Investigating Different Feedforwards for Disappearing Interaction in Textile Interface

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ABSTRACT
Currently, interactive devices disappear into a wide range of physical context due to the development of microcontrollers, sensors and actuators. This disappearing interfaces may cause confusion regarding where and how to interact with them. Therefore, inherent feedforward is significant regarding providing interaction information between human and computers. As visual information is more widely used in traditional screen-based interaction, the shape-changing modality also has the ability of communicating possibilities of action. This paper presents the study investigating different inherent feedforwards for disappearing interaction scenario in textile surfaces and how users perceive and interact with them. To do so, a textile-based prototype was designed and user tests was conducted. Based on the results, this paper discusses the intuitiveness and user experiences of different feedforward, and provides insights of future works in terms of feedforward.

AUTHOR KEYWORDS
Tangible interface; shape changing; textile interface; inherent feedforward; affordance.

ACM CLASSIFICATION KEYWORDS
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces.

INTRODUCTION
As the development of microcontrollers like Arduino, the new forms of computer can be easily integrated into a wide range of physical context [16]. Thus, the human-computer interface is no longer confined to tabletop screens, but emerging into ambient environment and soft surfaces. Based on the concept of tangible computing, this study was framed concerning both ubiquitous computing and tangible user interfaces (TUI), with a focus on the interaction through manipulating physical soft surfaces which are integrated in to daily objects [2].

While traditional user interface devices such as keyboards, are physical in forms, which afford the action possibilities of the devices and the perceptual-motor skills of the users. This property was defined as inherent feedforward by Wensveen et al. [17]. On the contrary, graphical user interface (GUI) on the screens does not possess this property, and the interaction was limited to two-dimensional information and the information heavily rely on visual perception [7]. The similar problem emerged with the disappearing user interfaces – the ubiquitous interactive space has too many "faceless" objects and does not provide enough interaction cue for the users [9]. Although TUI usually has a physical carrier for the interaction procedure, interaction based on soft surfaces like the sofa could still be confusing for users regarding where to perform the interaction and how to interact.

From an interaction design perspective, feedforward plays a significant role in term of providing information to the users and facilitate human's reaction towards the intended function [17]. Based on the framework developed by Wensveen et al, four different feedforward modalities, based on visual perception and haptic perception, were proposed in this study in order to provide more meaningful information and pleasant user experience to the interaction.

With a focus on soft-surface-based TUI, a textile-covered prototype was designed and built. Within this prototype, I proposed new carriers for interaction information using visual feedforward modality based on the LED light and shape-changing feedforward modality. In this case, LED based modality is more related to traditional screen display while shape-changing modality provides third dimension of information through haptic perception. In order to limit the complexity and novelty effects associated with TUI, both shape-changing modality and visual modality were designed in simple geometric shape of the circle, which was inspired by the work of Tiab et al. [15].

Afterwards, a mixed design (including the characteristics of between-subjects design and within-subjects design) user test was conducted [12]. Based on the findings of the user test, this paper ends with a discussion on the insight about how to integrate different feedforward modalities to generate intuitive and meaningful interaction and the reflection on the relation between feedforward and feedback.

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RELATED WORK

Dourish suggested that under the broad concept of tangible computing, TUI and ubiquitous computing shared similar characteristics [2]. One of the characteristics is the design of interface objects required the affordance to guide the user in how to interact with it [2]. The concept of affordance was suggested by Gibson in 1986, which states that people perceive the world in relation to possibilities of action - what we can do with it [4].

Resonating with Gibson's ecological theory, Wensveen et al. mentioned that the shape of an object affords the action possibilities in terms of person-product interaction [17]. They also developed the framework of mapping user's action and interface's function by distinguishing different type of interaction information of feedback and feedforward [17]. While feedback occurs during or after the user's action, feedforward shows the information before [17] . There are three different types of feedforward, which are inherent feedforward, augmented feedforward and functional feedforward [17].In this study, I mainly investigated inherent feedforward in interaction design, which focus on the intuitiveness of the information and exclude the use of additional source like language. Yet at the end of this paper, I reflect on the relation between feedback and feedforward.

Under the concept of tangible computing, this study also shared a root with ubiquitous computing as envisaged by Weiser [8] [10]. In the previous projects, novel interactive systems are designed, for example, Vallgarda proposed designing form for computational things with physical and temporal forms[16]; Bakker et al. argued that due to seamless integrated computing technology, peripheral interaction can present information to the users in a subtle manner [1]; Nieto et al. researched on the possibility of using shape-changing modality to express affordance of intelligent computing system [9]. This study present a soft surface as the interface of user-computer interaction, which communicates information in subtle changes in peripheral environment such as variations of light or movements.

Moreover, the miniaturization and higher resolution of microcontrollers as well as electronical components enable the integration of interactive devices integrating into daily objects and soft surfaces [e.g.]. As visual information is more widely used in offering interaction information, such as in traditional screen display and LEDs indicators, the shape-changing interface also obtain the function of communicating possibilities of action [10]. Shape-changing modality, or TUI in general provide more freedom to provide interaction information. For example, Harrison et al. designed physical shape button on a visual display for affordances [5].

With a special interest in shape-changing interface modality, on the one hand, this study also demonstrate the application design of shape-changing - as feedforward in interaction, which contribute insight to the design challenge with shape-changing [6].

Based on the contribution and scarcity of the related works mentioned above, this study focused on investigating different inherent feedforward modalities in the textile surfaces concerning how users perceive and interact with them.

DESIGN

This design focused on integrating different inherent feedforward modalities in a textile surface and provided a prototype that can be used in further research through design process.

Exploration

As a part of early exploration, several shape-based lo-fi prototypes were designed to explore how people interact with them. Afterward, I select the prototypes with simple geometric shapes which remind people of basic user interface elements such as buttons and slides (Figure 1. Shape Exploration). Inspired by the work of Tiab et al., it limits the complexity and novelty effects associated with tangible interfaces and the users can focus on the study goal [15]. On the basis of the shape exploration, feedforward modalities based on a circular shape were designed for the final prototype.

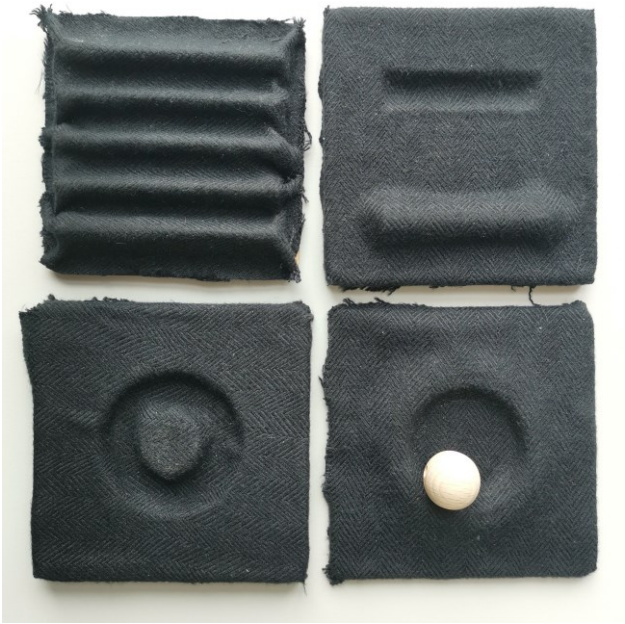

Figure 1: Shape Exploration

Feedforward

The prototype can provide a variety of inherent feedforward modalities, which are all based on a circular shape (Figure 2. Four Designed Feedforward Modalities).

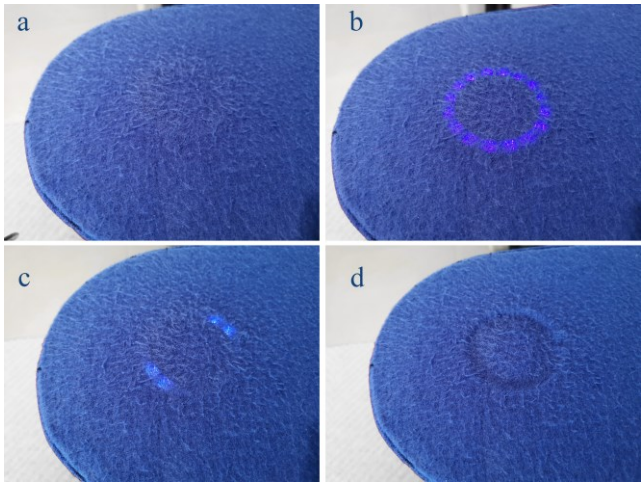

Figure 2. Four Designed Feedforward Modalities (a). Non-feedforward, (b).Static-pattern feedforward, (c). Dynamic-pattern feedforward, (d) Shape-changing feedforward

The designed feedforward modalities are described as followed:

Non-feedforward (Figure 2.(a)): the prototype does not give feedforward before the interaction. However, it provides light feedback when the users touched the sensor, the light feedback follows the users' finger rotating. This will be used as the control group.

Static-pattern feedforward (Figure 2.(b)): the prototype demonstrates a static light circular pattern through the LED ring.

Dynamic-pattern feedforward (Figure 1.(c)): the prototype provides constant counterclockwise light animation through the LED ring.

Shape-changing feedforward (Figure 1.(d)): the prototype sinks downwards and forms a ring shape before the interaction. In this study, the shape-changing modality were designed through mechanical

The intended action based on the feedforwards is touching with the finger and rotating motion (Figure 3. Touching and Rotating Motion), and the designed function is adjusting the volume.

Figure 3. Touching and Rotating Motion

Prototype

This frame of the prototype is constructed of 2mm and 4mm Medium-density fiber board (MDF) and 4mm Acrylic sheet, which was laser cut (Appendix 2: The Construction).

The surface is covered by stretchable artificial wool felt. Under the moveable part, a Membrane Potentiometer (Appendix 4: Datasheets) was integrated as the input for adjusting the music. The soft Potentiometer can measure different resistance value when being touched in different positions.

NeoPixel LED ring WS2812 (Appendix 4: Datasheets), which is integrated under the Potentiometer, is used to create the static pattern and dynamic pattern feedforward modality.

For the shape-changing feedforward modality, two Micro Servo SG92r (Appendix 4: Datasheets) is installed at the bottom of the prototype, using fishing line to pull the moveable part down to generate the shape-changing movement.

An Arduino Uno is used for the communication between Arduino and interface, which was created by Processing (Appendix 3: Schematic and Code).

User Test

The user test aimed at comparing the affordance and the user experience of the designed feedforwards in terms of interaction. The non-feedforward modality was used as the control group. The central console in the vehicle will be investigated as one of the user contexts.

Method

The user test included a between-subjects design part and a within-subjects design part [12]. Different feedforward modalities will be provided randomly to each participant. Only the first provided feedforward for each participant was used for the measurement of task completion scale, which indicate the affordance of action. All feedforward modalities were used for the rating of user experience with the Likert Scale UEQ questionnaire [14] (Appendix 6. UEQ Questionnaire). Chi-square test of homogeneity was used to analysis the results of task completion scale [13]. UEQ Data Analysis Tool and the Friedman test were employed to understand the results of user experience scale [14] [11].

During the user test, I actively took notes while observing participants' behavior. At the end of the user test, a semi-structured interview was conducted [3]. The interview questions are decided beforehand, yet additional questions might be asked to further explain certain situation based on the performance of the participants. All the interviews were recorded, yet the analysis of the interview mainly focused on the notes written during the interview (Appendix 9: Interview Note), which has the advantage of being relatively compact to work with [3]. The informal analysis was based on the content analysis method [3] and focused on interpreting the context of the research and structuring the stories.

Participants

Twenty-five participants (10 female) between the age of 20 and 29 participated voluntarily in the user test. They were recruited by an announcement on social media (facebook) of TU Eindhoven.

Setup

The prototype was positioned on a chair, which provided a suitable height for the participants like the central console in the vehicle. Participants were asked to remain sitting during the user test. A screen located in front of the participants to play a driving recorder video to simulate the context of driving or sitting in the vehicle. A tablet was used for filling in the questionnaire for user experience (Appendix 10: Setup). A smart phone was used to time and voice-record.

Procedure

All participants signed an informed consent form before the formal user test (Appendix 5. Consent Form).

Then participants will be briefly introduced to the prototype and be provided a context to use the prototype, for example, while driving a car. During the trials, the same video was played on the screen to provide the driving context. The same piece of music was played for each participant at a relatively lower volume. Participants were asked to adjust the volume of the music by using the prototype, however, they will not be informed how to use the interface exactly.

The task remains the same for all participants: adjusting the volume from 0 to 1.0 with the designed rotation hand motion. The task completion time will be recorded manually and if it is longer than 60 seconds, the task will be marked as unfinished.

After each trial of each feedforward, the participants were required to fill in the UEQ questionnaire on the tablet. After all the trials, they attended a short interview, during the interview, the exact action possibilities of the prototype will be explained.

Results

First, the results of the task completing scale are presented; secondly, the user experience resulting from the UEQ questionnaire, and the subjective experiences based on interview data are demonstrated.

Task Completion Scale

The task completion scale evaluates the affordance of the action possibilities regarding different feedforwards. The results were analyzed using the Chi-square test of homogeneity, which is used to determine if a difference exists between the three or more independent factors (in this case, four different feedforwards) on a dichotomous dependent variable (in this case, if task complete: yes or no) [13] (Appendix 7).

Twenty-five participants were randomly assigned to one of the four feedforwards in the first trial. Group sizes were unequal. In the task completion of the non-feedforward, 0 out of the 6 patients had finished the volume change task (0.0%), compared to 3 out of the 6 participants with static pattern feedforward (50.0%), 4 out of 6 participants with dynamic pattern feedforward (66.7%) and 4 out of 7 participants with shape-changing feedforward (57.1%).

The results of task completion scale showed that a largest proportion of the participants can finish the task based on dynamic feedforward, followed by shape change and static pattern feedforward. Non participants can finish the task without feedforward. The results are summarized in Table 1 below.

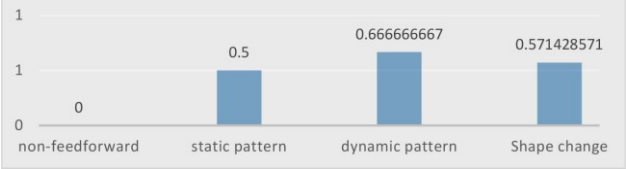

Table 1: Task Completion Scale for Each Feedforward

Table 2: UEQ Questionnaire Scale Mean Graphic

User Experience - UEQ

The UEQ questionnaire evaluates the user experience on five different qualities, attractiveness, efficiency, perspicuity, dependability, stimulation and novelty, which can be grouped into pragmatic quality (Perspicuity, Efficiency, Dependability) and hedonic quality (Stimulation, novelty) [14].

The results were analyzed using the UEQ Data Analysis Tool [14] and the Friedman test [11] (Appendix 8). The UEQ Data Analysis focused on the mean of the data (Table 2. UEQ Questionnaire Scale Mean Graphic), while the Friedman test is used to explore any statistically significant differences between the four different feedforward [11]. The Friedman test is a non-parametric alternative to the one-way repeated measures ANOVA test [11].

Pairwise comparisons were performed with a Bonferroni correction for multiple comparisons, which revealed statistically significant differences in attractiveness from non-feedforward (Mdn = -1.00) to static-feedforward (Mdn = 1.50) ($p < .0005$), to dynamic feedforward (Mdn = 1.50) and to shape-change feedforward (Mdn = 2.00) ($p < .0005$), but not between static pattern and dynamic pattern. The shape-changing was rated higher on attractiveness in general.

With or without feedforward has a significant effect on the pragmatic qualities and hedonic qualities as well ($p < .0005$). The shape-change was rated higher compared to the static pattern feedforward ($p = .013$), yet only a small significant effect was found for dynamic pattern and shape-changing feedforward ($p = 0.052$).

Interview

The interview focused on the subjective experience of the participants and exploring their perspective on certain behavior. Through reading the interview note actively and critically, some meaningful insights were revealed.

Participants who like shape-changing feedforward regarded it as the most creative design. They also expressed that it provides the shape that constraints users to act with their fingers. By relating to the vehicle context, it is more practical since it takes advantage of haptic perception concerning where the finger is without paying much attention to the interface. However, they also mentioned that shape-changing actually provides more information during the interaction, yet not providing enough information of action beforehand.

The participants also experienced that dynamic pattern feedforward is the only one gives kinetic modality showing the possible direction of the action. Participants also expressed that it is still confusing if there is no feedback when they touch then interface even with feedforward. They showed the demand for instant feedback.

DISCUSSION

Comparing the task complete scale, feedforward has the potential of providing affordance to the users regarding the designed action possibilities. The results indicate that the task completion scale evidently increased due to the use of feedforwards, which suggest that the inherent feedforward assist the users to react on the interface. With a dynamic pattern, 66.7% of the participants finished the volume adjusting task, which indicates the temporal quality of dynamic pattern helps the participants to understand the possible direction of the action. However, the highest task completion scale can only reach 66.7%. This could indicate that only using inherent feedforward to afford the functionality of the user interface seems not enough for the users.

The results from the UEQ Likert Scale questionnaire shows that among the designed feedforward modalities, the shape-changing modality has the potential to improve user experience. Combining the analysis of both UEQ questionnaire and interview, the possible reason could be 1.it is innovative and creative, which cause pleasant expectation 2.shape-changing is more expressive comparing to traditional LED display, which triggers the users to interact with it; 3.due to its constraint of the fingers, it takes advantage of haptic perception which makes it easier to find and use than purely visual perception based interaction; this reduces the attention demand. The findings also suggest that the shape-changing feedforward has the potential of supporting better interaction when it comes to peripheral vision, for example, while driving a vehicle [1].

The interview results demonstrated that participants either prefer the combination of different feedforwards or the combination of feedback and feedforward. This supports the suggestion of Wensveen et al. that there are many aspects regarding better communication in interaction design [17]. Since the feedforward and feedback co-resist in the interaction, it is almost impractical to separate the two aspects and talk about them alone. Feedback is significant for users to communicate with the system during the interaction, while feedforward can provide affordance before the interaction. Therefore, I argue that by combining light and shape-change feedforward could generate more intuitive and enjoyable interface design.

During the interaction, the feedforward modality transferred into feedback right after users start acting on it, the information given by the feedforward transferred into feedback. Although shape-changing is not the most intuitive modality for the first-using users, the information through constraints seems to be more directional during the interaction as feedback.

Future Work

This study was an attempt to explore the potential of different inherent feedforwards to provide affordance and user experience based on the theory of Wensveen et al [17]. However, the relatively lower task completion scale indicate that only using inherent feedforward to afford the functionality of the user interface might not enough for the users. Further work needs to be done to extend my findings through the design of variation of feedforwards. Further

study could focus on the transition between feedforward and feedback, in order to design better carrier for inherent information within the whole interaction.

Another possibility of the future work could be more detailed studies on how to improve the intuitiveness through the deliberately designed dynamic light pattern and animation, as well as shape-changing modality. The numerous combinations of different feedforwards modality need to be explored and studies, in order to generate framework of how to design interaction semantics.

In this study, the prototype was designed to adjust the volume. The habits of adjusting volume by pressing buttons could affect the way people interact with the prototype. There is a possibility that different task, or different traditional habits, could influence the user experience. Therefore, more research need to be done and focus on how to scale the findings of this study to broader functionalities.

CONCLUSION

In this paper, I presented the research project that accesses the effect of four different feedforwards and their affordance and user experience in terms of human-computer interaction. Based on the findings, I suggested that inherent feedforward can coordinate the human-computer interaction to some extent. Dynamic light feedforward could provide more intuitiveness regarding the action possibilities of the interface. Shape-changing seems to be an eligible modality to provide a better user experience that could make the interaction more easy and enjoyable. The findings provide insight into how to design more intuitive and enjoyable interfaces.

ACKNOWLEDGMENT

I would like to express my appreciation to Professor Miguel Bruns Alonso for his valuable suggestions during the design research process. The constructive advice given by Professor Jan Rouvroy form D.Search Lab has been a great help in building the prototype. I would also like to thank all the participants for the user test.

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APPENDIX

Appendix 1: Personal Reflection

Individual Reflection

Haoyu Dong| M1.2 Design Research Project

2019.6

Looking back at the semester, I can conclude that this research project has been a very valuable experience for me as a designer and person. During the project, I went in depth in several expertise areas, especially in Technology & Realization (TR), Constructive Design Research (CDR) and User & Society (US), as well as improved my professional skills and overall competence.

Expertise Area

Regarding CDR and US, I experienced the entire research process from the literature review, research question, design artifact, to user test, analysis, and research paper writing. I gained new knowledge about specific research tools, such as between-subjects design and within-subjects design user test, user evaluation tools such as UEQ questionnaire and AtrrakDiff, and analysis methods such as one-way repeated measures ANOVA. I also learned how to wrote a user test protocol and examine it with a pre user test.

I especially developed my expertise in TR. Firstly, I have finished a large amount of literature review regarding interaction design and shape-changing interfaces, and I also look into several important projects with a focus on the technologies that are used to develop the shape-changing interface. This experience helped me to build up my own repository of interaction design.

The smart materials developed by Chemical Engineering seems very provocative, however, it is impractical to experiment. Then I turn my attention to the research on interaction design itself, instead of the new technology and materials. Furthermore, I looked into different techniques to make lo-fi prototypes. Using tools within the reach is the learning goal. After experimenting with the conductive fabric and conductive yarn, I decided to use simple mechanical structures to build the prototype. The sensors and actuators are not hard to find, yet how to integrate them into one prototype and make it work is the most difficult part, which also required my skills in 3D modeling and the use of laser cutting.

Professional Skills & overall competence

As a result of this research project, I was given the opportunity to expand my professional skills to a new level. Unlike a problem solving based design project, a research project focused on finding a general topic and explore the possibilities. At the beginning of the project, I was confused about what I need to find out. Yet the result of a research project is unpredictable and what I need to do is starting doing research. I have learned through this project how to narrow down a research topic and find out what I am really interested in. Generally speaking, this project equipped me with a better understanding of tangible interaction design. This, I believe, is essential for me to shift from traditional industrial designer to a new level.

I also developed the ability of fast review literature and summarize useful and relevant information. I have refined my presenting skills during the final demo day concerning research project is mainly about the logical process.

Vision

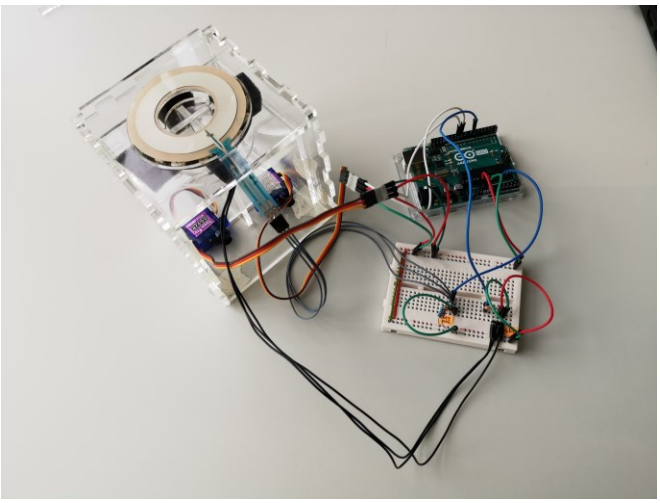
Considering my different background, it is difficult but also interesting to look deeper into how to use electronics to realize my design concept. What is more interesting is, I can also combine the vision from my vehicle design with interaction design. In my opinion, this is essential for me to develop as an industrial designer who can get inspiration from bachelor background as well as new knowledge.This project verified my long-term imagination and formulation of tangible interfaces that can be integrated into daily soft surfaces. I was able to research on it from research through design perspective and through scientific research methods. I believe, this experience is very important for my future projects, how to do research through design, how to verify the hypothesis concerning interaction design.

Aligning with my personal development plan, I explored my vision and interests as a designer, as well as a researcher. I have followed the instruction from the theoretical background and found depth in the problem I am looking at. I believe that in the future project I will be able to think from both design and research perspective and employment design through research and research through design methodology. The extension of my theoretical knowledge enables me to generate ideas from a broader perspective, with a focus on human, context and society.

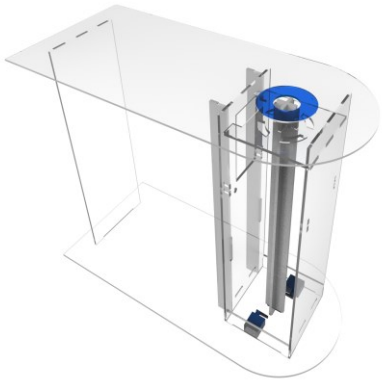
Furthermore, this project makes me even more familiar with the whole working process and education system in TU/e, which I believe would help me to take advantage of the system and strive to be a capable designer By working on research processes I am not used to, I ensured that I became more confident as a designer and it has thought me that my technical skills are very valuable.

Appendix 2: The Construction

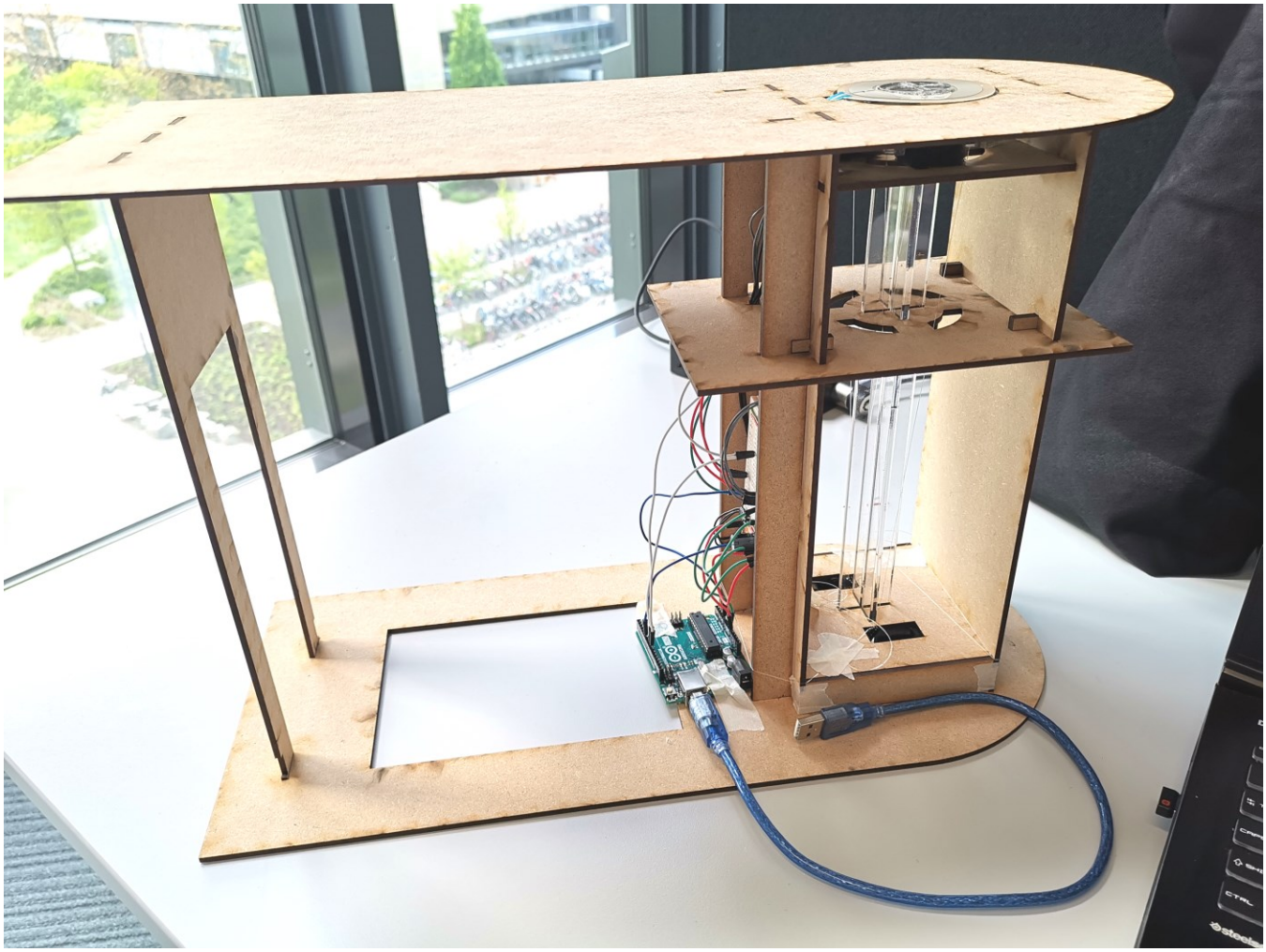
Prototype exploration



Construction in 3D software

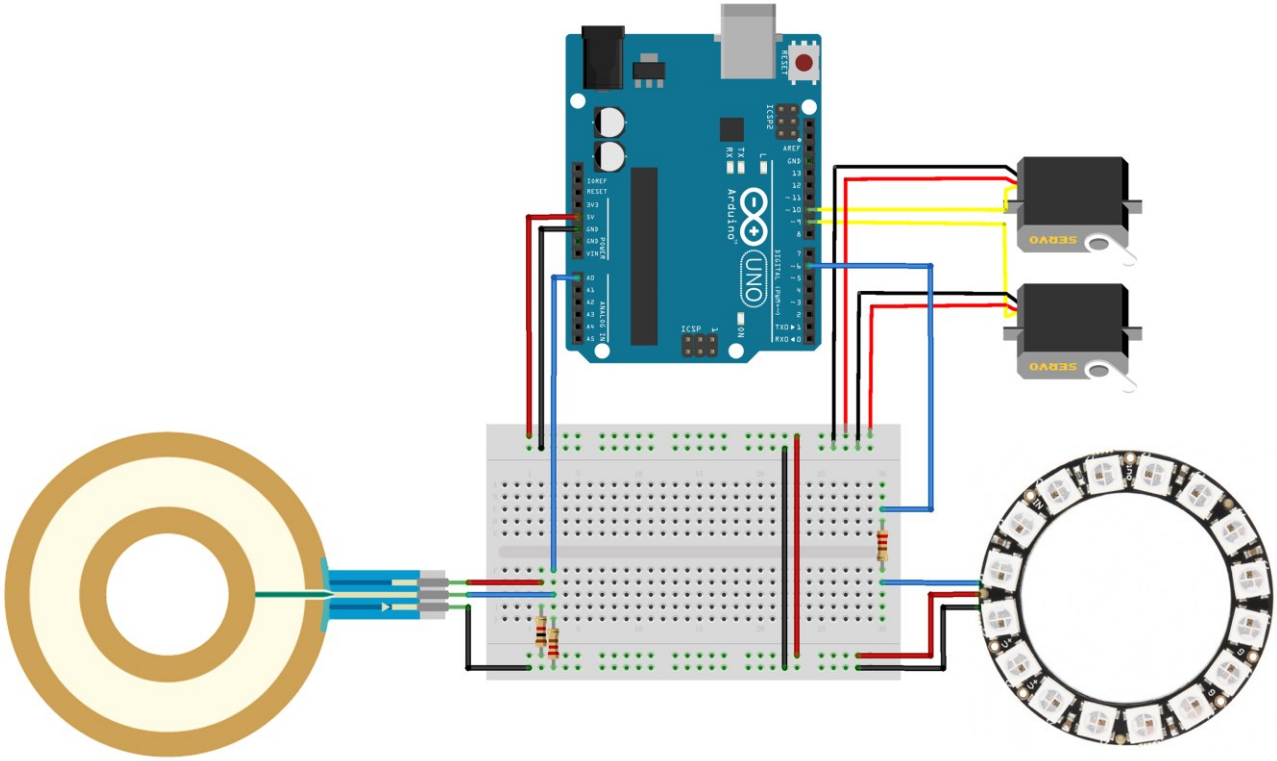


Construction



Appendix 3: Schematic and Code
Code (GitHub): https://github.com/HayleyDDD/DRP_M1.2_HaoyuDong

Schematic (Pic)



Appendix 4: Datasheets
In Appendix 4, all the related datasheets for the components can be found

Servo SG92 Datasheet: https://drive.google.com/open?id=1DNzq3CbS0_fM3n8nLdappwomQBU7n1xF
SoftPot Datasheet: https://drive.google.com/open?id=1AmqGQR8nuT_JwChh5U6Fx_uRvXvFYHuG
WS2812 Deatasheet: https://drive.google.com/open?id=1iY66O1FK-E71nPo-nI_DKZR_-jbvBOQe

INFORMED CONSENT FORM - Technische Universiteit Eindhoven

Student researchers: Haoyu Dong

Course: DPM120 Project 2 Design Research (Industrial Design)

Lecturer: Miguel Bruns Alonso

Description of the research

You are invited to participate in research within the Design Research Project at TU/e. The project investigates the interaction between users and tangible interfaces through different type of inherent feedforwards. This user test aimed at exploring the perception and user experience of the feedforwards with a tangible interface.The results will be published in a research report which will be the property of TU/e.

Procedure

You will be asked to use the tangible interface (prototype) to raise/ lower the volume of the music. After all the trials, you will be asked to fill in a short questionnaire and participate in a small interview. By signing this form you consent to use the recorded materials during this study. The content will be used for research and educational purposes.

I agree to participate in this study about feedforward in tangible interfaces and that the anonymized results are used in papers or reports.

Full Name _____ **Signature** _____

I agree that video/voice recording material of me can be used for presentations, papers or reports, which are all internal in my project and won't be spread beyond.

Full Name _____ **Signature** _____

Date _____

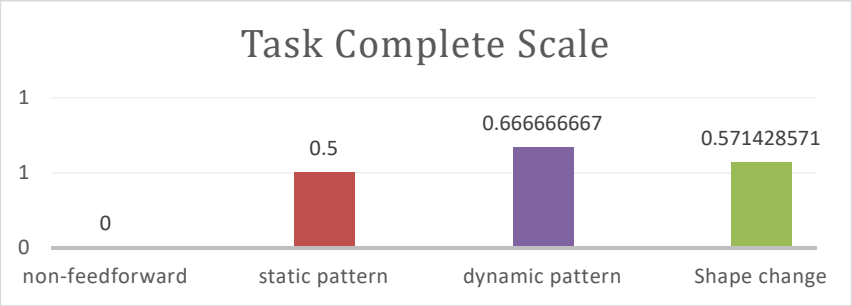
Appendix 6: UEQ questionnaire

https://docs.google.com/forms/d/1U-efBULrdbsAVpizUk5qZ2rPGO2Zk-68i_CNU6ifuRg/edit

Appendix 7: Task Completion Scale Analysis

This is the analysis for the task complete scale.

Type of Feedforward	N:1	Task Complete	Task Complete Scale
non-feedforward	6	0	0
static pattern	6	3	0.5
dynamic pattern	6	4	0.666666667
Shape change	7	4	0.571428571



Crosstabs

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Task Completion * type of feedforward	25	100.0%	0	0.0%	25	100.0%

Task Completion * type of feedforward Crosstabulation

			type of feedforward				
			non_feedforward	static_pattern	dynamic_pattern	shape_change	Total
Task Completion	no	Count	6	3	2	3	14
		% within type of feedforward	100.0%	50.0%	33.3%	42.9%	56.0%
	yes	Count	0	3	4	4	11
		% within type of feedforward	0.0%	50.0%	66.7%	57.1%	44.0%
Total		Count	6	6	6	7	25
		% within type of feedforward	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

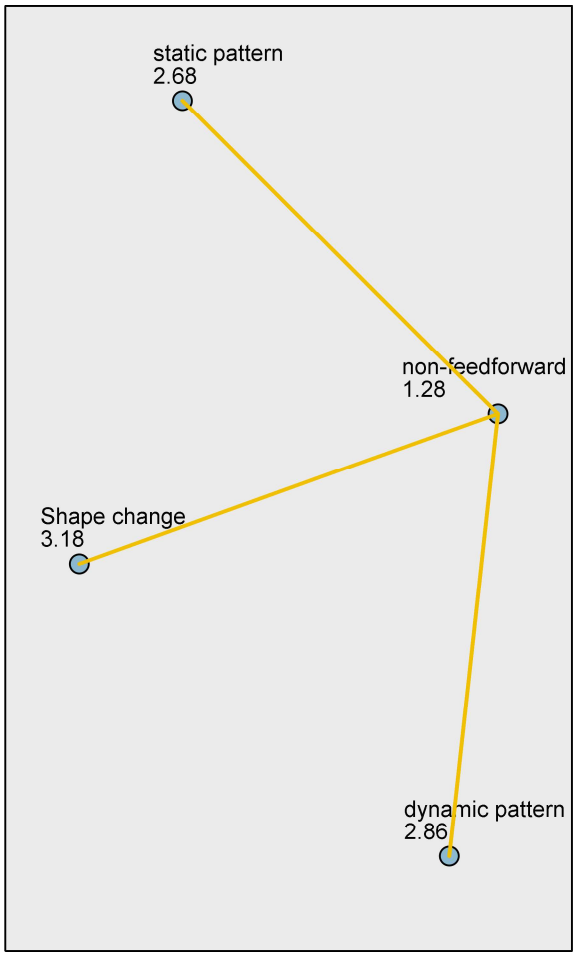
	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	6.544[a]	3	0.088	0.108
Likelihood Ratio	8.780	3	0.032	0.072
Fisher's Exact Test	6.688			0.084
N of Valid Cases	25			

a. 8 cells (100.0%) have expected count less than 5. The minimum expected count is 2.64.

Appendix 8: UEQ Questionnaire Analysis

Attractiveness

Pairwise Comparisons



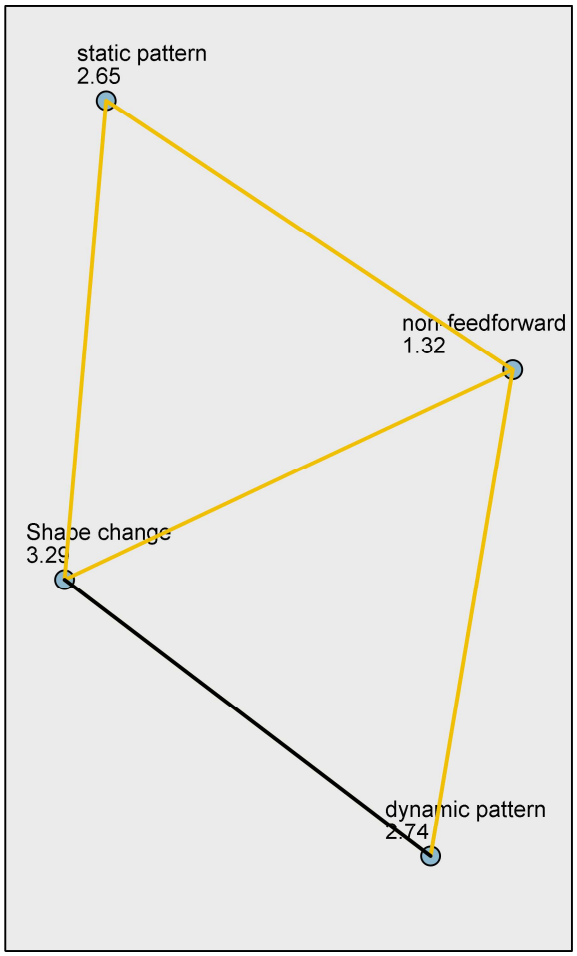
Each node shows the sample average rank.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
non-feedforward-static pattern	-1.400	.365	-3.834	.000	.001
non-feedforward-dynamic pattern	-1.580	.365	-4.327	.000	.000
non-feedforward-Shape change	-1.900	.365	-5.203	.000	.000
static pattern-dynamic pattern	-.180	.365	-.493	.622	1.000
static pattern-Shape change	-.500	.365	-1.369	.171	1.000
dynamic pattern-Shape change	-.320	.365	-.876	.381	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.
Significance values have been adjusted by the Bonferroni correction for multiple tests.

Pragmatic Quality

Pairwise Comparisons



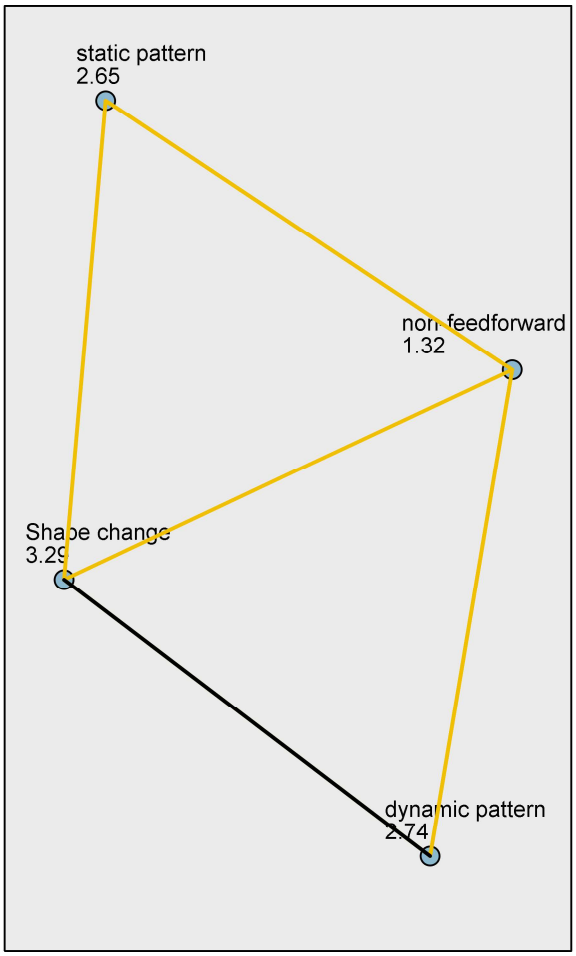
Each node shows the sample average rank.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
non-feedforward-static pattern	-1.327	.211	-6.293	.000	.000
non-feedforward-dynamic pattern	-1.420	.211	-6.736	.000	.000
non-feedforward-Shape change	-1.973	.211	-9.360	.000	.000
static pattern-dynamic pattern	-.093	.211	-.443	.658	1.000
static pattern-Shape change	-.647	.211	-3.067	.002	.013
dynamic pattern-Shape change	-.553	.211	-2.625	.009	.052

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.
Significance values have been adjusted by the Bonferroni correction for multiple tests.

Hedonic Quality

Pairwise Comparisons



Each node shows the sample average rank.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
non-feedforward-static pattern	-1.327	.211	-6.293	.000	.000
non-feedforward-dynamic pattern	-1.420	.211	-6.736	.000	.000
non-feedforward-Shape change	-1.973	.211	-9.360	.000	.000
static pattern-dynamic pattern	-.093	.211	-.443	.658	1.000
static pattern-Shape change	-.647	.211	-3.067	.002	.013
dynamic pattern-Shape change	-.553	.211	-2.625	.009	.052

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.
Significance values have been adjusted by the Bonferroni correction for multiple tests.

Appendix 9: Interview Note This is the interview note for the user test. Some answers maybe edited based on the voice recording.

No	Age	N:1	N:2	Order	task complete?	Observation note	did you get how to control the volume? can you describe?	Which experience with the interface you like the most? main reason?	How do you think about the shape-changing interface? (ux, future, any opinion)	Do you think feedforward is important for human-computer interaction in this disappreating computer	Do you think the facric/textile influence the interaction comparing to traditional screen?	Other
1	24	static pattern	dynamic pattern	1.static pattern 2.dynamic pattern 3.shape-changing	no	pressing	yes	dynamic pattern.at least it is moving. But no feedback.	it can show a shape like a button. It is interesting and innovative I would say, maybe combine with the light.		yes.	Why do you have press movement? Because you can see the circle. Traditional way to adjust the volume
2	23	non-feedforward	dynamic pattern	1.non feedforward 2.dynamic pattern 3.shape-changing	no	not get what to do with non-f	not really	dynamic pattern is more directing(?) show the direction	maybe it is useful when u cant look at it. Relaxing. Playing with it.	I think it is important, with non-feedforward one, I am really confused about what to do with it.	yes.	
3	21	Shape change	dynamic pattern	1.shape-changing 2.dynamic pattern 3.static pattern	no	quite confusing	not really. I do not get the idea	Shape changing more creative. More fun. If you get used to it. Just want to feel what happened. trigger	it is interesting. Mind-blowing.	I think feedback is more important, I do not know what to do with the interface because I do not get any feedback, so I don't know if I did it right or wrong.	yes.	
4	22	dynamic pattern	Shape change	1.dynamic 2.shape 3.static	no	move finger up/down	yes. But I don't like thinking about clockwise and counter- so I don't wanna do the rotate	dynamic pattern. It is moving, more clear about the direction	still wanna press it.	I will get more stressed because I do not know what to do. More and clearer feedforward can be designed.	Tactile influence. I like the way it feels	Give the direction to raise the volume.
5	25	static patte	Shape chan	1.static 2.shape 3.dynamic	yes	immediately	it is obvious.	shape-changing. Clear.		it is important. At least for me it is really clear with the feedforward.	not really. But it is interesting. Maybe for other people it is good	
6	24	non-feedforward	static pattern	1.non 2.static 3.shape-changing	no	shape yes	not really.	shape-changing. This is Innovating. And something of futurie	I can also use it when I sitting in sofa. If this is intuitive enough, so maybe with light	feedforward is important,definitely.I would prefer combining shape-change with the light, then gives more information.	yes. It is pretty cool. If something shining under the surface.	
7	23	Shape change	static pattern	1.shape 2.static 3.dynamic	yes	immediately	clockwise/counter-clockwise is reasonable	shape-changing. It is quite sastifiying to look at it showing the shape	It is relaxing. Don't have to look. Just feel		yes.Also because of the fabric. I am stressed . don't wanna watch screen.	
8	23	non-feedforward	Shape change	1.non 2.shape-changing 3.static	no	enjoying the shape-changing		shape change. Because it is easier to move hands without noticing. Without pay attention. also like the non-feedforward	creative and interesting. Kind of attract me to do something with it.	if you can combine the light with shape-change, like traditianal display combining with shape-changing.	yes. If you use different fabric, maybe you will generate different tactile exp.	Music is relaxing as well add the feeling.
9	24	Shape change	static pattern	1.Shape 2.static 3.dynamic	no	pressing	not really, I think	shape-c. don't have to look at it. But the dynamic light shows more motion information.	For old people maybe it is hard, because it is new technology.If I get to know how to use it, it is practical. personally I prefer the light with different brightness, then it shows the volume I already changed.	it would nice if there is more feedback. When I touch or adjusted the volume, there is some light change that shows me: oh, I already did something right, it will be more obvious	maybe. It feels different of course.	
10	23	Shape change	non-feedforward	1.shape 2.non 3.dynamic	yes	immediately	find out the following dot in the non-feedforward (only one)	really enjoy the following dot. More feedback. More friendly, like conversation with a person. But it is too hard to find it at the very beginning.	Yea, I think it is promising. good looking and minimum. Can be integrated into the environment.	Still hard to give really specific information, for example the I thought the dynamic light is loading something. But it can assist the understanding of the interface	no.	
11	26	non-feedforward	static pattern	1.non 2.static 3.shape-changing	no			shape-changing. Don't have to look at figures.	Not sure about stress.			Don't need to think much. Easier.
12	22	dynamic pattern	static pattern	1.dynamic 2.static 3.shape 4.non	yes	20s		shape-changingTrack. No look at the fingures	for people who can not see, it is quite interesting.	really important. feedback is more important. you have instruction.		Raise the hand is the more intuitive way to do it No feedback. If can reduce stress. Only touch. Screen position
13	22	Shape change	dynamic pattern	1.shape-changing 2.dynamic 3.static 4. non	no	no idea what is going on	didn't really finish the task, but immediately rotating the finger.	shape-changing it is creative. But I don't know what is going on. Because no feedback.	it is futuristic. Especially for daily based task.	for this application, it is important. Otherwise, it is not so clear.	Fabric. Come comfortable. Not hard. Placed on the sofa.	This is better, it could transparent. How much volume you already do.
14	22	dynamic pattern	Shape change	1.dynamic 2.shape 3.static 4.non	yes	try to use the whole prototype to control.		dynamic pattern maybe. It is showing the direction. Don't have to think about it.	it depends. constantly use thing, don't need to hide. But some functions you maybe don't need it a lot.	yes. I wasn't sure where to touch.		
15	23	non-feedforward	static pattern	1.non 2.static 3.shape 4.dynamic	no	quite confusing	I am not sure	Shape-changing: physically different. Go with tracks.		yes. But need more concret. I don't really get it, too subtle.	Fabric. Good touching.	

16	24	Shape change	static pattern	1.shape 2.static 3.dynamic 4.non	yes	immediately	yes	shape-changing, it is creative. But dynamic is also clear and understandable	only for simple function. There is 40 buttons- Confusing.quite clean interface	yes	Pleasant to touch, then it is important.	
17	28	static pattern	Shape change	1.static 2.shape 3.dynamic 3.non	yes	shape-changing: say ohhhh! Get how to use it	yes	shape-changing. It is clearly showing where I need to touch		not really, if you have instruction, right.		
18	20	Shape change	dynamic pattern	1.shape-change 2.dynamic 3.non 4.static	yes	immediately	yes	shape-changing is quite triggering? Inviting. Stimulating.	light is to show.it depends. interesting. depends on the situation and senarior.	yes. not really intuitiive	nothing special. comfortable.	static. it is beautiful. I like the color
19	22	static pattern	Shape change	1.static 2.shape-change 3.dynamic 4.non	no	shape-yes	yes. circlar ring on the top of this device. Move your finger around. Clockwise/counter-.	with light. Static or dynamic. Because it help me to know how it works. Dynamic one. Clearly show the direction.	the middle part looks like a button. sometimes useful. Don't have to hold control remote all the time. For extra function you always have a remote.not complicated function.	I wouldn't say it is that important. More important is when I put my hand, I know what is going on.	yes. Not like a glass. Feel good to touch.	
20	22	static pattern	non-feedforward	1.static 2.non 3.dynamic	no		not really. not easy to figure out.	dynamic: it is clear showing the direction. Shape-changing is cool but it didn't help	it is cool. it is promising. not everywhere. Some special applications maybe	yes. Maybe need to find more type of feedfoward	no different.	waterproof. It covering up all the sensors.
21	29	dynamic pattern	static pattern	1.dynamic 2.static 3.shape 4.non	no	try to press, then rotate shape-changing rotate.	yes and no. I mainly press. Took me while to realize the whole circle is touchable.	design part, I like the shape-changing. It is futuristic. When I watch tv, I don't not have to look at it. I feel interesting, triggered to interact with it. Do not have to look where I pressed.	the circle shows where I touch. I don't necessary need to look at it.	But it didn't give you any idea of what to do, what to expect. Non-feedback is kind of useful for me. Good idea to combine shape-changing with light. Shape-changing shows where is the active zone.	quite creative.	
22	24	non-feedforward	Shape change	1.non 2.shape 3.static 4.dynamic	no	Shapechanging: rotate.	not really.	shapechanging is interesting.	handy.	yes. if is helpful.	feeling.	
23	22	dynamic pattern	non-feedforward	1.dynamic 2.non 3.shape 4.static	yes	immediately	It is quite understandable. It goes certain direction, so I thought it would reasonable to follow it since there is only one task for me	shapechanging. in the car. don't have to look into it. You can feel the space, the circle.	I definitely see it userful. probably.not long ago car has a lot of buttons. In a car feedback is very important. I prefer buttons than screen	useful. interested in car.if the shape-changing can combine with the circlar rotating light one, it would be better.	not really. But if this concept, so the seamless thing, you kind of need the fabric.	
24	25	static pattern	Shape change	1.static 2.shape 3.non 4.dynamic	yes	immediately	for me it is really logical, for tunning. Even traditional button goes clockwise/counter- to adjust the volume	shape-c: I like the feel, my finger perfectly fit in the track thing	you can not watch, but you can touch.can be. people can not see, for them it is promising.	yes. If a new tech based interface.	fabric matters. harder. rip/more control.	
25	22	dynamic pattern	non-feedforward	1.dynamic 2.non 3.shape 4.static	yes	immediately	yes. I just followed the light.	dynamic: at least it is moving. I like it. Before I touch it, it already change the shape, when I touch it, it didn't show anything	no watching. But personally prefer sound-control	it is. The light is clear showing direction	not really.	

Appendix 10: Setup