User Test Design for a Sensitive Interactive Wall

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Abstract
The presented project is part of an ongoing PhD research project focused on the role of the sense of touch in interactive architectural environments. The aim is to explore how touch based interaction and stimuli can be applied in context of interactive architecture and what new design paradigms have to be developed. Based on the research through design approach [2], different tactile stimulating surfaces are developed. In an iterative design cycle gathered knowledge from one built and tested prototype is used to develop subsequent surface designs and establish new design guidelines. The user testing of these research prototypes becomes a crucial part of the process to gather new design knowledge. Along with the description of the recent prototype this paper provides insights in the setup of ongoing user test sessions and presents preliminary user feedback.

Keywords
Sense of touch, interactive architecture, prototype, user tests

Introduction
Architectural environments are in general experienced as static in their structural and material formation. But in recent years we can observe a shift towards more dynamic spaces enhanced and expanded by novel
sensor, actuator and material technology. From a sensual perspective this physical activation was mainly centered around visual cues. This perceptive orientation is currently moving towards tangible and embodied interaction with physical environments. Inspired by tactile interaction with our everyday devices, designers are starting to question the role of the sense of touch in interactive environments. Several projects are featuring tactile interaction on an architectonical scale [4] as well as in material development [6].

This paper introduces a prototype developed as part of an overall research project exploring the following questions: How can the sense of touch be applied in interactive architectural environments? How do people perceive tangible surfaces also according to a touch aesthetic? This research outline is based on iterative design processes and prototyping. It involves systematic user testing to receive relevant evaluation data.

So far a series of prior surface prototypes influenced the current surface design. In the following section I provide a brief description of the design, actuator choice and their function. Subsequently the main focus of the paper lies on the user testing process. Besides the test setup also behavioral surface design is discussed, followed by an analysis of preliminary user feedback and emerging patterns in user statements, which contribute to upcoming test adjustments.

**Prototype Design**
The design concept is inspired by natural folding principles and their structural advantages. The setup and purpose of this prototype is to function as an interactive wall. The surface consists of a folded tessellation pattern giving it a distinct form and tactile as well as visual appearance (see figure 1). This pattern is based on a folding grammar invented by the American mathematician Ron Resch [5].

![figure 1: Folded interactive wall forming different zones of activity.](image)

Due to the folding the surface produces three dimensional boxes (45 by 45 millimeters) encasing three kinds of actuators: thermoelectric elements for different temperature ranges, servo motors for movement and RGB LEDs for visual output. This array of actuators is controlled via four Arduino boards. Every kind of actuator serves a specific purpose in engaging the sense of touch (see figure 2) and its correlation to the sense of sight. Visual cues are predominating in western culture therefore its integration serves to investigate the sensual interplay between touch and sight. RGB LEDs produce color coded output in regards to temperature (red for warm, blue for cold). But their purpose is not limited to influencing temperature sensation. The function is not fixed but rather the object of experimentation to be answered in the user
test sessions. While moving, the surface reveals and conceals the colored output of LEDs placed in between the cellular boxes. Thermoelectric elements are embedded directly in the boxes. These elements also contribute to create a different tactile appearance, or digital materiality, in combination with the folded cover layer.

The material choice for the cover layer was influenced by tactile quality and structural parameters. The material should be able to transmit actuator output but at the same time be stable and robust. These requirements are fulfilled by a normal blind textile which, scored with the laser cutter on both sides, produces foldable creases. The folded formation reveals different spatial areas and a transforming landscape due to the servo motor movement. The surface consists of a high granularity in relation to stimulating the sense of touch throughout the sensory system. Hence interaction is not restricted to the hands but is instead expanded to the entire body, in order to investigate different sensible zones throughout our distributed touch organ. In this regards not only the stimulated body zones influence the perceptual experience but also the activity of the person and the surface behavior [3]. Passive behaving people tend to concentrate on subjective, qualitative and aesthetic experience, whereas an active exploration is addressing objective aspects in the perception process.

![Diagram of the sense of touch](image)

**Figure 2.** Overview of the sense of touch which forms the underlying principles of surface designs in this research, also outlining the functions of the actuator’s output to stimulating the sense of touch. The heterogeneous receptor network in the skin, muscles and tendons is responsible for the manifold of tactile sensations we can perceive.
**User tests**

Like the previous prototypes in this research, this one is also equipped with a variety of touch stimulating actuators. They can be programmed to dynamically respond to human touch or movement. The changing properties of these technical elements (see figure 3) vary in intensity as well as in their combination.

![figure 3: Embedded actuators with a strict cable management](image)

Within this research, user tests became a crucial part of the process in acquiring new knowledge to identify design potentials for subsequent prototypes. Users provide new and sometimes missed or unexpected perspectives for the designer. The preparation and elaboration for this empirical method is a pivotal point and is explained in detail in the following section.

**Test stages**

Three different development-stages form the overall test setup. The sample size ranges between three and eight participants for each of the three evaluation states. All three stages have already been conducted. The first stage involved three subjects in order to test the basic interaction between surface and user. It focused on a consideration of technical and usability issues in regards to the positioning of the surface as a vertical interactive wall. The results are used to identify any obvious hardware or software issues and serves as a guideline for advanced behaviour programming and modification.

For the second and third sessions eleven participants were recruited. The focus was on testing the prototype to elicit people's experience with the varying stimuli offered by the prototype.

**Test design and process**

The surface is examined under the lens of possible architectural applications and designing for the sense of touch. These two strands are the focal point in the user interaction process, the questionnaire and interview.

Since the subject does not necessarily have a design background or is familiar with this form of technology, all aspects are explained in lay language. By having test persons with mixed profile regarding age, gender and profession, I seek to gather a variety of different perspectives. Also the end user might not have a design or technical education. Patterns in user feedback and evaluation from such a diverse group might indicate more distinct and reliable results.

A test session starts with an introduction of the surface and the additional features: its purpose as interactive architectural element, the actuator output and a brief explanation of touch-physiognomy.
Participants are advised to use the entire body as interaction platform and to be aware of the different sensible zones. There are no additional restrictions or guidelines for bodily interaction or even predefined choreography. The bodily interaction process should take place in a more natural and personal explorative way.

After the introduction participants are asked to clean their hands with a wet wipe although the surface is sanitized after every test session. This preoperational ritual is followed by a dry wash to stimulate the body for touch cues. During this wash people pretend to take a shower and scrub the entire body. People are wearing clothes at all time but in order to perceive the stimuli more intense they are requested to wear a t-shirt and take off unnecessary accessories.

Thereupon 10 minutes are dedicated to acquaint, explore and experience the surface. This test part is videotaped for later video-analysis. In this interaction part three predefined surface behaviours are replayed in order to have a systematic way to investigate user's perception, likes and dislikes. Three minutes are estimated for each behaviour, whereby the surface activity varies in activity, spatial formation, temperature and light combination. In the subsequent ten minutes the questionnaire is completed. Besides demographic questions people are specifically asked to evaluate aesthetic, tactile sensations as well as to describe the role of the RGB LEDs and the combination of both senses. Three images of the body from different views are provided (front, back, side) to highlight the most used body parts.

The test session concludes with an interview in an open-ended question format. As well as the interaction part this section is also videotaped for analyzing purposes. Similar to the questionnaire the interview is centered around perceptual experiences.

Behavioural surface design
Like mentioned above the user's activity affects perceptual processes in a subtle but crucial way. In the same manner, the surface's behaviour plays a major role in the experimental process with its altering mix of actuators and their intensity. A set of programmed behaviours provides a structured way to test the effects of the surface output on the user's perception and aesthetic evaluation.

![User interacting with the surface during a public exhibition.](image-url)
For the first test stage, the surface was split into two separate sections of programmed behaviour. This division gives subjects the possibility to experience both states at the same time, compare them and maybe choose a favorite. The more passive side was barely distorted by moving servos and focused on slowly changing temperature ranges and color. This transformation took approximately four minutes. On the other side the surface was transformed into convex and concave bended areas, creating spatially evolving formations. Besides these dynamically altering geometrical features, this side also provides faster changing thermolectric and LED output. This gradually evolving surface setup will be refined into more distinct and consistent performance of the interactive wall for upcoming tests.

Again nature is a great source of inspiration for more complex and engaging variations [1]. The aim is to developer output patterns which mimic natural shape, locomotion and color change. For instance the movement of snakes are already imitated by some robots as well as octopus color and shape change. For the second test stage one pattern imitated the movement of a stingray.

**Preliminary user feedback**

Although the three test subjects have different backgrounds their responses are almost uniform. A main difference was observed on how people are interacting. It ranges from a very active use and change in bodily position often to a very observing behaviour. Also the use of different body parts was quite individual. The most commonly used areas are the hands and the side of the body from shoulder to the lower leg.

Twelve out of fourteen subjects mentioned on their own initiative that the sound from the servo motors was perceived as a positive element. Neither the questionnaire nor the interview questions referred to this acoustic output. The sonic stimulus was used as guidance to hear and feel the slight vibration of motor and detect the next moving zone. A main interpretation was that the sound gives the wall an additional characteristic almost like something alive, the term creature was used a couple of times.

Temperature is a very subjective element. Some people liked the warm parts especially in concave zones, they described it as a protective and cozy experience while being more passive. Others tended to prefer colder areas. Also the convex shaped formations were more interesting when actively interacting with the surface.

The light output was considered as a motivation to approach the surface at the beginning. The correlation to temperature was reasonably high. Apart from red and blue the entire color range was used, which was described by the subjects as an atmospheric element. But in the end subjects closed their eyes to eliminate this stimulus. Light encouraged people to approach and interact with the surface, arousing their curiosity. Over time this visual element functions to create an atmospheric environment. Over time this element was perceived by half of the participants as almost distracting and some users suggested to turn the LEDs off in order to not disturb their experience.

Apart from this controlled test environment the prototype was also exhibited in public without any standardized procedure, people were free to approach the surface.
A brief description text was available to explain the purpose of the surface but most people just explored the wall without any prior knowledge with an average interaction of two minutes. The responses were similar to the test sessions. People were attracted by the colored lights and movement. They enjoyed the sonic feature and interpreted it as a sort of living creature.

Overall, test subjects preferred the active site and had no immediate associations with architectonical environments after the interaction, although this purpose for the surface was focused on in the introduction part. Nevertheless subjects made suggestions to use it as a bed, for engaging environments for children or for waiting rooms to calm or entertain people. So there was no intrinsic association with architecture during interaction but persons had to make an intellectual bridge to suggest possible scenarios. This might be a result of the surface novelty - in our everyday environment we don’t get in contact with such walls. Therefore I intend to test people twice so that they already know the surface and might provide some refined feedback.

Further development
For further test session, additional and more complex surface behaviours will be designed informed by natural phenomena which should then be interactive hence establishing a dialog with the user. The design of the surface response will be based on the collected data which will be analyzed to identify common themes in participant experience, key issues in participant experience of touch-based stimuli. Also the feedback on how people are evaluating these stimuli regarding their interaction and use will be influencing the behaviour design. This entire reflection process and interactive design cycle will lead to improved understanding of positive features and weak points and possible improvements for subsequent prototypes.

Reference
[3] Loomis, J. M. and Lederman, S. J. What utility is there in distinguishing between active and passive