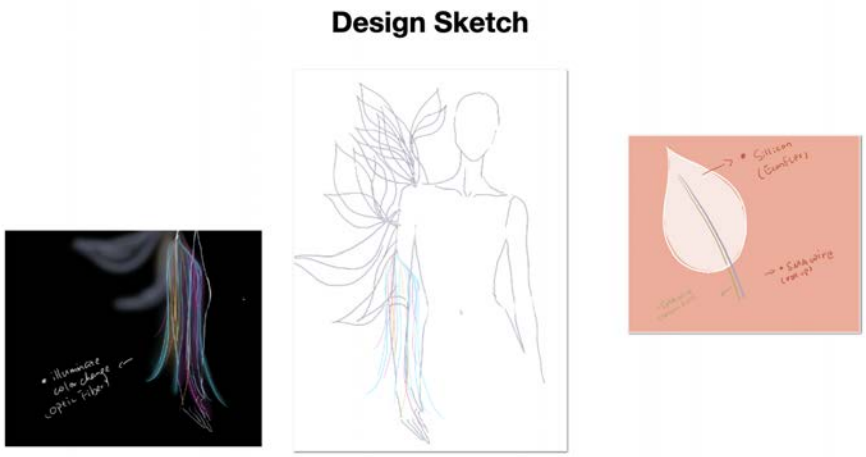

Figure 3.4 The first Emolleia design sketch

3.2.1 Sketch

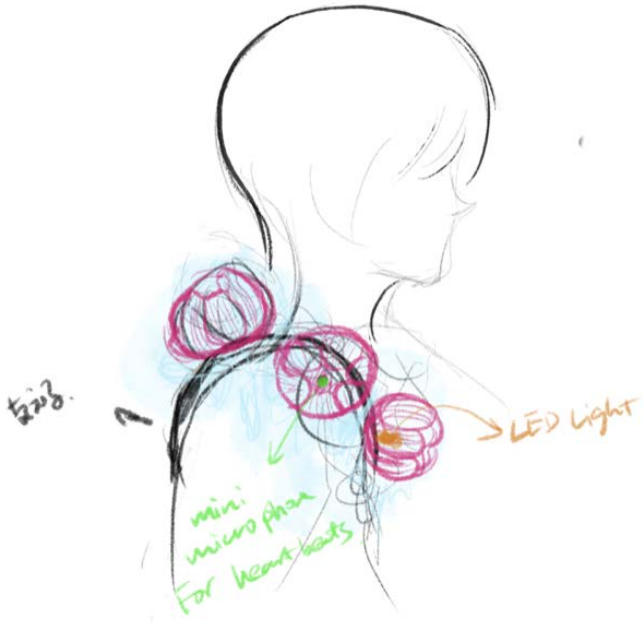

Figure 3.5 The Emolleia design sketch - profile

The sketch of 'Emolleia' was inspired by a poetry 'Shy Flower'.

"To the little shy flower hiding beneath brush
petals extended
smiles pink-white colors
for the butterfly she drew"

The outlook of garment was designed in a poetic and arty way, the flower design was inspired by Diphylleia Rotans, also known as skeleton flower. The flower has white petals which turn transparent when it makes contact with water. [43]

According to the result we got from previous pilot study, we selected to use multiple flowers as it can be related to social interactions more.

3.2.2 Prototyping

Paper Prototype

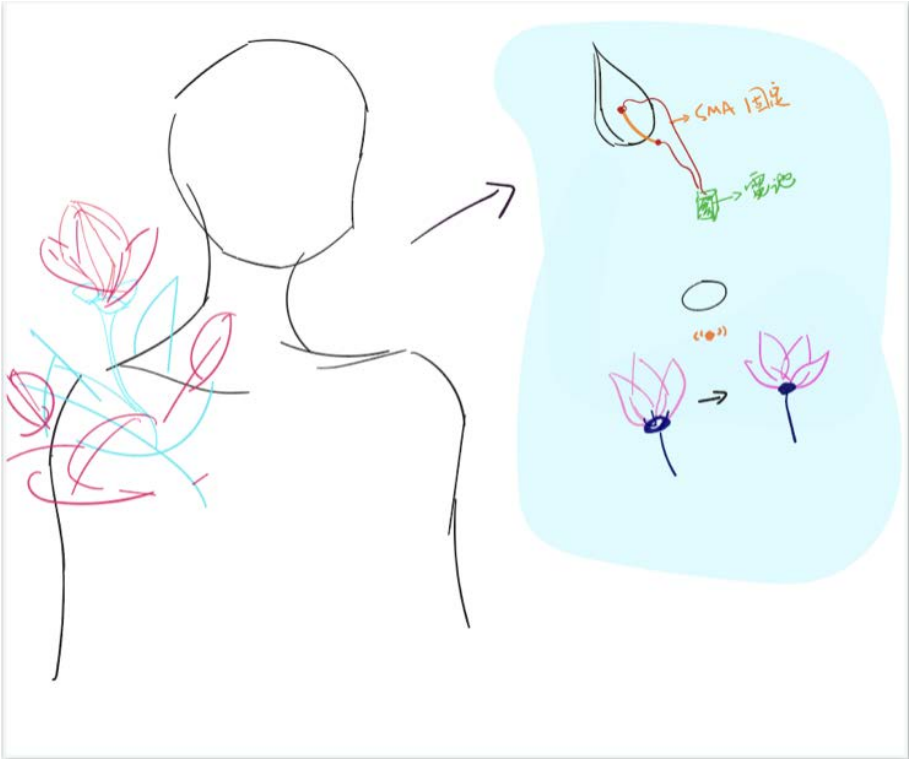

Figure 3.6 The Emolleia design sketch - front

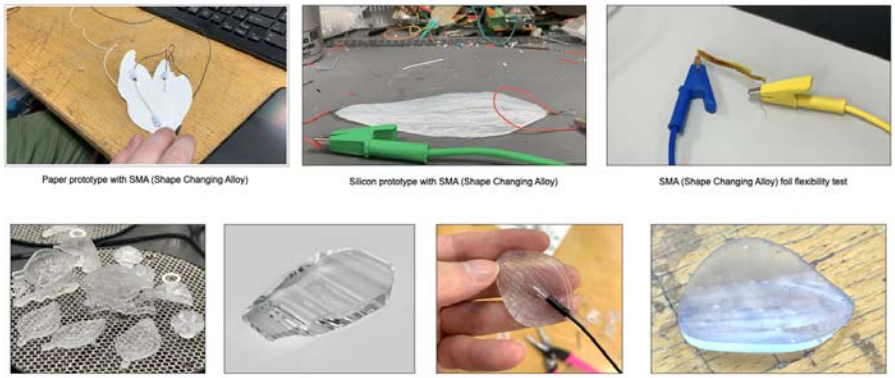

Figure 3.7 Test prototype & 3D modeling images

As the test prototype, goal of this paper prototype is to try out different materials to see which one would work best as the main actuator for flower shape changing motion.

In order to perform petal opening and closing motion, a few of methods to actuate this kinetic movement have been considered. For example, using foldable structure like Kirigami, Origami or self-folding material as Shape Memory Alloy , magnetic or polymer swelling. Or inflatable structure by insert gas, normally air, helium, hydrogen or nitrogen.

After few literature review and discussion, we firstly considered to use Nitinol, also known as memory or muscle wire, a shape memory alloy made of nickel and titanium once treated to acquire a specific shape, has the ability to indefinitely remember its geometry. [44] It performs quiet shape changing motion, with light weight would be ideal material for wearing on the body.

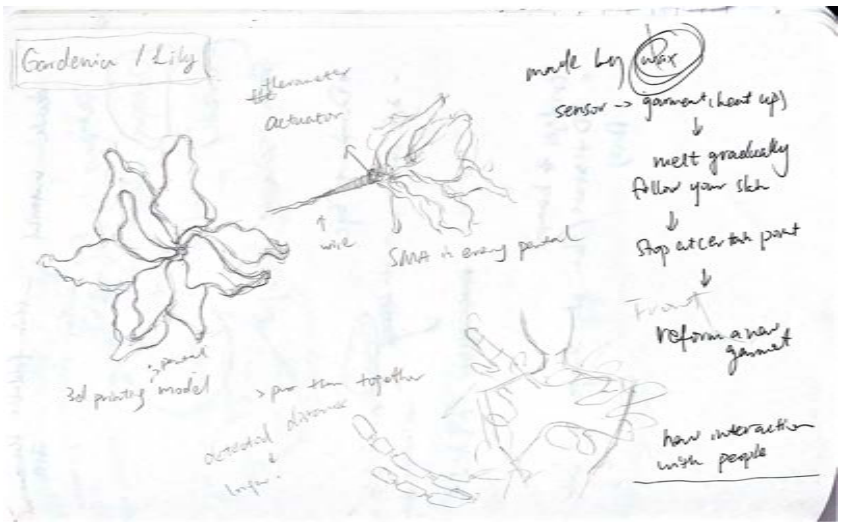

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Figure 3.8 Emolleia sketch SMA ver.

Shape memory alloys (SMAs) have been successfully commercialized in the

biomedical, electrical, automotive, aerospace, and oil industries Since initially developed in the 1960s,. [45]It is the material that undergo a mechanical deformation under the influence of direct or indirect electrical stimuli. They are by nature dynamic, in addition to the static properties that we find in other conventional polymers or alloys. [46]

The idea of utilizing Nitinol wire as actuator to perform shape changing in wearables is not new, however the process is complicated. Before the test, the material needs to be constrained in the desire shape, we firstly fixed the wire as spring shape, continuously heat it up in 500°C for 30 seconds, then drown the wire into cold water to let it cool down to return the shape. After the shape-set process done, the Nitinol wire with silicon tube wrapping around would be attached on the paper petal surface, when a battery is connected to the ends, the metal gets hot and activated to the shape we formed beforehand. Meanwhile, the Nitinol wire will bring paper petal bend over with shape changing process.

The benefit of using SMA was due to SMA's special quality, unlike other mechanical structure, the whole moving process of the prototype was very quite. The heat up time also gained some special effect on presenting the subtle beautiful feeling of flower blooming. Which matches our design concept, performing the gentleness acceptance and rejection.

However, the limitation was plain as well. As the Figure 3.2 & Figure 3.3 presented, after heaten up, the angle of bending petal was around 30 degree. It was obvious weak for flower open and close motion.

Silicon Prototype

In the second prototype, we replaced paper to silicon as the material of flower, due to it's high plasticity which allows to attempt different aesthetic outlooks. Also, silicon is able to contact with Nitinol wire directly without necessarily being protected by another layer of tube. After comparison, we chose Silicon Sealant 8060 clear type.

During the model making process, we found that shaped Nitinol wire was difficult to be planted in uncured silicon. The shaped Nitinol wire remained slightly curved spring shape which would penetrate through silicon surface.

In general, SMA is a great actuator to use, but considering the difficulty of equipping it in 3d printed model, and the limitation of using Nitinol, especially

the degree of bending was slightly weak with 0-15-30 degree angle, we decide to replace it.

3.2.3 System Description

For final prototype, considering the movement's accuracy and product delicacy, we select 3d printing to develop the prototype.

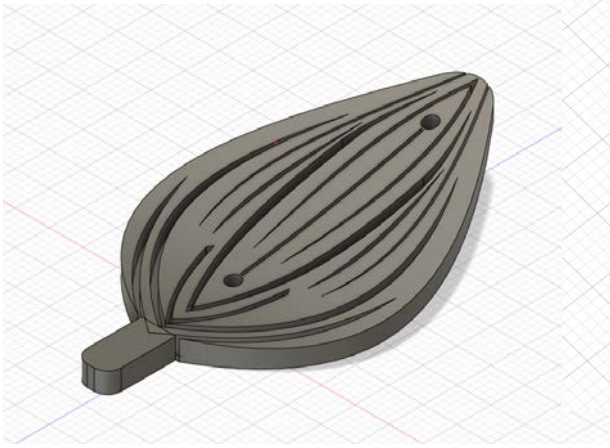

Figure 3.9 The 3d model of petal

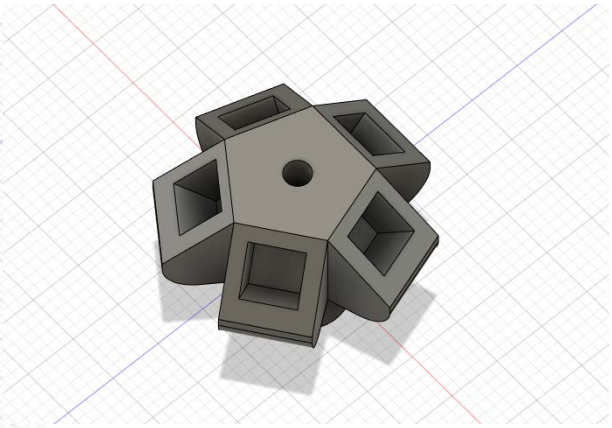

Figure 3.10 The 3d model of Emolleia support

The 3d model of flower petal (length: 43mm, thickness: 2mm, width:30mm), basement case and serve motor case were built in Fusion 360. A petal support (length: 15mm, width: 15mm, height 15mm) has also been built for holding 5 petals together and as the connector between flower itself with basement case.

The basement case (length: 42mm, width: 38mm, height:30mm) is created for containing servo motor, motion strings and wheel. The 4 small attached boxes (length:12mm, width, 12mm, height, 3mm) under were designed for placing magnets in order to attach every Emolleia part on the chain. This design was out of fashion consideration, for wearer is able to wear Emolleia in daily life.

We chose Form Labs Form 3 and Elastic 50A resin as printing material. Elasticity is the ability of an object or material to resume its normal shape after being stretched or compressed with high transparency. The softness of Elastic 50A allows the prototype has bending over and reform motion freely, the special transparency of this material also matched our designed sketch.

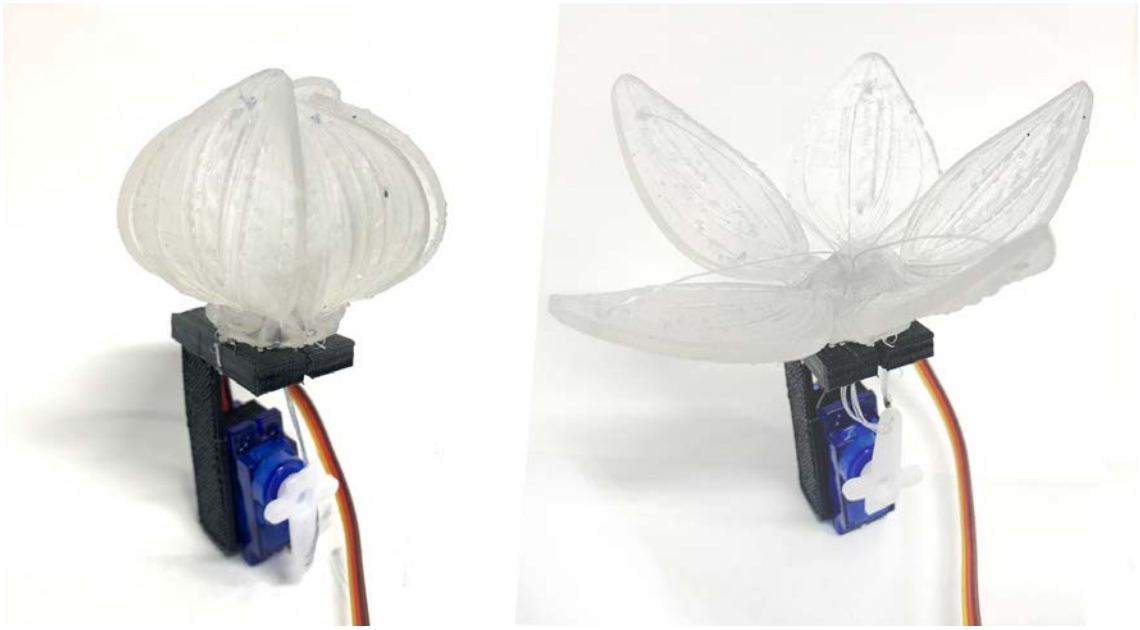

Figure 3.11 Final prototype of emolleia

The device was constructed by three main parts, flowers, servo motor case and Velcro strap to fix the device on body. The 3d printing flowers are fixed at the stem and consist of five petals with a diameter of 6 [cm] designed with a transparent resin with a hardness of 50 A (Elastic Resin).

Flowers are connected with servo motor by strings on petals. With strings pulled off by the servo motor, the flower will close up. On the other hand, the blooming motion will be triggered when the servo motor loosen up the strings. These operations are controlled by M5Stack Core. The motor uses SG-90. The specially designed servo horn rotates in the range of 0-180 degree and can pull up a strings to 3.14[cm].

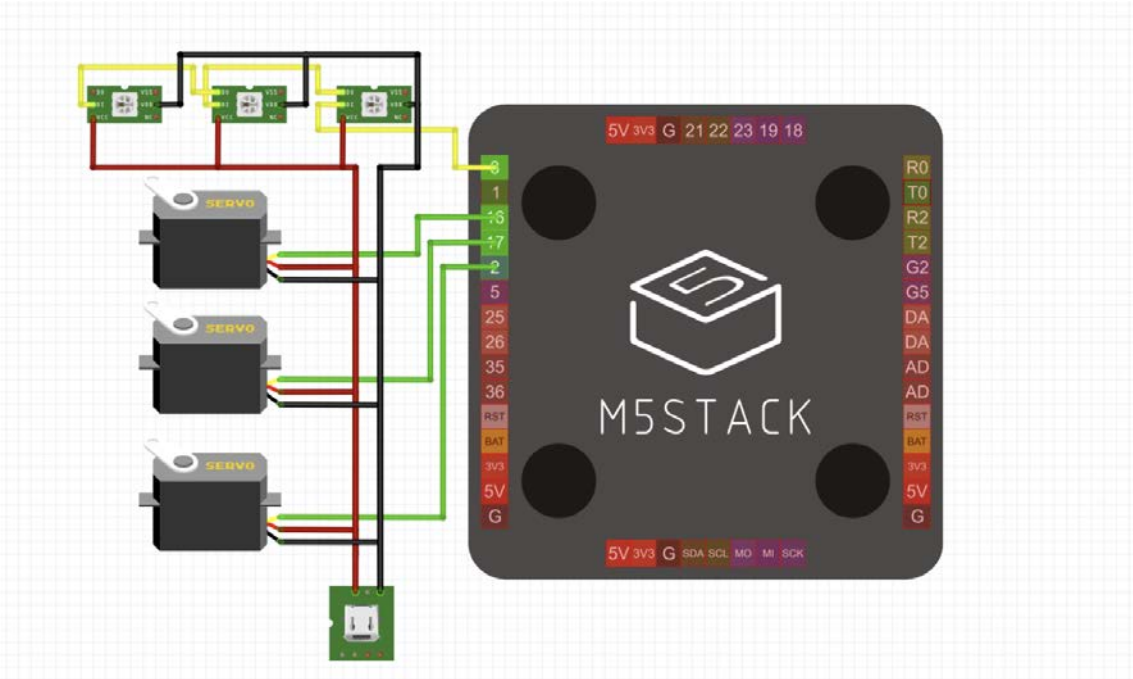

Figure 3.12 System description of M5STACK

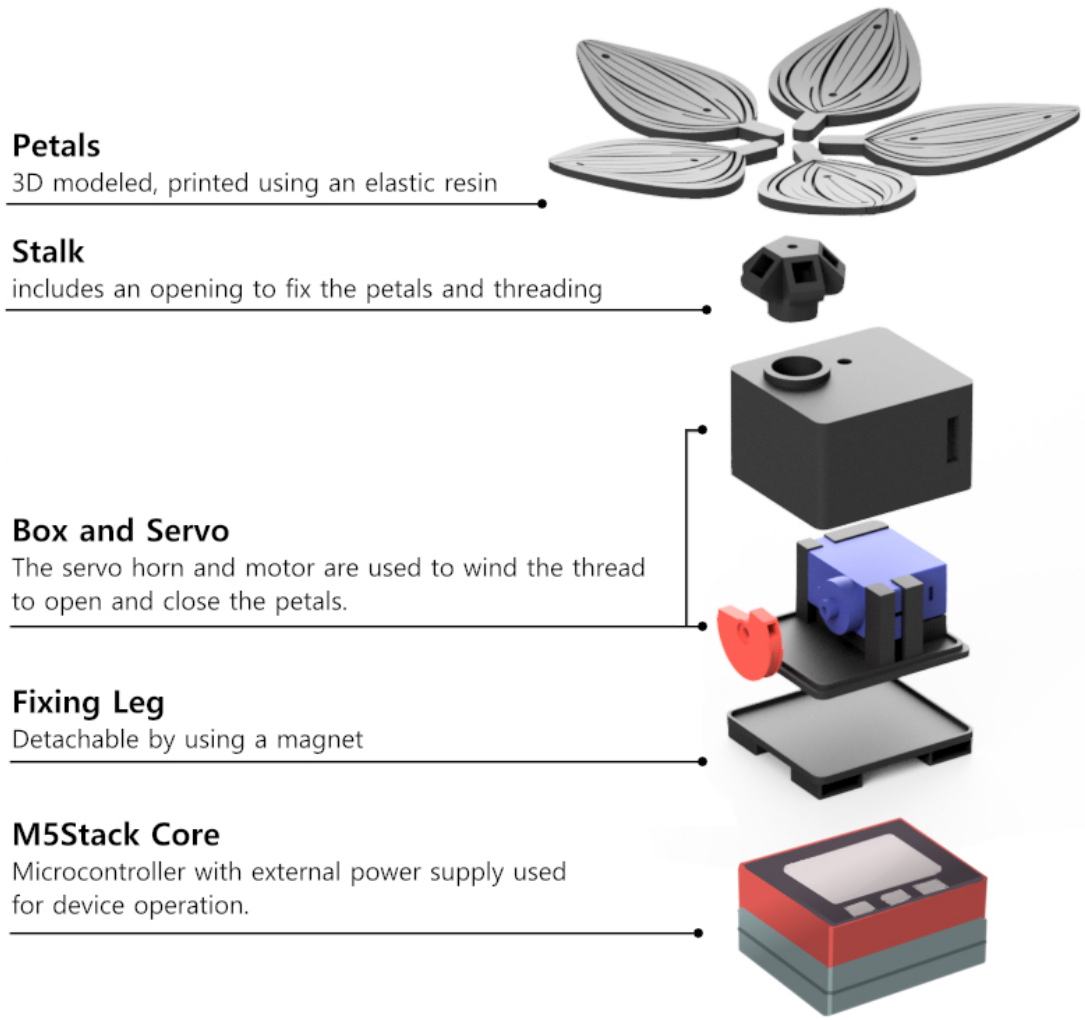

Figure 3.13 Overview of the assembly of Emolleia

3.3. Pre-study

3.3.1 Design Research

With billions of years of evolution, creatures have developed almost perfect structures and have exhibited various functions. [47] Poets and artists draw their inspiration from nature, scientist and engineers mimic creatures structure to better assist human construct living life.

Color and shape changing in response to predators or mating process are not new for animals. The color change often helps animals communicate their mood or regulate body temperature.

Elytron, Seahorses change their color for camouflage or frighten predators, moon jellyfish switches color depending on what they have been eating lately, male reef octopuses, rapidly change from white to red to signal to females that they're ready to mate. 3.16

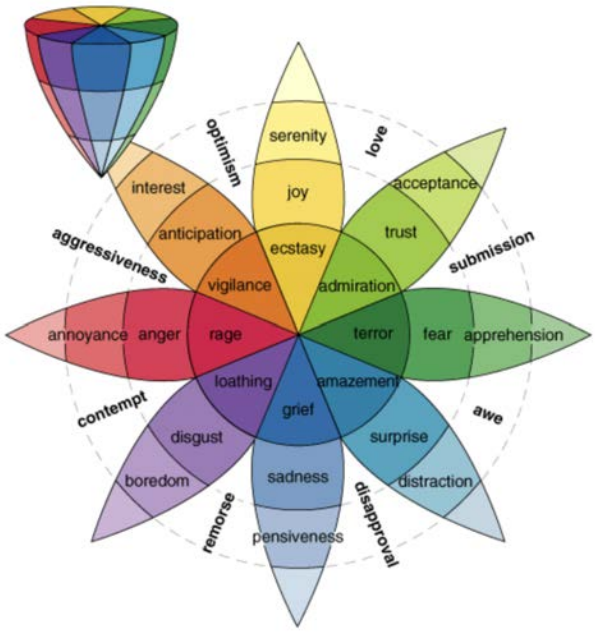

Figure 3.14 A color wheel to help categorize intensities of eight primary emotions-anger,fear,sadness,disgust,surprise,curiosity, acceptance and joy [1]

Our color design followed the color wheel created by Plutchik's Model [1], the detailed usage will be described in the last user study 2 section. 3.14

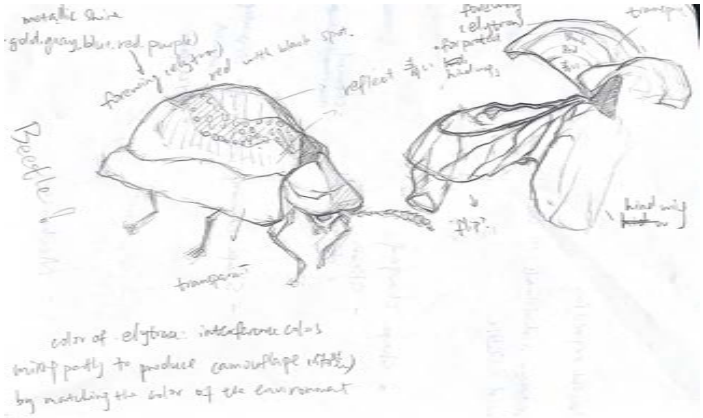

Figure 3.15 Beetle color change observing sketch

About initial concept for shape changing part, the garment was considered to be designed as something representational like bird, butterfly or flower. The whole project is about using a poetic and arty method to convey user's message, the design of this wearable device should be gentle, beautiful and harmless. It is the garment to help user express their acceptance or rejection in the soft way.

The rhythm cuttlefish moves raised out interest. Cuttlefish have a fin fringe running along their sides. By undulating these fins cuttlefish are able to hover, crawl and swim. They can also move by 'jet propulsion', which can be an effective escape mechanism. [48] Inspired by the cuttlefish's movement, the first sketch came out. **??** However, out of the consideration of time and effort, we decided to move to the design with better notice and smaller size.

We also conducted a research on plants in order to find inspirations. Mimosa, well known as the plant represented as Shy, bashful, timid. When touched, Leaves of mimosa fold up, returning to full leaf in a few minutes. The motion of leaves usually being interpreted as 'shyness', which would be used in the garment design

as symbol of wearer prefer to stay undisturbed.

Mimosa leaves close up successively gives people a strong image of social rejection. This will be described detailed in pilot survey parts.

3.3.2 Pilot Survey

In order to find out which motion and color would be related to what interactive intention. A survey and pilot study have been conducted.

In the survey, we divided participants to extrovert and introvert by asking them finish the I-E scale. Through answering how much they feel connected to a statement via a 5-Likert scale (5 = Almost Always 4 = Frequently 3= Occasionally 2 = Rarely 1 = Almost Never 0 = Does not Apply).

We also made a questionnaire to find what kind of movement people can relate to social interactions the most and which basic shape they think can be used to describe the introvert and extrovert. The questionnaire was combined by 3 parts, demographic survey, I-E scale and interactive relation survey. In the second part, The I-E scale [49] was used to identify participant's characteristic into extrovert, introvert or Average. Most of participants were defined as AVERAGE or Like the Typical Member.

In the third part, we selected 3 botany movement GIF, the first one is an inflorescence (six flowers on the string in total) blooming successively blooming successively (length: 3 seconds), the second one is one flower open up (length: 5 seconds), the third one is mimosa leaves being touched on the top then close up successively (length: 5 seconds). After each of the GIF, participants were required to assess Which best describe the GIF through a 6-likert scale (1= introvert, 6= extrovert), and How well does this GIF relate to social interactions via a 7-Likert scale (1 = not at all, 7= very much). The purpose of this study is to see based on the introverted and extroverted tendency, how participants defined with different personality interpret these motions

3.3.3 Result

Among 25 results we received, 96 percent participants consider mimosa close up movement represented introverts, 60 percent of participants related this motion

with social interactions the most.

More than 60 percent of participants consider the movement of inflorescence blooming to interpreted as extrovert, also more than 55 percent participants relate this successive movement with social interaction.

However, participants have diverse opinion towards the GIF 2 with one flower open motion.

Hence, for the garment design, we select 3 flowers' successive motion as main interaction to express wearer's emotion.

3.3.4 Pilot Study

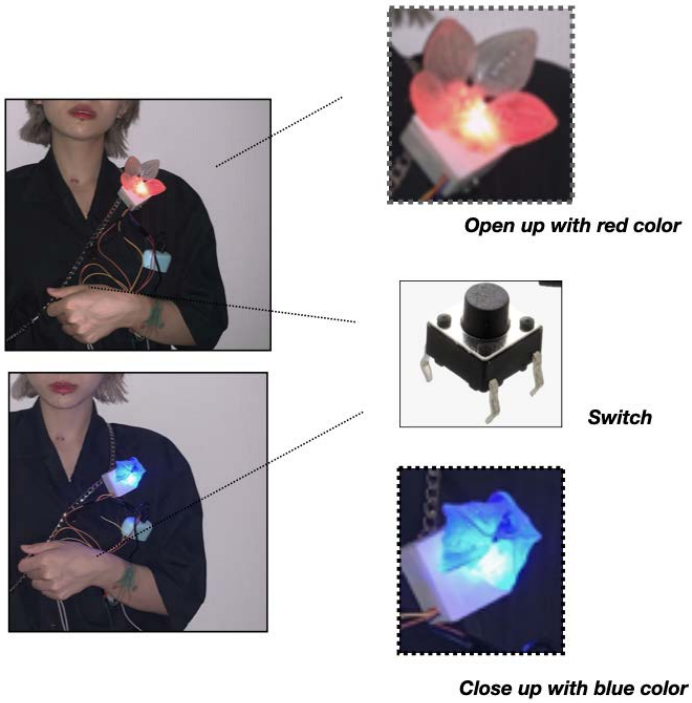

Figure 3.16 Implementation explanation of prototype used in pilot study

Participants completed the pilot study in a rented office room to simulate a social environment. The study was conducted in both standing and sitting position, where participants wore the prototype (with a single flower) on there left

Figure 3.17 Pilot study set up 1

Figure 3.18 Pilot study set up 2

shoulder.

The purpose of this pilot study is to evaluate how people would decode to the prototype's simple motion, and also the social acceptability of the prototype.

The prototype consisted of one 3d printed flower, a LED light performs red and blue light, a servo motor, a micro controller, a switch and portable battery. The initial prototype is able to preform simple open motion with red color and close motion with blue color controlled by wearer using a switch.

We simulated a social situation with 20 participants stay in one open room (10 female, aged 23-35), with beverage and food prepared to support the interaction better and more natural. Participants were asked to put mask on the whole session under the consideration of Covid-19. Before the session going, we only notify the wearers the meaning and function of Emolleia. When wearer wanted to be alone, he/she would choose close up the flower with dark blue lights on, in reverse, when he/she prefer interacting with others, they are able to choose the open-up flower motion.

2 sessions in total have been conducted, each session lasted 30 minutes. In the beginning of every session, the wearer was asked to wear Emolliea around their left shoulder, with a switch hold in hand to control motion and light changing. The wearer was walking around the room and talking with other participants freely until the 30 minutes session over.

In the followup interview, we discovered most of participants are able to decode

the motion of flower open-up/ close-up as acceptance and rejection of further social interaction and most of participants are satisfied with wearing flower design wearable as both decoration and functional device. However, some of participants raised concern above color choosing on red as welcoming intention. The red color was interpreted danger sign of showing rejection and they would stay away and suggested to replace red as pink or orange.

We used the result in future study and updated final prototype.

Chapter 4
Evaluation

4.1. Study 1: Emotion Elicitation

To explore potential use cases, self-expression possibilities and the general perception of the prototype, we conducted a user study.

The main purpose of this study was to measure how people perceive Emolleia's motion in relation to emotional states and gain more insight into what people would like to use this prototype for and estimate prototype's social acceptability in different contexts. We refer to the PAD model which categorizes emotional states by three dimensional scales: pleasant/valence, arousal and dominance. [50].

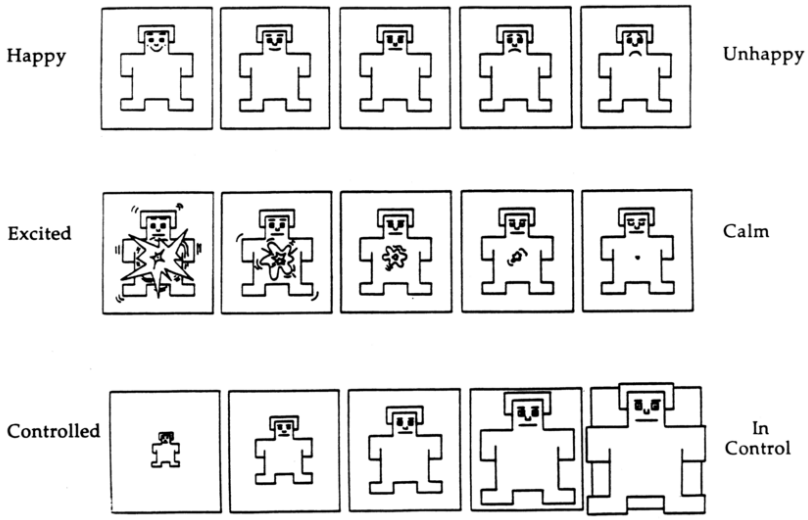

Figure 4.1 The-Self-Assessment-Manikin-SAM-Measure-Scales-valence-arousal-and-dominance-pole

Lang et al. later develop a non-verbal pictorial self-assessment also known as

SAM (self assessment manikin) [6]. In our user study, we let subjects report their perceptions by SAM using a 5-likert scale (we are mostly interested in the valence and arousal dimensions, yet conducted the self-assessment according to related work) [51]. The study was conducted according to the rules and regulations of **blinded for review** with approval of the Ethics Committee.

4.1.1 Participants

We collected survey answers from 50 participants aged from 21 to 37 (Male: 26, Female: 19, Diverse: 2, Prefer not to say: 3). Most of the participants (83%) came from Asian countries

4.1.2 Study Protocol

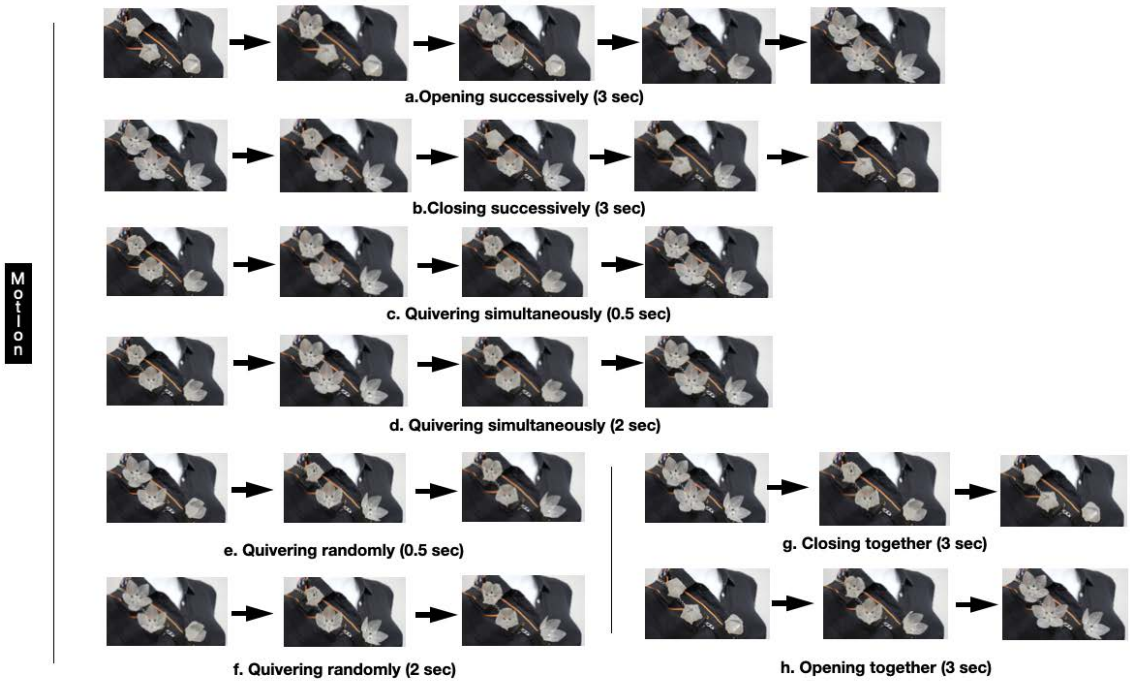

Figure 4.2 The Emolleia motion used in Animation Study

The survey takes approximately 20 minutes to complete. It consists of four

parts: 1) demographic questionnaire 2) personality test by the Introversion-Extroversion Scale (I-E scale) [52] 3) the device utility study 4) the device animation study.

The I-E Scale can assess if a participant is more introverted or extroverted by answering how much they feel connected to a statement via a 5-Likert scale (5 = Almost Always 4 = Frequently 3 = Occasionally 2 = Rarely 1 = Almost Never 0 = Doesn't Apply).

In the device utility study, we presented a 3-second video of one of our prototype's motions – one flower with simple open-up and close-up. We then asked questions about their general opinion, perceived function, and attitude towards this device. We asked participants willing to use the device to imagine the particular social contexts and under whose company they would like to wear it.

In the Animation study procedure, eight pre-recorded videos displaying different prototype on-body motions were shown to participants. Under each of the eight motion, participants were asked to rated the valence/arousal/dominance space of emotion using SAM on a 5-Likert scale where the participants choose one option from valence space (Pleasant, Pleased, Neutral, Unsatisfied, Unpleasant) arousal space (Excited, Wide-awake, Neutral, Dull, Calm) and dominance space (Dependent, Powerlessness, Neutral, Powerful, Independent) for rating three categories (pleasant/unpleasant and neutral) of motions [51].

The Animation Study was first planned as an in-person study. Yet, due to the COVID-19 pandemic, we decided to conduct it online. The participants were able to play back the pre-recorded eight prototype motion videos until they choose to move on to the next.

4.1.3 Results

We discover the participants' personality traits using the I-E scale. Among 50 participants, 27 participants were rated as average, 15 participants were rated as extremely introverted or more introverted than usual, and eight participants were rated as more extroverted than usual or extremely extroverted.

69% of the participants showed a positive attitude towards wearing the device, one participant stated that "I love wearing wearable devices and hope this helps to track my mood or mind." Some participants expressed concern towards the size and suggested it might be inconvenient to wear and would like to decide whether

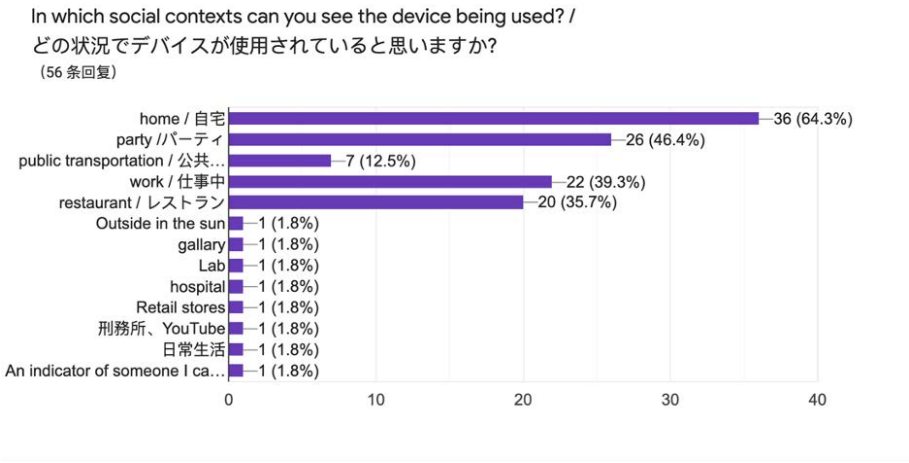

Figure 4.3 Replies of where people would like to wear the device

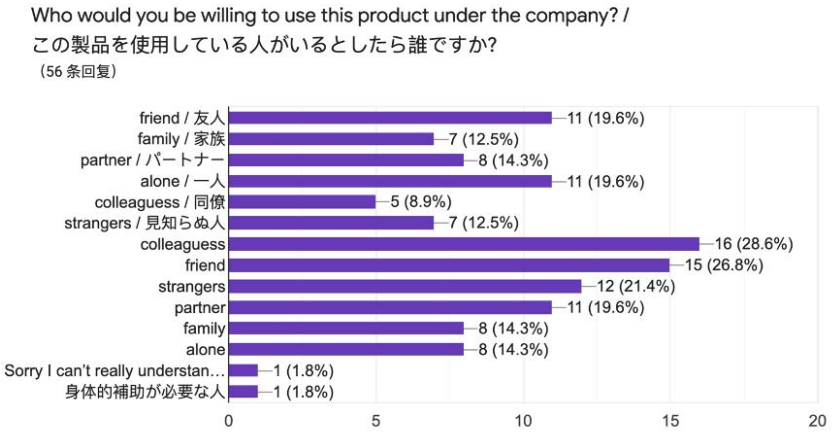

Figure 4.4 Replies of Who would you be willing to use this product under the company?

	Valence		**Arousal**		**Dominance**		**Potential**
	Mean	SD	Mean	SD	Mean	SD	**Emotion State**
a	2.26	1.10	3.22	1.30	3.14	1.25	Pleased, Content
b	3.80	1.05	3.66	1.22	2.68	1.33	Unsatisfied, Dull
c	2.38	1.54	1.58	0.84	3.30	1.42	Delighted, Excited
d	3.06	1.02	3.44	0.99	3.20	1.14	Bored, Depressed
e	2.76	1.45	1.96	0.95	3.22	1.37	Wide awake
f	3.20	1.00	3.62	0.97	2.82	0.98	Dull
g	3.78	1.27	4.02	1.15	2.90	1.45	Unsatisfied, Dull
h	2.56	1.07	3.56	1.15	3.00	1.11	Satisfied, At ease

Table 4.1 Descriptive statistics of SAM scores over eight types of motions. Figure. 4.1 illustrates differences among eight animated motions.

to wear it after knowing more about the functions. For social acceptance, 62% of the participants reported it was acceptable to wear it at home, with the question of accompanying selection, 47% of the participants would wear it under friends' company. 4.44.3

Table. 4.1 reports descriptive statistics of reported SAM scores about eight motions. We operated repeated measures of ANOVA with Greenhouse-Geissers correction in SPSS to examine the scores' difference. There were statistically significant differences for valence ($F(4.84, 237.14) = 13.46$, p ¡ .001) and arousal ($F(5.45, 267.11) = 38.28$, p ¡ .001) across eight motion types. However, significant difference did not exist in the reported dominance ($F(4.40, 215.39) = 1.71$, p =.14).

Figure 4.3 and Figure 4.4 reported the valence and arousal mean value of eight motions. The values are mapped in Figure 4.5 for further discussion.

4.1.4 Discussion

We found extrovert showed stronger willingness to wear Emolleia than introvert and average. For other answers, we did not find obvious difference among introvert, average, and extrovert people.

Regarding to the potential scenarios of wearing Emolleia, answers mainly re-

arousal							
Motion	1	2	3	4	5	6	7
1	3.22						
2		3.66					
3			1.58				
4				3.44			
5					1.96		
6						3.62	
7							4.02
8							

Figure 4.5 The mean value of Emolleia's arousal

valence								
Motion	1	2	3	4	5	6	7	8
1	2.26							
2		3.8						
3			2.38					
4				3.06				
5					2.76			
6						3.2		
7							3.78	
8								2.56

Figure 4.6 The mean value of Emolleia's valence

lates to self expressing (present wearer's mood, feeling, mental status, emotional arousal, social attitude) and notification purpose (weather or noise display, hygrometer, message notice, daily water drinking reminder, plant hydration levels monitor, fire detection). One participant suggested that "It could be a really good device for children with special conditions, such as autism, vision or hearing challenge. The children can use the device to show their willingness to talk or other emotional status."

Among all the feedback we received in survey, the most common usage scenario is to utility Emolleia for self expressing or social interaction to build deeper connection with others. For example:

- I'd love to know how my family is doing through this. Especially grandparents, as they're wellness is my strong interest.
- Like the tail of a dog, it can be an enjoyable way to use for emotional communication. Also, based on the functionality of communication, seems that the device can be diverted to medical care and counseling using.
- can be a implicit inner world reflection to show others and connect with others with extimacy.

We also received some interesting answers regarding to utility as:

- new type of conveyor belt sushi dish
- Grab meat ball...

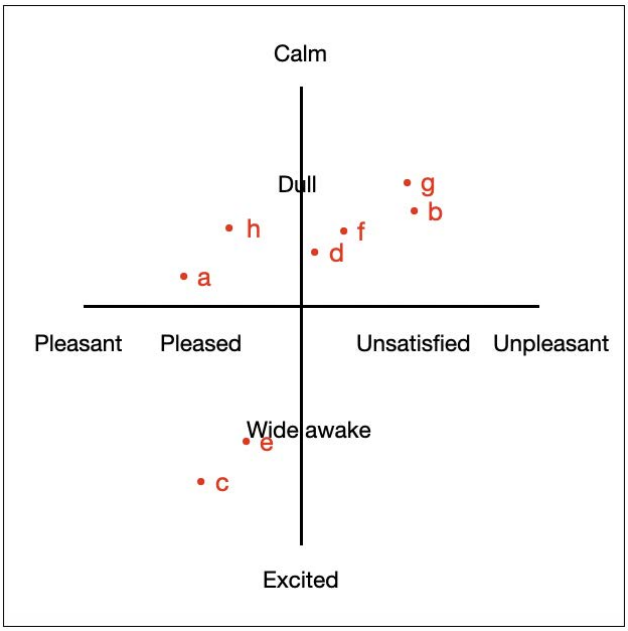

Figure 4.7 Eight Motions mapped to valence-arousal coordinate axes based on average SAM scores from survey results

- Since I don't have many chances to see the moment when a flower blooms, a device that analyzes emotional changes caused by seeing the moment when a flower opens and activates mental stability and brain movement.

As for the feasibility to communicate different emotional states, the results of repeated measures ANOVA proves shows the potential of using eight motions to convey different emotions. By mapping the average SAM score of eight motions to the valence-arousal coordinate space, we further have more insights into matching animated motions with emotional feelings (see Figure. 4.7). For example, flowers opening motions (motion a & h) would be perceived as the represent of pleasant, satisfied and serene. Closing motions (motion b & g) was interpreted as unsatisfied, frustrated and relaxed status . In general, the arousal of motion h and motion g which presented flowers opening/ closing together was noticeably stronger than motion a and b which represent the flowers opening/ closing successively. The quivering motions with higher speed (motion c & e) was perceived more pleasant and excited than quivering motions with lower speed (motion d & f).

4.2. Exhibition

A facial tracking camera which programmed to recognize wearer's 7 facial expression ('angry','disgust','fear','happy','sad','surprise','neutral') was placed to trigger three patterns Emolleia motion reaction, 1) correlated 2)in contrary 3) on looker's facial.

Due to the results limitation of previous study, only five emotion 'happy, sad, surprise, neutral and disgust' have been selected to correlate with motion a, g, c, d, which related to the emotion defined as pleased, unsatisfied, calm, nervous, neutral five emotions from the previous study result. 4.1

For the color choice, we referred the Emotional Wheel created by Robert Plutchik. [31] The decided correlated final prototype as follow table.

The updated prototype Emolleia was presented in KMD Forum 2021. During the period of two days exhibition, we received many positive feedback from the audience.

- " Its beautiful, love the outlook"

Figure 4.8 Poster of Emolleia in KMD forum 2021

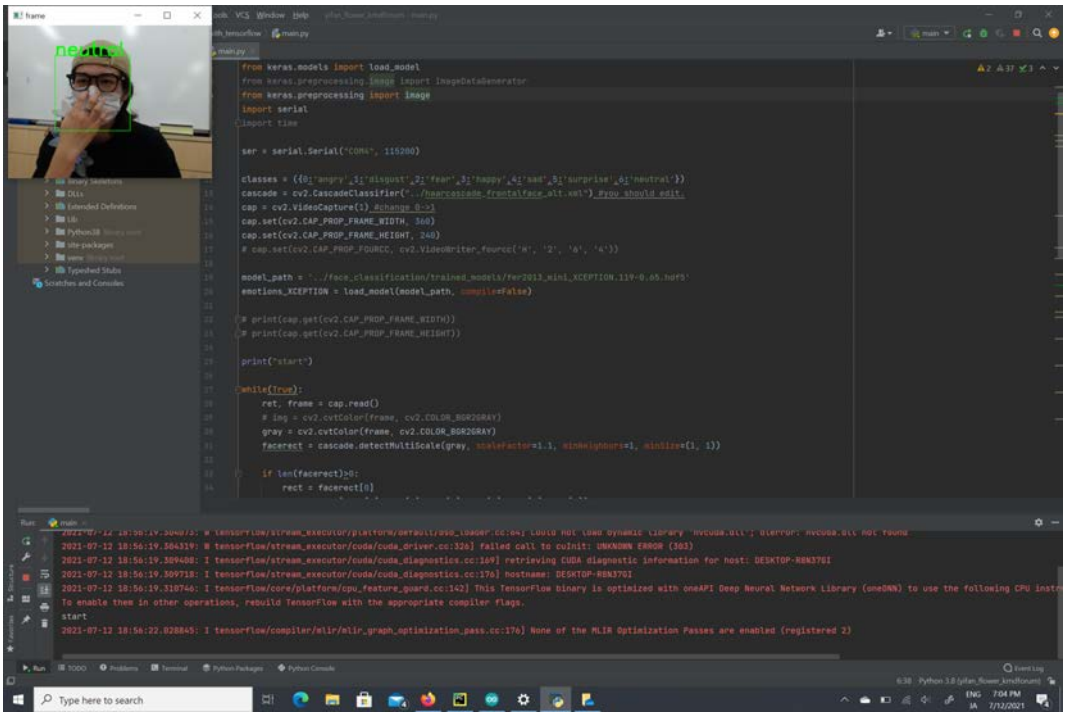

Figure 4.9 Description of facial recognition system

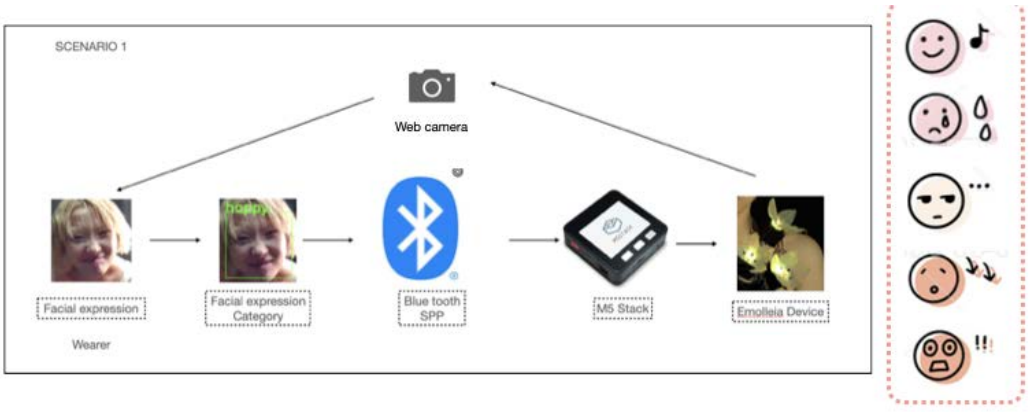

Figure 4.10 Emolleia interactive process step interpretation

Figure 4.11 Exhibition - KMD forum 2021

Table 4.2 Emolleia's Motion & Color Design

motion	emotion	color	Decimal CodeR,G,B
a	happy	yellow	246,219,103
g	sad	dark blue	122,157,197
c	surprise	blue shade	91,163,189
d	neutral	white	255,255,255
f	disgust	purple	153,123,182

- " Can't stop thinking about touch it"
- " I'd like to wear it in daily life"

4.3. User study 2: Conversation Use Case

The purpose of this study is to answer research question 3, "Will participants who relatively express their opinions less than others be motivated to speak out their thought, and will participants who relatively talk more than others realize that those who talk less have something to say and offer them a chance to speak out?"

4.3.1 Participants

Six new participants (4 female, aged 21-28) was recruited. Most of Participants were from Asia countries.

4.3.2 Study Protocol

Before beginning the conversation task, participants were given a brief explanation about the procedure of the user study. The aim of the study was to answer the research question 3: Will participants who relatively express their opinions less than others be motivated to speak out their thought, and will participants who relatively talk more than others realize that those who talk less have something to say and offer them a chance to speak out?

The study consisted of 3 conversation sessions, each lasting 5 minutes. There were three conditions in the experiment: condition A - normal interaction (no

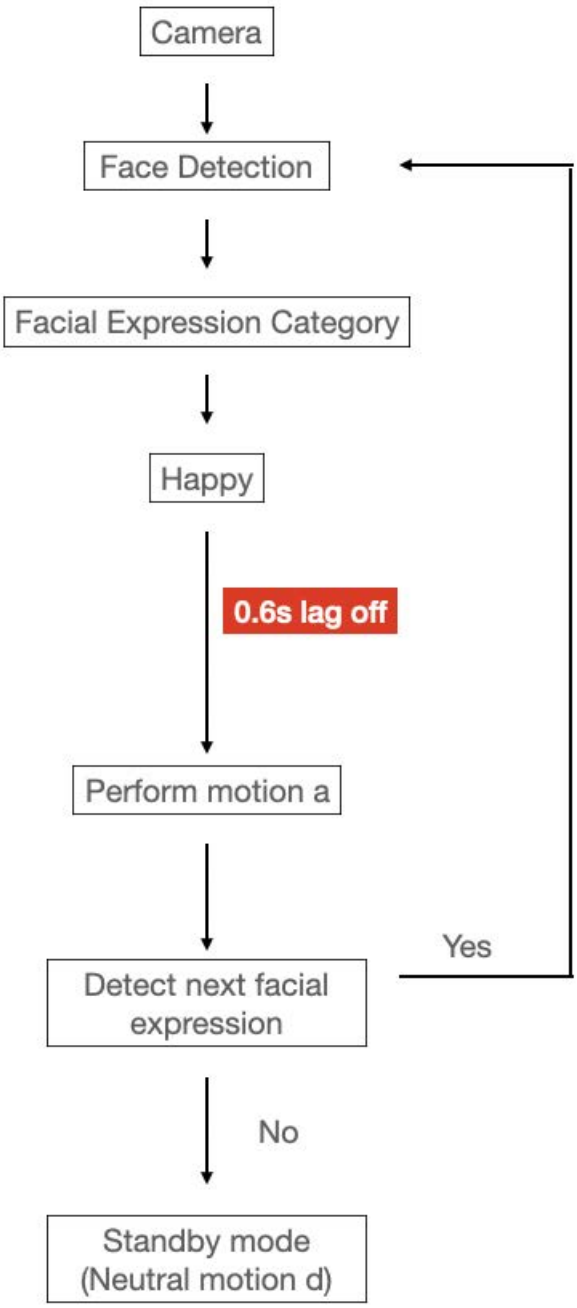

Figure 4.12 Face recognition process flow diagram

Figure 4.13 Conversation use case set up

wearable device), condition B – device present but not switched on and condition C – device present and switched on. A repeated measures design was used with each pair of participants taking part in each of the three conditions. [**?**] There was a moderator to observe the test process. After each session, participants rated a set of statements about the Emolleia' influence on attention and concentration, on natural behavior and on understandability of the emotional state of the wearer, also how much wearer feel wanting to express themselves more (than usual) on a 5 Likert scale (1 = strongly disagree, 5 = strongly agree).

During the conversation sessions, one participant was asked to wear Emolleia, the web camera on the table will be turned toward wearer's face to recognize wearer's facial expression. After the facial expression got categorized by M5 stack, Emolleia would perform corresponding motion. 4.13 Every motion lasts 3 seconds long, before the next command received, Emolleia would stay stand-by mode with performing motion d with white color which categorized as expressive of neutral emotion.

Following the conversation sessions, a semi-structured interview was conducted to collect qualitative feedback on the Emolleia from the participants.

4.3.3 Results

In the semi-structured interview after conversation test, we received some feedback:

- Emolleia is an adorable device, it made me feel like being a flower.
- It's such a nice thing to show how my mood changed through this equipment, I love the technological feeling.
- With this device I feel more encouraged to express my emotion, I was literally laughing all the time when I see another person's reaction of watching Emolleia change motion.
- It becomes easier for me to notice another person's emotion.

4.3.4 Discussion

According to the comment received from participants, most of feedback are positive on both outlook and utility side. Participants who wear the device Emolleia found it decreased their nervous or uncomfortable on having a conversation with stranger. The conversation going better than they thought since they could interact with the device, and motions of Emolleia do assist to improve a more comfortable atmosphere of conversation.

However, the imitation is also mentioned by participants during the semi-structured interview. For example, one participant found that the noise of Emolleia performing motions might be a little loud as wearable device. The device is somehow quite distractive for wearer during the conversation.

Not every participant is able to decode the emotion expression of Emolleia is also a key problem. Participant who doesn't wear the device sometimes got confused on what the current motion stands for, if the wearer is in happy or sad status.

Another concern is toward size of the device, some participant mentioned although Emolleia is a beautiful fashionable piece, it might still be inconvenient as a wearable people could wear in daily life.

Chapter 5
Conclusion

5.1. Finding

We introduced our novel kinetic wearable device which is able to performs eight pre-defined animated motions – Emolleia. We conducted a user study with 50 participants to elicit potential usages and social scenarios. We also collected their perceptions about eight animated motions by SAM scale to help us further improve our motion design. Feedback from the participants prove the feasibility of our concept about communicating emotional feelings via Emolleia.

Then we selected 5 motions to match with facial expression, combined with the strong ground truth, Emolleia is capable of interacting with surroundings. We tested how Emolleia enhance people social interaction and self expression by conducting explorative cases study with 6 participants.

Although using wearable computers to enhance social interaction is not new in HCI field, our study still brought up new sight on exploring how people would define prototype animation with emotion, and how well wearable device would be accepted in daily social context. Further more, it is a attempt on building a bridge between design, engineering, art and science. Wearable computers can be fashionable to wear, and accessory is capable of expressing emotions.

5.2. Limitation

Size: As some of feedback we collected from participants in User Study 1, the reason they have concerns on wearing the device was mainly due to the Emolleia's size. It might be tiny big for the device to wear in daily life, and wearer might be discreet when they wear it.

Position: Although participants didn't mention they feel uncomfortable wearing

the device around shoulder, but we are considering other possibilities wear it more noticeably. Like around neck, wrist, or in front of chest, or probably on the head.

Emotion trigger: So far we have tested two triggers: 1) proxemics sensor, 2)simple switch, 3) facial expression. Three of them are all categorized as interact in conscious. We are wondering would we get different perspective with unconscious by using bio-sensors to detect wearer's heart rate, EDA, EEG.

Material: It would be interesting to test other flexible material to see the different movement.

System implementation: we tried to use SMA to perform shape changing in the first prototype, and using strings to pull off & loose to perform flower blooming % closing movement as final method. But for sure there will have many methods to complete the same movement. We will be thrilled to test them out.

Other than the limitations we mentioned above, although we have defined eight animations to let participants correlate them with emotions, also most of normal expressions can be corresponded to the motion, we still found that two important emotions were missing. There were no motion mapped in the quadrant of unpleasant and excited which represents regular emotion angry and fear. 4.2

5.3. Future Work

Based on the limitations we found above, the first thing we may need to do is update prototype design, adjust it with smaller size. Then conduct a survey or interview with more participants on where they would like to wear this device on and why. According to the answers, analyse a better place for wearer. It would also be interesting to combine Emolleia with biometric sensors (heart rate/ galvanic skin response), in constant contact with the user as unconscious switch to trigger the motion change. We will also conduct further user studies in real-life social conditions to test the usability of our device.

To decrease the noise of servo motor make when Emolleia perform motions, we will try other actuator to perform shape changing. Inflatable material or electrical material would also be interesting to attempt in the future.

We made a soft for wearer to definite their own animations to express their emotions. We would like to conduct a user study with this function as well in the

future.

If the improvements above are implemented, Emolleia would be ready to wear on everyone in the society everyday. It is possible to see an upcoming wearable computers time when on-body device become one indispensable part of us to express ourselves emotion in daily life. Just like we use cellphone texting, use Emoji, meme or stamps to assist better emotion express.

In fact, although the main target of Emolleia are the type of shy introverts who want to interact with others but may lack of social skills, Emolleia can also be used for anyone who wants to interact with surroundings in a fun way or just simply assist wearer express themselves with more encourage.

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Appendices

A. Questionnaires

Wearable Emotion Expressing Device Design

*Required

1. Where are you from? *

2. what's your gender? *

Mark only one oval.

- Female
- Male
- Prefer not to say

3. what's your age *

4. what's your highest educational level *

Mark only one oval.

- Less than High School diploma
- High School
- Associate Degree
- Bachelor's Degree
- Master Degree
- Phd
- Other:

5. What do you consider your ethnicity to be? *

Mark only one oval.

- Asian or Pacific Islander
- Black or African American
- Hispanic or Latino
- Native American or Alaskan Native
- White or Caucasian
- Multiricial or Biricial
- A race/ ethnicity not listed here

The I-E Scale

Directions: Respond by indicating the degree to which each statement agrees with the perception you have of yourself.

Record numbers 0-5 on the lines provided below, based on the following scale:
5 = Almost Always, 4 = Frequently, 3 = Occasionally, 2 = Rarely, 1 = Almost Never, 0 = Doesn't Apply

6. A. I show individuality and originality in written reports. *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

7. B. I dislike test questions in which the information tested is in a different form from that in which it was learned. *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

8. C. I avoid exaggeration when sharing personal experiences. *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

9. D. I lose control when I get angry. *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

10. A. I engage in reflective, philosophical thought. *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

11. B. I prefer to have a theory or principle explained rather than studying it out for myself *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

12. C. I conceal disappointments. *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

13. D. I shed tears when I hear a sad story. *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

14. A. I spend leisure time reading poetry, stories, or plays. *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

15. B. I am uninterested in discussions of The Ideal Society. *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

16. C. When people displease me, I refrain from saying anything. *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply	◯	◯	◯	◯	◯	◯	Almost Always

17. D. I get excited when I argue. *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply	◯	◯	◯	◯	◯	◯	Almost Always

How would you relate the following images with social behavior?

18. Which best describes this GIF? *

Mark only one oval.

	1	2	3	4	5	6	
introvert	◯	◯	◯	◯	◯	◯	extrovert

19. How well does this GIF relate to social interactions? *

Mark only one oval.

	1	2	3	4	5	6	7	
not at all	◯	◯	◯	◯	◯	◯	◯	very much

20. Which best describes this GIF? *

Mark only one oval.

	1	2	3	4	5	6	
introvert	◯	◯	◯	◯	◯	◯	extrovert

21. How well does this GIF relate to social interactions? *

Mark only one oval.

	1	2	3	4	5	6	7	
not at all	◯	◯	◯	◯	◯	◯	◯	very much

22. Which best describes this GIF? *

Mark only one oval.

	1	2	3	4	5	6	
introvert	◯	◯	◯	◯	◯	◯	extrovert

23. How well does this GIF relate to social interactions? *

Mark only one oval.

	1	2	3	4	5	6	7	
not at all	◯	◯	◯	◯	◯	◯	◯	very much

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Google Forms

wearable device survey（ウェアラブルデバイスに対する調査）

*Required

1. Where are you from? / 出身国 *

2. what's your gender? / 性別 *

Mark only one oval.

- Female / 女性
- Male / 男性
- Prefer not to say / 未回答希望
- Diverse / 多様

3. what's your age / 年齢 *

4. what's your highest educational level / 最終学歴 *

Mark only one oval.

- Less than High School diploma / 中学校
- High School / 高校
- Associate Degree / 准学士
- Bachelor's Degree / 大学(学士)
- Master Degree / 修士
- Phd / 博士
- Other: _____

The I-E Scale

Directions: Respond by indicating the degree to which each statement agrees with the perception you have of yourself.

Record numbers 0-5 on the lines provided below, based on the following scale:
0 = Doesn't Apply , 1 = Almost Never , 2 = Rarely , 3 = Occasionally, 4 = Frequently, 5 = Almost Always

指示: 各質問内容の状況に対して、あなたが自分自身について持っている認識と比べて、どの程度同意できるか教えてください。

次のスケールに基づいて、0～5番のいずれかを選択してください。
0 = 当てはまらない、1 = ほとんどない、2 = めったにない、3 = ときどきある、4 = 頻繁にある、5 = 常にある

5. A. I show individuality and originality in written reports. レポートを書く際には自分のオリジナリティを発揮する。 *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

6. B. I dislike test questions in which the information tested is in a different form from that in which it was learned. / テストに出題された問題が、学習した範囲と違う形式で出題されるのが嫌いである。 *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

7. C. I avoid exaggeration when sharing personal experiences. / 個人的な経験を共有するときに、話を誇張することを避ける。 *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

8. D. I lose control when I get angry. / 怒ると自制心を失ってしまう。 *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

9. A. I engage in reflective, philosophical thought. / 私は熟慮的であり、哲学的な考えを持っています。 *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

10. B. I prefer to have a theory or principle explained rather than studying it out for myself / 自分で勉強するよりも、理論や原理を説明してもらうことを好む *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

11. C. I conceal disappointments. / がっかりしたことなどを隠してしまう。 *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

12. D. I shed tears when I hear a sad story. / 悲しい話を聞くと涙がこぼれる。 *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

13. A. I spend leisure time reading poetry, stories, or plays. / 私は暇な時に詩、物語を読んだり演劇を見たりする。 *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply							Almost Always

14. B. I am uninterested in discussions of The Ideal Society. / 私は理想的な社会への議論に興味がありません。 *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply	◯	◯	◯	◯	◯	◯	Almost Always

15. C. When people displease me, I refrain from saying anything. / 人に嫌われたときは、何も言わずに離れる。 *

Mark only one oval.

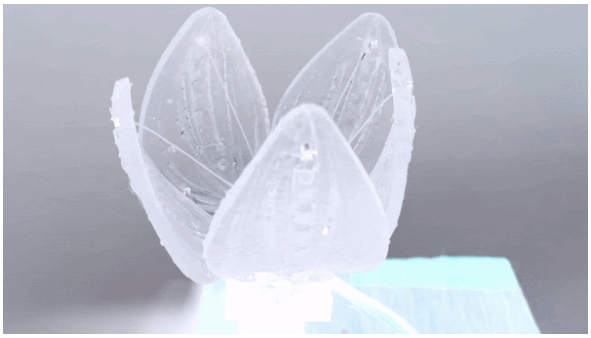
	0	1	2	3	4	5	
Doesn't Apply	◯	◯	◯	◯	◯	◯	Almost Always

16. D. I get excited when I argue. / 言い争いの時にエキサイトする。 *

Mark only one oval.

	0	1	2	3	4	5	
Doesn't Apply	◯	◯	◯	◯	◯	◯	Almost Always

Utility / 実用性



17. What do you think the functionality of the device is? (What does it display?) / このデバイスの機能は何だと思いますか？（何を表現していると思いますか？） *

18. Can you imagine a new use for the device? Assuming you can connect the movements of the flowers to any kind of information/ data. / このデバイスの新しい用途を想像できますか? 花びらの動きをあらゆる種類の情報・データに結びつけることができると仮定します。 *

19. Would you use the device? If so for what? / このデバイスを使用したいですか？ もしそうなら何のために利用したいですか？ *

20. In which social contexts can you see the device being used? / どの状況でデバイスが使用されていると思いますか? *

Tick all that apply.

- [ ] home / 自宅
- [ ] party /パーティ
- [ ] public transportation / 公共交通機関
- [ ] work / 仕事中
- [ ] restaurant / レストラン

Other: [ ] _____

21. Would you wear the device? / あなたはデバイスを装着しますか?

Mark only one oval.

- ◯ Yes / はい
- ◯ No / いいえ
- ◯ Maybe / 多分

22. Why? Why not? / はい、いいえそれぞれの理由を教えてください。 *

23. Who would you be willing to use this product under the company? / この製品を使用している人がいるとしたら誰ですか? *

Tick all that apply.

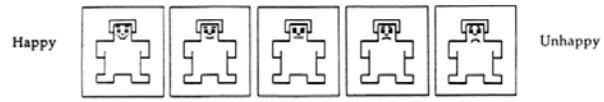
- [ ] friend / 友人
- [ ] family / 家族
- [ ] partner / パートナー
- [ ] alone / 一人
- [ ] colleaguess / 同僚
- [ ] strangers / 見知らぬ人

Other: [ ] _____

Animations

Pleases select in the range of 1-5 according to what you feel from the GIF. 自身が感じる感情及び感覚で1-5の範囲で答えてください。

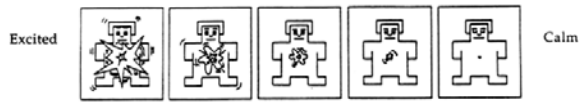
24. *



Mark only one oval.

1	2	3	4	5
◯	◯	◯	◯	◯

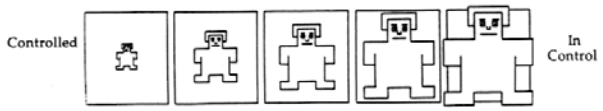
25. エキサイト - 穏やか *



Mark only one oval.

1	2	3	4	5
◯	◯	◯	◯	◯

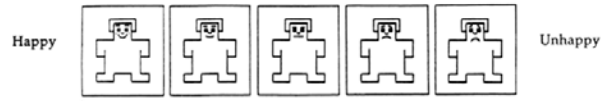
26. 外部から制御されている- 自分で制御している *



Mark only one oval.

1	2	3	4	5
◯	◯	◯	◯	◯

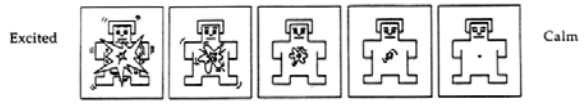
27. *



Mark only one oval.

1	2	3	4	5
◯	◯	◯	◯	◯

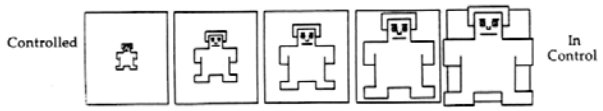
28. *



Mark only one oval.

1	2	3	4	5
◯	◯	◯	◯	◯

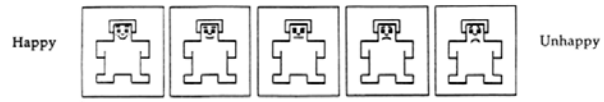
29. *



Mark only one oval.

1	2	3	4	5
◯	◯	◯	◯	◯

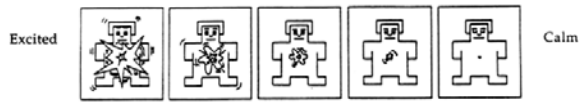
30. *



Mark only one oval.

1	2	3	4	5
◯	◯	◯	◯	◯

31. *



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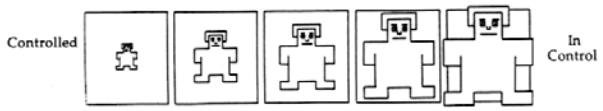
32.



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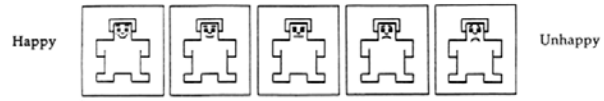
33. *



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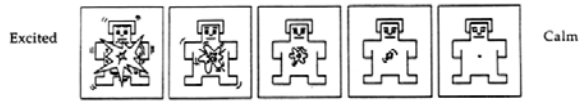
34. *



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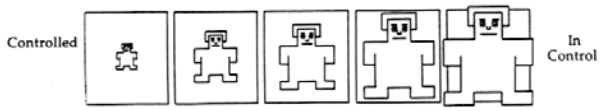
35. *



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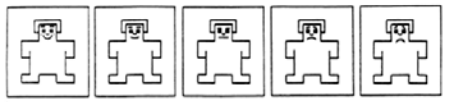
36. *



Mark only one oval.

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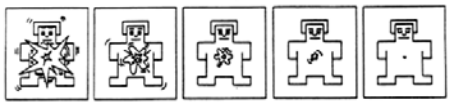
37. *



Mark only one oval.

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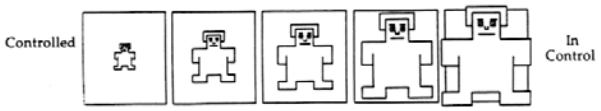
38. *



Mark only one oval.

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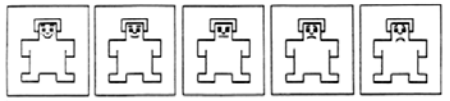
39. *



Mark only one oval.

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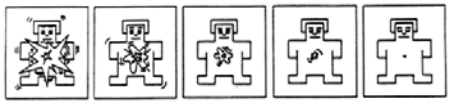
40. *



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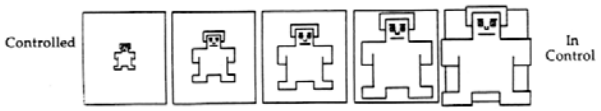
41. *



Mark only one oval.

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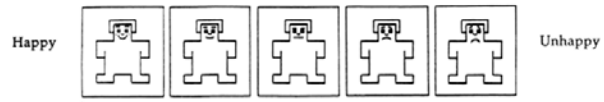
42. *



Mark only one oval.

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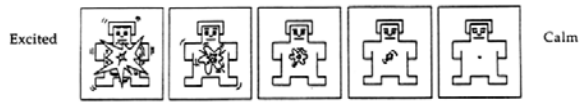
43. *



Mark only one oval.

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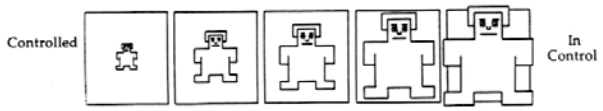
44. *



Mark only one oval.

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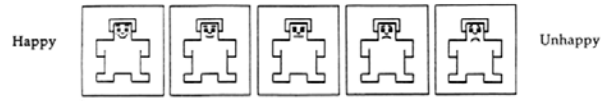
45. *



Mark only one oval.

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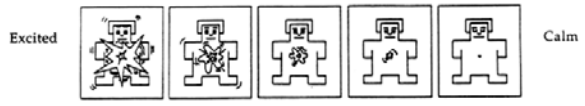
46. *



Mark only one oval.

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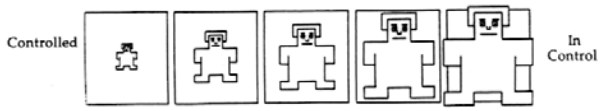
47. *



Mark only one oval.

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