Repurposing Everyday Objects as Controllers Using Signifiers

Bachelor's Thesis at the
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Abstract

Tangible controllers are often designed for special tasks and they can be expensive, as the design process might need many assistants, resources and time. To avoid the costs one possibility is to replace them by everyday objects. Those are always available and do not need to be designed additionally. Using everyday objects as tangible controllers implies repurposing them from their usual purpose. When repurposing everyday objects as controllers, it is challenging to explain how to use them. This bachelor thesis investigates the visualization and design of signifiers which indicate how to repurpose everyday objects. *Signifiers* give signals to indicate what actions are possible and how those should be executed [Norman [2013]]. The signifiers' design and how well they communicate between an application and the everyday object will be tested in user studies.

Überblick

Meistens werden greifbare Kontroller zweckmäßig für bestimmte Tätigkeiten entworfen. Der Aufwand des Entwurfs benötigt eine Menge Designer, Ressourcen und Zeit. Infolgedessen ist der Entwurfsprozess aufwendig und teuer. Eine Möglichkeit, um diese Kosten so gering wie möglich zu halten, ist die greifbaren Kontroller zu ersetzen, beispielsweise durch alltägliche Gegenstände wie Tassen, Flaschen etc. Ein Vorteil dieser Gegenstände ist ihre ständige Präsenz im Alltag und dass sie nicht extra entworfen und produziert werden müssen. Bei der Nutzung von Alltagsgegenstände als greifbare Kontroller werden die Gegenstände von ihrer herkömmlichen Verwendung zweckentfremdet. Die Herausforderung bei der Zweckentfremdung der Gegenstände ist die Frage, wie man den Nutzern verständlich und möglichst einfach klar macht, wie sie den Gegenstand benutzen sollen. Diese Bachelorarbeit untersucht die Visualisierung und das Design sogenannter "Signifier", die dem Nutzer anzeigen wie die Alltagsgegenstände zweckentfremdet werden. *"Signifier"* signalisieren mit Zeichen welche Interaktionsmöglichkeiten möglich sind und wie diese Möglichkeiten ausgeführt werden sollen [Norman [2013]]. Das Design der "Signifier" und wie gut sie zwischen Anwendung und Alltagsgegenstand kommunizieren wird mit Hilfe von Nutzerstudien untersucht.

Acknowledgements

First of all, I would like to thank all people who spent their time in my two user studies that investigated the labeling of everyday objects to repurpose them as everyday controllers. I appreciate your constructive feedback, that helped me improving my design.

Secondly, I want to thank all the people at i 10 that helped me during my thesis to fulfill my work.

Thirdly, I thank my supervisor Christian Corsten for his help and feedback to improve my thesis.

Conventions

Throughout this thesis we use the following conventions.

Definitions of technical terms or short excursus are set off in coloured boxes.

EXCURSUS:
Excursus are detailed discussions of a particular point in a book, usually in an appendix, or digressions in a written text.

Definition:
Excursus

The whole thesis is written in British English.

For reasons of politeness, unidentified third persons are described in female form.

All numbers are rounded up to three decimal points.

Chapter 1

Introduction

1.1 Tangible Controls

Tangible controls such as buttons, rotary knobs, sliders etc. exist in diverse parts of people's everyday life. Technical devices like mixing boards (figure 1.1, left) are often designed out of those tangible controls. Besides, the designs mostly exploit the affordances [Norman [2011], Norman [2013]] of the tangible controls that attract the users to execute actions. Furthermore, tangible controls usually give the users some kind of feedback, e.g. haptic feedback. The tangible controls' feedback is advantageous for the interaction with technical devices. Due to feedback and affordances, the importance of tangible controls in people's life is apparent.

Affordances suggest how to interact with an object. Norman [2013]

1.2 Everyday Objects as Tangible Controllers

Everyday objects such as cups, glasses, boxes in various sizes and shapes are ubiquitous in people's daily routine. Those objects come along with various affordances that give the user hints to understand what they should be used for. Now imagine that affordances of the objects could

Tangible controls are designed to interact with technical devices.

embody affordances of tangible controls e.g. the mixing board slider can be embodied by the tube's rills on the edge (figure 1.1). Moreover, everyday objects could function as tangible controllers to interact with technical devices, since the designed affordances of tangible controls can also be found on everyday objects . Likewise, because of the ubiquity of everyday objects they offer great potential to be used in other contexts than their common ones. In this thesis this potential is going to be used to repurpose everyday objects as tangible controllers for applications, e.g. video editing programs, as demonstrated in figure 1.1.

Everyday objects provide affordances that are found on tangible controls.

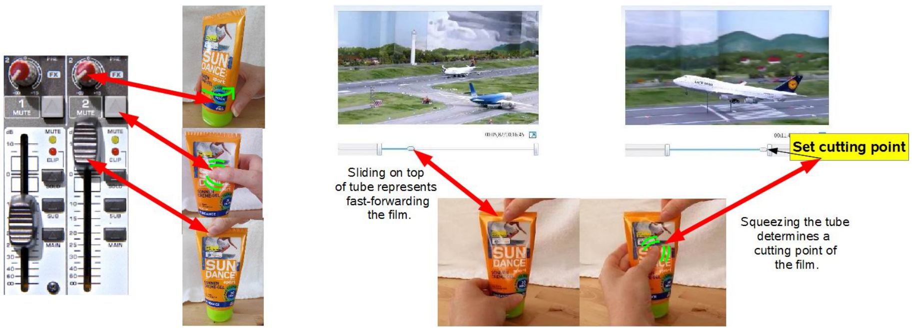


Figure 1.1: Left: Example of an everyday object that represents the affordances of physical controls. / Right: Example of how a tube could be used as controller to cut a film.

1.3 Benefits of Everyday Objects

Furthermore, everyday objects have benefits that motivate the idea to use them as controllers [Corsten et al.]:

Everyday objects provide benefits, which suggest to use them as controllers.

- Spontaneity
  A user may decide while operating a program if she wants to utilise a physical controller. The user simply can choose an object to perform as a controller spontaneously.

- Affordances
  Everyday objects contain affordances that are similar to controls in tangible controllers (e.g., figure 1).
- Variation
  Everyday objects differ in size, material, shape etc. and also in their ergonomics which could match different tasks in a program when the object is used as a tangible controller.

These benefits show that everyday objects do have potential to function as tangible controllers, indeed for non-professional users. Imagine coming home from holidays and wanting to cut holiday videos. This task is done repetitively and extensive to execute with a laptop. An everyday object could be used for the task, e.g., as the tube shown in figure 1 (right). Beneficially, by using the tube the user can exert the tube due to its ergonomics eyeless and focus on the screen at the same time.

Repurposing is a very creative process and is interpreted individually.

Everyday objects are repurposed from their usual purpose to function as physical controllers. Repurposing is a very creative process and every person has different ideas how to interpret repurposing. Therefore, the main question when using everyday objects as tangible controllers is how to display the way of repurposing the object?

1.4 Signifiers

One possible solution to display the way of repurposing the everyday objects is the use of signifiers that label the objects.

Signifiers are helpful to repurpose objects.

> ***Signifiers*:**
> Signifiers give signals to indicate what actions are possible and how the actions should be executed. Norman [2013]

Definition: *Signifiers*

These signifiers can inform users when repurposing the objects. The design of these signifiers is the main topic of this thesis. Its aim is to find a visualised design that is the most understandable for the users. Moreover, the design has to be highly intuitive.

1.4.1 Displaying Signifiers

Two ideas to display the signifiers are paper prototypes or projection.

Another important issue when using signifiers as labels for everyday objects is the visualisation of the signifiers. Imaginable are paper-based labels but those need to be attached to the objects constantly, i.e. the objects do not look as usual. Another way to communicate between user and objects are projected labels. Projected labels also establish the possibility to manipulate the objects directly, e.g. by projected touch interfaces. Besides, projected labels are dynamic and due to the fact that everyday objects are used as controllers spontaneously, this way of labelling is advantageous.

1.4.2 Outline of the Thesis

This thesis involves two user studies to investigate the design and usage of signifiers.

Following this introductive chapter, the second chapter deals with related work concerning everyday objects as controllers and projection. The third chapter of this thesis describes the creative process to define an approach of a design space for signifiers. Furthermore, the requirements and the basic data like outer requirements of the repurposed everyday objects are described. This design space of the signifiers and the according objects are evaluated in a first user study in chapter four. The experimental design and the study's results are presented in this chapter. The first user study is conducted with the use of paper prototypes of the signifiers.
The first part of chapter five describes the implementation process and the use of a projector to display the signifiers on the objects dynamically in a real use-case. The second part of chapter five evaluates the dynamic signifiers in a second user study. Finally, chapter six sums up the main findings and the contribution of this thesis and presents ideas for future work.

Chapter 2

Related Work

As described in 1 "Introduction" everyday objects have the potential to be repurposed as tangible controllers. Repurposing objects establishes opportunities in people's everyday life to experience a creative way to interact with technical devices, e.g. using them as a mouse to operate an image or video editing program. Moreover, for non-Graphical User Interface (GUI) related tasks it is conceivable to control those by everyday objects, e.g. for tasks like operating the electric lightning at home. This chapter introduces existing concepts that repurpose everyday objects from their usual use. In this context, the following papers deal with the opportunities objects offer in matters of repurposing them in the context of interaction with technical devices.

Non-GUI related scenarios offer more possibilities to use repurposed everyday objects than GUI scenarios.

2.1 Objects as Projection Surfaces and their Potential

Various research deal with the use of everyday objects as screens by projecting common GUIs onto them. Additionally, other options to make use of the objects' potential are examined in the following papers.

2.1.1 LightBeam

'LightBeam' describes how everyday objects can be used as tangible projection surfaces by the help of pico projectors.

The paper 'LightBeam' by Huber et al. [2012] explains how pico projectors can be used to turn everyday objects into tangible projection surfaces. The authors point out the advantages of pico projectors and how they can be integrated in today's everyday workflow. 'Light Beam' distinguishes between three situations how the pico projector and the surface (alias the objects) stand in relation to each other:

- Fixed projector and fixed surface
- Fixed projector and mobile surface
- Mobile surface and fixed projector

Figure 2.1: A pico projector used to project an interface onto an object, in this case onto a cup. Huber et al. [2012]

'LightBeam's' prototype consists of a pico projector placed on top of a Kinect.

In a field study the authors of the paper investigated a deeper understanding on how the projector and the surface are able to function together. With the result of the study they created an implemented prototype, in which the interaction between the object as a tangible projection surface and the projector is realised. The implementation includes several interaction techniques, e.g. the beam is able to capture an object. Huber et al. [2012] demonstrate a hardware prototype as an example: a Kinect with a pico projector placed on top. The Kinect is important because object tracking is necessary to assure that the projection of an interface takes place at the right position.
All in all, this work shows how to exploit everyday object's affordances to use them as tangible controls for projected

interfaces instead of using extra designed tangible controls for certain tasks.

2.1.2 OmniTouch

'OmniTouch' [Harrison et al. [2011]] is a system that enables interactive multi-touch applications on everyday objects and on human skin. It presents possibilities to interact with projected interfaces via touch controls. Therefore, Harrison et. al built a prototype consisting of a depth camera to receive coordinates, a pico projector and a form fitting metal frame [Harrison et al. [2011]]. This metal frame can be worn on the shoulders so that the camera and the projector have unrestricted sight onto everything the user sees.

The technology 'OmniTouch' converts objects as well as the skin into touch surfaces.

One important aspect in 'OmniTouch' is the proper and

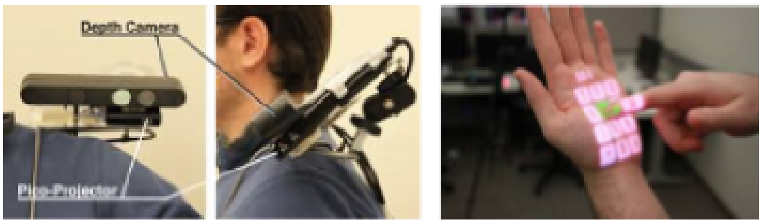


Figure 2.2: Left: The 'OmniTouch' prototype. / Right: Interaction with the skin. Harrison et al. [2011]

robust finger tracking, which facilitates that every arbitrary surface can be used for multitouch input. Even the skin can function as a projection surface if no other sensible object is available. A further feature of 'OmniTouch' is the support of multi surface interaction. The system is able to track multiple objects in its view. This fact leads to even more interaction possibilities with multitouch surfaces. To evaluate and test the proper functionality of their finger tracking system to generate input, Harrison et al. [2011] conducted a user study.

With 'OmniTouch' touch input gets available everywhere.

In summary, 'OmniTouch' presents the possibility of making touch input available everywhere, which enlarges the touch surfaces horizon.

2.1.3 Projected Interfaces

The paper by Molyneaux and Gellersen [2009] describes the possibility to let objects function as *smart tangible objects*. In this context, a great challenge is to preserve the objects original appearance because the objects should still function in their usual manner. Therefore, the possibility of projection is deployed, i.e. by the help of a projector an interface is shown on the object. Moreover, the smart objects are not only used as output devices by projection: they also function as input devices which is realised by cameras that track the object during the interaction process. Consequently, it is a question of bi-directional user interaction with so-called *smart tangible objects*.

Objects are turned into projection surfaces.

In contrast to Huber et al. [2012], this research additionally

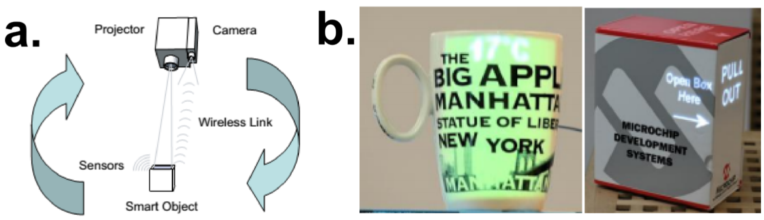


Figure 2.3: (a.) A pico projector used to project an interface onto an object is shown. / (b.) Interfaces are projected onto a cup and a box. Molyneaux and Gellersen [2009]

intends that the objects can display information about themselves like their temperature by projection to improve everyday handling with them. On these grounds the objects are called *smart tangible objects*.

Objects operate as smart tangible objects by displaying information about themselves.

Molyneaux and Gellersen [2009] concentrate on the necessary theory to realise a working system for projecting interfaces *smart tangible objects*. The paper presents a design approach that can put theory into practice.

2.1.4 Smarter Objects

This paper [Heun et al. [2013]] introduces a new idea for users to interact with everyday objects. The idea consists of combining a graphical user interface with a tangible user interface to achieve new methods for the users' interaction with everyday objects. 'Smarter Objects' are developed with the help of an Augmented Reality (AR) application which is able to recognise everyday objects and helps to program the objects behaviour as 'Smart Objects'.

Combining TUI and GUI enables a new dimension of interaction between everyday objects and technical devices

Another feature of Heun et al. [2013] is the smart object's

Figure 2.4: Left: A handicraft worked radio (TUI) / Middle: GUI is programed with the help of tablet / Right: User manipulates the TUI and the changes are visible in the GUI. Heun et al. [2013]

opportunity of sharing its functionality with other physical objects.

2.1.5 Display Objects

Akaoka et al. [2010] discuss the idea of physical models that become a 3D physical interactive screen. Therefore, the following components are necessary:

'Display Objects' are reusable mock-ups because the design is projected onto the 'Display Object'.

- Physical models of everyday objects made out of styrofoam or cardboard. On their outer layer reflective markers are assigned in order to assure the models can work as a projection surface.
- Several Vicon near-infrared cameras, that surround and observe the user and the physical object.

The profit of 'Display Objects' can be found during the design process of new devices, e.g. mobile phones or drinking cans: The physical models function as mock-ups in order to allow users to receive haptic feedback of the design approach during the design process. But instead of manufacturing the mock-up including the outer appearance

'Display Objects' are the most advantageous in an early stage of the design process.

like colour etc., the appearance is projected onto the object [Akaoka et al. [2010]]. This leads to more flexibility during the design process because the outer appearance can be changed dynamically if it is not working well enough.
With the help of case studies Akaoka et al. evaluated that

Figure 2.5: Physical models equipped with reflective markers of the Vicon motion capture system. Akaoka et al. [2010]

'Display Objects' accomplish the biggest benefit in the very early conceptualisation phases of a design process.

'Display Objects' are extra designed objects and thus no usual everyday objects are repurposed.

In comparison to the three papers mentioned before, this paper does not deal with utilising everyday objects to operate as classical input, output devices for a projected GUI. In addition, the physical models are designed out of cardboard which does not satisfy the aspect of diverting usual objects from their intended use. Nevertheless, this system states an opportunity how projected interfaces and everyday objects can work together. It is imaginable to use usual everyday objects for the system instead of the designed physical models.

2.1.6 World Kit

Xiao et al. [2013] created the 'WorldKit' system, which enables the opportunity of ad-hoc interactive applications on everyday objects. The hardware components for the system consist of a Microsoft Kinect depth camera and a Mitsubishi short-throw projector. In combination with a suitable implementation the 'WorldKit' system gets alive. Interacting with an interactive application on everyday objects surfaces requires creating an interface. For this purpose the user chooses a part of an object and draws the interface wherever she wants the interface to exist. The interaction itself

The technology 'WorldKit' allows users to create ad-hoc interfaces everywhere.

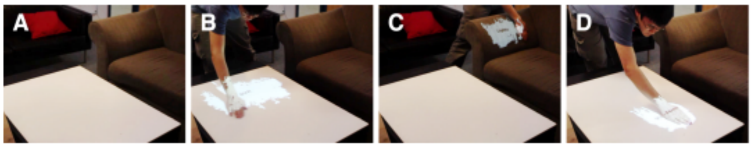


Figure 2.6: Example how to convert an everyday object into an interface. Xiao et al. [2013]

is executed by touch input that is recognized by the Kinect depth camera. With the help of the hardware it is possible to give the user feedback while they interact with the created interfaces.
The system opens a step towards ubiquitous computing because it makes interfaces accessible everywhere and every time. The idea to repurpose everyday objects as ad-hoc interactive surfaces can be applied in various parts of people's lives because the objects are always available. Thus, systems as 'WorldKit' are imaginable in the future.

'WorldKit' is a step towards ubiquitous computing.

2.1.7 Opportunistic Controls

Henderson and Feiner [2008] deal with the use of everyday objects' affordances in the context of Augmented Reality (AR). These affordances are not utilised so far and Henderson and Feiner describe the affordances' potential to improve interaction techniques for AR. This potential consists of the opportunity of tangible, haptic feedback for the user and therefore Henderson and Feiner designed 'Opportunistic Controls' which are implemented with the help of optical marker tracking and gesture tracking [Henderson and Feiner [2008]].

Everyday objects' affordances can improve users' interaction in AR.

In order to verify the usage of their system, a user study has been conducted. This user study revealed that 'Opportunistic Controls' supports users to fulfill their tasks in AR

'Opportunistic controls' helps users to fulfill tasks faster.

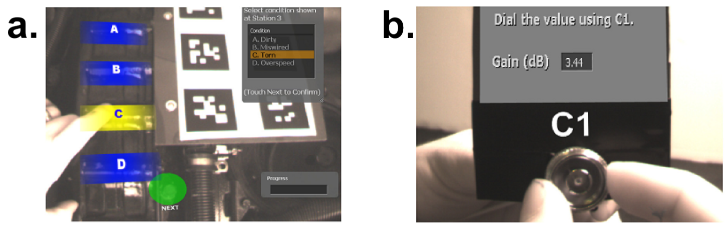


Figure 2.7: (a.) User manipulates virtual interface by receiving haptic feedback from the engine housing. / (b.) User rotates the rotating knob in order to change the virtual interfaces content. Henderson and Feiner [2008]

faster than without them. Thus, the study underlines the potential of everyday objects' affordances.

2.1.8 Touché

'Touché' makes objects touch and grasp sensitive.

Sato et al. [2012] present the system 'Touché', which has the power to let everyday objects be more interactive. The interactivity arises from the technology 'Touché' provides: It provides touch and gesture sensitivity for various objects because it is a touch sensing technology. Furthermore, 'Touché' is able to recognise exact movements of people's extremities and body. 'Touché' makes objects touch and

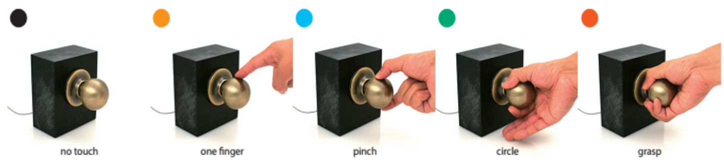


Figure 2.8: Various touch and grasp events. Sato et al. [2012]

A method indicating the user how objects should be touched is missing.

grasp sensitive. This sensitivity enables the opportunity to allocate certain touch or grasp events with certain effects while the user interacts with an everyday object.
Nonetheless, the paper does not tell the user e.g. via projection how and where to touch the object for a certain effect. Sato et. al introduce a system which has the potential to recognise human gestures, but the explanation for the user how to interact with the objects is missing [Sato et al. [2012]].

2.2 Everyday Objects as Tangibles

Tangibles have become an interesting research area and everyday objects offer benefits to function as tangibles. 'Tangible Bits' by Ishii and Ullmer [1997] introduces the idea of connecting cyberspace and physical environment by using physical objects as tangible controllers.

2.2.1 iCon

Cheng et al. [2010] open a step towards using everyday objects as controllers for technical devices by introducing the platform 'iCon'. Turning objects into controllers requires pattern stickers stuck onto the object. These pattern stickers

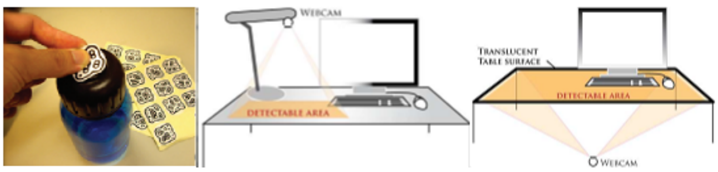


Figure 2.9: Left: object equipped with pattern sticker. / Middle: eagle-type view installation. / Right: under-desk installation. Cheng et al. [2010].

Everyday objects are equipped with pattern stickers and function as tangible controllers.

can be recognised by a webcam to identify the objects. Different gestures can be executed with the repurposed everyday objects to control technical devices. Cheng et al. [2010] developed two types of installation:

- The eagle-type view installation that observes the objects as tangibles from above.
- The under-desk installation that assures the webcam is not in the user's sight.

2.2.2 SLAP

The 'SLAP (**S**ilicone i**L**luminated **A**ctive **P**eripherals) Widgets' by Weiss et al. [2009] are tangibles made out of silicone, which can be used to interact with tabletops and provide feedback during the interaction. The system in Weiss et al. [2009] combines the tangible 'SLAP Widgets' with the virtual images of a touch-sensitive table.

'SLAP Widgets' are silicone tangibles to interact with touch interfaces.

As aforementioned, 'SLAP Widgets' are extra designed

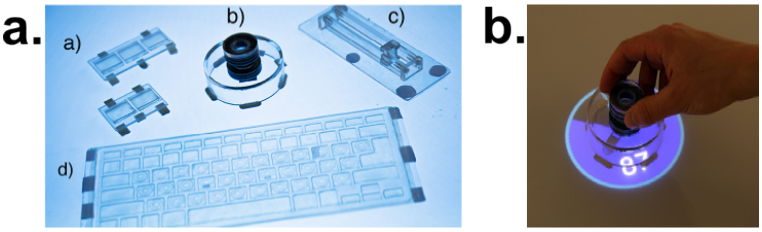


Figure 2.10: (a.) Examples for 'SLAP Widgets' / (b.) A 'SLAP Widget' on a touch table. Cheng et al. [2010]

tangibles out of silicone. Thus, no usual everyday objects are used as controllers. Hence, Weiss et al. [2009] do not deal with repurposing everyday objects as tangibles but demonstrate the idea of how tangibles function.

2.3 Contribution of the Thesis

All named papers repurpose everyday objects.

All introduced papers deal with the idea to divert objects from their intended use. One main idea is to use the objects as displays to show the content of a GUI via projection. 'Paper Windows' by Holman et al. [2005] describes the idea of turning usual paper sheets into screens by projection. Another aspect in this context is providing the possibility to let the objects function as input devices as well as output devices with the help of the display as in Huber et al. [2012] and Molyneaux and Gellersen [2009]. The papers use projectors, like a pico-projector to realise the output device component and camera-system, e.g. the Vicon motion capture systems [Akaoka et al. [2010]] to track and to identify the input on the objects. Kane et al. [2009] developed the system 'Bonfire' that enlarges an usual computer screen by projecting an interactive display to both sides of the computer screen, i.e. a table is repurposed as a projection surface.

The papers Harrison et al. [2011], Huber et al. [2012] and Molyneaux and Gellersen [2009] put their focus on using everyday objects or skin as projection screens to interact with the content of usual interfaces.

Everyday objects as projection surfaces is a common approach.

Unlike this, another approach to repurpose everyday objects is using them as tangible controllers for a certain interface, e.g. the computer, or for a disassociated task from classical user interfaces, e.g. controlling the electric lighting. In contrast to the use of everyday objects as described in the mentioned papers, e.g. in Molyneaux and Gellersen [2009], Huber et al. [2012] or Xiao et al. [2013], this approach focuses on repurposing the objects in a new creative dimension. Liu et al. [2012] discuss methods how mobile devices can improve people's interaction with them by giving feedback. In contrast to manipulate everyday objects by controls like touch commands, Liu et al. [2012] deal with usual mobile devices with screens that are meant to be controlled by touch commands.

Another approach is repurposing the objects as tangible controllers.

Nevertheless, the objects do not function as classical Tangible User Interfaces (TUI). In fact, the overall everyday object should function as a tangible controller to interact with a GUI or other scenarios. This approach repurposes everyday objects in a new extent. In this context a big challenge is to make the user understand how to repurpose the everyday objects: what gesture they are supposed to execute with the objects as controllers to achieve a certain effect in the target system. To assure a good communication of the gesture and the according effect this thesis investigates the use of *signifiers* [Norman [2013]] to label the objects. All listed papers do not survey the communication between the user and the everyday object in matters of executing the right gesture for the desired effect in the target system. Consequently, they do not reflect the labelling with *signifiers* of those objects to explain the users how to repurpose the objects. Focusing on the visualisation of *signifiers* that communicate between the user and the object is not considered. For example, Henderson and Feiner [2008] deal with utilising everyday objects' affordances for Augmented Reality purposes but

The users need to be informed how and where to interact with the repurposed objects.

Designing and visualising signifiers is no aspect of the presented papers.

they do not examine the design of a communicator into focus.

The thesis evaluates the best working design for the labels.

The contribution of this thesis is the exploration of how to inform users with signifiers to make the way of repurposing everyday objects as tangible physical controllers comprehensible best. Therefore, different visualisation types are designed and then evaluated to find out the best communicating design and underline that they are beneficial in the context of repurposing everyday objects as tangible controllers.

2.4 Overview

This thesis deals with informing users how to repurpose the objects because this topic has not been investigated so far.

Paper	**Objects as projection surfaces**	**Objects are repurposed**	**Inform user how to repurpose**
LightBeam	✓	✓	
OmniTouch	✓	✓	
Projected Interfaces		✓	
Smarter Objects	✓	✓	
Display Objects	✓	✓	
WorldKit	✓	✓	
Opportunistic Controls	✓	✓	
Touché		✓	
iCon		✓	
SLAP		✓	
Labelled objects (thesis topic)	✓	✓	✓

Table 2.1: Overview of related work content and clarification of this thesis' contribution.

Chapter 3

Design of Labels

The first important step of the thesis is the design of suitable labels for the user studies. As described in the introduction, repurposing everyday objects as controllers is a very creative and complex process. Additionally, it is very individual because everybody has got different ideas and another background, which influences the way how to repurpose the everyday objects as controllers. Therefore, distinct signifiers have to be designed such that they communicate how the object has to be repurposed. Moreover, the design should be understandable for every person. Therefore, some research on icons and symbols that are common in people's everyday life is done to get an overview of suitable ones, which can be used for the label designs.

As a first step suitable signifiers need to be designed.

3.1 Everyday Objects

Before starting the design of the labels, everyday objects are identified that are suitable for the research. To be suitable the objects should fulfill the following requirements:

Suitable objects for the research need to be found.

- The everyday objects should cover the shapes cylinder, cuboid, cube and ball. Hence, the objects need to be shaped as general as possible and should not have too many details that do not suit the shapes.

- For each shape one rigid and one soft object is needed.

The objects need to satisfy certain demands.

- In order to avoid that users are distracted by the colours and marking of the objects they objects are coloured white. This also assures that the labels are visible properly.

Furthermore, the following two aspects are assumed to bring the significant key topic into focus, namely the label design of the signifiers:

- It is the designer who includes support to use everyday objects in scenarios.
- To avoid the problem of actuation the thesis concentrates on symmetric objects. Weiss et al. [2010] deal with actuation of tangible widgets called 'Madgets'.

  As a result ten everyday objects have been chosen to be repurposed as tangible controllers. They are depicted in the table 3.1 and are displayed in figures 3.1 and 3.2.

Shape	**Rigid**	**Soft**
Cylinder	Glas and Box (e.g. for cacao, coffee)	Bottle
Cuboid	Tin can	Plastic box
Cube	Decorative box	Sponge
Ball	Tennis ball	Soft ball
In between shape		Tube

Table 3.1: Overview of the everyday objects that are repurposed as controllers in the user studies.

3.2 Labels Design

After the design space of the everyday objects has been defined the next step is designing signifiers. Those signifiers

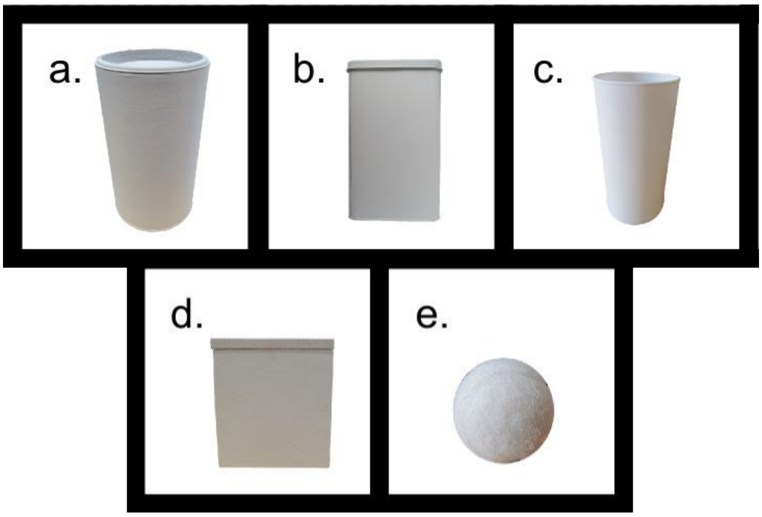


Figure 3.1: Rigid objects: Box, Tin Can, Glass, Decorative Box and Tennis ball.

are visualised by labels that function as signifiers to repurpose the objects as controllers. For the signifiers' design four different types are visualized:

Four different types of design were defined.

a. Voodoo design: labels are miniature images of the objects with instructions.
b. Affordance-based design: labels that imitate affordances of tangible controls.
c. Text-based design: labels out of text instructions.
d. Abstract design: labels consist of arrows and dots.

For each of the following seven tasks one label in each design type is designed:

Seven tasks were determined concerning the interaction with everyday objects.

1. *Push*
2. *Squeeze*
3. *Tap*
4. *Move (in 3D)*
5. *Rotate*

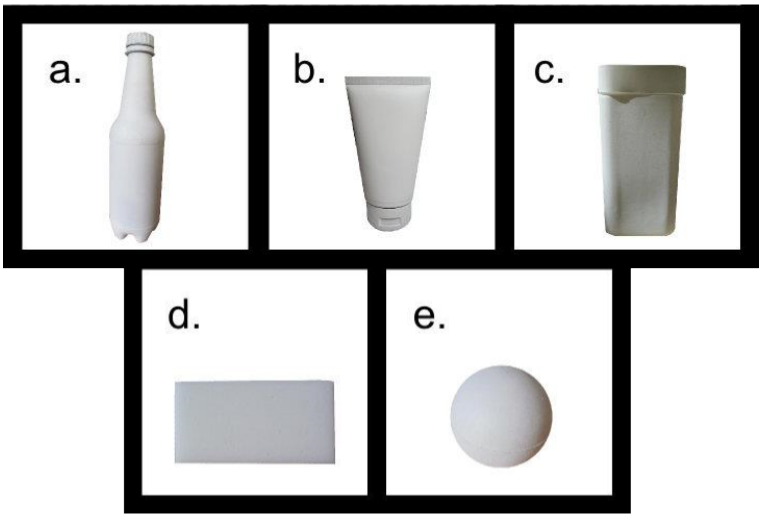


Figure 3.2: Soft objects: Bottle, Tube, Plastic Box, Sponge, and Soft ball.

6. *Slide*
7. *Squeeze and Hold*

On the following page, figure 3.3 shows all labels for each task of each design type.

3.2.1 Pilot Studies

Finding sensible labels took time.

Pilot studies test the studies procedure.

Designing the labels takes several cycles. The designs are geared to icons and affordances, which people are used to in their everyday life. In order to learn if the labels are going in the right direction or rather are understandable, some pilot studies are conducted. The pilot studies were also necessary to test whether the procedure of the first user study is convenient or not. The next chapter of the thesis deals with the first user study, which evaluates the signifiers' design.

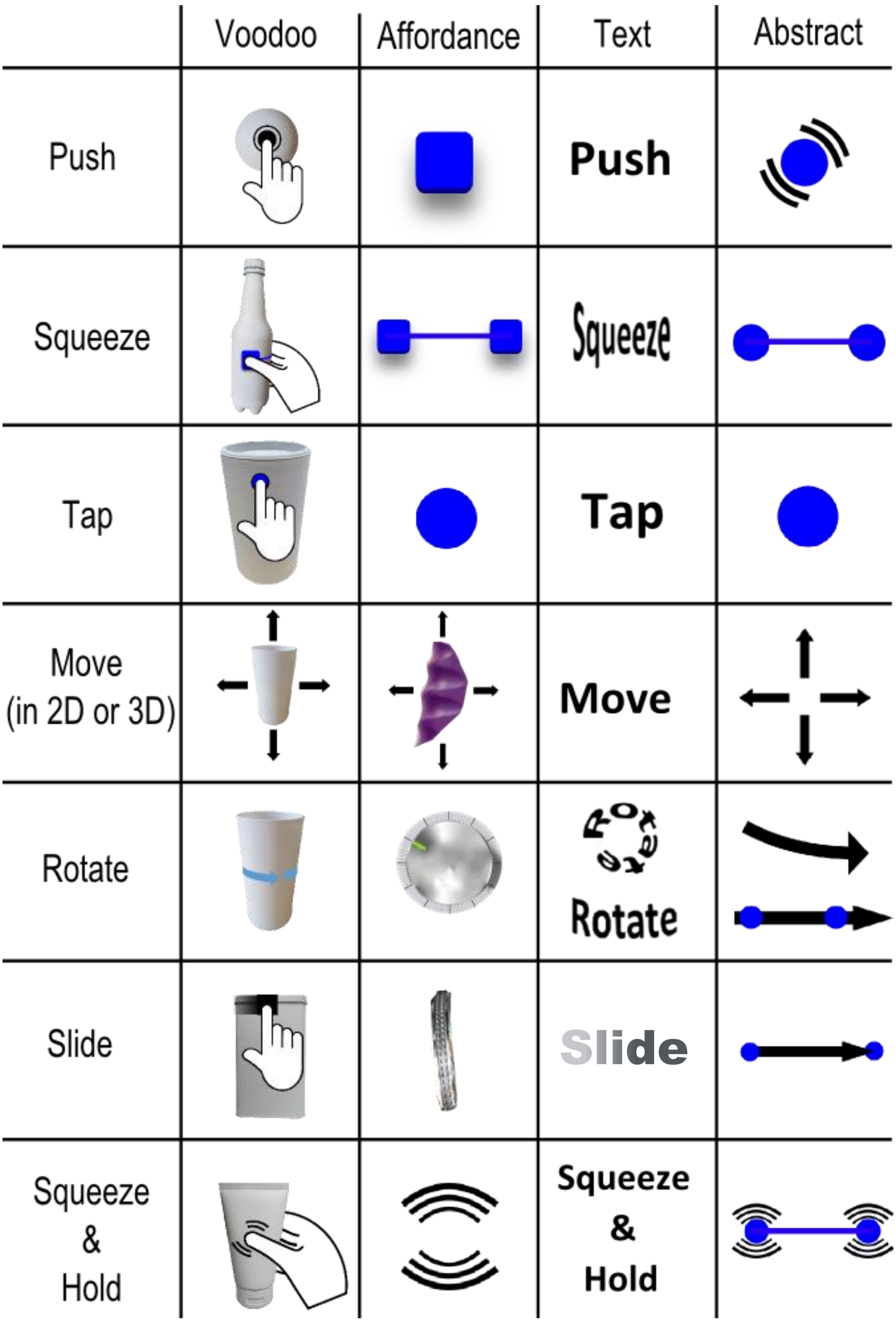


Figure 3.3: Overview of all signifiers for each design type.

Chapter 4

First User Study

After designing signifiers and conducting the pilot studies, the first user study gets prepared. In this study paper prototype labels are used, which are able to be adhered to the everyday objects and are removable again. The studies goal is to find a tendency which labels work best for the users and to improve the labels accordingly to the users' feedback. The improved labels are analysed in a second user study, in which the labels will be projected in order to provide dynamic change of the labels.

First study makes use of paper prototypes to identify the most understandable design.

4.1 Research Questions

- What design of signifiers' helps users best to understand how to repurpose an object?

  a. Voodoo design
  b. Affordance-based design
  c. Text-based design
  d. Abstract design

- How to communicate where to execute a gesture on the object?

4.2 Hypothesis

Definition: *Hypotheses of the first user study*

HYPOTHESES OF THE FIRST USER STUDY:
H1: Different types of signifiers explain the user how to repurpose an object with various degrees of success.

H2: Signifiers of Voodoo design and Abstract design are more precise and easier to understand for the user.

4.3 Experimental Design

The study is within-subject.

The study is within-subject to achieve a result that is as significant as possible and we suppose that the learning effect is not a big issue in this task. Therefore, all participants need to test all relevant objects and their according signifiers.

The order of testing the designs is randomised.

In order to guarantee a significant result the order of the four designs in which each participant tests the signifiers is randomly assigned to each participant. During the experiment snacks are provided because breaks of approximately five minutes are necessary due to the change of paper prototypes labels on the objects.

4.3.1 Hardware Setup and Surrounding

- Ten everyday objects (as listed in table 3.1).
- Labels for all four types of signifiers according to the task and the everyday object they belong to (figure 3.3)
- A quiet room, where the participant is able to test the labelled objects without any interruption from outside that could influence her.

4.3.2 Experimental Procedure

First of all, all relevant objects including the eligible paper prototype, signifiers the questionnaire and the experiment setup were prepared. The whole questionnaire can be viewed in appendix B, figures B.3-B.10.

All components for the study need to be prepared.

When the participant entered the user study room, she was requested to inscribe her details, i.e. age, sex, and if she is right-or left-handed. Secondly, the participant was asked to sign the consent form and if she approved to be recorded. Recording is important for the reason of good evaluation after the experiment. The next step adhered explaining the participant the task of the study and what she is expected to do. I.e. explain the 'Think Aloud' method and that they should execute the task intuitively. The participant got to know the used everyday objects by presenting the unlabelled objects to them before starting the experiment.

The users were informed about the studies procedure and what they are supposed to do.

At this point the experiment itself began as the participant received the first object with a suitable label. During the whole experiment the participant was always observed what she was doing with the labelled objects. As explained before, in the experiment the participant said out loud what she thought according to the 'Think Aloud' method. In order to be able to evaluate the experiment later on, notes were taken if the expected task has been executed or not and where the participant touched the objects. When the participant had finished an object she received the next labelled object.

Each object was tested with all sensible tasks by the users.

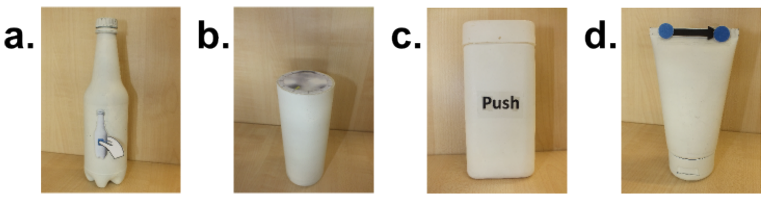


Figure 4.1: Examples of labelled objects during the study: (a.) Voodoo design label *Squeeze* / (b.) Affordance-based design label *Rotate* / (c.) Text-based design label *Push* / (d.) Abstract design label *Slide*

The users' actions were observed.

At this point, everything from observing the participant while she is interacting with the object was repeated for each signifier of one design. After all signifier of one design have been examined, I handed the according part of the questionnaire out to the participant. While the participant filled out the questionnaire, I was able to change the labels of the objects to test the next type of signifiers. The described experiment procedure was repeated for all four designs of signifiers.

Users had to answer a questionnaire.

In the end the participant was requested to answer the last questions of the questionnaire, which deals with the comparison of all four designs. This comparison is important to analyse the results properly.

4.3.3 Independent Variables

In this first user study three independent variables are defined, which represent the input of this study:

1. Type of design for the signifier with four different conditions:
   a. Voodoo design
   b. Affordance-based design
   c. Text-based design
   d. Abstract design
2. The everyday objects that are repurposed (as listed in table 3.1).
3. The tasks or rather gestures that are intended to be executed by the participant with each object. Sensible combinations of the tasks and the everyday objects are chosen, which cover all possibilities. This distribution leaves out similar ones in order to decrease the tasks the participant needs to perform (appendix B. figure B.1).

4.3.4 Dependent Variables

The dependent variables of the first user study are the following ones:

1. The understandability of the labels by the participant.
2. The participant's handling of the gestures.
3. The according effect of an executed gesture.

4.4 Subjects

Twelve participants, six female and six male, aged 18-26, took part in this study. The participants' mean age is 22.25 and the standard deviation amounts to 2.3. One female and one male are left-handed, five of each sex are right-handed. Ten of the testers are studying computer science in various semesters. The remaining two are studying medicine and psychology. Consequently, ten participants have a meaningful background in computer experience. Still the other two do have basic computer experiences, mainly with the internet and word processing. All participants were familiar with the shapes of used everyday objects and the objects itself. None of the students has repurposed everyday objects as controllers before.

The participants' age range is 18-26.

All participants have basic experiences with computers.

4.5 Results

With the help of the participants' feedback during the experiment, the video recordings and the questionnaire's answers, the results of the study were evaluated. The video recordings of the experiment sessions were really helpful in case I could not note everything the participant said during the experiment in detail. Especially because they were asked to speak out loud their thoughts according to the 'Think Aloud' method, much information could be collected.

The study was evaluated with the help of the video recordings, the questionnaire and the notes during the study.

The Likert-Scales are evaluated by statistical values and statistical methods.

All Likert-Scales and the points, with whom the participants rated the several labels, were analysed with several statistical methods. The Likert-Scales overall points are summarised for each design type concerning the aspect of how well the labels communicate the intended actions. The participants were asked to rate how strong they agree or disagree. The participants put the Text design first, second is the Abstract design before the Voodoo design and on the fourth place is the Affordance design. The exact points can be seen in figure 4.2. For each design the

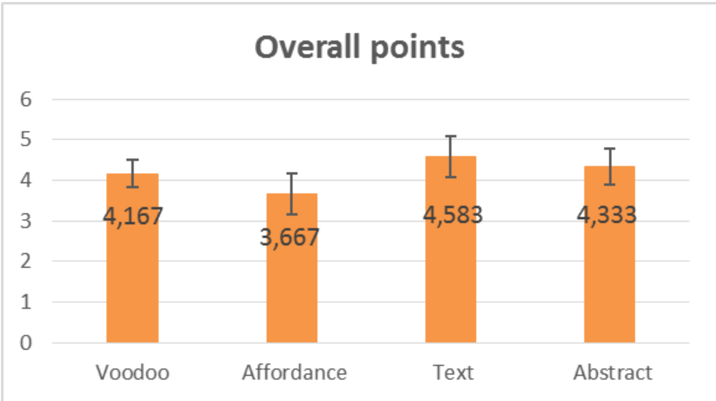


Figure 4.2: Mean overall points and confidence intervals of designs according to the users' rating.

participants also gave points from 1 (not good at all) to 5 (very good) for each label and also named feedback and ideas how to improve labels or why certain labels are not well designed. The following abstracts discuss the results for each of the four designs in detail. For establishing the best design the arithmetic mean, the standard deviation and the confidence interval are calculated.

Best label is *Tap*, followed by *Push* and *Rotate*. *Squeeze* and *Squeeze and Hold* cannot be distinguished.

Voodoo design In the Voodoo design (figure 4.3) the best label is *Tap*, the second place is shared between *Push* and *Rotate*. The worst rated label is *Squeeze*. General improvements for the labels of this design are the following ones: The *Rotate* label should better be without the dots because they mostly distracted the participants from the label's meaning. The tasks *Squeeze* and *Squeeze and Hold* could not be distinguished by the labels. Usually the participant decided by chance which label should represent which of the two tasks.

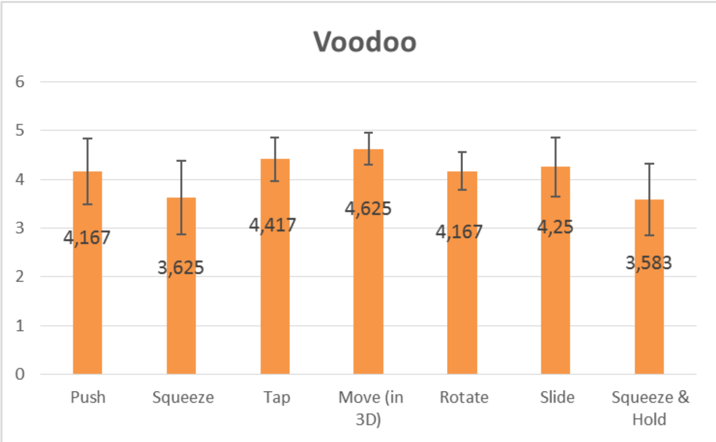


Figure 4.3: Mean points and confidence interval for each label of Voodoo design.

Affordance-based design The Affordance-based design (figure 4.4) shows another ranking: The *Rotate* label gets the most points concerning understandability, second comes the signifier for the task *Move (in 3D)* and on the third position is the *Push* label. The label for *Squeeze and Hold* is identified worst but *the Squeeze* label only scored slightly more points. Again, an argument to reconsider the design of those two tasks completely. Even if the design for the *Move (in 3D)* signifier comes second, most participants suggest to delete the purple handle from the label. They state the arrows are enough to understand the intended action.

The label for *Rotate* scores most points.

Again, *Squeeze* and *Squeeze and Hold* cannot be distinguished.

Text-based design The Text-based design (figure 4.5) is very comprehensible for all users. The tasks *Tap*, *Squeeze* and *Rotate* share the first place, shortly before *Squeeze and Hold* on the second position. The signifier for *Slide* comes third. As mentioned before, all users know exactly what the signifier asks them to do but only because all of them can speak and understand English. In one of the pilot studies I have undertaken the study with a non-English speaking

The user must speak the labels' language.

The *Tap*, *Squeeze* and *Rotate* labels share the first place.

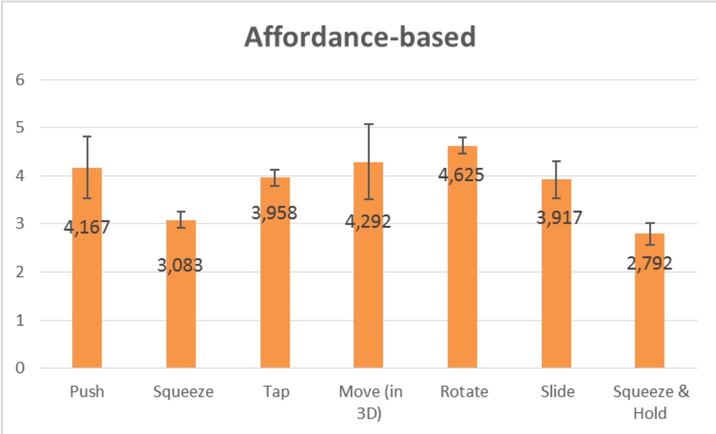


Figure 4.4: Mean points and confidence interval for each label of Affordance-based design.

person who naturally has problems conducting the asked actions. Therefore, I prefer icon-based signifiers to assure people despite of the spoken language are able to repurpose the everyday objects.

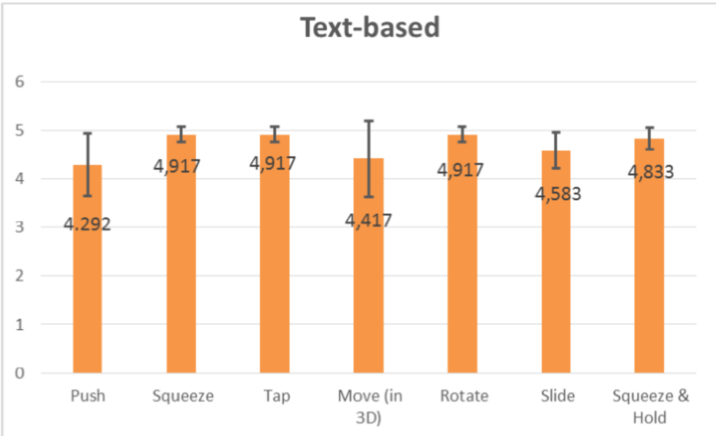


Figure 4.5: Mean points and confidence interval for each label of Text-based design.

Abstract design In the fourth design, the Abstract one (figure 4.6), the signifier for *Slide* comes first. After that follows the *Tap* signifier on the second place before the one for *Move (in 3D)*. The least understandable label is the one for

Rotate, whose rating has to be distinguished due to the fact that for *Rotate* two different signifiers were designed, which can also be seen in the overview in figure 3.3. In contrast to the arrow with the blue dots, which are reviewed poorly by the users, the arrow itself is rated very well. Thus, I have to reduce the design space for this task to only one label, namely only the arrow itself.

The label for *Slide* scored the most points, the *Rotate* label came last.

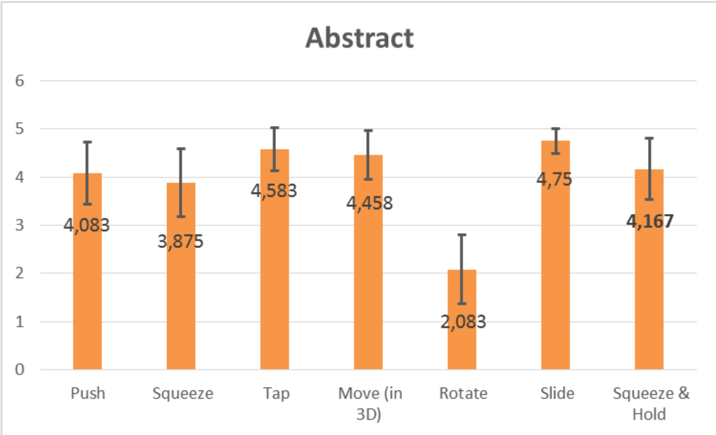


Figure 4.6: Mean points and confidence interval for each label of Abstract design.

Touching points By taking notes during the experiment and by viewing the recordings of the sessions a tendency where the participants touch the objects is identified.

In the Voodoo design for the tasks *Tap*, *Push*, *Squeeze* and *Squeeze and Hold* the users predominantly conduct the action directly on the signifier. For the remaining three tasks they perform the action in relation to how they are visualised on the signifier label.

The points of contact with the everyday objects depend on the gesture and the design.

When the objects are labelled with the Affordance-based design the users execut the tasks on the spot where the signifiers are placed.

In the Text-based design no tendency is able to be identified which signifiers influence the users to execute the action on the signifier itself or somewhere diverse on the object.

In contrast thereto, in the Abstract design the same tendency as for the Affordance-based design is detected: users tend to execute all tasks at the spot where the signifiers are placed.

4.5.1 Justifying the Results

Chi-Square test was used to evaluate the Likert-Scales.

As already mentioned in the beginning of the result paragraph, statistical methods to evaluate and verify the results are consulted, i.e. verifying a significant difference between the designs to verify the best one. Due to the fact that I use Likert-Scales in my questionnaire the Chi-Square test is applied in the first step. In the study's questionnaire the participants are asked to decide which signifiers work best for which task after they get to know all designs. The results of this ranking are the basic data to evaluate whether a significant difference between the designs exists or not.

Statistical Tests

H0 assumes the following:

Definition: *H0 hypotheses for statistical test*

H0 HYPOTHESES FOR STATISTICAL TEST:
H0: There is no significant difference between the four designs.

Based on the Chi-Square test analysis' there exists a significant difference between the designs.

The level of significance alpha is 0.05. By applying the Chi-Square test to all four designs at the same time the critical Chi-Square value constitutes clearly less than the calculated Chi-Square value. The critical value is 28.869 and the computed value is 35.516. Therefore H0 has to be rejected, i.e. there exists a significant difference between the four designs. The next step is to find out how strong this difference is and into which direction. The goal is to reveal the best working design.

Users prefer the Voodoo design.

Pairwise comparison of the designs with a Friedman test between all preferences of all users reveals the fact that users prefer the Voodoo design the most. Additionally, the test states that there exists a significant difference between Voodoo design and Affordance-based design: the Voodoo design is favoured. The exact values are listed in table 4.1.

To underline that the users prefer the Voodoo design a closer look at the ranking diagram is helpful:

By having a look at figure 4.7 it is apparent that the Voodoo design is better than the Abstract one in four cases, in two they are even and in one Abstract is better than

Design 1	Design 2	p-value (adjusted value)
Affordance	Abstract	1.0 (n.s.)
Affordance	Text	1.0 (n.s.)
Affordance	Voodoo	0.005
Abstract	Text	1.0 (n.s.)
Abstract	Voodoo	0.161 (n.s.)
Text	Voodoo	0.239 (n.s.)

Table 4.1: Pairwise comparison of all four design types concerning significant difference with the help of the Friedman Test.

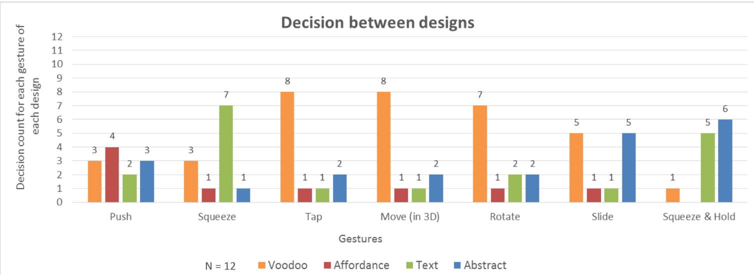


Figure 4.7: The users had to decide for one design for each task. This diagram shows the absolute points of each design. The table is shown full-size in appendix C, figure C.6.

Voodoo. This result leads to the assumption that there exists a difference between those two designs: the Voodoo design might communicate better than the Abstract one. Generally, neglecting the Text-based design because of the language concern, figure 4.7 displays that the Voodoo design is the most understandable for four tasks: *Squeeze*, *Tap*, *Rotate* and *Move (in 3D)*. Taking Text-based signifiers into account Voodoo is still ranked best for three tasks. In both cases, it is ranked as good as the Abstract design for the task *Slide*.

The Text-based is not chosen due to the language concern.

Also the Abstract design is ranked better for five tasks compared to the Affordance design. Hence, for the users Abstract design is better than Affordance design but as aforementioned design is even better than the Abstract one.

All in all, research question one can be answered with the first user study: design a., the Voodoo design, explains

The Voodoo design is preferred and thus, the first research question is answered. Voodoo users best how to repurpose the everyday objects as controllers. For the second question a tendency can be revealed in the user study.

H1 must be retained.

The H1 hypothesis can be proved by the data that was collected in the first user study: The four designs work differently well. Analysing the users' ratings the Voodoo design is preferred the most and works best: The Voodoo design holds a significant difference towards the Affordance-based signifiers. However, the Text-based design would be the most suitable if all people do understand the signifiers' language. H2 can be proved for the Voodoo design it is preferred over the other designs. In contrast, for the Abstract design H2 cannot be proved.

H2 must be retained for the Voodoo design.

4.6 Lessons Learned to Redesign the Signifiers

Some labels need improvement concerning their visualisation.

As already evaluated the Voodoo design is the most understandable and the best working visualisation for the signifiers. Nevertheless, the labels need some improvements, especially those labels for the tasks that are not ranked first in the user study in the comparison diagram. Consequently, *Squeeze*, *Slide*, the *Rotate* and the *Squeeze and Hold* label design must be revised. For the *Push* label teh points are more or less the same for the four designs. Even if the Affordance design scored most points tightly, the label for *Push* of the Voodoo design is retained to achieve having labels of the same design type for all tasks. For the redesign the participants' feedback and ideas to improve the labels are applied to the individual signifiers:

The labels for *Squeeze*, *Slide*, *Rotate* and *Squeeze and Hold* are redesigned.

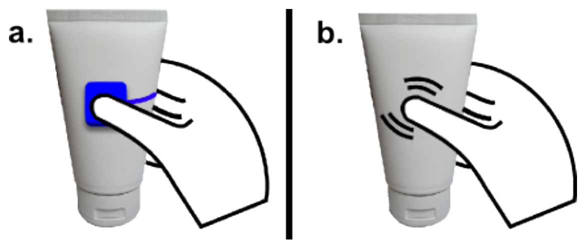


Figure 4.8: (a.) Old *Squeeze* signifier./ (b.) Redesigned *Squeeze* signifier.

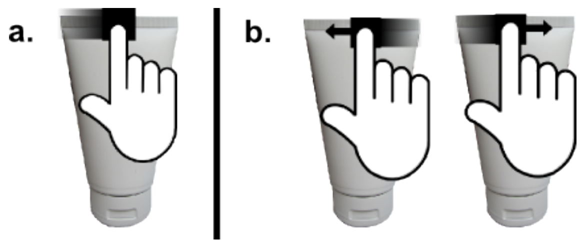


Figure 4.9: (a.) Old *Slide* signifier./ (b.) Redesigned *Slide* signifiers.

- ***Squeeze***: Most participants executed the Squeeze task with the intended *Squeeze and Hold* signifier. The *Squeeze* signifier was not clearly understandable, consequently the former *Squeeze* label is substituted by the *Squeeze and Hold* label (figure 4.8).
- ***Slide***: The first kind of design did not indicate properly in which direction the user is supposed to slide. This is improved by arrows that indicate this direction (figure 4.9).

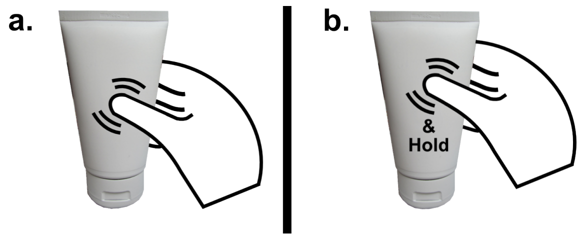


Figure 4.10: (a.) Old *Squeeze and Hold* signifier./ (b.) Redesigned *Squeeze and Hold* signifier.

- ***Squeeze and Hold***: During the study it became clear that it is really difficult to communicate the task Squeeze and Hold only with the help of an icon or symbol. The Text-based signifier is understandable. On this basis the redesigned label combines an icon and text. Even if labels without text are preferred due to the language problem this case is a sensible exception to communicate the task (figure 4.10).

As a compromise the label *Squeeze and Hold* is visualised with text to assure it is understandable.

- ***Rotate***: During the study it became apparent that the label for rotate tells the user to rotate the object. It was interesting to observe that there exists the tendency

A hand helps indicating where rotation should take place.

that users touch the object in order to rotate it proportionately to where the arrow is sketched. Several participants state the idea of underlining at which spot to rotate the bottle by adding a hand symbol that touches the object in the signifier. During the execution of the study it became clear that such a hand attracts the user to touch the object where the hand is displayed. The improved design is shown in figure 4.11.

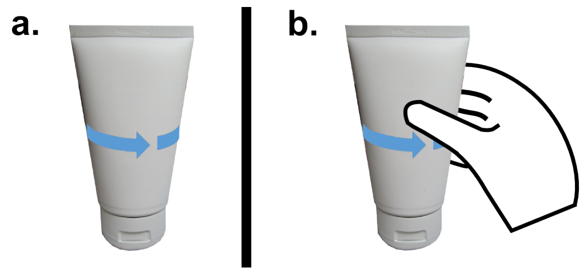


Figure 4.11: (a.) Old *Rotate* signifier./ (b.) Redesigned *Rotate* signifier.

4.7 General Lessons concerning Signifiers

Apart from the design of the signifiers, the following statements sum up important observations for the general use of signifiers:

There exists a tendency where a certain gesture is executed.

- Users tend to execute the task *Tap*, *Push*, *Squeeze* and *Squeeze and Hold* at the position of the according signifier.

Hands on the labels indicate where to perform a gesture.

- Users tend to execute the remaining tasks *Slide*, *Rotate* and *Move* proportionately to where they are represented on the signifier.
- Hands on the labels support the user to understand what she is supposed to do.

The next chapter deals with a second user study that investigates the usage of signifiers to display how to manipulate an everyday object in a real use-case scenario.

Chapter 5

Second User Study

In the first study I evaluated the best working design of the signifiers to communicate the intended actions. With the results I redesigned the labels in order to improve them as effectively as possible.

Paper prototypes as signifiers are not the best way to connect the signifiers to the everyday objects. Thinking about the way how to visualise signifiers the idea of animated labels turns up. Animated labels describe the representation of the signifier in a little video animation instead of a static label. In the first user study only static labels are considered. The following question arises: Can animated labels improve the understandability of signifiers? To investigate this question the aim is to develop, prepare and execute a second user study that is capable of evaluating the benefit of signifiers more interactively. The signifiers are going to be projected onto the everyday objects. Additionally, with a projector the idea of animated labels can be processed and projection enables displaying the signifiers dynamically. A dynamic change of signifiers assures that the everyday objects keep their appearance and still can be used in the usual manner because no labels are stuck onto the objects.

Animated labels visualise the gesture in a little video animation.

The first study analysed static labels.

Projection enables changing the labels dynamically.

5.1 Interactive Prototype

According to the idea of an interactive prototype a substantial use case is needed, which represents a scenario where repurposed everyday objects, equipped with signifiers, function as controllers. The following scenario is chosen: With the help of an everyday object light bulbs are controlled. In this scenario the light bulbs are Philipps Hue system light bulbs. This system enables the possibility to manage the light bulbs in matters of brightness, colour and saturation and on/off control. Managing this is possible via communication with wireless Lan: A so-called bridge communicates with the light bulbs by identifying them via IP-address. More precisely: every time the user commands a certain action for a bulb, this command is assimilated by the bridge and subsequently send to the respective bulb.

The light bulbs of the Philipps Hue system should be controlled in the user study.

The Philipps Hue system works via WLAN.

Apps are available for Android and iOS smartphones which facilitate the user to control the Philipps Hue system and the electric lighting in the user's home. Philipps Hue is able to perk up and represent individual atmospheres in people's homes. Realising the scenario into an interactive and working prototype needs implementation and designing work.

The realisation of an interactive prototype requires four main aspects that need to be accomplished:

A suitable program controls the effects of the Hue light bulbs. The interactive prototype requires four key aspects.

- A suitable implementation with whom the Philipps Hue light bulbs can be managed and manipulated. I decided to leave out the option of changing the saturation for the interactive prototype. Thus, the program has to implement the ability to change colour, brightness and on/off control.
- A choice of everyday objects, which function as controllers to manipulate the light bulbs).
- Suitable signifiers that label the choice of everyday objects and display how to manipulate them to manage the light bulbs. Signifiers will be realised in a static form and in an animated one. For displaying the signifiers onto the objects a projector is used. Pro-

jection enables dynamic and easy change of the signifiers.

- Icons or text that indicate the effect of a signifier and the according gesture. Indicators respective brightness, colour and if a light bulb is switched on or off are necessary.

The following sections describe each of the named aspects.

5.1.1 Implementation in Objective-C

The goal of the implementation is a working program that interacts with the hue bridge and with the light bulbs via the bridge. Brightness and colour manipulation should be possible. The whole implementation is done in Objective-C to allow reusing the code in later projects and it is implemented with the help of the tool Xcode.

The program is implemented in Objectiv-C.

Philipps provides an example implementation for the Philipps Hue system and with the help of this implementation a connection to a Philipps Hue bridge can be established. Therefore, it is indispensable to assure that the computer and the hue bridge are within the same network.

The example app is used to get an easier and quicker start with the manipulation of the Philipps Hue light bulbs. Options to change the brightness, colour and on/off status of the light bulbs are implemented. Therefore, it is important to obtain the actual status of the light bulbs concerning colour, brightness and if the bulb is on or off in order to manipulate the bulbs realistically.

The program includes options to change colour, brightness and if the light bulb is switched on or off.

5.1.2 Choice of Objects

As a follow up of the first study the idea is to take one everyday object out of the pool of the first user study objects. When choosing the object it was necessary to ponder which of the objects is able cover most gestures reasonable. As a result it is determined that a bottle can fulfill a wide

Bottles are used in this study because they cover a wide range of gestures.

range of gestures. Additionally, bottles are everyday objects that are common in our daily life. As mentioned before, in the second user study teh goal is to investigate the impact of animated labels. In this context the idea arises that animated labels can have a different impact on soft and on rigid objects. Thus, I went to find two bottles of the same shape, one soft or rather deformable one and one rigid one. To assure no distraction happens by the outer look of the bottles, both were painted with white colour. Besides, white painting ensures displaying the signifiers with the projection looks reasonable because a white background is a neutral colour (figure 5.1).

Animated labels might act differently for rigid and soft objects.

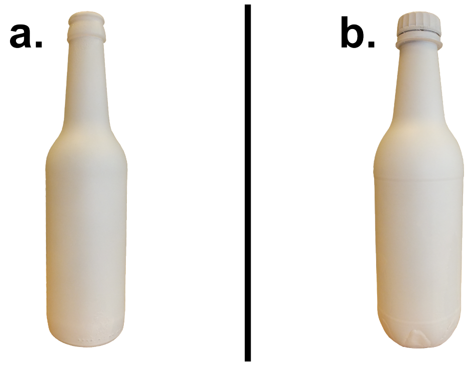


Figure 5.1: (a.) Rigid glass bottle. / (b.) Deformable plastic bottle.

5.1.3 Signifiers

Two types of signifiers are important in the second user study: static signifiers and animated signifiers. For the static signifiers I refer to the labels of the first user study. In fact the redesigned signifiers are used with the change of the basic colour to red because a white label on a white object is apparently no good option. The indications on the white labels are no longer black, they are coloured yellow.

Static and animated signifiers are used in the second study.

In figures 5.2 and 5.3 a choice of red coloured static labels for the deformable bottle and the rigid bottle are presented, figures 5.4 and 5.5 show a choice of red coloured animated labels for the deformable bottle and the rigid bottle. A

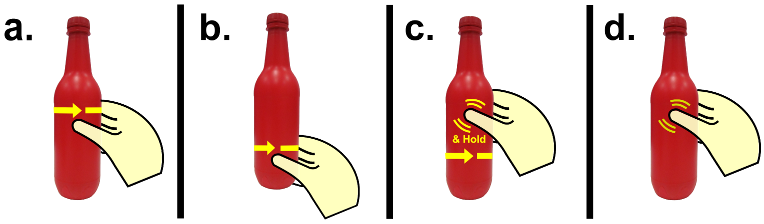


Figure 5.2: Signifies of the deformable static scenario.

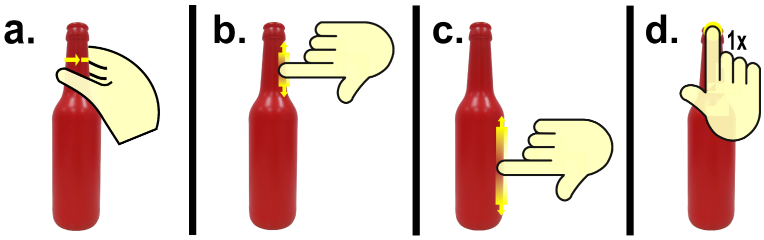


Figure 5.3: Signifies of the rigid static scenario.

whole overview of the static and animated labels may be viewed in appendix D.

While designing the animated labels it is necessary to visualise them as connatural to the static signifiers as possible. Key aspects need to be shown in the same method, i.e. the yellow indications on the static and animated labels on the red bottle need to coincide. I recorded short videos which show the signifier and the according gesture to achieve the desired effect.

Animated and static labels have to match concerning the main components of the visualisation.

Figure 5.4: Cuts of the deformable animated signifier for the gesture *Push*.

Figure 5.5: Cuts of the rigid animated signifier for the gesture *Rotate*.

5.1.4 Indicators for Effects

During the process of repurposing everyday objects the users need to be informed about the effect at the technical device after a performed gesture. Accordingly, for controlling the Hue light bulbs indicators are created.

Indicating the effect of turning a light bulb on or off is displayed by a light bulb icon. This light bulb icon is either a light bulb without any colour filling (figure 5.6 a.), indicating a switched off bulb or a yellow light bulb (figure 5.6 b.), notifying it is switched on.

Suitable icons that indicate the effect of the gestures are created.

Signalising brightness requires the usage of the icons in combinations. Firstly, the mentioned yellow light bulb from before is applied for the effect of turning up brightness and a yellow light bulb with shorter rays indicates shading the brightness (figure 5.6 c.). As a second option to indicate shading the brightness light bulb in figure 5.6 a. is used. The last effect that needs to be displayed is modifying the colour. A colour range icon which represents the colour spectrum of the hue light bulbs is applied for showing the user that the colour is meant to be modified (figure 5.6 d. shows the horizontal and the vertical version of the spectrum).

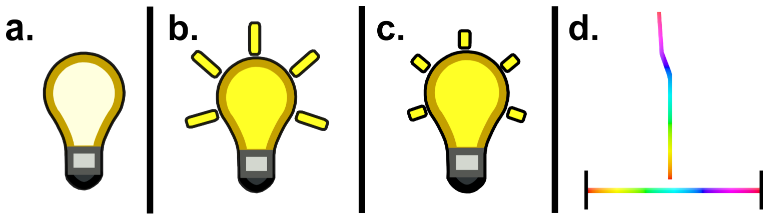


Figure 5.6: Icons to indicate the effects.

After preparing all aspects that are essential for the second user study, the following sections describe the study design, its execution and analysis.

5.2 Second User Study

In a second user study the aim is to investigate the impact of animated labels in contrast to static labels. Therefore in a use case scenario the labels are projected onto everyday objects to signify the users how to repurpose the object as controller.

The second user study evaluates the effect of animated labels.

5.2.1 Research Questions

- Do animated labels lead to fewer errors(*) for everyday object interaction (manipulation) compared to using static labels to signify the interaction (manipulation) options?
  (*) an error is referred to a wrongly performed gesture - i.e., a different gesture than the intended one by the label that is displayed

5.2.2 Hypothesis

HYPOTHESES OF THE SECOND USER STUDY:
H1: For **rigid** objects, using animated labels does **not** lead to fewer errors compared to static labels.

H2: For **deformable** objects, using animated labels lead to **fewer** errors compared to static labels.

H3: For **rigid** objects, users do **not** prefer animated labels over static labels.

H4: For **deformable** objects, users do **prefer** animated labels over static labels.

Definition: *Hypotheses of the second user study*

5.2.3 Experimental Design

The second user study is within-subject.

The second user study is again within-subject to achieve a significant result. To assure that the learning effect does not take place in this user study four different scenarios are created. According to the within-subject design, each participant has to test all four scenarios and their according signifiers.

Hardware Setup and Surrounding

- A table and a chair. The user sits on a chair in front of the table (figure 5.7).

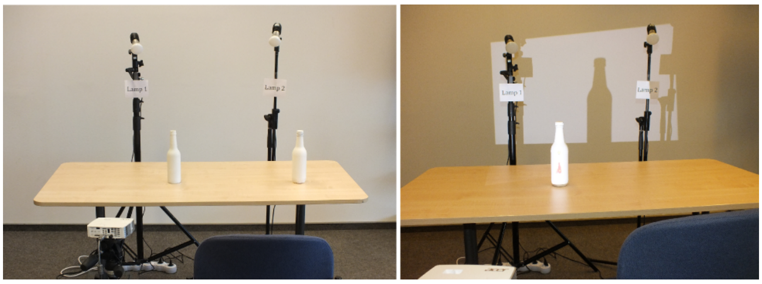


Figure 5.7: Left: Set up and surrounding of user study. / Right: Displaying a signifier in the experiment setup.

- An Acer projector that is placed next to the user in order to project the labels onto the objects.
- Two hue light bulbs, which are placed behind the table, assuring that the user has a free view towards them.
- Two everyday objects consisting of a rigid glass bottle and a deformable plastic bottle (see above figure 5.1).
- Two set of labels, one for static and one for animated signifiers according to the tasks and the bottles.
- A quiet room, where the participant is able to test the labelled objects without interruption from outside that could influence her.

- Four different scenarios, two for the rigid bottle and two for the deformable bottle. Figure 5.8 displays the two scenarios for the rigid bottle and 5.9 the two scenarios for the deformable bottle including the according gestures.

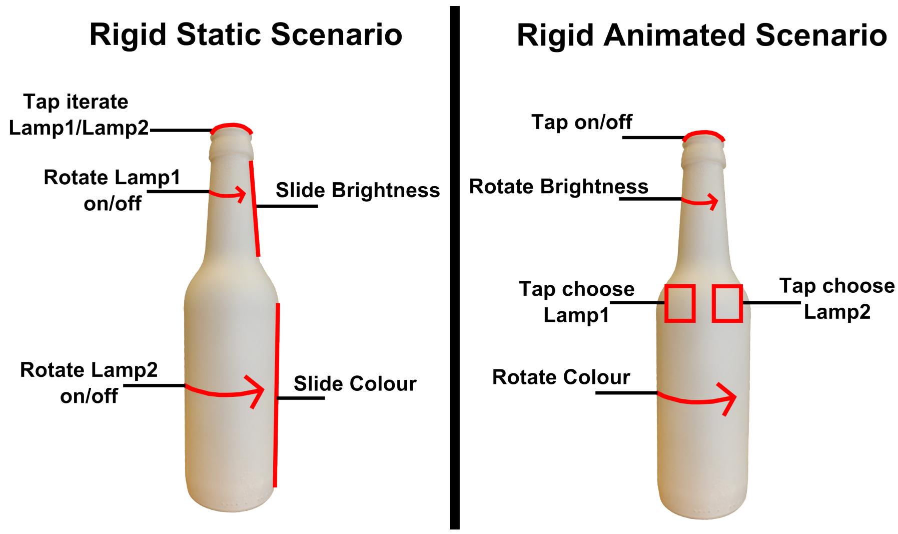


Figure 5.8: The two scenarios for the rigid bottle.

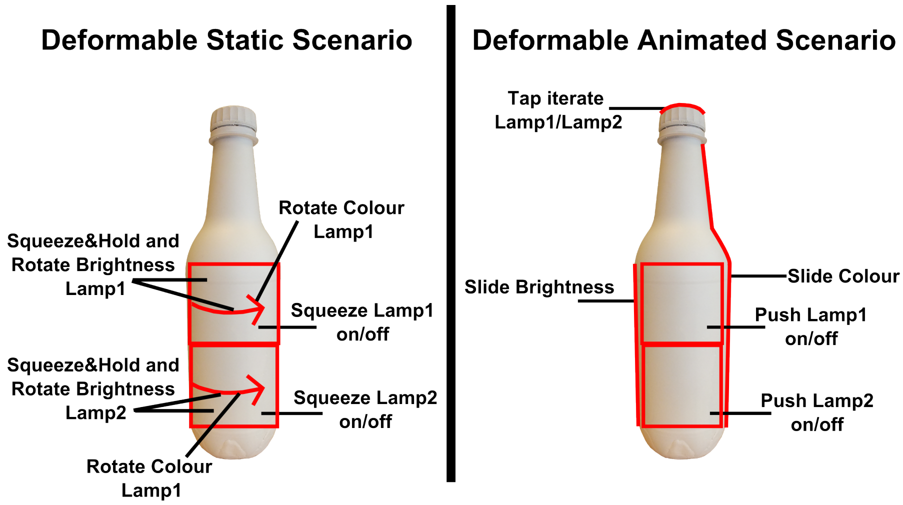


Figure 5.9: The two scenarios for the deformable bottle.

Experimental Procedure

Details and procedure of the second study is explained to the participant.

The experimental procedure was tested in a pilot study to assure a convenient procedure. First of all, the user took place at the table on the chair and saw the two Hue light bulbs in front of him. The user was introduced to the study and asked to read and to fill out the consent form. By signing the form the user agreed to recording the study and therefore, recording the study started from that point on.

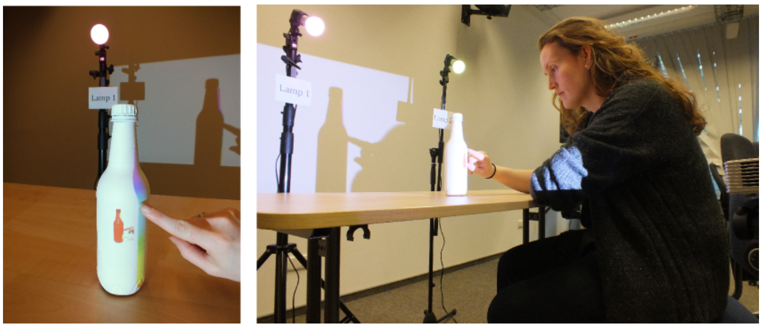


Figure 5.10: Participant executes a task with the deformable bottle to change the colour of a light bulb.
Left: Participant's view / Right: Overview of complete scenario

The study involves the 'Think Aloud' method.

In order to assure that the user understood how the study is proceeded procedure and further details were explained again. Hence, the two everyday objects were presented to the user in order that the participant got to know how the objects feel like. Next, the hue light bulbs were introduced to the user and the idea of manipulating the light bulbs with the help of the bottles. The participant was asked to speak out what she thought according to the 'Think Aloud' method. Getting to know the participants' thoughts helps evaluating the use of animated vs static labels.

The Latin Square was used to randomise the order of the scenarios.

After all question were answered the first scenario started. The four scenarios were randomised with the help of a Latin Square. Thus, four groups were generated, which test the scenarios in different orders. While executing the scenarios each task of the scenario was presented after the

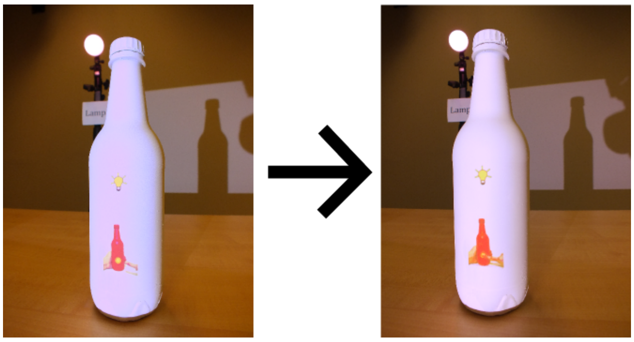


Figure 5.11: Projecting animated task *Push* and effect icon onto the deformable bottle during the study.

other. After naming the task the according signifier and effect were displayed via projection onto the object. While displaying the signifiers, the user were asked to execute the task how she thought she was supposed to do it according to the shown signifier and effect. During the whole time I observed the participant's actions. Ensuring that the user believed she really manipulated the light bulbs was important for a sensible study performance.

Figure 5.12: Participant executes a task with the rigid bottle to control the light bulbs.
Left: Participant's view / Right: Overview of complete scenario

The study was executed with the help of the 'Wizard of Oz' scheme.

In fact, the interaction and effect at the light bulbs was imitated according to the 'Wizard of Oz' scheme. The effect of the executed task was adapted for the according light bulb. The order of the tasks was different for each user to assure a reasonable result. The steps were repeated until all tasks of the first scenario were finished. The other three scenarios were performed in the same way. After all scenarios were executed, the user was asked to fill out the corresponding questionnaire which evaluates the users' preferences.

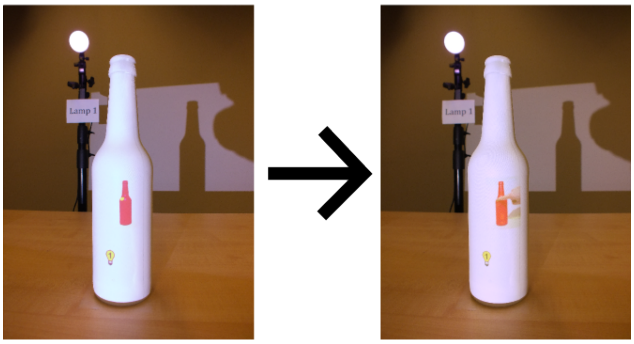


Figure 5.13: Projecting animated task *Tap* and effect icon onto the rigid bottle during the study.

Independent Variables

In this user study the following independent variables are necessary:

1. Objects:
   - Rigid bottle
   - Deformable bottle
2. Gesture sets:
   - Gestures for the rigid bottle
   - Gestures for the deformable bottle
3. Rigid gestures := *Tap*, *Rotate*, *Slide*
4. Deformable gestures := *Push*, *Squeeze*, *Tap*, *Rotate*, *Slide*, *Squeeze and Hold*
5. Label sets:
   - Labels for rigid bottle
   - Labels for deformable bottle
6. Task: depend on Object x Gesture x Label

7. Scenarios:
   - Two scenarios for the rigid bottle
   - Two scenarios for the deformable bottle

Dependent Variables

In this study's context three dependent variables exist:

1. The error count for each gesture in each scenario that consists of the frequency and the gesture type.
2. The users' preferences concerning what label method they find the most understandable.
3. The users' preferences concerning what label method they like the most.

5.2.4 Subjects

All participant have basic experiences with computers.

Participants are familiar with the everyday objects.

Sixteen participants, eight female and eight male, aged 19-53, took part in this study. The participants mean age is 26.44 and the standard deviation amounts to 10.19. None of the participants is colour-blind. One female and one male are left-handed, seven of each sex are right-handed. Eight participants are studying computer science in various semesters. The remaining six either study business studies, geography or are working full-time. Consequently, eight participants have a meaningful background in computer experience. Still the others do have basic computer experiences, mainly with the internet, word processing and other tools, which are handy in everyday life. All of them are familiar with the use of technical devices like smartphones. Smartphones need to be operated by certain gestures, mainly touch events, as well. All participants were familiar with the shapes of the used everyday objects and the objects themselves. None of the participants has repurposed everyday objects as controllers before.

5.2.5 Results

The results are evaluated based on the questionnaire data, video recordings and observations.

In the user study data and feedback is collected concerning the understandability and preference of the scenarios with the help of a questionnaire that the participants were asked to fill out in the end. Furthermore, I observed how participants interact with the everyday objects and the signifiers and took notes about this. In order to testify whether the results of the questionnaire are significant and valid, statistical methods like the Marginal Homogeneity test are applied. With the help of the results investigating is possible whether the four hypotheses can be approved or not. The next paragraphs deal with the examination of the questionnaire.

Questionnaire

Each question will be evaluated and interpreted separately. As a reference figures E.2-E.8 of appendix E show the complete questionnaire of the second study. As H0 the following assumption is supposed:

Definition: *H0 hypotheses for statistical tests*

H0 HYPOTHESES FOR STATISTICAL TESTS:
H0: There exists no significant difference.

The level of significance alpha is 0.05.

Q1a vs. Q1b is not significant.

- Question 1a vs. 1b:
  Evaluation of animated vs. static signifiers concerning understandability: By applying the Marginal Homogeneity test the p-value adds up to 0.157. This value stands for the fact that the H0 hypothesis must be retained. No significant difference between animated and static labels for deformable and rigid objects is present concerning the aspect of understandability.

Q2a vs. Q2b is not significant.

- Question 2a vs. 2b:
  Evaluation of animated vs. static signifiers concerning favoritism: By applying the Marginal Homogeneity test the p-value adds up to 0.157. This value means that the H0 hypothesis must be retained. Again, no

significant difference between animated and static labels for deformable and rigid objects is apparent concerning what the user likes more.

- Question 1a vs. 2a:
  Evaluation of animated vs. static signifiers concerning deformable objects: By applying the Marginal Homogeneity test the p-value adds up to 0.683 and therefore, the H0 hypothesis must be retained. No significant difference between animated and static labels for deformable objects is present concerning comparing the aspects of understandability vs. favoritism.

Q1a vs. Q2a is not significant.

- Question 1b vs. 2b:
  Evaluation of animated vs. static signifiers concerning rigid objects: By applying the Marginal Homogeneity test the p-value adds up to 0.683. Consequently, the H0 hypothesis must be retained. No significant difference between animated and static labels for rigid objects is present concerning comparing the aspects of understandability vs. favoritism

Q1b vs. Q2b is not significant.

- Question 3a vs. 3f:
  By applying the Marginal Homogeneity test the p-value adds up to 0.357 and therefore, the H0 hypothesis must be retained. No significant difference between the scenarios is identified. Hence, user do not prefer any scenario over the other.

Q3a vs. Q3f is not significant.

- Question 3b vs. 3e:
  By applying the Marginal Homogeneity test the p-value adds up to 0.951 and again the H0 hypothesis must be retained. This means there exists no significant difference between the scenarios. Thus, no tendency which scenario users prefer is identified.

Q3b vs. Q3e is not significant.

- Question 4:
  Ranking the four scenarios concerning their understandability: By applying the Friedman test the p-value adds up to 0.193 and the H0 hypothesis must be retained. Even if the Deformable-Animated scenario comes first, the statistical test cannot prove a statistical significant difference that this result would remain constant conducting a new study.

Q4 is not significant.

- Question 5:
  Ranking the four scenarios concerning which one the participants like most: By applying the Friedman test the p-value adds up to 0.665. This value means that the H0 hypothesis must be retained. For question 5 holds the same as for question 4: even if the Deformable-Animated scenario comes first, this result would not remain constant for a new study.

  Q5 is not significant.

- Question 6:
  Animated labels are annoying: The mean of this question is 2.5625. The mean value points into the direction that animated labels are not annoying. Still, this question has been asked to get a first impression of how animated labels appear in a user's eye. A detailed study has to be applied to examine the questions if and when animated labels are annoying for a user.

  The tendency is that animated labels are not annoying.

- Question 7:
  Animated labels are distracting: The mean value of this question sums up to 2.3125. The question 7 reveals the same impression just as question 6: with the question a first impression is revealed and this impression shows a tendency towards animated labels are not distracting for the user.

  The tendency is that animated labels are not distracting.

Compared questions of questionnaire	**Arithmetic mean**	**Standard deviation**
Q1a vs. Q1b	3	0.707
Q2a vs. Q2b	3	0.707
Q1a vs. Q2a	10	2.45
Q1b vs. Q2b	10	2.45
Q3a vs. Q3f	0.052	0.093
Q3b vs. Q3e	0.154	0.167
Q6	2.563	1.368
Q7	2.313	1.352
Q8	4.063	1.063

Table 5.1: Overview of statistical values of various questionnaire's questions in matters of the users' evaluation.

- Question 8:
  A certain amount of labels can be remembered by heart after an introduction like e.g. a tutorial: The mean value is 4.0625. The mean shows a tendency into the direction that signifiers and their according gesture can be kept in mind so that displaying the signifiers is not necessary after a while.

The tendency is that a tutorial and remembering the signifiers is imaginable.

Compared question	Used statistical test	p-value
Q1a vs. Q1b	Marginal Homogeneity test	0.157 (n.s.)
Q2a vs. Q2b	Marginal Homogeneity test	0.157 (n.s.)
Q1a vs. Q2a	Marginal Homogeneity test	0.683 (n.s.)
Q1b vs. Q2b	Marginal Homogeneity test	0.683 (n.s.)
Q3a vs. Q3f	Marginal Homogeneity test	0.357 (n.s.)
Q3b vs. Q3e	Marginal Homogeneity test	0.951 (n.s.)
Q4	Friedman test	0.193 (n.s.)
Q5	Friedman test	0.665 (n.s.)

Table 5.2: Overview of the significant difference between questionnaire's questions in matters of the users' evaluation.

As a summary all statistical values are presented in table 5.1 to gain an overview of the statistical values for the questions. Table 5.2 sums up all values concerning significant difference between various questions.

Evaluating the users preferences state that the difference between animated and static labels is not significant.

In summary reflecting the results of the questionnaire suggests that no significant difference exists between the animation of labels and their static version. Neither for deformable objects nor for rigid objects. Thus, H3 must be retained because for rigid objects users do not prefer animated labels over static labels. In contrast, H4 cannot be proved and must be rejected. Summarised, users do not prefer a type of visualisation no matter what material the object consists of.

H3 is proved and H4 is rejected.

Error Rate

Performing a gesture correctly requires executing it at the right spot and intuitively.

To reject or retain H1 and H2 the video recordings of the user study are reviewed and analysed. For each signifier of each scenario I evaluate whether the user executes the supposed gesture at the expected spot of the bottle. In doing so it is important that the user executes the gesture correctly at first sight to be able to state that the gesture is performed intuitively because of what the signifier communicates. After calculating the absolute and relative error rate for each scenario concerning each participant, statistical methods are applied to verify the error rate.
Using the Friedman test no significant difference between the error rates of the four scenarios can be proved because the p-value amounts to 0.110

The deformable scenarios hold a significant difference.

H2 is proved.

Further analysis evaluates the deformable bottle and the rigid bottle individually. Applying the Wilcoxon Signed Ranked test a significant difference between the error rates of the deformable animated scenario compared to the deformable static scenario is identified. The p-value is 0.041, which states a significant difference. The mean error rate of the animated scenario is only 5.2 percent, whereat for the static scenario the mean is 16.25 percent (figure 5.14). Therefore, for deformable objects animated labels do lead to a lower error rate concerning understandability of the signifiers and consequently H2 is proved and must be retained.

The rigid scenarios hold a significant difference.

H1 is rejected.

To evaluate the rigid animated scenario vs. the rigid static scenario the Wilcoxon Signed Ranked test is used again: In this case the p-value amounts to 0.032, which is even smaller once more the meanthan the value for the deformable bottle. Thus, between the rigid scenarios exist a significant difference and error rates indicate that the animated labels lead to fewer errors while interacting with the everyday object. The mean error rate of the rigid animated scenario is 5.4 percent and for the rigid static 14.6 percent (figure 5.14). On these grounds, H1 must be rejected because H1 claims that for rigid objects animated labels do not lead to fewer errors compared to static labels.

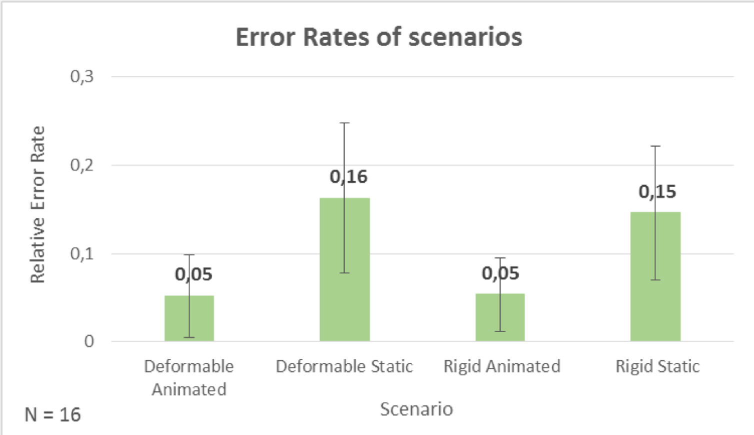


Figure 5.14: Mean error rate and confidence interval of each scenario.

However, the study finds out that for rigid objects the error rate is less for animated labels than for static labels.

Condition	**Arithmetic mean**	**Standard deviation**
Deformable animated	0.0521	0.100
Deformable rigid	0.163	0.178
Rigid animated	0.054	0.088
Rigid static	0.146	0.16
Animated labels	0.053	0.093
Static labels	0.154	0.167
Deformable objects	0.108	0.153
Rigid objects	0.1	0.135

Table 5.3: Overview of statistical values of various conditions in matter of their error rate.

So far, a significant difference between animated and static labels concerning one object, either the rigid or the deformable bottle, has been proved. Thus, the question arises if this difference is valid for animated vs. static labels in general. Figure 5.15 displays that the error rate for animated labels in general is 5 percent and for static labels

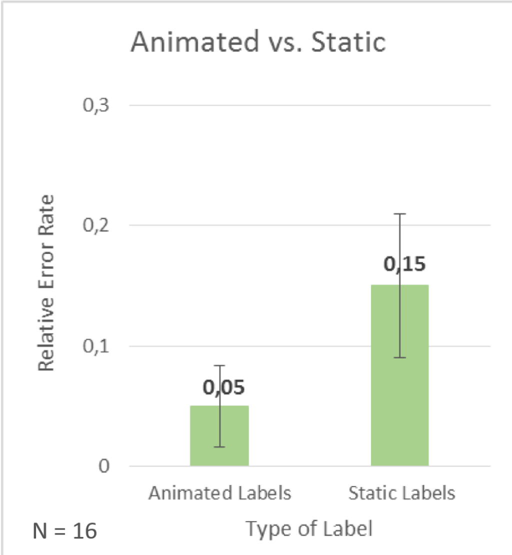


Figure 5.15: Mean error rate and confidence interval of animated vs. static labels.

Animated labels are significantly better than static labels but the difference between rigid and deformable objects is n.s.

15 percent. Wilcoxon Signed Ranked test proves once again that there exists a significant difference between animated and static labels concerning their understanding. The p-value is 0.004, nearly zero, which indicates a really strong significant difference. Applying the test to deformable and rigid objects in general produces the result of no significant difference between the objects as the p-value is 0.714.

Conditions	**Statistical test**	**p-value**
Compare all four conditions	Friedman Test	0.110 (n.s.)
Deformable animated vs. deformable static	Wilcoxon Signed Ranked Test	0.041
Rigid animated vs. rigid static	Wilcoxon Signed Ranked Test	0.032
Animated labels vs. static labels	Wilcoxon Signed Ranked Test	0.004
Deformable objects vs. rigid objects	Wilcoxon Signed Ranked Test	0.714 (n.s.)

Table 5.4: Overview of the significant difference between various conditions in matters of their error rate.

All relevant statistical values are shown in table 5.3 to gain an overview of the statistical values for the questions. In table 5.4 the values concerning significant difference are displayed between different conditions in matters of the error rate. Concluding, with the help of statistical tests a significant difference between animated and static labels in matters of error rate can be revealed towards animated labels, which signify the intended gesture more understandably. Additionally, animated labels assure a better performance of the gestures.

Evaluating the error rates reveals that animated labels communicate the gestures more understandable.

General Observations

During the study the participants were observed to reveal important aspects concerning their way of interaction with an everyday object as a controller for a technical system, in this case the Philipps hue light bulbs system.
The first observation is that the tendency of the first user study regarding where users touch the labelled object has been verified: the labels for *Push*, *Squeeze*, *Tap* and *Squeeze and Hold* are touched at the spot they are placed on the object. Labels for the gestures *Rotate* and *Slide* are executed in relation to where they are displayed on the object. This tendency is very interesting because it enables the possibility to control and influence users where they are supposed to execute a certain gesture.

The tendency of the first study concerning the touch points is shown again.

The second observation in this study is examining if users are entangled if the signifier for rotating the object displays rotation in only one direction but rotation needs to be executed into the other direction as well to achieve the desired effect. Around one-third of the users mention that the signifier only communicates rotation in one direction but the indicated direction does not lead to the desired effect. Hence, they firstly execute the rotating gesture but do not reach the asked goal. They realised with the help of the effect icons that rotating into the other direction solves this problem but obviously indicating rotation in one certain direction misleads into executing a wrong gesture. The remaining two-third of the participants either do not realise the fact of indicating only one direction at all

The gesture *Rotate* should be displayed into both directions to prevent misunderstandings.

or interprete it with the effect icons correctly at first sight.

Left-handed users tend to execute the gestures with the right hand.

The third identified aspect affects how left-handed persons interact with the object. Two left-handed persons take place in the study and both of them execute the tasks with the right hand. As reasons for this they name the fact that the signifiers are presented with a right hand on the icons. This aspect cannot be proved statistically but it depicts an interesting fact, which may be investigated in a separate user study.

5.2.6 Conclusion

Most users either prefer only animated or only static labels.

Analysing the results of the second user study reveal that the users sense no significant difference between the use of animated and static labels. Most users tend to either prefer only animated labels or only static labels with no relation to the everyday object. But analysing the error rate identifies that for the deformable bottle as well as for the rigid bottle there exists a significant difference between animated and static labels. Furthermore, a significant difference between animated labels and static ones towards animated labels can be proved. The error rate of the animated labels is lower compared to the static error rate (fig. 5...).Reasons for that might be that users tend to imitate what they see. If the hand in the animation demonstrates what gesture to execute at which point of the object, users tend to do the same.

Animated labels improve the user's understandability how to interact with an everyday object as controller.

As a summary it can be recorded that by the help of a little animation of the signifier its understandability can be improved. Hence, the research question of the study can be answered with the positive statement that animation leads to fewer errors for everyday object manipulation.

Chapter 6

Summary and Future Work

The first part of this last chapter sketches a summary of this thesis and the contribution of its results. The second part of the chapter deals with ideas for future work. Furthermore, ideas are listed to investigate the usage of signifiers and the signifiers' application in people's everyday life.

6.1 Summary and Contributions

This work examined the term signifiers in matters of repurposing everyday objects as controllers. Repurposing everyday objects enables different opportunities to achieve another kind of interaction with technical devices. Everyday objects are always present and come along with benefits for tangible controllers. Repurposing everyday objects is a very creative process and every person imagines it individually. Therefore, a communicator is necessary which mediates between the object's possible interactions and the user.

Repurposed objects enable new methods to interact with technical devices.

This is the point where signifiers Norman [2013] arise: a signifier denotes a certain action and can function as communicator. Norman [2013] explained the term as follows: Signifiers give signals to indicate what actions are possible and how the actions should be executed. Talking about signifiers, one major question is: how should signifiers look like? What is the best way of visualisation, which assures all users are able to understand the meaning of the signifier? The contribution of this thesis is answering those two questions. Hence, four options of visualisation were designed. These designs have been evaluated in a first user study. With the help of the users' feedback and observation during the study the best working design could be revealed.

The thesis' investigates how signifiers can be visualised best.

The first user study was conducted with the help of paper prototypes. In a second user study the user should have the opportunity to experience an authentic situation in which she uses the everyday object as a controller for a technical device. In this context the technical device was the Philipps Hue system, a wireless system to manage light bulbs concerning colour, brightness and saturation. The everyday objects were represented by a rigid glass bottle and a deformable plastic bottle. In this study the signifiers were displayed by projection to enable changing them dynamically and to assure the object is not modified in its outer appearance constantly by paper prototypes. Projection establishes the possibility of showing not only static pictures as labels. Furthermore, animated images are possible and therefore the idea of animated signifiers arose. Thus, the second user study explores whether an animated version of the signifiers or the static version functions more understandably as a communicator.

Second study used projection and involved a use-case scenario.

Analysing the results of the second user study revealed that the users sense no significant difference between the use of animated and static labels. Most users tend to either prefer only animated labels or only static labels with no relation to the everyday object. But evaluating the error rate identified that for the deformable bottle as well as for the rigid bottle there exists a significant difference between animated and static labels: The error rate of the animated labels is less compared to the static labels' error rate.

Users detect the difference between animated and static labels as n.s., the error rate states a significant difference.

All in all the contribution of this work is the visualisation of signifiers to communicate a certain gesture and its according effect when everyday objects are repurposed as controllers for technical devices. The thesis surveyed and examined a good working design of signifiers. This design consists of a little image of the repurposed object. The image provides information what gesture should be executed and additionally other icons can show the according effect. Secondly, with the second study this work detected the aspect that animation of labels is able to enhance the understandability of the labels significantly. Thus, the usage of animated labels improves the error rate concerning the understandability of the label.

The Voodoo design works best and animated labels support the signifiers' understandability.

The thesis illustrates that the idea to repurpose everyday objects as controllers with the help of signifiers has the potential to become realistic in peoples' everyday lives.

6.2 Future Work

During the procedure ideas for research in the future concerning the repurposing of everyday objects turned up. Generally, scenarios which are released from the desktop background might have a bigger potential to profit from the reuse of objects as controllers because for working with your desktop usual computer mice are already available.

6.2.1 Use-Cases

In the field of repurposing everyday objects different use-cases are conceivable. Even if the second user study revealed the fact that animated labels improve the signifiers understanding scenarios are imaginable, in which static labels are more superior: E.g. the scenario to provide an everyday object with a certain choice of signifiers and additionally putting those in the packaging of the object. These signifiers could be stuck onto the object and the object is able to be repurposed as controller automatically and ad hoc for e.g. peoples' lightning systems at home.

Use-cases for static labels and animated labels are reasonable.

Another idea for a use case refers to the labels in general: The signifiers and the according icons for the effect are displayed on the object, either by hardware prototypes or by projection. The users participate in a tutorial to get to know what options are available to manipulate the objects

Learning the signifiers by heart by a tutorial helps keeping the objects outer appearance unchanged constantly.

to achieve an effect. After the tutorial the user should be able to remember the gestures by heart and the signifiers are not displayed anymore. Thereby, the chance is enabled that the object keeps his usual outer appearance constantly. This idea was presented to the users in the second user study as well and the users stated the tendency that such a tutorial and keeping the gestures in mind is imaginable. Thus, research concerning this idea is an option for future work.

6.2.2 Research concerning Animated Labels

In the context of animated labels, research is necessary concerning how the animation should look like in detail. Questions like the following need to be answered:

Research concerning animated labels needs to be done.

- How often should the animation be repeated?
- What is the right balance to assure the animation is neither annoying nor distracting for the user but the message how to execute the gesture is still communicated correctly?

Animated labels could be visualised by computer animations.

This thesis investigates the fact that animated labels improve the understandability of signifiers because the animation leads to fewer errors. Nevertheless, the animated labels need improvement concerning their duration and what style of animation works best. This thesis made use of animations with real hands. Another idea to be examined are animated labels with designed hands like e.g. computer animated hands. Apparently, animated labels establish a new field of research topics.

Appendix A

Everyday Objects

The following pages show the used everyday objects for the first user study in this thesis after they have been whitened.

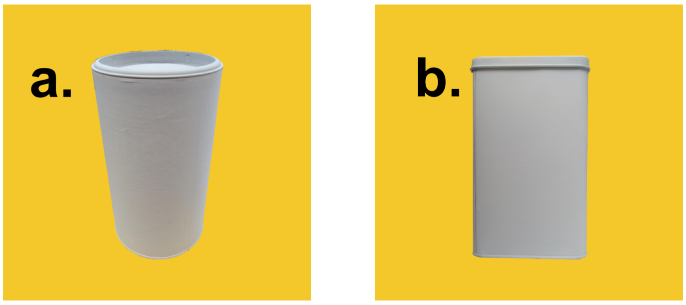


Figure A.1: (a.) Box / (b.) Tin can

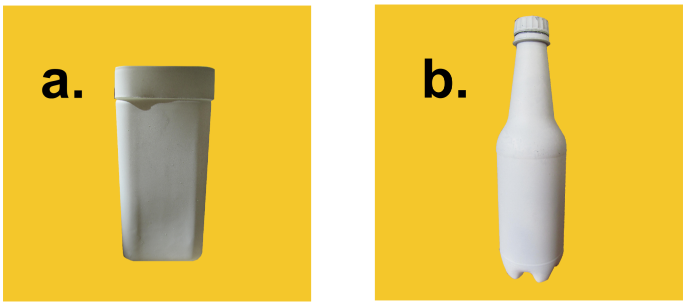


Figure A.2: (a.) Plastic box / (b.) Bottle

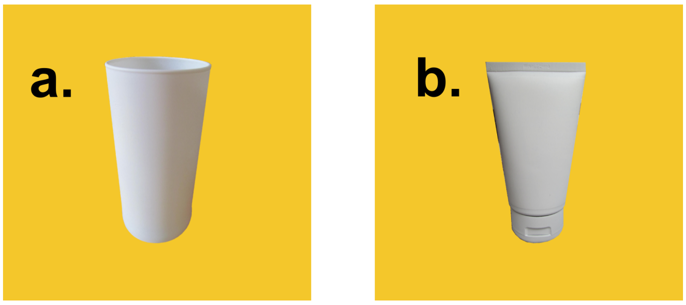


Figure A.3: ((a.) Glass / (b.) Tube

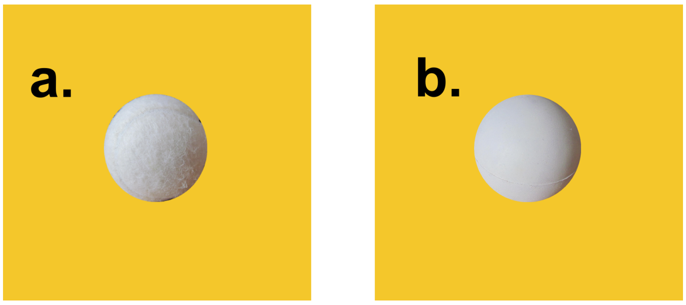


Figure A.4: (a.) Tennis ball / (b.) Soft ball

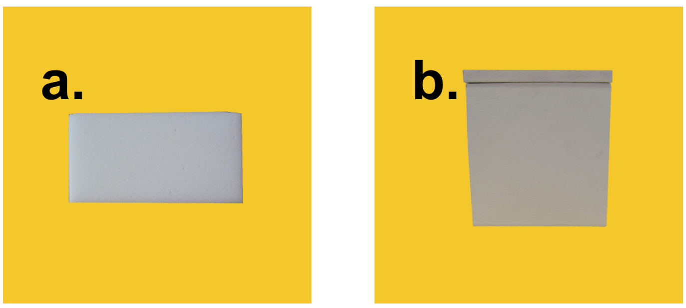


Figure A.5: (a.) Sponge / (b.) Decorative Box

Appendix B

First User Study

The following pages show important sheets for performing the first user study. The questionnaire was filled out by the participant during the first user study.

Objects	1.Push	2.Squeeze	3.Touch/ tap	4.Move 2D	5.Rotate (cylinder, ball)	6.Slide	7.Squeeze 'n hold/	Combining actions 1. – 7.
Glas				X	X (from above)			
Box			X			X		
Bottle		X			X (from the side)		X (SH)	2. + 6.
Plastic box	X						X (SH)	
Tin can				X		X		
Decorative box			X		X			
Sponge				X			X	4. + 7.
Tennis ball			X		X			4. + 5.
Softball	X	X						5. + 7.
Tube	X					X	X	5./6. + 2.
(vase)								

Figure B.1: Division of the tasks in relation to the everyday objects.

Informed Consent Form

Evaluating Signifiers to Repurpose Everyday Objects as Controllers:

PRINCIPAL INVESTIGATOR Anke Brocker
Media Computing Group
RWTH Aachen University
Email: anke.brocker@rwth-aachen.de

Purpose of the study: The goal of this study is to evaluate which labels (also called signifiers) communicate best to the user how to use an object as a controller. Participants are asked to execute the action which they think the labelled object tells them to execute.

Procedure: Participants will receive various objects which are labelled with labels of four various types. They receive one object after the other. Additionally they get a list which enumerates all actions that should be executed with the labels. Each action is mapped to only one label of each type. During the study the participants will be recorded for the purpose of analysis. The participants are asked to say aloud what they think and why they execute a certain action. This study should take about an hour to complete.

After the study, we will ask you to fill out the questionnaire about the tested objects.

Risks/Discomfort: You may become fatigued during the course of your participation in the study. You will be given several opportunities to rest, and additional breaks are also possible. There are no other risks associated with participation in the study. Should completion of either the task or the questionnaire become distressing to you, it will be terminated immediately.

Benefits: The results of this study will be useful for getting knowledge how labels are designed best to repurpose everyday objects as controllers.

Alternatives to Participation: Participation in this study is voluntary. You are free to withdraw or discontinue the participation.

Cost and Compensation: Participation in this study will involve no cost to you. There will be snacks for you during the participation.

Confidentiality: All information collected during the study period will be kept strictly confidential. You will be identified through identification numbers. No publications or reports from this project will include identifying information on any participant. If you agree to join this study, please sign your name below.

_____ I have read and understood the information on this form.
_____ I have had the information on this form explained to me.

Participant's Name	Participant's Signature	Date
	Principal Investigator	Date

If you have any questions regarding this study, please contact Anke Brocker at email: anke.brocker@rwth-aachen.de

Figure B.2: Consent form of the first study.

Experiment Questionnaire

Evaluating Signifiers to Repurpose Everyday Objects as Controllers.

Information about yourself:

1. How old are you? __________________

2. What is you gender? ☐ male ☐ female

3. Are you left-or right-handed? ☐ left ☐ right

1

Figure B.3: Questionnaire of the first user study (p.1).

Design A:

1. Rate whether you agree that the labels communicated the intended actions well (1: totally disagree – 5: totally agree):

Totally disagree				Totally agree
☐ **1**	☐ **2**	☐ **3**	☐ **4**	☐ **5**

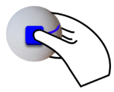
2. Please evaluate the labels for all actions by filling in the values 1 to 5:

1: not good at all, 2: not good, 3: no opinion, 4: good, 5: very good

Push

____

Squeeze

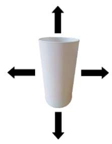


____

Tap

____

Move (in 3D)



____

Rotate

____

Slide

____

Squeeze & Hold

____

3. For those labels that did not communicate the intended action well, why were they difficult to understand?

2

Figure B.4: Questionnaire of the first user study (p.2).

Design B:

4. Rate whether you agree that the labels communicated the intended actions well (1: totally disagree – 5: totally agree):

Totally disagree … Totally agree

☐ **1** ☐ **2** ☐ **3** ☐ **4** ☐ **5**

5. Please evaluate the labels for all actions by filling in the values 1 to 5:

1: not good at all, 2: not good, 3: no opinion, 4: good, 5: very good

Push

____

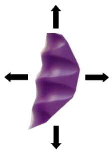
Rotate

____

Tap

____

Move (in 3D)



____

Squeeze

____

Slide

____

Squeeze & Hold

____

6. For those labels that did not communicate the intended action well, why were they difficult to understand?

3

Figure B.5: Questionnaire of the first user study (p.3).

Design C:

7. Rate whether you agree that the labels communicated the intended actions well (1: totally disagree – 5: totally agree):

Totally disagree				Totally agree
☐ **1**	☐ **2**	☐ **3**	☐ **4**	☐ **5**

8. Please evaluate the labels for all actions by filling in the values 1 to 5:

1: not good at all, 2: not good, 3: no opinion, 4: good, 5: very good

Push	Squeeze	Tap	Move (in 3D)
Push	**Squeeze**	**Tap**	**Move**
_______	_______	_______	_______

Rotate	Slide	Squeeze & Hold
Rotate	**Slide**	**Squeeze & Hold**
_______	_______	_______

9. For those labels that did not communicate the intended action well, why were they difficult to understand?

4

Figure B.6: Questionnaire of the first user study (p.4).

10. It is helpful that the Text-based label for 'Rotate' is written aligned in a circle to emphasize the label's meaning (1: totally disagree – 5: totally agree).

Rotate

Totally disagree				Totally agree
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

11. It is helpful that the Text-based label for 'Squeeze' is written compressed towards the middle to emphasize the label's meaning (1: totally disagree – 5: totally agree).

Squeeze

Totally disagree				Totally agree
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

12. Consider the two variations of the Text-based label for the action 'Slide' and check the box relating to in which direction you would execute the action 'Slide':

i. **Slide**

☐ left -> right ☐ right -> left ☐ can't tell

ii. **Slide**

☐ left -> right ☐ right -> left ☐ can't tell

5

Figure B.7: Questionnaire of the first user study (p.5).

Design D:

13. Rate whether you agree that the labels communicated the intended actions well (1: totally disagree – 5: totally agree):

Totally disagree				Totally agree
☐ **1**	☐ **2**	☐ **3**	☐ **4**	☐ **5**

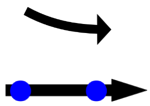
14. Please evaluate the labels for all actions by filling in the values 1 to 5:

1: not good at all, 2: not good, 3: no opinion, 4: good, 5: very good

Push

____

Rotate

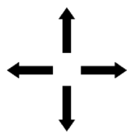


____

Tap

____

Move (in 3D)



____

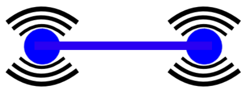
Squeeze

____

Slide

____

Squeeze & Hold

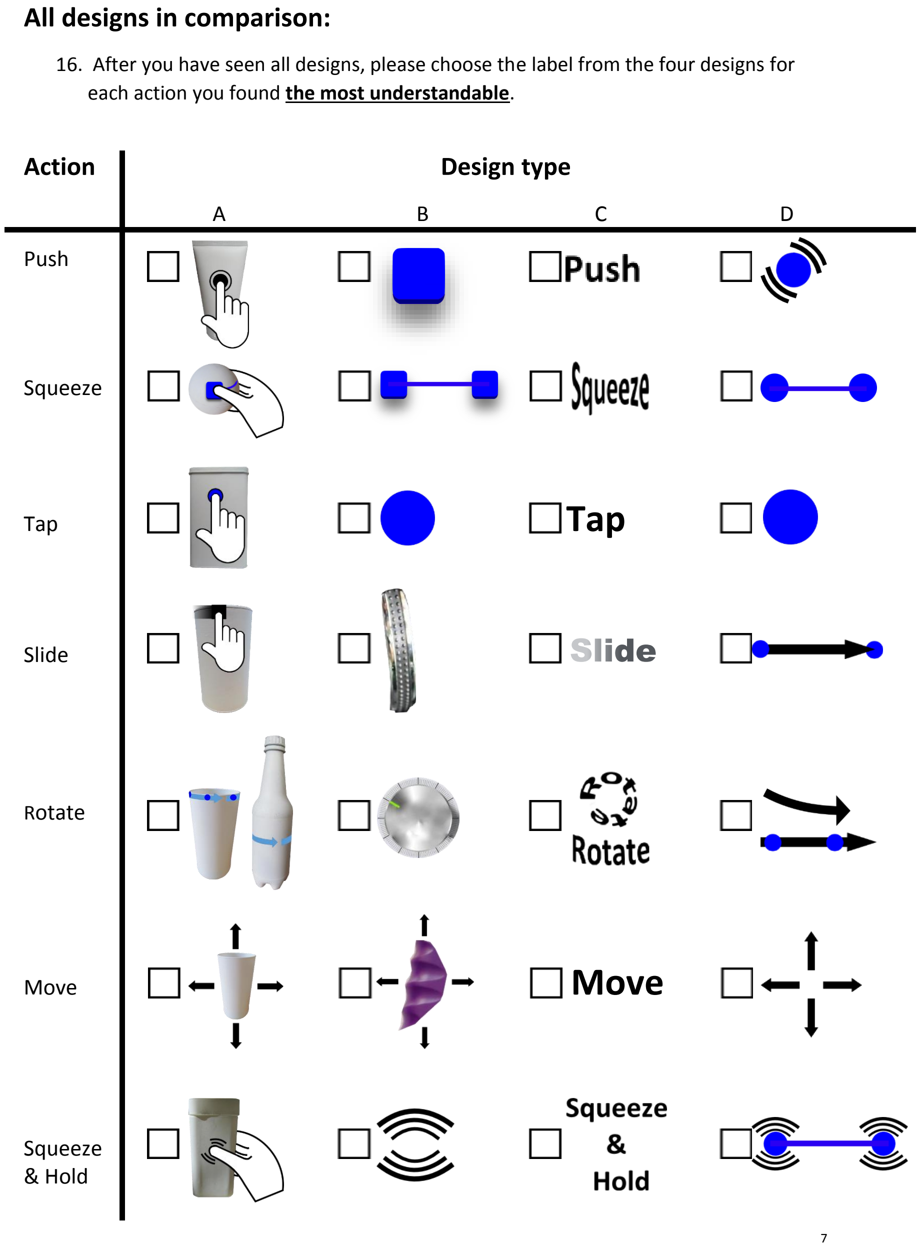


____

15. For those labels that did not communicate the intended action well, why were they difficult to understand?

6

Figure B.8: Questionnaire of the first user study (p.6).



All designs in comparison:

16. After you have seen all designs, please choose the label from the four designs for each action you found **the most understandable**.

Action	Design type A	B	C	D
Push	☐	☐	☐ Push	☐
Squeeze	☐	☐	☐ Squeeze	☐
Tap	☐	☐	☐ Tap	☐
Slide	☐	☐	☐ Slide	☐
Rotate	☐	☐	☐ Rotate	☐
Move	☐	☐	☐ Move	☐
Squeeze & Hold	☐	☐	☐ Squeeze & Hold	☐

7

Figure B.9: Questionnaire of the first user study (p.7).

17. Which design type (A, B, C or D) for the labels did you like the most?

☐ **A** ☐ **B** ☐ **C** ☐ **D**

18. Why did you choose for this design?

Thank you very much for participating in our study!

8

Figure B.10: Questionnaire of the first user study (p.8).

Appendix C

First User Study Results

After conducting the first user study, the results were analysed and are displayed in the following diagrams.

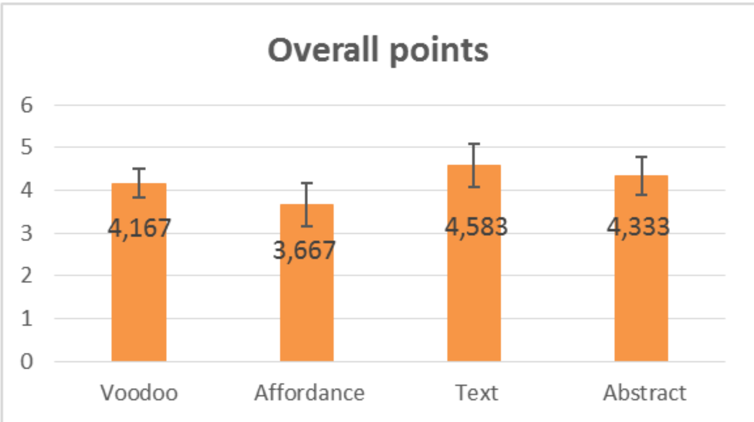


Figure C.1: Mean overall points and confidence interval of designs according to the users' rating.

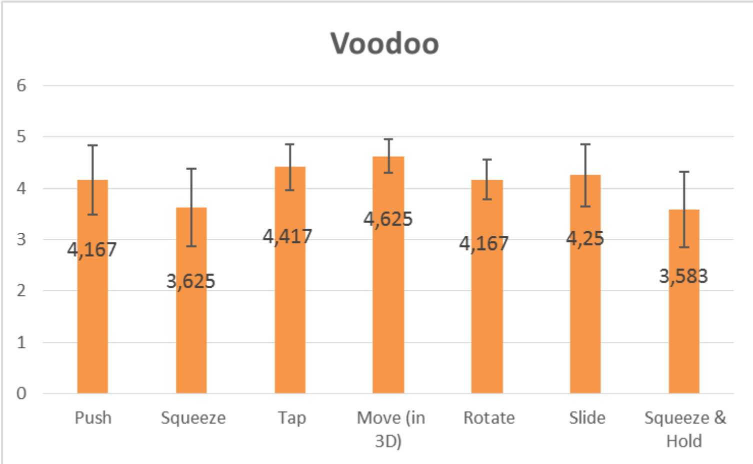


Figure C.2: Mean points and confidence interval for each label of Voodoo design.

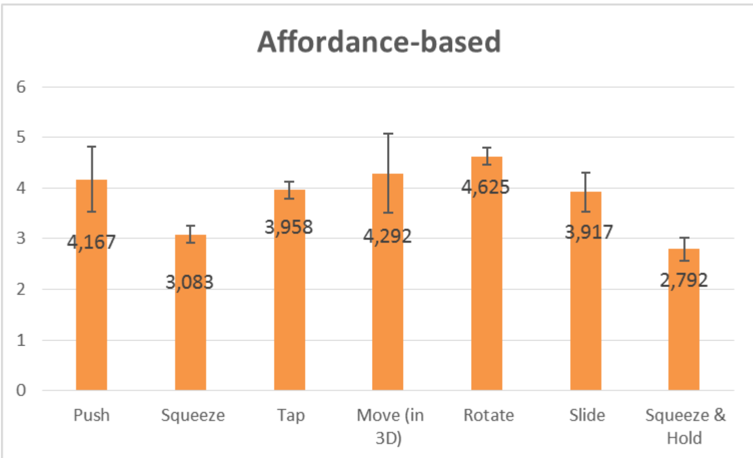


Figure C.3: Mean points and confidence interval for each label of Affordance-based design.

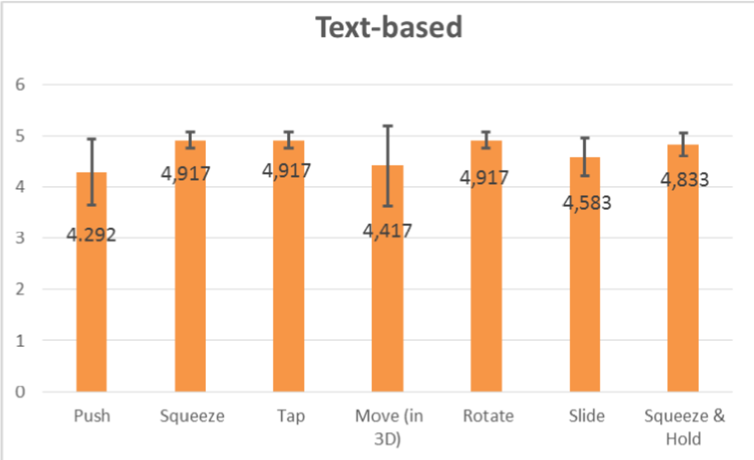


Figure C.4: Mean points and confidence interval for each label of Text-based design.

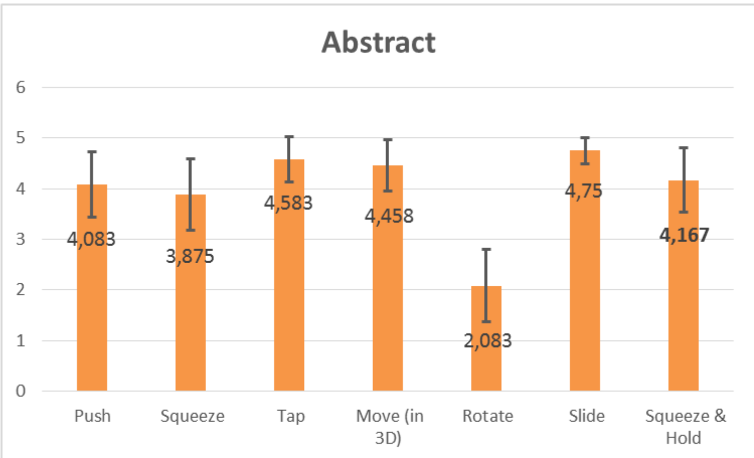


Figure C.5: Mean points and confidence interval for each label of Abstract design.

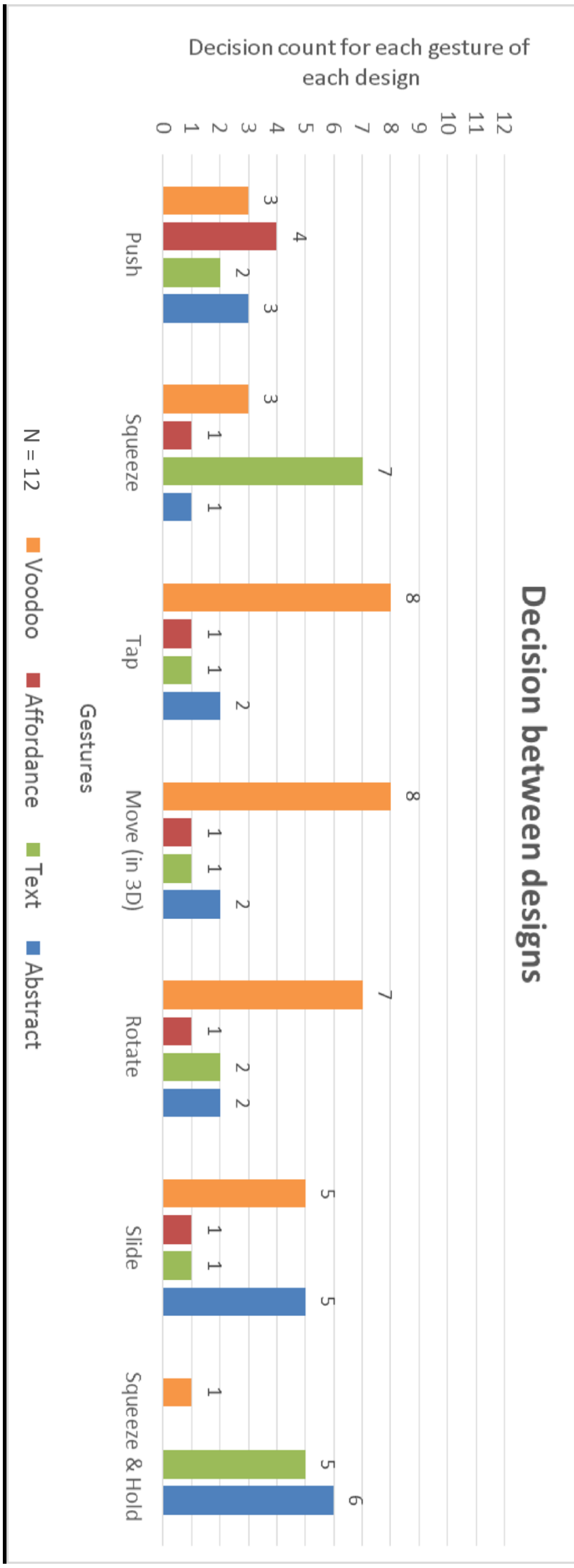


Figure C.6: The users had to decide for one design for each task. This diagram shows the absolute points of each design.

Appendix D

Labels for Second User Study

The following figures D.1-D.4 display all labels that were used in the second study for the rigid static scenario. Figures D.5-D.9 show the labels for the deformable static scenario. The attached CD-ROM contains the labels for the animated scenario of each bottle.

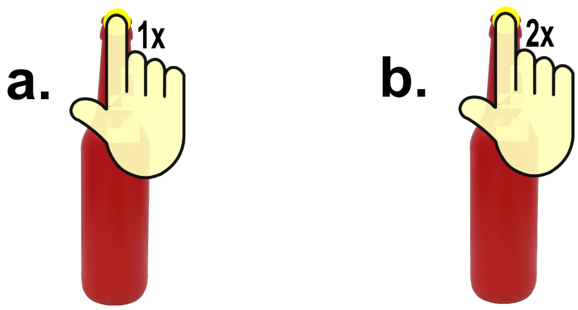


Figure D.1: (a.) *Tap* once / (b.) *Tap* twice

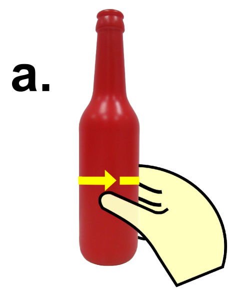


Figure D.2: (a.) *Rotate* right at lower part of the bottle / (b.) *Rotate* left at lower part of the bottle

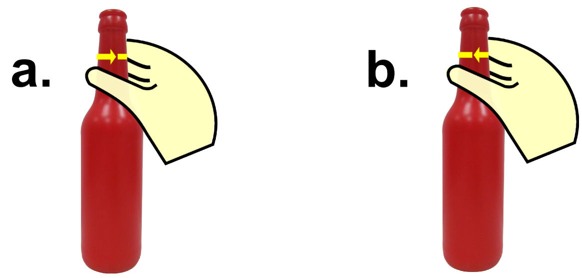


Figure D.3: (a.) *Rotate* right at bottleneck / (b.) *Rotate* left at bottleneck

Figure D.4: (a.) *Slide* at lower part of the bottle / (b.) *Slide* at bottleneck

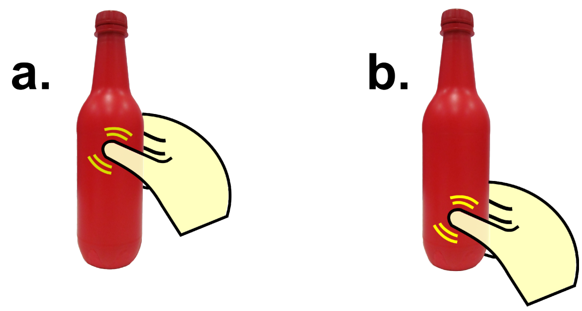


Figure D.5: (a.) Upper *Squeeze* / (b.) Lower *Squeeze*

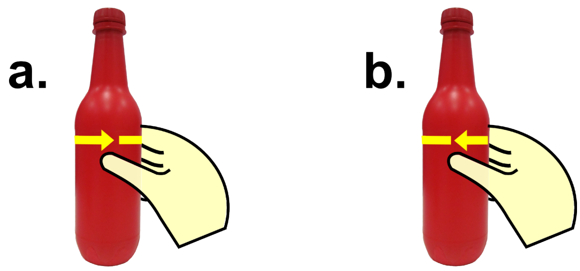


Figure D.6: (a.) Upper *Rotate* right / (b.) Upper *Rotate* left

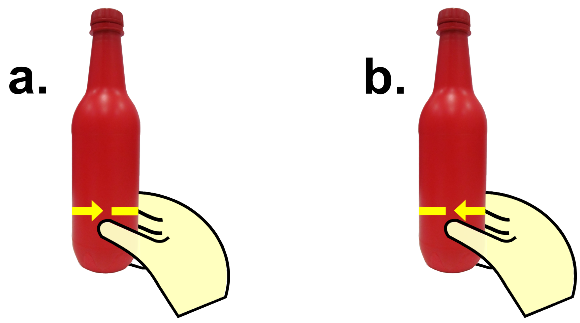


Figure D.7: (a.) Lower *Rotate* right / (b.) Lower *Rotate* left

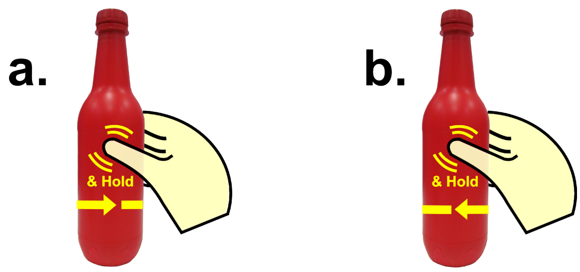


Figure D.8: (a.) Upper *Squeeze and Hold* and *Rotate* right / (b.) Upper *Squeeze and Hold* and *Rotate* left

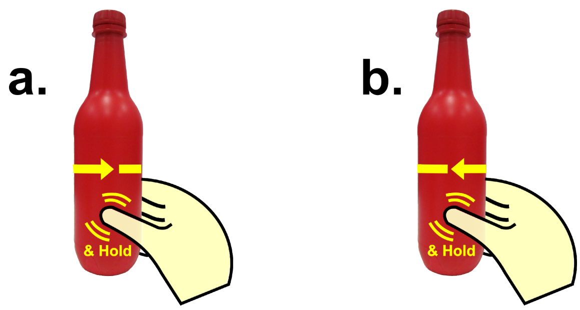


Figure D.9: (a.) Lower *Squeeze and Hold* and *Rotate* right / (b.) Lower *Squeeze and Hold* and *Rotate* left

Appendix E

Second User Study

The following questionnaire was filled out by the participant during the second user study.
After the questionnaire follows the label reference: the user might have forgotten what the labels look like in each scenario. In order to assure the users are able to fill out the questionnaire, the following label reference was handed to them while they were answering the questionnaire.

Informed Consent Form

Evaluating Signifiers to Repurpose Everyday Objects as Controllers

PRINCIPAL INVESTIGATOR Anke Brocker
Media Computing Group
RWTH Aachen University
Email: anke.brocker@rwth-aachen.de

Purpose of the study: The goal of this study is to investigate whether animated labels or static labels support the users understanding of the signifiers better. Therefore participants will execute different scenarios with animated and static labels.

Procedure: Before the study, the participants are asked to fill out a questionnaire with some information about themselves. Participation in this study involves executing four scenarios with two different everyday objects. With each object two scenarios are performed and each scenario is different from all the others. The whole study is video recorded in order to evaluate it more detailed afterwards. Participants will perform one scenario after the other, interrupted by short breaks. After executing the scenarios, participants are asked to fill out the questionnaire about the scenarios. This study should not last longer than 45 minutes to complete.

Risks/Discomfort: You may become fatigued during the course of your participation in the study. You will be given several opportunities to rest, and additional breaks are also possible. There are no other risks associated with participation in the study. Should completion of either the task or the questionnaire become distressing to you, it will be terminated immediately.

Benefits: The results of this study will help to reveal the usefulness of animated labels in contrast to static labels.

Alternatives to Participation: Participation in this study is voluntary. You are free to withdraw or discontinue the participation.

Cost and Compensation: Participation in this study will involve no cost to you.

Confidentiality: All information collected during the study period will be kept strictly confidential. You will be identified through identification numbers. No publications or reports from this project will include identifying information on any participant. If you agree to join this study, please sign your name below.

_____ I have read and understood the information on this form.
_____ I have had the information on this form explained to me.

Participant's Name	Participant's Signature	Date
	Principal Investigator	Date

If you have any questions regarding this study, please contact Anke Brocker at email: anke.brocker@rwth-aachen.de

Figure E.1: Consent form of the second study.

Experiment Questionnaire

Evaluating Signifiers to Repurpose Everyday Objects as Controllers.

Information about yourself:

1. How old are you? ________________

2. What is you gender? ☐ male ☐ female

3. Are you left-or right-handed? ☐ left ☐ right

4. Do you have any sight restrictions? ☐ Yes ☐ No

5. Are you color-blind? ☐ Yes ☐ No

   If yes, referring to which color (Please fill in)? ____________________

1

Figure E.2: Questionnaire of the second user study (p.1).

1. After you have seen all four conditions, please decide for the following options, which one you find **more understandable**.

   a. For a deformable plastic bottle, do you find static labels or animated labels more understandable? Please tick the appropriate box:

   ☐ Does not matter ☐ static labels ☐ animated labels

   b. For a rigid glass bottle, do you find static labels or animated labels more understandable? Please tick the appropriate box:

   ☐ Does not matter ☐ static labels ☐ animated labels

2

Figure E.3: Questionnaire of the second user study (p.2).

2. After you have seen all four conditions, please decide for the following options, which one you **like more**.

   a. For a deformable plastic bottle, do you prefer static labels or animated labels? Please tick the appropriate box:

☐ Does not matter ☐ static labels ☐ animated labels

   b. For a rigid glass bottle, do you prefer static labels or animated labels? Please tick the appropriate box:

☐ Does not matter ☐ static labels ☐ animated labels

3

Figure E.4: Questionnaire of the second user study (p.3).

3. Please rate for each combinations of two conditions which one you prefer:

   a. I prefer the deformable animated condition to the deformable static condition:
   (1: totally disagree – 5: totally agree):

Totally disagree				Totally agree
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

   b. I prefer the deformable animated condition to the rigid animated condition:
   (1: totally disagree – 5: totally agree):

Totally disagree				Totally agree
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

   c. I prefer the deformable animated condition to the rigid static condition:
   (1: totally disagree – 5: totally agree):

Totally disagree				Totally agree
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

   d. I prefer the deformable static condition to the rigid animated condition:
   (1: totally disagree – 5: totally agree):

Totally disagree				Totally agree
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

4

Figure E.5: Questionnaire of the second user study (p.4).

e. I prefer the deformable static condition to the rigid static condition:
(1: totally disagree – 5: totally agree):

Totally disagree				Totally agree
☐ **1**	☐ **2**	☐ **3**	☐ **4**	☐ **5**

f. I prefer the rigid animated condition to the rigid static condition:
(1: totally disagree – 5: totally agree):

Totally disagree				Totally agree
☐ **1**	☐ **2**	☐ **3**	☐ **4**	☐ **5**

5

Figure E.6: Questionnaire of the second user study (p.5).

4. After you have executed all four conditions which one do you find **the most understandable**?

Please rank the four conditions with the ranks 1 to 4 by writing the rank number in the box of the according condition:

1: The best 4: the worst

Deformable animated	Deformable static	Rigid animated	Rigid static
☐	☐	☐	☐

5. After you have executed all four conditions which one do you **like the most**?

Please rank the four conditions with the ranks 1 to 4 by writing the rank number in the box of the according condition:

1: The best 4: the worst

Deformable animated	Deformable static	Rigid animated	Rigid static
☐	☐	☐	☐

6

Figure E.7: Questionnaire of the second user study (p.6).

6. Rate whether you find the animation of labels annoying?
(1: totally disagree – 5: totally agree):

Totally disagree ... Totally agree

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

7. Rate whether you find the animation of labels distracting?
(1: totally disagree – 5: totally agree):

Totally disagree ... Totally agree

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

8. Think of the following scenario: You get to see all signifiers and their according effect in the beginning, e.g. like a tutorial. After that the signifiers are not displayed anymore, you would need to know them and the according effect by heart. Can you imagine to get used to the set of possible gestures after e.g. a tutorial and to repurpose the objects without displaying the signifiers? Rate whether you can imagine this or not:
(1: totally disagree – 5: totally agree):

Totally unimaginable ... Totally imaginable

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

7

Figure E.8: Questionnaire of the second user study (p.7).

Deformable plastic bottle

- Deformable plastic bottle with animated labels (you can see some labels as example to remind you how they look like):

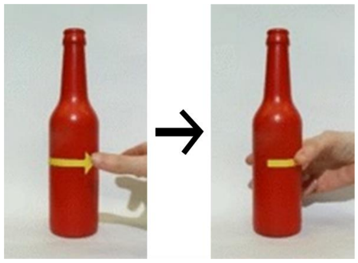
- Deformable plastic bottle with static labels (you can see some labels as example to remind you how they look like):

1

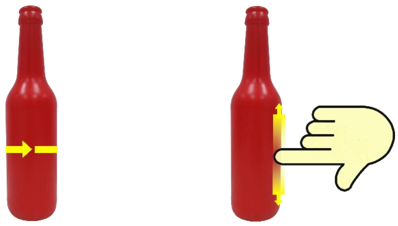
Figure E.9: Reference for second study (p.1).

Rigid glass bottle

- Rigid glass bottle with animated labels (you can see some labels as example to remind you how they look like):



- Rigid glass bottle with static labels (you can see some labels as example to remind you how they look like):



2

Figure E.10: Reference for second study (p.2).

Appendix F

Second User Study Results

After conducting the second user study, the results were analysed and are displayed in the following diagrams.

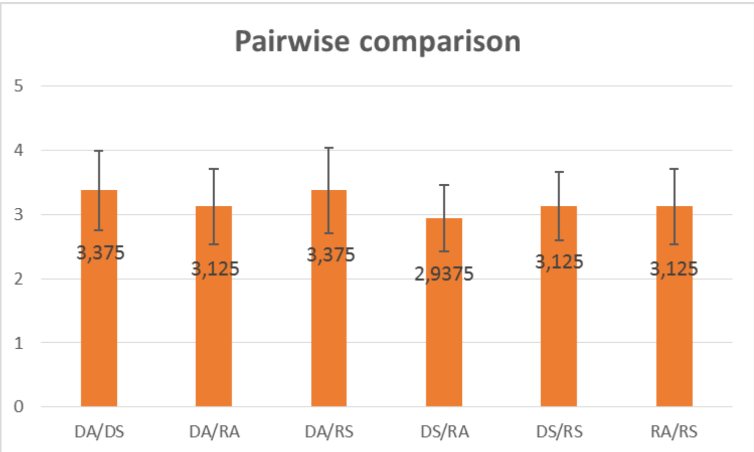


Figure F.1: Means and confidence intervals in matters of pairwise comparison of the scenarios concerning the users' preference.

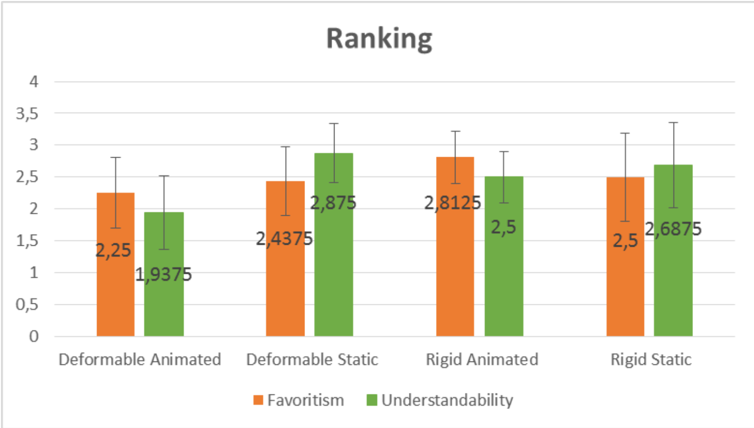


Figure F.2: Means and confidence intervals of the scenarios' ranking concerning the users preferences.

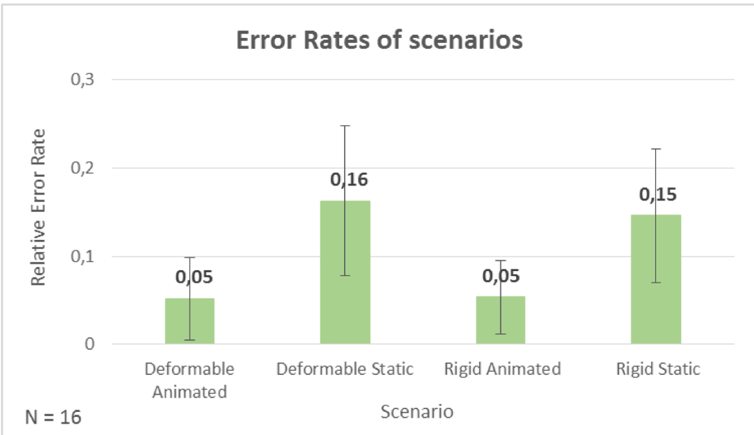


Figure F.3: Error rate mean and confidence interval of each scenario.

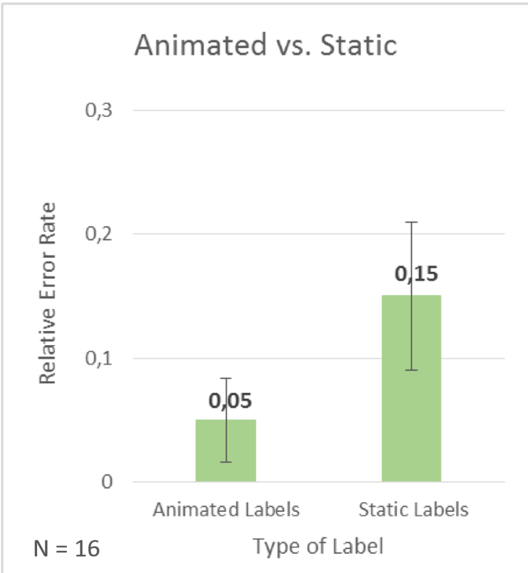


Figure F.4: Mean error rate and confidence interval of animated vs. static labels.

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