June 9, 2016, Eindhoven, The Netherlands

Which emotions can be experienced by a medium-sized, responsive plank?

Tzu Wei Wang[1], Shama Khalil[2] and Stijn Ebbers[2]

[1]*Student from National Taiwan University of Science and Technology*

[2]*Students at faculty of Industrial Design Eindhoven University of Technology*

Abstract

There is design and research in the field of shape-changing interfaces and tangible interaction is increasing. In this study design students were asked to interact with a shape-changing, medium-sized, responsive plank with actuation that changes its surface with a bump with a certain shape and speed. This research aims to better understand how users feel and think about the shape-changing interface, and to explore the design space of the object tested. Six different behaviors were designed, which is differ in accerlaration direction and react timing after touching. During tests experiences and data for different behaviors were collected with a repertory grid interview. The results show that participants use different constructs to describe the behavor of the interface, with a trend in certain categories. People still experience almost the same feeling while interacting with the interface.

Introduction

Tangible and reciprocal shape changing interfaces are interfaces that respond to (physical) user input in a physical manner at the same place of the interaction (M. Bruns). There is a growing research interest on shape-changing interfaces in the tangible interaction community. (Rasmussen et al., 2012) In previous studies the effect of such interfaces have been researched in different contexts (Kinch et al., 2014), different shape changes and the experience of participants have been measured (Kwak et al., 2014), and research has been conducted on how to create different transformable surfaces using mechanical elements (Coelho & Zigelbaum, 2011). In Kwak et al. the design space of shape changing interfaces was studied with a repertory grid study, focussing on user's point of view.

The goal of this repertory grid study is to understand the design space from a user's point of view of one specific tangible and shape changing interface.
This direction was inspired by the work done by Kwak et al. Furthermore the study of Kwak et al. (2014) state that design students as participants because they could be better at expressing experiences with objects than the average user. Our criteria for the participants was based on this. The object in this study used 6 programmed behaviours had impact on the way the object changed shape.
Kinch et al proposed further research in situ on the user's experience with shape-changing interfaces and 'how these aspects may impact the performance of and preference for shape-changing interfaces'. (Kinch et al, 2014, Rasmussen et al., 2012). Because different contexts have an impact on the experience and the user group of shape-changing interfaces (Kinch et al, 2014), only the lab context was taken into account in this research. This was done to be able to set a basis for further research.

Deckers researched the perceptive qualities of systems and intelligent and interactive artefacts. In her research she shows that a system's activity can be made meaningful to users by designing for perceptive qualities. In addition to this she shows that user activity can become meaningful to a system during the interaction. (Deckers, 2013)
Within Deckers' thesis, masters student J. de Bont did a design research. He designed an interactive table, Manoeuvre, which he used in his design research as an artefact 'to explore and compare the implementation of static and moving sensor(s)'. (Deckers, 2013) The object used in this research was mostly based on De Bont's Manoeuvre prototype.
This study was conducted in a project group lead by Miguel Bruns, with a focus on tangible and reciprocal shape changing interfaces.

Interfaces'. Within this project the focus lied upon setting up a research to explore the possibilities of medium sized tangible and shape changing designs. This research built upon work done by second year Industrial Design BSc students, who conducted a design project in the same project group. This paper focuses on the expression of characteristics in a shape changing object. The research question that is answered in this paper is: Which characteristics can be experienced by a medium-sized, responsive plank?

Repertory Grid Study

The repertory grid is an interview method and analysis technique in which people describe their reaction to and experiences with a certain context or object in short descriptions or words called constructs(Kwak et al, 2014). In a repertory grid interview each participant comes up with their own unique set of constructs that are important and relevant to them, which come forward during exposure of the object or element to be assessed. In this research six elements were used, in the form of six programmed behaviours in one object. This method was selected for this paper to avoid bias by the researchers regarding the object's range of emotions and expressions. Previous research using this method are Hassenzahl & Trautmann (2001), Hassenzahl & Wessler (2000), and Kwal et al (2014).

In past research using the repertory grid in HCI typically between 6 and 8 elements were used (Kwak et al. (2014), Turner & Turner (2011)). In this research one artefact was used with 6 different behaviours, a total of 6 elements were assessed.

Defining the Behaviours

All behaviours used in this test were designed from scratch. The design of the first behaviour started from neutral reaction to touch, which was moving up when touched and moving down when touch was released. To design the remaining five behaviours certain variables were taken, namely the reaction order (react when touch or react when released touch), and reaction method (wiggling up and down or moving only up, or only down, or once up and down). The full behaviours are described below. This decision was based on the wish to create six behaviours that clearly differ from each other, so that the design space can be explored as broadly as possible.

An overview of the six behaviour programs used:

Program 1
During touch, the bump went up and stayed up when contact was remained. Bump went down when touch was released.

Program 2
During touch, bump stayed idle. When released, bump moved up. When touched again, bump stayed idle. When released, bump moved down.

Program 3
During touch, bump wiggled up and down randomly. When released, bump stopped moving.

Program 4
During touch, bump was idle. When released, bump wiggled up and down randomly.

Program 5
Bump was constantly wiggling up and down randomly, not responding to the user input.

Program 6
During touch, bump moved all the way up then all the way down rhythmically. When touch was released, bump moved all the way down and rested.

Figure 1.This photo shows a participant interacting with the prototype. A video has been made in which the six different behaviors are shown[14].

Method:
Participants

Four Dutch participants (3 female, 1 male) and one English participant (male), all aged 20, were recruited at the department of Industrial Design. Students with a background in design were recruited as they might be better at expressing emotion, experiences and feelings they have regarding the shape changes than an average person. Participants had no visual or motor impairments.

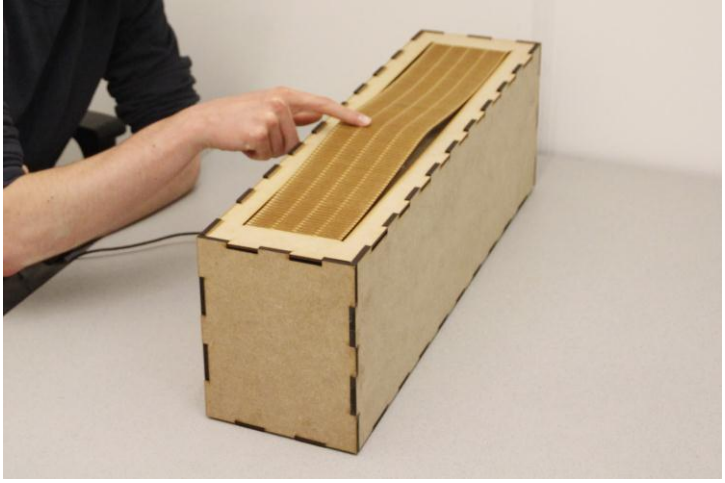

Figure 1. The prototype used for conducting the research.

Apparatus/Materials

Materials used during the test were a medium-sized box object, writing utensils, a camera mounted on tripod, and two laptops.
The box design was 650 mm long, 160 mm wide and 200 mm high. The top part of the box had a flexible plank of 560 mm long and 100 mm wide. Underneath this flexible plank was a circular shaped piece of Perspex, connected to a gear, which was connected to a servo. This allowed this circular shape to move up and down underneath the flexible part, creating a type of vertical movement. The movement of the vertical object was controlled by one researcher from a laptop.
During the research a laptop with an opened up empty excel document was also used to the fill in the participants' constructs, and was used for the execution of the repertory grid.

Setting

The test took place in a meeting room of 8 m^2, with white walls, of which two half walls were glass. The door was closed during the test. The room contained a grey table of 75 cm by 150 cm. After permission for recording was requested, a DSLR camera was set up at an angle of the participant at 1 meter distance, recording their full upper body, facial expression, object manipulation, and sound recording. The camera was used to be able to re-examine the expression on the participant's faces, to record dialogues, and to record interaction with the prototype.
Two researchers were present throughout each test: one to take off the interview, and one to control the movement of the prototype. Two laptops were set up and used by the researchers: one was to control the different behaviours of the prototype, and the other to create and fill in the repertory grid.

Procedure

Each session started with an explanation of what the research was about, namely to discover which emotions and expressions were present in our tangible design. The procedure of the test was explained to each individual participant and they were informed on the goal of the test, which was to find out how they would react to our responsive design, and which emotions our design would express in their experience. In addition the research methodology was shared, which was a repertory grid study, and it was explained that this is an interview methodology that allows to research experiences in an unbiased manner, relying on user input.
During the test the participants interacted with the flexible plank on top of the box. In this plank the shape change took place, where the plank elevated with a certain height with a certain motion in the center of the box as a response to the touch from the participant.
During the test the expression of the object was researched. Each program had their own number ranging from 1-6, and in this way the programs were communicated in the test.
The test consisted of two phases: The triading phase and the rating phase. In the triading phase, three arbitrary programs were given to the participant to interact with. The participants were asked to compare each program to two others, and were asked which expressions they took from the programs. Out of this exercise the constructs were built up. After the participant shared that they felt they had fully described the programs and their differences, the constructs were arranged in a positives and negatives, the rating phase began. In the rating phase the participant interacted with all 6 programs in arbitrary order, and each program was assessed according to their constructs on a scale from 1-9, 1 being the positive construct and 9 being the negative.

Results

All the collected construct pairs that the participants provided during the tests were discussed with the same participants who came up with them, to get a better understanding of what they wanted to express by using these constructs. Using these discussions and a thesaurus, we were able to form seven main categories under which we could group these constructs.
Through each category we were able to see how many constructs were used to describe the different topics.
After that a comparison of all the grades the participants gave to their construct pairs was made. The averages of all the grades of the construct pairs within specific categories can be found in [table 2].

Category	Description of the category	Examples of constructs	N
Way of interacting	This category concerns the level of interactivity In the prototype. Including level of initiative, responsiveness and stubborness	Obedient/Stubborn, Motivational/Frustrating, Respectful/Provoking, Following/Assertive, Proactive/Reactive	9, (18.37%)
Sociality	Concerns the prototype's need for connection and interaction	Open/Shy, Connected/Disconnected, Curious/Uninterested, Extravert/Introvert, Quiet/Talkative	8, (16.33%)
Way of Reacting	This category is used to describe the reaction of the prototype to the participants input	Fast/Slow, Absent/Present, Direct/Slow, Subtle/Pushy(Harsh)	4, (8.16%)
Predictability	The category "Predictability" covers the predictability of the behaviors	Surprising/Repetitive, Predictable/Unpredictable, Clear/Unclear, Wild/Predictable	4, (8.16%)
Way of Moving	This category concerns the movement of the prototype, whether it moves suddenly, is interesting to the participants or completely monotone	Diverse/Monotone, Fast/Slow, Mellow/Hyperactive, Smooth/Sudden, Fluid/Rigid	7, (14.29%)
Mood	These constructs describe the state of mind of the prototype	Playful/Serious, Cheerful/Dull, Fun/Annoying, Nice/Annoying, Playful/Boring	7, (14.29%)
Energy	This category describes the level of energy in the movement in relation to the mood of the prototype. For example whether it is enthousiastic, lazy or very bored	Peaceful/Annoying, Calm/Energetic, Calm/Restless, Active/Lazy, Wild/Calm, Relaxed/Nervous	9, (18.37%)
Misc	This category catches constructs that do not fit in the other catergories	Animated/Robot-like	1, (2.04%)

Table 1. Categories and examples of construct pairs. Each construct pair was placed in one category only.

Each category has their own meaning to a high or a low grade, because the categories are filled with different construct pairs. Below, you can find a summary of what the grades mean to each category.

Way of interacting: A lower grade means a higher level of for example obedience and respectful behavior, where a higher grade means more stubbornness and provoking behavior.
Sociality: A low grade means the behavior shows a high need for connection and interaction. A high grade means the behavior feels disconnected and shy.
Way of reacting: Here a lower grade means the reaction is fast and direct. A higher grade means that the reaction is slow and subtle.
Predictability: If the grade is lower, the behavior is more predictable and clear, where if the grade is higher the behavior is perceived as unclear and wild.
Way of Moving: A low grade means rigid or sudden movements, where a high grade means fluid and gentler movements.
Mood: The lower the grade the more playful and cheerful the behavior is perceived. If the grade is high the behavior feels more annoying and serious.
Energy: A low grade means the prototype show energetic and enthusiastic behavior. A high grade means it comes off as peaceful and relaxed.
Miscellaneous: There was one construct pair that did not fit the other categories. Here a lower grade means the prototype feels as if it is alive, where a higher grade means that it feels more machine-like.

The constructs placed in the categories 'Way of Interacting'' and 'Energy' were most often reported (both 18,37%). Following was 'Sociality' (16,33%). The third most discussed category was 'Way of Moving' and 'Mood' (both 14,29%). In fourth place was 'Way of Reacting' and 'Predictability' (both 8,16%). 'Miscellaneous' contained one entry (2,04%). From the table we see that the way of interacting and the energy of the object claimed most attention from the participants. In the category of way of reacting the participants described whether, for example, the object

was provoking, had control, or were obedient. The category described the properties of the object, the position it took with regards of taking action and responsiveness to the participant.

Way of reacting and predictability were both least mentioned, with four entries each.

Programs #1, #2 and #6 were perceived to be equal in their way of interacting and their way of moving and their predictability, but differed in their mood, their sociality and their energy. Program #1 and #6 were perceived to be in a better mood, to be more energetic, and to be more social than program #2.

The mood of program #1, #4 and #5 were all between 4,29 and 4,57. Program #2 was perceived to have the most serious mood, with a score of 6,71. Following is program #6 with a score of 5,57. The best most was for program #3, with a score of 2,86.

CATEGORY	#1	#2	#3	#4	#5	#6
Way of interacting	2,56	2,22	4,78	6,78	7,33	3
Sociality	4,67	6,44	3,22	3,89	3,33	4
Way of Reacting	5,5	3,67	2	2,5	1,5	6,25
Predictability	2	1,5	5,25	5,5	5,75	1,5
Way of Moving	7	7,17	3,71	2,71	2,43	6,86
Mood	4,57	6,71	2,86	4,57	4,29	5,57
Energy	5,67	8,33	2,89	2,44	1,56	6
Misc	7	5	4	2	5	7
	AVERAGE SCORE PER BEHAVIOR					

Table 2. Average scores of the six different behaviors in the different categories.

Discussion

The main goal of this study was to explore which expressions/emotions could be evoked by a medium-sized responsive, flexible plank. The focus laid on 6 behaviours that were pre-programmed into an object. Using a repertory grid study, the most frequently reported expressions by participants were grouped into 8 categories: Way of interacting, sociality, way of reacting, predictability, way of moving, mood, energy and miscellaneous. The outcome of the repertory grid were mostly characteristics instead of emotions, indicating mostly characteristics were experienced in our shape changing object with six behaviours.

Our research compared to other research

From our results we can see the participants mostly characterized shape-change in terms of intended approach, personality and state of mind. This corresponds to the results of the study conducted by Kwak et al. (2014) The elements used in their study differ from ours as their elements had their own mechanical movement, whereas we had the same mechanical movement with different 'choreographies'. In their study 'the speed with which the artifacts change their shape relates directly to the perceived assertiveness' and 'Artifacts that change shape slowly and retract are perceived as calm and introverted' (Kwak et al, 2014). This correlates to our result as in our results, program 1, 2 and 6 were perceived to be the most calm, and were also the programs that changed their direction of movement more slowly than programs 3, 4 and 5. Furthermore the way of interacting in program 1, 2 and 3 was perceived to be more obedient than programs 3, 4, and 5.

Specific findings and General conclusion

By using a thesaurus to compare and validate all the constructs given by the participants and by personal experience from discussing the constructs with the participants when they came up with them. We can clearly see that the participants wanted to express very similar things about the prototype and its different behaviors.

Everybody had his or her own constructs to say something similar. Most of the grades

people gave to these constructs compute with that.

Different behaviors asked for different constructs. Some behaviors inspired participants to come up with emotional constructs, other behaviors made them talk about reaction and movement speed.

The programs that move up and down without wiggling are perceived to be most similar in regards of way of interacting, predictability, way of moving, and energy. The program that reacted after touch, program 2, was released was perceived to be the most relaxed, and to have the lowest mood. The program that didn't react to input and wiggled constantly, program 5, was perceived to have the fastest reaction. Program 6, where the bump would move up and down constantly during touch and moved down when touch was released, was experienced to have the slowest reaction.

Further Investigation
In this study we used six behaviours that were pre-defined by us, and they were tested in no context. With this approach we got insight in which expressions were perceived by our five participants. This decision was made as we think that it's important to first understand the abilities of an object before testing its abilities in a more defined context, or to design for a specific goal using our object. During the triading phase of our research, when constructs were ordered to be positive or negative, the participants indicated that it was dependent on the context where they would order it. Eventually they all choose the way they felt about the expression in that moment, however a next step would be to do a context research, as recommended in the research of Kinch et al. (2012).

If you were to repeat the study, what would you change?
The flaws and limitations in our study were that the behaviours were controlled by one of the researchers, and thus there is a realistic chance that there was a slight difference in reaction time for each behavior, with the exception of behavior 5 (all over the place). Furthermore the test was conducted with only 5 recipients. We aimed to conduct the test with 11 to 15 people, as in Hassenzahl or Kwak et al.
If the study were to be repeated, we would recommend to conduct the test on a larger scale, using a likert scale methodology. Although the repertory grid gives interesting insight in which emotions are experienced by people, we feel that sometimes people might have difficulty wording the emotions present, which might put a bias on our unbiased method. A likert scale interview could create a more clear execution, and an easier and safe analysis. We believe a likert scale questionnaire could achieve the goal of this research just as well.

Contribution to the field
We have explored the design space for one object with different programmed behaviours, offering a reference point for further design projects that would like to show different characteristics and evoke different experiences with one object.

Conclusion
This research has been conducted in the design space of: Tangible and Reciprocal Shape Changing Interfaces. In this research a Repertory Grid Study has been used to gather and analyze data from the participants. We have discussed the results in the context of future research of shape-changing interfaces and behavior.

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