ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

# ACTION PATTERNS: NON-VERBAL COMMUNICATION METHODS IN CONSUMER ELECTRONICS

M.Sc. THESIS

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**ISTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ**

# HAREKET ÖRÜNTÜLERİ:
# ELEKTRONİK CİHAZLARDAKİ SÖZSÜZ İLETİŞİM YÖNTEMLERİ

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Muhammet Ramoğlu, a M.Sc. student of İTU Graduate School of Science Engineering and Technology student ID 502161907, successfully defended the thesis entitled "ACTION PATTERNS: NON-VERBAL COMMUNICATION METHODS IN CONSUMER ELECTRONICS", which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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**FOREWORD**

I would like to thank my supervisor Gülname Turan for her guidance. I would like to thank Arçelik UX/UI Design Team for their expert review on user studies and their support. I would like to thank my family and friends who emotionally and intellectually supported me on this journey. I would like to thank İrem Çakıroğlu for her great contribution to this thesis. She is always excited about my ideas, which keeps me interested and motivates to continue this journey.

If this work inspires a single person, it will reach its goal. I am glad to work on a topic that I was curious about. I hope curious people will have faith to go after what they want to explore.

May 2018 Muhammet RAMOĞLU
(Designer)

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## ABBREVIATIONS

**1D** **:** 1-Dimensional

**2D** **:** 2-Dimensional

**3D** **:** 3-Dimensional

**DW** **:** Dishwasher

**DW-S** **:** Dishwasher with scenario

**HCI** **:** Human-computer interaction

**M** **:** Mobile phone

**M-S** **:** Mobile phone with scenario

## GLOSSARY OF TERMS

**Action patterns** : Action patterns represent a specific message by a system through physical movement, sound, vibration, or changes in light intensity. Users can recognize those patterns by changes in duration and intensity.

**Body movement** : Body movements refer to 3D movements of an object, in a physical or virtual environment, involving the motion of the whole body or parts of the body.

**Device messages** : Device messages are informational states, feedback, or notifications of devices such as warning, processing or task completed.

**Graphic animation** : 2D animation on a display.

**Point light** : Light element in user interfaces e.g. light-emitting diodes (LEDs).

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## ACTION PATTERNS: NON-VERBAL COMMUNICATION METHODS IN CONSUMER ELECTRONICS


### SUMMARY

In consumer electronics, non-verbal communication methods such as point light, graphic animation, and body movement have been used to express different informational device states. Previous studies have examined these actions to reveal an emotion, intention, or state of a device. However, the applicability of expressive actions across devices and media has not as yet been discussed. An *action patterns* hypothesis was presented in this thesis to discuss the relationships between blinking point light, graphic animation, or body movement able to express a device message with identical or similar timing and intensity patterns. The hypothesis aims to examine whether a universal action pattern dictionary can be established via comparison of the patterns over different media. Rather than designing new motion patterns for each feature, product, or medium, it should be possible to define a more inclusive and intuitive level of human-computer communication. Additionally, these abstract messages could be more comprehensible if users are exposed to similar patterns in various products. Thus, the applicability of action patterns over different media may increase the learnability and usability of user interfaces. Two user studies were conducted to analyze the applicability of identical action patterns with different devices and different media to express the same device message. Following that, the main contribution of this thesis and the application areas of non-verbal communication in interface design were discussed.

The thesis is based on three research questions to examine action patterns hypothesis. First research question (RQ1) aims to classify device states, feedback, and notification to define action patterns that represent these device messages. A taxonomy of device messages is presented in this study. Second research question (RQ2) focuses on the applicability of identical action patterns in different products. Same point light actions were compared on a dishwasher and a mobile phone in an online survey. The last research question (RQ3) aims at examining whether similar action patterns in different media such as blinking light, graphic animation, and body movements are inferred as similar device messages by participants and it was tested in an online survey.

**HAREKET ÖRÜNTÜLERİ: ELEKTRONİK CİHAZLARDAKİ SÖZSÜZ İLETİŞİM YÖNTEMLERİ**

## ÖZET


Tüketici elektroniğinde, ışıklı geri bildirim, grafik animasyon ve ürünün fiziksel hareketleri gibi sözel olmayan iletişim yöntemleri, cihazların durumları hakkında bilgi vermek için kullanılmaktadır. Bu hareketler cihazın duygularını, amacını veya cihazın çalışma durumunu gösterebilmek için önceki çalışmalarda incelenmiştir. Ancak, bu hareketlerin cihazlar arası ve medyalar arası uygulanabilirliği henüz incelenmemiştir. *Hareket örüntüleri* hipotezi, noktasal ışık, grafik animasyon ve fiziksel hareketler arasındaki ilişkiyi incelemek üzere tezde sunulmuştur. Bu hipotez, hareketin yapılma sıklığı ve hareketin ne yoğunlukta yapıldığı parametrelerinden oluşan anlamların farklı medyalarda ve ürünlerde aynı cihaz geri bildirimlerini vermek için kullanılabileceğini öngörmektedir. Hipotezin amacı, aynı hareket örüntülerini farklı cihaz ve medyalarda kıyaslayarak, cihazlarda evrensel bir hareket dili tanımlanıp tanımlanamayacağını sorgulamaktır. Her yeni cihazda ve yeni fonksiyonda kullanıcılarla iletişim kurabilmek için yeni hareketler tasarlanması yerine, insan-bilgisayar etkileşiminde daha genel bir seviye tanımlamak bu sayede mümkün olabilir. Ayrıca, kullanıcılar farklı cihazlarda benzer geri bildirim hareketlerini gördüklerinde bunlara aşina olacaklar ve yeni kullandıkları bir cihazda bile bu mesajları anlamaları kolaylaşacaktır. Bu sebeple hareket örüntülerinin farklı cihazlara ve medyalara uygulanabilmesi, kullanıcı arayüzlerinin öğrenilmesini ve kullanılmasını kolaylaştırabilir. Hareket örüntülerinin farklı cihazlarda ve medyalarda uygulanabilirliğini analiz etmek amacıyla iki farklı kullanıcı testi çalışması yapılmıştır. Testler sonucunda sözsüz iletişim yöntemlerinin arayüzlerdeki kullanım alanları tartışılmıştır.

Tez, hareket örüntüleri hipotezini incelemek üzere üç araştırma sorusuna dayanmaktadır. İlk araştırma sorusu, hareket örüntülerini tanımlayabilmek için, hareket örüntülerinin temsil edeceği cihaz geri bildirimlerini ve cihaz durumlarını sınıflandırmayı amaçlamaktadır. Bu çalışmada cihaz geri bildirimlerinin bir taksonomisi sunulmuştur. İkinci araştırma sorusu, farkı ürünlerde aynı hareket örüntülerinin uygulanabilirliğine odaklanmaktadır. Bu amaçla, aynı noktasal ışık hareketleri, bulaşık makinesi ve cep telefonu üzerinde gösterilerek çevrimiçi kullanıcı çalışması ile karşılaştırılmıştır. Son araştırma sorusu, aynı hareket örüntülerinin, noktasal ışık, grafik animasyon ve gövde hareketleri gibi farklı medyalarda aynı cihaz mesajı olarak anlaşılıp anlaşılmadığını incelemeyi amaçlamaktadır ve çevrimiçi kullanıcı çalışması ile test edilmiştir.

# 1. INTRODUCTION

## 1.1. Motivation

Any user interface has two primary functions: Machine control without the technical knowledge of how the machine works, and informing states of a device such as ready, warning or task completed. While display interfaces can provide sophisticated information via text and graphics such as on websites, computer software, and mobile applications, designing interactive communication for products without screens remains a challenge. Interfaces of every day electronic products like home appliances are simpler than display interfaces due to various factors such as cost and size limitations. Most consumer electronics with simple interfaces interact with users by point light. Not only products with simple interfaces but also products with displays such as printers and cars communicate common messages with point lights. Other than expressive point lights, device movement has been used to communicate with users. Although body movements are not as common as graphical interfaces, researchers have examined motion cues to express the intention of robots in human-robot interaction (HRI) studies. Though it is possible for robots to express their intentions with text on a large screen or with voice, movement is a more natural and intuitive way for us to interact. In fact, our ability to understand action patterns, or rather body language, probably allowed humankind to communicate without spoken language for eons. So, the most natural method of communication used well before computers is today discussed in HCI to design more intuitive, understandable, and less attention-demanding actions to interact with users. Furthermore, there are 750 million illiterate adults on the planet that cannot understand text-based device messages (UNESCO, 2017) and 217 million people have moderate to severe vision impairment (World Health Organization, 2017) having difficulty in reading small text. Thus, action patterns can enable inclusive feedback methods with devices that allow more users to interact more naturally and fluidly.

Light-emitting diodes (LEDs) for blinking lights, buzzers for auditory icons, vibration motors for tactile icons or the use of movements for already mobile devices such as robots and drones is sufficient to define many messages. In this thesis, the general term *device message* is used to pertain to device status, feedback and notification messages of a device (Jung, Bae, Lee, & Kim, 2013). These non-verbal cues not only use simple technologies but also require minimal user attention while providing more user-friendly ways of communication. Previous studies examined point lights, graphic animations, and physical movement by objects to express the status of a device or the intention of an agent. However, their inherent contextual differences have not yet been thoroughly examined, so the applicability of these blinking lights or movement patterns to other devices is unknown. While several studies have set out to establish action parameters and the meanings of specific patterns, these actions were only tested upon single devices. In order to avoid repetitively testing these actions on every new device, the applicability of non-verbal communication methods for different devices has been analyzed in the thesis. If these expressive actions can represent an identical device message in many different products, then designers can apply these actions to various devices to express the same states. The *action pattern* hypothesis is presented in this thesis by clustering abstract communication methods recognizable by patterns such as blinking point lights, moving graphics, and the physical movements of a 3D object. For example, users can infer a *warning* message from either fast blinking point lights or quick movement by an object. Although point light, graphic animation and body movements are different types of media, identical patterns in different media can be inferred as the same message because of human pattern recognition abilities. The applicability of patterns via different media (point light, graphic animation, and movement) to express the same message has also been examined in this work. The *action pattern* hypothesis will be described in the next sections, but in the main the patterns are recognizable actions based on the time, frequency and intensity of the action. For example, people understand if a person at the door is angry by their door knocking pattern, or that a flickering of headlights means a driver behind wishes to pass. Identical action can even be inferred differently through changes of timing. This concept was brilliantly explained in *12 Animation Principles* (Thomas & Johnston, 1981), showing that the speed at which an animation character turns its head can differentiate meaning from fast to slow accordingly:

“1 frame between two actions – character has been hit by a brick

2 frames – it has a muscle spasm

3 frames – it is dodging a brick

4 frames – it is giving a crisp order "move it"

5 frames – it is more friendly "over here"

6 frames – it sees a good-looking girl or a nice sports car"

So, identical head movement can express different meanings because of minute changes in action pattern that an observer is able to recognize. Many psychology studies have noted how humans perceive and interpret these actions. This thesis hopes to contribute to user experience design by classifying device states and feedback, examining the applicability of action patterns across different products, and the applicability of action patterns through varying media. The findings of the thesis may help designers to understand how users infer abstract messages from consumer electronics, and how to transmit existing action patterns to different products and different media more fluidly, naturally, and intuitively.

### 1.2. Action Patterns

Whether there is a designed metaphor or not, users try to assume the reason behind an action or the intention of a machine. Reeves and Nass (1996) stated that humans treat computers as they are human beings and infer non-designed intentions. For example, a computer's fan noise or engine noise of a car might be interpreted by its owner as meaningful messages. Likewise, in animations, users interpreted movement patterns of simple geometric shapes and objects as meaningful actions and emotions (Heider & Simmel, 1944; Michotte, 1963; Scholl & Tremoulet, 2000). So, humans tend to give meaning to patterns of actions such as movements and light behavior in computers and similar media as a natural consequence of human pattern recognition.

*Action patterns* represent a specific message by a system through physical movement, sound, vibration, or changes in light intensity. The main characteristic of *action patterns* as defined in this thesis are those patterns users can recognize by changes in duration and intensity. For example, if a point light blinks slowly and mimics human breath, it can show the device to be in a standby or pause state, while the same light blinking at a higher frequency might then refer to an urgent state in the device. In this way, the message communicated by the light is changed by the actions on a timeline and users can recognize these patterns. Similar iconic representations of messages can be exemplified by ship and train horns, smoke signals, and other communication strategies using visual or auditory cues. Although most people are ignorant of smoke signals or ship horn patterns and their specific meanings, we are exposed to many *action patterns* from electronic devices in daily life. Therefore, we are able to recognize and understand *action patterns* in a system that we have never used before by transferring knowledge learned previously. The main hypothesis in the thesis is *action patterns* in various media (sound, vibration, graphic animation, point light, body movements) can represent identical messages, and a pattern can be transferred from another media. So, if the frequency of a blinking light is transferred to the movement of a robot, both can represent the same message such as *warning* or *processing*. The applicability of patterns to different media brings these different human-computer communication methods together as *action patterns*.

## 1.3.Research Questions

Hypothesis: Blinking point lights, movement of 2D graphics, and the body movements of a 3D object can carry identical device messages through applying the same behaviors. The patterns of these actions can be transferred from one to another to express the same meanings. Thus, these expressive communication methods are grouped as *action patterns* in this study. These actions are far more influential than the product types or the media in the perception of a device message.

The parameters of point lights, motion in graphic animation, and body movements have been examined in previous studies to various specific cases. However, the relationships between these abstract communication methods has yet to be thoroughly discussed. Thus, the following research questions were addressed in this thesis.

RQ1: How to classify device states, feedback, and notifications to define action patterns that represent these device messages?

RQ2: Do users infer an identical device message from the same action patterns in different products?

RQ3: Do users infer an identical device message from the same action patterns that are expressed through different media?

In the first research question (RQ1), device messages were examined to define their action patterns. The term *device messages* was used in this study to refer to status in and feedback from devices such as warning, ready, and processing. Jung et al. (2013) also mentioned the term product messages and defined the terms *status* and *feedback* as sub-categories in its classification. Previous studies discussed the device messages in various domains from various perspectives (Harrison, Horstman, Hsieh, & Hudson, 2012; Jung et al., 2013; Saffer, 2013). In this study, device messages were classified based on these previous discussions to define action patterns accordingly. Thus, it becomes important to generalize device messages to define applicable action patterns to differing products (RQ2) and media (RQ3). In addition, this taxonomy can guide researchers and designers in further studies of device messaging in HCI. The classification of device messages was constructed based on point lights as they are found in so many devices across product fields.

The second research question (RQ2) focuses on the applicability of identical action patterns in different products. This study was conducted with only one action pattern to compare different products in isolation and fix other variables. As stated, point lights were chosen to test this research question as they are commonly used in most consumer electronics. Previous studies examined what different blinking light patterns may mean (Harrison et al., 2012; Liu, Lee, Chuang, Liang, & Chen, 2017; Szafir, Mutlu, & Fong, 2015); however, these researchers conducted their studies upon single products. Since the applicability of previous light behavior definitions to other devices is unknown, instead of applying and testing light behaviors on each new device, identical blinking light patterns were examined to discover if they were interpreted similarly on different devices. This study aims to examine whether action patterns can be applied universally to all products or whether the product itself affects the meaning of a given action pattern. Moreover, the test conditions of light behavior research are examined by providing a scenario to test groups as previous studies only showed light behaviors on a single product and did not state at what stage of use participants were exposed to such feedback. To fill this gap, a between-subject study was conducted to find the effect of product type on expressive light behavior. Three light behavior animations were shown to four different groups. Two of these groups viewed specific light actions on a mobile phone while the other groups did so from a dishwasher. These groups were divided in two by providing limited information about the scenario. The first group saw expressive light behavior with "the video shows the state of the device after you give a command" clause, and the control group saw identical light patterns without the scenario and were asked to comment on the perceived status of the device. This part of the thesis contributes to the HCI field by examining the applicability of light behavior in different products and exploring how a scenario can affect the test conditions in light behavior research. This study could guide interaction designers to apply existing light behavior definitions to various devices and help designers understand how users interpret blinking light patterns in products with distinct usage differences. In addition, creating an *expressive pattern dictionary* may help users understand familiar actions to perform the same functions on different devices.

The last research question (RQ3) focuses on the main part of the *action pattern* hypothesis and was tested through a user study. This study was aimed at examining whether similar action patterns in different media such as blinking light (1D), graphic animation (2D), and body movements (3D) are inferred as similar device messages by participants. A between-subjects design was used to conduct the study examining three conditions. Each participant saw one of these conditions included in one of three videos. In each video, there was a different action representing messages such as *complete*, *error,* and *process*. In each video, participants rated how much they agreed with the four different device messages. Responses were then compared between 1D, 2D, and 3D conditions to examine whether participants who viewed identical device messages on different media inferred similar meanings. Previous studies only examined the meaning of patterns in device messages in a single medium such as blinking light or body movements of a product. So far, the applicability of action patterns across different media is unknown. The hypothesis is that blinking light, graphic animation, and body movement patterns of an object are all action patterns that can carry similar meanings across different media, so the patterns themselves are more influential than the method of representation to reveal meaning. If similar actions in different media are interpreted similarly, behaviors in one media are then transferred to another. Using existing metaphors is important to understanding the feedback of a given device, so applying well-known actions to other media can help users to understand them more easily in another. Moreover, the applicability of patterns in different media can help create a useful action pattern dictionary independent of device and feedback models. If designers use similar patterns in various media, then these device messages will become generalized and more accessible, assisting in the learnability of device messages.

## 2. RELATED WORK

Human-computer communication though abstract movement and signals (or action patterns) have been examined in a variety of fields. Semiotics studies have examined metaphors and the iconic representation of messages as well as how these metaphors are created and established; causal perception studies have investigated how humans infer meaning from motion; human-robot interaction studies have examined non-verbal communications like body movement in the expression of emotion and intention of robots; *calm technology* has been discussed as an intuitive way of communication with computers; and a few studies have noted action patterns as *microinteractions*, user experience, and usability issues. In the related work section, previous studies having different perspectives on creating meaning with action patterns will be discussed.

We use non-verbal communication every day via posture, gestures, touch, and even with non-verbal utterances. In HCI, non-verbal communication methods have mostly been examined in robotic studies (Harris & Sharlin, 2011; Novikova & Watts, 2014; Ribeiro & Paiva, 2012; Saerbeck & Bartneck, 2010; van Breemen, 2004), especially body movements and facial expressions. Iconic representation of graphic animation and point lights have not been previously referred to as non-verbal communication in HCI; however, all of these media that express the state of a device (point light, graphic animation, body movements) were clustered as action patterns in this study. In the related work section, previous studies and products available on the market using non-

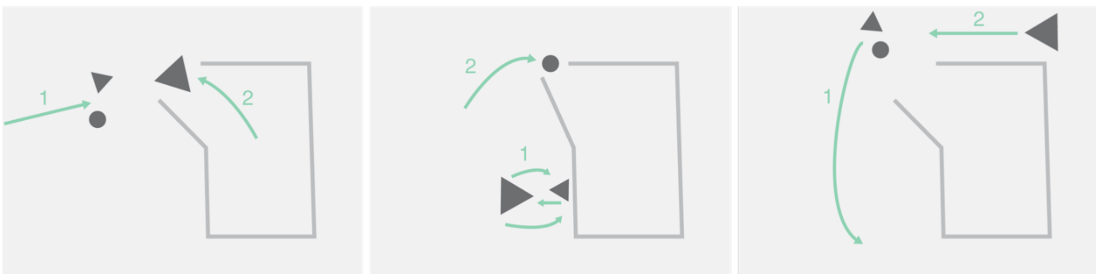


**Figure 2.1:** Sequences from the animation in Heider and Simmel's experiment (1944)

verbal communication have been examined. Point lights, graphic animation, and body movements are explained in this section to understand their application in user interfaces and their dynamics in expression of device messages.

### 2.1. Perception of Motion

Previous psychology studies have noted that movements can be interpreted as meaningful actions primarily due to previous experience and the human tendency to develop logical storylines to explain the behavior of other living beings and even inanimate objects. Heider and Simmel (1944) revealed that humans infer meaning from non-verbal motion cues by displaying to test participants a 2D animation of a large triangle, a small triangle and a circle (Figure 2.1). Participants explained the movement of these objects in different directions and speed as a story. Respondents also commented upon the characters and intentions of the objects simply from observing their movements. Furthermore, Heider and Simmel showed the same animation video in reverse to other test subjects finding that participant interpretations regarding the personalities and intentions of the objects changed radically. In the first video, users explained the story as two objects bullying the other one. In contrast, in the reversed video, participants defined the previously bullied object as bullying the other two. This result pointed out that the movement of an object is an important cue for observers in inferring intentions. Moreover, respondents related these actions to human behaviors such as hiding, escaping, or fighting. Therefore, participants interpreted the animation through previous experience of movement as behavior. Michotte (1963) found the effects of speed, duration, and direction of movement on the causal perception of events. While slow movement of two objects in the same

**Figure 2.2:** Michotte's study of causal perception (1963). Actions that were defined as *chasing* (left) and *leading* (right).

direction was generally interpreted as *leading*, the same action with faster movement was perceived as *chasing* (Figure 2.2). The findings of Heider and Simmel, and Michotte have been tested in cross-cultural studies (Barrett, Todd, Miller, & Blythe, 2005; Rimé, Boulanger, Laubin, Richir, & Stroobants, 1985) and with child participants (Barrett et al., 2005) in contemporary studies. Previous studies found motion cues alone help participants infer the intention of an object independent of age and culture.

The human ability to understand the actions of an object might be related to self-exposure or the mere-exposure effect (Zajonc, 2001). This effect was supported by several studies in which participants showed preference for things simply because they were already familiar with them. Humans try to understand nature and other living beings by taking human behavior as a model because their own actions are the most familiar reference points. If someone is moving quickly, it could be inferred as an urgent event and the person might be in trouble. Humans then apply the same notions of movement and behavior to animals and even devices. For instance, if a dog moves slowly with its head down, one may predict that it is sick. In parallel, that same or a similar action on a device could be used to express a low battery message (Jung et al., 2013). Human body language is one the main reference points assigning meaning to motion.

The term affordance was coined by Gibson (1979), but Norman (1999) brought the term to the field of user experience. Affordance is the perceptual information provided by the appearance of a device or interface about its functions. A common example of affordance is a door knob showing where to hold and turn it to open the door. In a user interface, affordance is important in guiding users visually such that a device could reveal its functions through movement as well as color and shape (Djajadiningrat, Overbeeke, & Wensveen, 2002; Hoffman & Ju, 2012; Vaughan, 1997).

## 2.2. Metaphors

Metaphors and icons have been widely used in HCI since the first graphical computer interfaces. Metaphors assist users in understanding a new system by providing cues about how it works. Metaphors are inherently cultural (Saffer, 2005), so the previous experiences of users help them understand user interface metaphors. For example, although Android and iOS operating systems are different mobile phone user interface designs, both of them utilize a red dot to represent the video recording function in their camera applications, which is a transferred metaphor from their ancestor, actual video cameras. Metaphors are useful tools for quickly communicating with users allowing them the ability to use a new system by referring to previous systems with which users are probably already familiar. There have been various discussions about the application of metaphors in user interfaces (Hekkert & Cila, 2015; Marcus, 1998; Saffer, 2005). Yet, there is no single formula to metaphor design as it varies according to context and message.

Icons represent a message or a function in systems by using metaphors such as the garbage bin icon representing the file delete function. Even though the most common icon types are visual icons in graphical user interfaces, icons have been used to represent information in various media types (Freeman et al., 2017). For example, haptic icons, vibrotactile icons or tactons are used to transmit information through vibration patterns (Chan, MacLean, & McGrenere, 2008; Choi & Kuchenbecker, 2013; Maclean & Enriquez, 2003; Ternes & MacLean, 2008). Auditory icons, earcons or musicons are sound messages giving feedback to users (Fröhlich, 2007). Researchers have even conceptualized thermal icons using changes in temperature to carry information (Wilson, Brewster, Halvey, & Hughes, 2012).

### 2.3. Point Light

The pattern of a point light or light behavior is one of the most common communication methods in interfaces of electronic products informing users about the state of a machine. Other media such as color variance, graphic icons, and sound mostly support the light behavior in user interfaces. Various products use expressive light as the only feedback method because of space, cost, or aesthetic issues. Products with displays such as laptops, mobile phones and televisions also use point lights to communicate the status of the device while its display is off or to emphasize variable states.

Expressive point lights have a broad application area not limited to traditional consumer products. Take for example, Szafir, Mutlu, and Fong (2015) used applied light behaviors on a drone to communicate the intention of the drone including where it would move and how fast it would do so, finding that light behaviors increased communication clarity, intuitiveness and user confidence in interpretation of drone

**Figure 2.3:** Autonomous car concept with LED signals.

intentions. Beyond drones, Ford Motor Company placed a light bar onto the windshield of their concept autonomous car (Figure 2.3) to inform other drivers of different, more complex messages than simple turn signals such as auto-drive active and accelerating from stop (Marsh, 2017). Thus, expressive light patterns can be applied in various domains. Liu et al. (2017) explored how expressive lights communicate with users about connectivity states as the Internet of Things (IoT) has emerged, making connectivity an essential aspect of consumer products. They designed several light behaviors for a group of objects such as waking up, joining the system, synchronizing, and broadcasting a message. Harrison et al. (2012) designed various light behaviors and examined their interpretation on mobile phone by asking users to rate several device messages. 24 different blinking patterns were designed and users rated how much they agreed with the given device messages. Average scores of *notification* states were higher than other device states as point light on a mobile phone with a black screen might refer to notifications over several mobile phone brands. This


**Figure 2.4:** Products with LED lights to express device messages (from left to right, Bluetooth speaker, laptop, guitar effect pedal, robotic toy, mobile phone, shaver, mp3 player, mouse and, mixed reality device)

study showed how different light behaviors can be related to different device messages such as low battery, inability to connect, and processing without any other information on the device.

Light behaviors are found in devices such as computers, phones, and mp3 players that we are familiar with, as well as new technologies such as robotic toys, Bluetooth speakers and mixed reality devices (Figure 2.4). The most popular states among consumer products expressed by light are turning on, turning off, charging, charged, and low battery. Recently, *connecting* and *connected* states have become common on various products as the prevalence of connected products have increased. For example, a Bluetooth speaker blinks when it was not connected, but shows a constant light on while connected. A robotic toy flashes three different light colors while waiting to connect, and the colors that appear create its name, Sphero-GRO (Green Red Orange). The Sphero shows blinking green, red and orange colors before turning to its default color when connected, providing a control if users have more than one robotic toy. New technologies may lead to novel device messages that will demand new expressions in interfaces. Although the mp3 player, robotic toy, shaver, and mobile phone all use point light to communicate a *charging* action, they express it through different light behaviors. The duration of blinking, with or without fade in/out, and so on exemplify these differing light behaviors. As users learn most of these expressive light metaphors from their previous experience with other consumer products, should not the *charging* information be the same on all devices or is simply blinking enough to describe all these actions identically? The first research question in this work analyzes whether users infer the same device message from different products with identical action patterns. If so, then designers can apply similar action patterns to represent the same device messages in different products and it could be easier for users to understand these iconic representations of information on any new device that they have never used before.

### 2.4. Graphic Animation

Early examples of meaning creation via 2D animation movement have been presented in perception studies in psychology (Heider & Simmel, 1944; Michotte, 1963). The storytelling power of movement has also been used in cinema. In 1965, a short animation movie based on the book The Dot and the Line: A Romance in Lower

**Figure 2.5:** MacOS with a bouncing icon on the left and Jibo is expressing an emotion with a graphic animation on its screen on the right.

Mathematics (Goldman & Noble, 1965) using the same title, was released and won an Academy Award. The animation was about a love story between a *line* and a *dot*. Although the story was voice-narrated, audiences were able to understand the behavior and emotions of the simple graphical elements simply through their movement. In user interfaces, expressing device messages by graphic animation may not be as common as light behavior. In the Mac Operating System (macOS), the graphic icons bounce to indicate that the software is initiating (Figure 2.5). In the operating system of Apple mobile phones, iOS, the application icons start shaking after a long press to show that all icons are ready to be moved or deleted. One of the most popular graphical animations for software, website and mobile application interfaces is the turning circle which indicates a loading message. This animation expresses a processing message through continuous movement, but most users comprehend the action without doubt due to previous experience. This animation is an early example of motion design in graphic user interfaces and has become an archetype that can be recognized in different products. As another example, Jibo (https://www.jibo.com/), a personal assistant robot with a non-humanoid form and a large screen similar to a head (Figure 2.5), uses graphical animations its screen to mimic the motions of the human eye in an exaggerated fashion. Although it makes a direct reference rather than indicating a message with movement only, its screen uses animations instead of writing error messages to communicate with users more intuitively.

## 2.5.Body Movements

In this study, body movements refer to 3D movements of an object, in a physical or virtual environment, involving the motion of the whole body or parts of the body to reveal a device message, intention or emotion. There have been various studies of human gestures and facial expressions, and their application in humanoid robots, but this study focused only on abstract motion cues in non-humanoid devices without faces, limbs, and so on. While graphical animation indicated two-dimensional movement, body movements contain three axes of movement.

Weiser and Brown (1996) noted a dangling network cable that intensely vibrates while experiencing heavy network traffic, but making small twitches while a network is quiet. They described this art installation as a natural interface and an example of *calm technology*. Later, researchers applied body movement to HCI to express the intention of objects and robots (Harris & Sharlin, 2011; Ju & Takayama, 2009; Ramoglu, Bostan, Obaid, Goksun, & Ozcan, 2016; Saerbeck & Bartneck, 2010). Jung et al. (2013) noted that body movements could be used to improve user experience in products such as "a webcam gazing at us for a video chat or a phone dancing for an incoming call". Previous studies examined the potential of motion to communicate with users. Burneleit, Hemmert and Wettach (2009) developed an interactive device called an *impatient toaster.* This toaster shakes nervously if it is not used for an extended period, while subtle motion of the toaster shows that is active, and when toasting is finished it makes excited movements. In another study, researchers tested a mobile plastic tube as a robotic faucet in a bathroom environment mentioning the feedback from users was both positive and conducted by curiosity (Togler, Hemmert, & Wettach, 2009).

The parameters of motion have been discussed in various studies. Laban Movement Analysis (Laban & Ullmann, 1971) is a notational system for dance choreography and was applied to HCI studies containing movement to express the intentions of robots (Novikova & Watts, 2014; Sharma, Hildebrandt, Newman, Young, & Eskicioglu, 2013). The main parameters used were *time (quick / sustained), weight (strong / light), flow (free / bound)* and *space (direct / indirect)* in Laban Movement Analysis. There are also other parameters, mostly related to the human body such as *body parts*, *opening*, *rising* and *enclosing the body,* as well as other similar actions. Several parameters are also described in animation art in *12 Animation Principles.* Thomas and Johnston (1981) explained the traditional animation techniques of the Disney Animation Studio in their pioneering book the Illusion of Life. They describe several parameters that can be used in traditional animation to create meaningful actions such as *timing*, *anticipation*, *slow in and slow out*, *exaggeration* and *appeal*. These techniques were also examined in robotic studies and results have shown that animation principles are useful in expressing the emotion or intention of an agent (Ju & Takayama, 2009; Ramoglu et al., 2016; van Breemen, 2004). The parameters of motion design were also noted by Novikova and Watts (2014) and applied to a ball shaped robot to reveal emotions (Novikova, Ren, & Watts, 2015). Essentially, they grouped the parameters of movement into two main groups as *shape* and *quality*. Their shape parameter contains movements related to parts of the body such as *reduce the body, extend the body* and *move the body* that can be considered directional attributes of an object. Quality was the other main parameter including *suddenness, duration, frequency* and *strength.* Saerbeck and Bartneck (2010) applied similar speed (or the duration of action) and directional patterns to two robots finding that movement of robots was perceived as similar despite their appearance being different.

Previous studies presented various parameters for design movements. In addition, the ability of body movements to reveal intention and emotions has been explored in previous studies. In the related work section, how people infer motion and previous studies that used motion design to reveal meaning in different domains was shown. The device messages that could be presented by movement were defined in the subsequent section.

## 3. CLASSIFICATION OF DEVICE MESSAGES

Point lights in a user interface express device messages that are informational states, feedback, or notifications. Even though feedback and status are common terms in HCI, the term *device messages* has been proposed in this study to refer to *feedback* and *status* as sub-categories of *device messages*. Device messages have been specifically analyzed and clustered in three studies by Harrison et al. (2012), Jung et al. (2013) and Saffer (2013). To move these studies forward one step, definitions that examined device states from various perspectives were compared and a novel classification for feedback and notification in consumer electronics was presented in this study. Jung et al. (2013) designed body movements for a simple standing product with a robotic torso to express device messages. They sorted device messages into status and feedback. Status, explained as "Informing absent of user's intention", included two sub-categories as general status and urgent status. Feedback, defined as "feedback on user's intention", was categorized into four types: *positive, negative, neutral, and processing* feedback. Harrison et al. (2012) grouped device messages as *notification, active, unable, low-energy state,* and *turning on*. Saffer (2013) discussed device messages in the Feedback chapter of his book Microinteractions, and defined the following six states: *Something has happened, you did something, a process has started, a process has ended, a process is ongoing,* and *you can't do that*.

All of these studies categorized device messages from different approaches. Jung et al. (2013) systematically divided these messages into status and feedback. However, there is a grey area between the status of a device and feedback to a user action. For example, while a dishwasher is working, it can inform a user about an error such as no water or the process is completed. These messages can be interpreted as the status of the device because it shows whether it is working or not, or long-term feedback to user action, as users see these actions after they have started a process in the machine. If feedback is defined as information given after user action, then it might refer to an immediate device response or one later on after a given action. In the previous studies, device messages were shaped according to the products used. For example, Jung et al. first described movements with emotions, such as sad, angry and surprised, then passed on device messages (Jung et al., 2013). Thus, in their work, the product messages were categorized into positive, negative, and neutral, similar to emotions. Also, the device messages such as “detecting user”, “long time no use” (Jung et al., 2013) and “incoming call”, “received a message” (Harrison et al., 2012) were soley based on the functions of the robot and mobile phone respectively, and they are specific states of those products.

Based on previous works classifying states (Harrison et al., 2012; Jung et al., 2013; Saffer, 2013), four categories were defined without focusing on the functions of a specific product (Figure 3.1). *Complete and confirm* include confirmation feedback to a user’s successful action or when a process is completed. In contrast, *error and unable* categories contain negative feedback to user action and the unavailability of action performance. *Processing* messages show that a device is active or a process is ongoing. *Status and notification* messages express the general status of a device such as standby and sleep mode, or notifications such as missed calls, events, and updates triggered by the device without a user’s action. These categories in device messages also explained

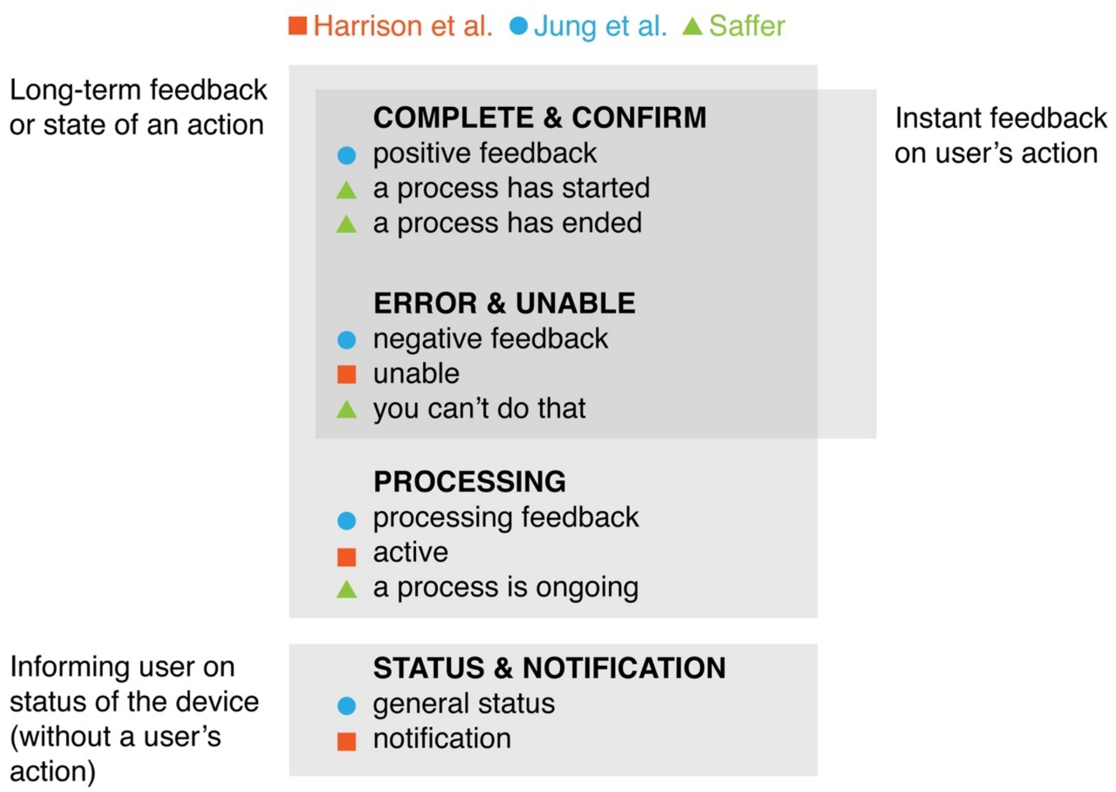


**Figure 3.1:** Classification of device states based on previous works (Harrison et al., 2012; Jung et al., 2013; Saffer, 2013).

by how they are triggered in Figure 6. For example, confirmation and error messages can be instant feedback after user action or long-term feedback if a process succeeds or fails, while a processing message is a state caused by a user's action. So, long-term feedback or the state of an action is the gray area between general status and instant feedback which includes the features of feedback because it is triggered by user action, but it also carries the characteristics of status because it can inform the status of a device such as processing. Also, Flaherty (2015) discussed states especially for website and application interfaces, and described these states by what triggers them such as user action, system event, or both. So, some states may be triggered by both a system event or user action as noted in the categorization.

Generalizing and clustering device messages help in the systematic examination of these messages. Researchers have defined informational states in the context of their studies; however, none compared different device message studies in the literature. In this study, device messages were identified based on comparison of other works, and contextual differences of light behavior were analyzed according to these device message groups.

# 4. USER STUDY: LIGHT BEHAVIOR ON TWO DIFFERENT DEVICES

## 4.1.Approach

Expressive light patterns have extensive potential for human-computer communication and can be applied to reveal device messages. Previous studies have shown the benefits of light behavior to intuitively communicate with users. Researchers examined device messages in single contexts such as mobile phone (Harrison et al., 2012), robot (Szafir et al., 2015), and connectivity (Liu et al., 2017). However, the meanings of light behavior in different products have not yet been examined. While numerous electronic devices use point lights to communicate with users, they exhibit limited light behavior vocabulary and the applicability of various light behavior definitions from previous studies to other devices is unknown. This study aimed to contribute to the HCI field by exploring how the characteristics of expressive light behaviors differ in two distinct products. Additionally, the effect of giving a scenario to users has been analyzed in this study to improve test conditions of light behavior studies.

## 4.2. Method

The aim of the study is to compare the effect of a product in the perception of light behaviors. A between-subject design was used to conduct the study to examine four conditions which are dishwasher (DW) (n = 34), dishwasher with scenario (DW-S) (n = 33), mobile phone (M) (n = 34), and mobile phone with scenario (M-S) (n = 32), respectively. Each participant saw one of these conditions and an accompanying three videos. In each video, there was a different light behavior such as complete, error or process. In every video, participants rated eight different device messages. Although the light behaviors are identical in every condition, they were exposed to a dishwasher in DW and DW-S conditions and displayed on a mobile phone in M and M-S conditions. In DW-S and M-S conditions, more information was provided to participants about the context in “The video you see shows the state of the device after you give the device a command”. In condition DW and M, participants were only informed via “The video you see shows a state of the device”. Thus, in the with scenario conditions, participants know that the expressive light on the device explains a status after they gave a command. Previous studies examined light behaviors without informing participants in which situation users will see this expression, which could affect the results regarding what they infer from an expressive light. Showing the same light behavior in a standby mode or after giving a command can differ the meaning. Thus, we added DW-S and M-S conditions to the study.

#### 4.2.1. Products

A dishwasher and mobile phone were chosen to be used in this study to examine the effect of contextual differences in light behaviors (Figure 4.1) because their features and user flow are quite different from each other, possibly changing user expectations of messaging types and meanings. Since a mobile phone has a screen for informing a user, participants might not expect many functions from a LED on a mobile phone. LED light on mobile phones most often inform users about notification or charging. However, in this study, we wanted to compare two products that do not have any similarity regarding usage or function. If participants understand the same feedback from different products via an expressive light, even though one of them has a screen that can use text and visuals to communicate, then it might point to these feedback types being universals to be applied to different products. Although these two products do not have the same functions, their feedback can be generalized. For example, many refrigerators do not receive any commands or show information. Thus, some consumer

**Figure 4.1:** Screenshots from study videos, mobile phone conditions (M + M-S) were exposed on the left scene and dishwasher conditions (DW + DW-S) were shown to participants on the right scene.

electronics were not suitable for this study as their device messages are rather limited and hard to generalize to other products. In this study, identical device messages were used in both the dishwasher and mobile phone conditions for comparison.

#### 4.2.2. Device messages

Device messages mean states, feedback, and notification in this study. Eight different device messages were shown to participants in each video for which they rated how strongly they agreed with the status. These informational states were created based on previous works (Harrison et al., 2012; Jung et al., 2013; Saffer, 2013) and limited to the states included in the functions of mobile phones and dishwashers:

Q1 - Command received

Q2 - Process completed

Q3 - Processing

Q4 - Working

Q5 - Unable to start the process

Q6 - Process failed

Q7 - Energy-saving mode

Q8 - In sleep/standby mode

Device messages were grouped by examining previous studies that distinguished informational states into different topics (Harrison et al., 2012; Jung et al., 2013; Saffer, 2013). These groups were defined as complete and confirm (Q1, Q2), processing (Q3, Q4), error and unable (Q5, Q6) and status and notification (Q7, Q8). 2 different device messages from each group were shown to alternate participant choices in the study and avoid guiding them to too few device messages.

#### 4.2.3. Light behavior videos

Comparing contextual differences of light behaviors on a single status might be unconvincing. Thus, three different expressive lights were designed based on the different device message groups as *process completed*, *processing* and *process failed*. Although there were four device message groups, only three videos were shown to prevent respondents from matching every video with one of the device message groups. The user study was designed based on the motion design of Harrison et al. (2012) and Jung et al. (2013). Every video lasted approximately three seconds. The control buttons were available for videos, so users were able to replay the light behavior while rating given device messages. The expressive light designs were evaluated by three interaction design experts, and the final videos were revised following their recommendations. Dishwasher and mobile phone pictures were placed in the backgrounds of the expressive lights. A blurred screen was used on mobile phone to prevent the perception of the device being in the sleep mode. Brands, text, and several buttons were removed from the products to anonymize them and allow participants to focus only on the expressive lights. The motion design and animation sequences can be found in Appendix A and videos can be reached online (https://vimeo.com/276123583).

#### 4.2.4. Study protocol

An online survey platform Qualtrics (https://www.qualtrics.com) was used to perform the study. 133 subjects (78 female) with a mean age of 28.1 years (SD = 6.1) participated. The online survey was shared on social media such as Facebook and LinkedIn and mailing lists of Istanbul Technical University. Participants registered for the survey voluntarily. The study was conducted in Turkish and all participants were native Turkish speakers to remove cultural and linguistic variables.

This online study started with a consent form and a brief demographics survey. Participants then rated "How often do you use electronic products? on a 5-point Likert scale (1 - Very rarely, 5 - Very often)" to ensure that all participants were appropriately relevant to consumer electronics. Then, subjects were exposed to one of the videos and rated eight states (Q1-Q8) individually, also on a 5-point Likert scale (1- Strongly disagree, 5-Strongly agree). This process was repeated by participants for three videos. The order of the videos and questions in every video were counterbalanced to eliminate bias.

### 4.3. Analysis and Results

#### 4.3.1. Analyses

The data was analyzed by two-way ANOVA with independent variables of *product* (dishwasher, mobile phone) and *scenario* (with scenario, without scenario) for each question in each video. The output variable was the Likert scale ratings (1- strongly disagree, 5- strongly agree) in the questions that were answered by participants. The model included all main effects and their interactions.

Although there are various discussions on using parametric statistics with Likert scales, many studies in different domains have applied parametric statistics with ordinal data and researchers have noted valid arguments for using parametric statistics (Carifio & Perla, 2008; Gaito, 1980; Norman, 2010). The user study was based on a previous study of Harrison et al. (2012).

#### 4.3.2. Result

Participants completed the survey in 4.6 minutes (SD = 2.5). Participants often use electronics products according to responses to the first question (M=4.62 SD=0.67). In the study, product and scenario factors were compared instead of examining whether users understood the designed light behaviors correctly. The study was instead focused on whether participants infer the same meaning from different products even if they infer the wrong device messages. Significant differences between mobile phone and dishwasher were found in the complete (Q4), error (Q1, Q3, Q4, Q5, Q6), and process (Q3, Q4) videos when each question was compared separately for every video (Table 4.1). A significant difference between with and without scenario was found in the process video (Q3). The interaction effect between product and scenario factors has been only found in the complete video (Q4). The frequency of answers (1– strongly disagree, 5– strongly agree) also showed similar results with mean scores (Appendix B). Most device messages were answered similarly for dishwasher and mobile phone in the complete (7 of 8 messages) and process (6 of 8 messages) videos. Almost half of the device messages were inferred differently by participants in the error video. The reason behind this result is various functions (in this case, error) might not quite fit the features and expectations of both products. Participants might expect error and unable messages from the screen of a mobile device. The user flow of a dishwasher is more linear: it starts, works and completes its process. A mobile phone, on the other hand, is always processing and active. If there is an error such as no internet connection or unable to send a message, other processes are still ongoing. Results in the error video also support this observation by the mean score of *error and unable* group (Q5-Q6) being the highest in the error video in dishwasher conditions, unlike mobile phone

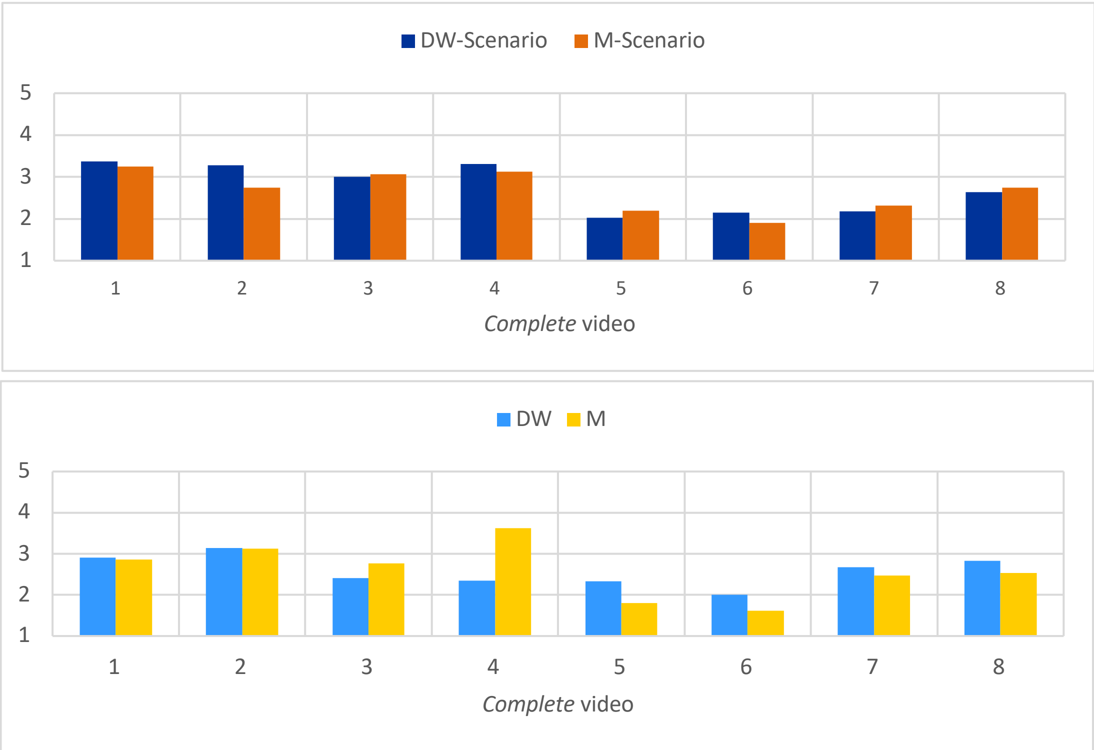


**Figure 4.2:** The mean scores of poducts with scenario (above) and without scenario (below) in *complete* video.

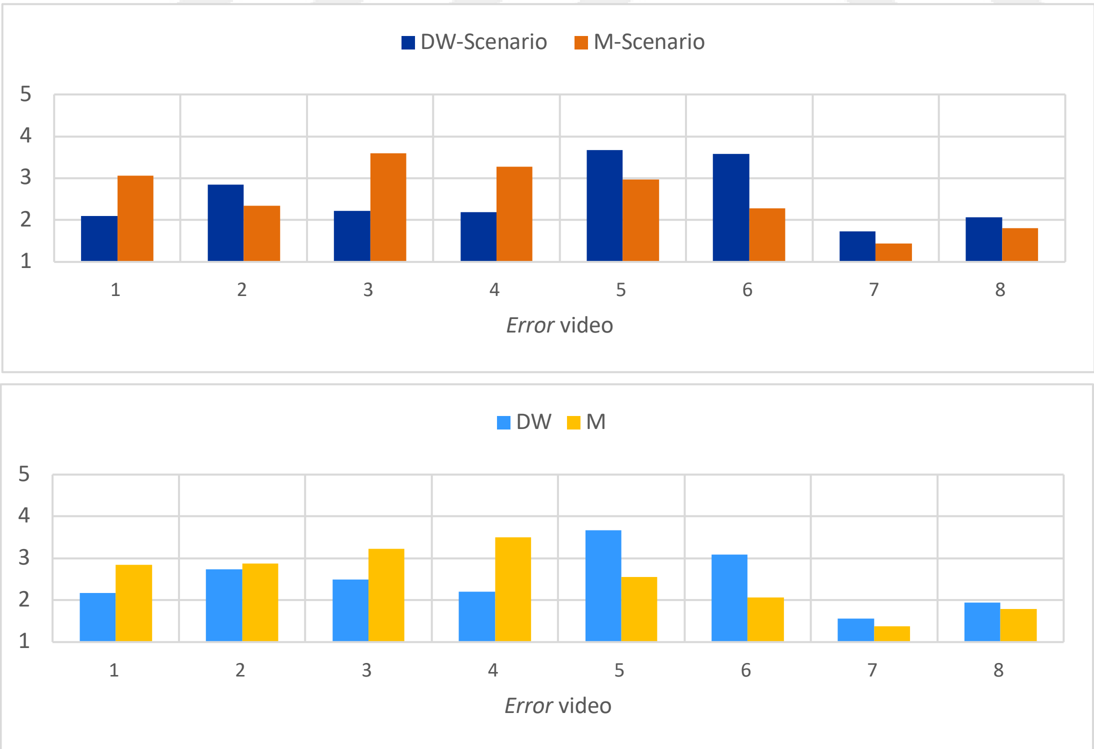


**Figure 4.3**: The mean scores of poducts with scenario (above) and without scenario (below) in *error* video.

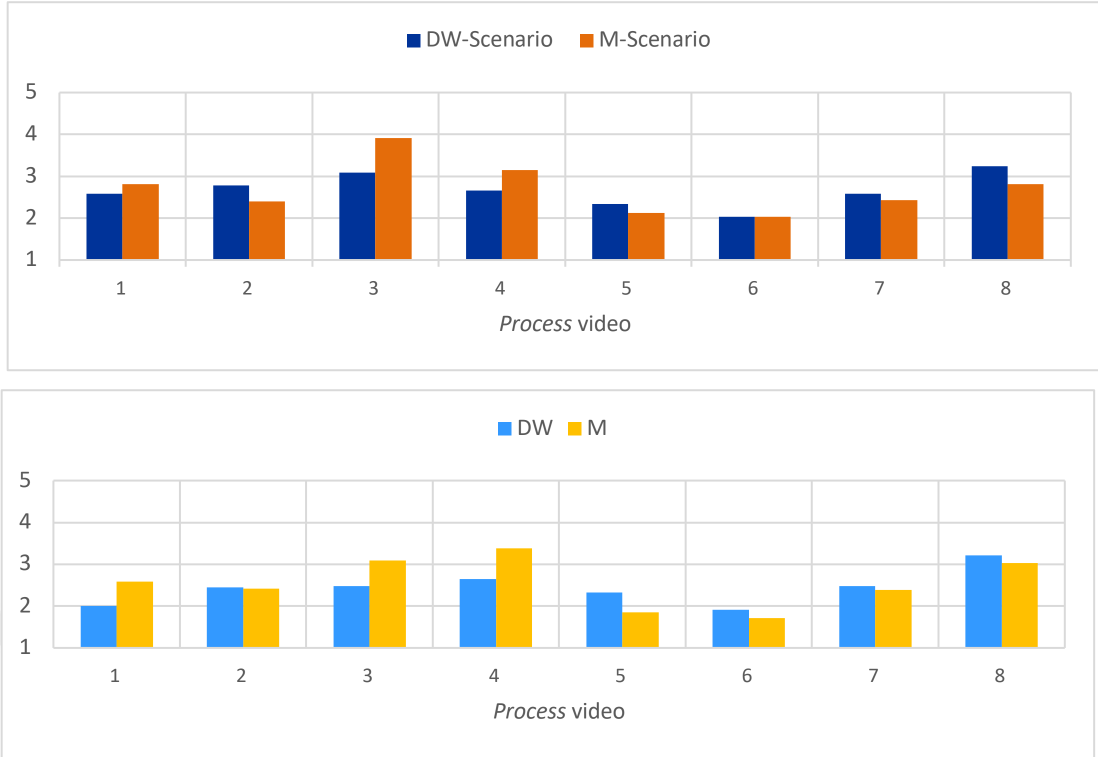


**Figure 4.4:** The mean scores of products with scenario (above) and without scenario (below) in *process* video.

conditions (Figure 4.3). Thus, the results can be interpreted to mean that identical light behavior can be applied to different devices only if they have similar working and usage logic. Specific feedback might have priority in one device's user flow while that same feedback is not important for another device. While an error message is crucial, and one of the main feedback types in the interface of a dishwasher, it is not a critical feedback on a mobile phone. The effect of the scenario was expected to help users to focus on one group of device messages and increase their mean score while decreasing scores on other device message rather it was an expected answer or not. However, a pattern in which the scenario affected observer understanding of the light behavior was not found. While videos with scenario generally increased the mean score of expected answers (Table 4.2), compared to conditions without scenario, the mean score of other answers also increased.

#### 4.3.2.1. Complete video

In the complete video, all questions except Q4 were inferred similarly for the dishwasher and mobile phone. The most significant difference was found in the working message (Q4) between the dishwasher and mobile phone, especially in the no scenario condition in the complete video. The *working* message (Q4) in the mobile

**Table 4.1:** ANOVA results with factors of product, scenario and their interaction. Significantly different results ($p$ < ,05) are highlighted.

| | | Complete video | | Error video | | Process video | |
|---|---|---|---|---|---|---|---|
| | | F | *p* | F | *p* | F | *p* |
| Q1 | Product | ,114 | ,736 | 12,666 | ,001 | 2,999 | ,086 |
| | Scenario | 2,772 | ,098 | ,072 | ,789 | 2,821 | ,095 |
| | Product *Scenario | ,012 | ,915 | ,406 | ,525 | ,544 | ,462 |
| Q2 | Product | ,938 | ,335 | ,449 | ,504 | ,633 | ,428 |
| | Scenario | ,180 | ,672 | ,635 | ,427 | ,436 | ,510 |
| | Product *Scenario | ,749 | ,389 | 1,490 | ,224 | ,465 | ,496 |
| Q3 | Product | ,674 | ,413 | 18,770 | ,000 | 8,850 | ,003 |
| | Scenario | 3,068 | ,082 | ,021 | ,885 | 8,916 | ,003 |
| | Product *Scenario | ,330 | ,567 | 1,750 | ,188 | ,168 | ,682 |
| Q4 | Product | 4,548 | ,035 | 25,220 | ,000 | 5,557 | ,020 |
| | Scenario | ,806 | ,371 | ,260 | ,611 | ,158 | ,692 |
| | Product *Scenario | 8,016 | ,005 | ,167 | ,684 | ,224 | ,637 |
| Q5 | Product | ,611 | ,436 | 12,092 | ,001 | 1,972 | ,163 |
| | Scenario | ,044 | ,834 | ,587 | ,445 | ,340 | ,561 |
| | Product *Scenario | 2,080 | ,152 | ,646 | ,423 | ,294 | ,588 |
| Q6 | Product | 2,165 | ,144 | 20,585 | ,000 | ,223 | ,637 |
| | Scenario | 1,065 | ,304 | 1,921 | ,168 | 1,047 | ,308 |
| | Product *Scenario | ,103 | ,748 | ,268 | ,606 | ,227 | ,634 |
| Q7 | Product | ,026 | ,873 | 2,357 | ,127 | ,218 | ,642 |
| | Scenario | 1,937 | ,166 | ,542 | ,463 | ,109 | ,742 |
| | Product *Scenario | ,515 | ,474 | ,139 | ,710 | ,011 | ,918 |
| Q8 | Product | ,137 | ,712 | ,880 | ,350 | 1,290 | ,258 |
| | Scenario | ,005 | ,945 | ,107 | ,744 | ,114 | ,736 |
| | Product *Scenario | ,699 | ,405 | ,058 | ,811 | ,225 | ,636 |

phone (M=3.62 SD=1.41) had a higher mean score than the dishwasher (M=2.35 SD=1.54) and it might be caused by the working status being more relevant with mobile phone features than the process completed message. However, participants that had been informed with the "video shows the state of the device after you give a command" message gave similar responses for both the dishwasher and mobile phone. So, when there is no scenario, users seemed to assume the device message based on the main functions of the device or the features expected for each device. In the complete video, the *working* message had a high mean score as it is an expected feature of a mobile phone. The *command received* (Q1) and *process completed* (Q2) messages were the highest in the with and without scenario conditions in the dishwasher.

#### 4.3.2.2. Error video

A significant difference between the dishwasher and mobile phone was found in the *process completed* (Q1), *processing* (Q3), *working* (Q4), *unable to start* (Q5) and *process failed* (Q6) messages. While mean scores were higher in mobile phone conditions for Q1, Q3, and Q4, the mean score for *error* messages (Q5-Q6) were higher for dishwasher conditions. This outcome may be the result of a reason similar to the complete videos in that an error message is not generally expressed via point light on mobile phones. Results also showed that the mean score for *processing* messages were higher in the mobile phone than the dishwasher conditions.

While the process and complete light behavior videos were answered almost identically for two different products (Figure 4.2 and Figure 4.4), the difference in the answers for the error video was interesting. Results in the complete and process videos have shown that users can understand the same feedback from identical light behavior on different products. However, the dissimilar results in the error video might be caused by error feedback in a dishwasher being a critical issue affecting its whole operation. In the mobile phone, an error such as connection lost or application stopped is not a crucial error regularly expressed with urgent light behavior. A simple pop-up on the display usually informs users about a problem on a mobile phone. Therefore, participants may have difficulty relating light behavior on a phone with error messages. The difference between devices in user flow possibly influenced the results for the error video more than for the process and complete videos.

#### 4.3.2.3. Process video

Respondents agreed on the *processing* (Q3) and *working* (Q4) states in the processing video for mobile phone (M=3.48 SD=1.43), (M=3.37 SD=1.50) more than for dishwasher conditions (M=2.78 SD=1.41), (M=2.66 SD=1.47), respectively. In general, scores for the processing group (Q3-Q4) were higher in all three videos for mobile phone conditions than most of the other device messages, showing that processing and working messages were natural options for respondents in mobile phone conditions. Giving scenario information affected the perception of participants in the process video. The *in sleep/standby mode* message (Q8) had a high mean score for dishwasher conditions possibly caused by the breath-like blinking being related to a paused dishwasher behavior since point lights of existing dishwasher user interfaces do not blink while the device is working normally, but instead stay constantly lighted. However, in this study device-oriented metaphors were not designed to develop the best light behaviors for mobile phones or dishwashers, in contrast, generation of generalized light behaviors that can be inferred in different products were targeted. The scenario only influenced results of the *processing* message (Q3) in the process video. The mean score of the *processing* message was higher in conditions with scenario. So, the confidence of users might be higher with the *processing* answer in scenario conditions because a process usually starts after a user command.

#### 4.3.2.4. Difference between with and without scenario

The mean scores of *complete* messages (Q1-Q2) in the *complete* video, *error* messages (Q5-Q6) in the *error* video and *processing* messages (Q3-Q4) in the *process* video slightly increased in with scenario conditions (Table 2). Increasing the mean score of one device message group and decreasing the mean score of all other device messages was expected under scenario conditions. However, such a regular pattern was not found when with and without scenario conditions were compared. Thus, the “giving scenario helped users to understand light behaviors better” hypothesis is hard to generalize with only the data herein. This result might have be affected by several factors.

The scenario sentence may not have gained the attention of participants or some of them may have ignored it while interpreting the light behaviors. The result might also be caused by the “after you give a command” information evoking certain device messages, and therefore the scenario not only increased the mean score of expected device messages but also the score of other device messages in the study. The scenario created a significant difference in the *processing* message (Q3) in the process video between mobile conditions (M-S vs. M), $F(1,65) = 5,718$, $p < ,05$ and the *workin*g message (Q4) in the complete video between dishwasher conditions (DW-S vs. DW), $F(1,66) = 6,606$, $p < ,05$. Thus, the “after you gave a command” information may have become associated with the processing messages (Q3-Q4).

In this study, expressive light behaviors were compared by isolating them from other media that support communication with users such as icons, text, and audio. Generalized light behaviors were designed to compare two different products and examined whether these light behaviors could be understood similarly, even if these light behaviors are unusual to the existing user experience of dishwashers and mobile phones.

### 4.4. Discussion

Feedback modalities such as blinking lights, physical movement, and auditory icons enhance the user experience by helping the user understand the device states better and use devices with less difficulty. Many consumer electronics only communicate through expressive light behaviors (Figure 4), while other products with displays use light behavior only to support the device states and feedback. Currently, light behaviors have been used with on, off and blinking states in consumer electronics, and the light behavior vocabulary is not very extensive. While a point light is on, it mostly shows that a feature or device is working. However, new expressive light definitions that increase the range of light behavior vocabulary might carry more sophisticated device messages than a fully lighted LED. In this study applicability of light behaviors, which is one of the action patterns, on different products to express the same device message was examined.

Mainly two parameters affected the meaning of the light behaviors. First, user flow of the devices and previous user experiences with these devices influenced the results. The *error* video was interpreted differently in the two products while the *complete* and *process* videos were perceived similarly. Respondents had not experienced the given light behaviors in the study on a mobile phone or a dishwasher before. Common light behaviors for *complete*, *error* and *process* states have generally been designed independently of devices. However, participants still interpreted *complete* and *process* videos similarly in the two products. In the error video, participants who saw the mobile phone condition could not relate the error messages with the point light. Also, all videos showed new, unique light behaviors, though only the *error* video was perceived differently. Probably, the previous experience of users influenced their decisions in the *error* video more than the other videos because they did not expect to receive this type of message from point light rather than from the display of the mobile

**Table 4.2:** Average scores of complete messages (Q1-Q2) in complete video, process messages (Q3-Q4) in process video and error messages (Q5-Q6) in error video.

| | M | M-S | DW | DW-S |
|---|---|---|---|---|
| Q1-Q2 (Complete video) | 2,99 | 3,00 | 3,03 | 3,32 |
| Q3-Q4 (Process video) | 2,56 | 2,88 | 3,24 | 3,53 |
| Q5-Q6 (Error video) | 2,31 | 2,63 | 3,38 | 3,62 |

phone. In addition, participants agreed on the *processing* messages (Q3-Q4) for the mobile phone conditions independent of the videos, so they might expect a *processing* message from a mobile phone. Second, the metaphors used in the light behavior design also affected the perception of the light behaviors. High mean scores of expected messages in all videos showed that participants inferred the *process*, *error* and *complete* messages. Results showed that the design of the motion patterns influenced participants, and these were designed based on existing metaphors. Users could associate them with similar motion patterns whether they saw them in a user interface or not. *Excited* or *alarm* messages could be inferred from a rapidly blinking light or a fast-moving robot. As these actions related to human beings, it could be understood by the majority of users. However, it is hard to design a novel pattern and expect that users will understand it. The real challenge is to decide with which metaphors most users may be familiar.

Previous studies examined the meaning of expressive light patterns in single products and the applicability of these light behaviors to other products was unknown. This study has demonstrated that identical light behavior across different products was most often inferred similarly. Usage flow of the devices, the previous experiences of users and light behavior design affected the perceived meanings of the light behaviors. The scenario did not create a significant difference, but it did increase the mean scores of expected answers in all videos.

The scenario factor was included in the study and asking users about their opinions on a single scene might not have delivered an accurate result. In real life scenarios, users observe these light behaviors in a situation in which they are more aware such as after giving a command or while a process is ongoing. Instead of informing users with a sentence, the effect of scenario could be better tested during a usability study while participants take action (such as pushing a button) and know that users see a specific light behavior in that condition. Light behavior was chosen to compare contextual differences in action patterns instead of vibration or body movements because point lights are currently the most common media in consumer electronics. If a light pattern was perceived as a similar message in different products, identical action patterns could be compared across different media to express the same device message.

In general, a rulebook for light behaviors that will fit every device is hard to define. However, defining a framework of light behaviors that expresses device messages is essential to guiding interaction designers. Although every device has its own context, products with a similar user flow could use same light behaviors to express the same device messages. Users most often learn metaphors in new interfaces from devices that they have used before. Therefore, this approach might increase the learnability of user interfaces. This study hopes to contribute to the HCI field by examining the effect of contextual differences of light behavior in the user interfaces of consumer electronics.

# 5. USER STUDY: ACTION PATTERNS ON THREE DIFFERENT MEDIA

## 5.1. Approach

Although various studies have discussed the meaning of movement patterns in point lights (Harrison et al., 2012; Liu et al., 2017), graphic animation (Heider & Simmel, 1944; Michotte, 1963; Scholl & Tremoulet, 2000), and body movement (Jung et al., 2013; Saerbeck & Bartneck, 2010), these modalities have been examined individually and, most importantly, separately. None of the previous studies have compared the applicability of these patterns to other media. This study aims to find the relationship between different feedback methods and discuss their parameters to understand how they can be applied to different modalities to express device messages. If the same action pattern is perceived as the same device message from different actions such as a blinking light or a moving object, then these action patterns can be generalized into an action pattern dictionary. In addition, behavior definitions for specific device messages from previous studies can be applied to other modalities.

## 5.2. Method

A between-subjects design was used in the study to examine the differences between point light (1D), graphic animation (2D) and body movements (3D). Each participant was exposed to one of these conditions and corresponding videos. In each video, a different action depicted the following device messages, *complete*, *error,* and *process*. After each video, respondents rated how much they agreed with the four different device messages. Then, responses were compared between conditions to analyze whether participants who saw identical device messages on different media inferred similar meanings.

### 5.2.1. Product and environment

Videos in all conditions had the same blurry kitchen background and the same square prism representing the product. In the 1D condition, the intensity of point light changed in front of the device. In the 2D condition, a smaller circular black graphic moved across the front surface of the device within a larger white circular screen. A cubical

**Figure 5.1:** Videos from the user study. From left to right: the point light, graphic animation, and body movements

prism turned and bent in the 3D condition to express its device messages (Figure 5.1). The prism was used because of its abstract form did not give away any clues about its function, so participants could only interpret device messages through its actions in the videos. Moreover, using such a simple object encouraged participants to focus only on the expressive action patterns of the prism, which was an ideal form for applying body movements such as bending and turning. The kitchen environment was chosen to emphasize that the device was consumer electronics intended for home usage. The device had an abstract form, but from context participants might expect functions typical of consumer home electronics.

### 5.2.2. Device messages

Four different device messages were shown to participants in each video, and they rated how strongly they agreed with each status. As mentioned in the previous study, device messages were grouped into four as *complete and confirm*, *processing*, *error and unable* and *status and notification*. These device messages were also used in this second study. However, instead of creating two similar questions for each group, in this study participants were shown one question for each group:

Q1 – Process completed

Q2 – Processing

Q3 – Sleep/standby mode

Q4 – Process failed

In the previous study, two different device messages from each group were shown to alternate the choices and avoid guiding participants to too few device messages. Four questions might not be sufficient to guide participants beyond single questions; however, this study was not testing if users could comprehend the designed device message in the videos correctly. Instead the focus of the study was on whether participants understood the same meaning in the compared conditions. Thus, one device message for each group (four device messages in total) were shown to participants.

### 5.2.3. Videos

In each condition, three different expressive action patterns were designed to represent various device messages as follows: *process completed*, *processing* and *process failed*. The sequence of graphical animation and body movements can be found in Appendix C and Appendix D, respectively. Point light actions were identical to the first study. The videos can be reached online (https://vimeo.com/276177889). Instead of comparing the action patterns across different media with one device message, three device messages were shown to participants for more accurate results. Three videos were shown instead of all four to prevent respondents from matching every video with one of the device messages in question. Every video was shown with the expressive action of that condition. For example, there was a blinking light in the 1D condition, a graphic animation on the screen of the device in the 2D condition, and body movements of the device in the 3D condition indicating the *process completed* message. In all three conditions, the same action pattern was used such that for the *process completed* message the intensity of light, the movement of the graphic, and the body movement of the prism changed at the same frame. The changes in intensity or position and timing were identical for all conditions. Thus, the same action patterns over different media were compared in this study.

Control buttons were available for the videos, so users were able to replay the actions while rating the device messages. Three interaction design experts evaluated the expressive action designs, and the final videos were revised following their recommendations. In the 2D and 3D conditions, there was a *direction* parameter different from the 1D condition, so the directions of the actions also affected the meanings. Moving left or right at the same frame when the intensity of light changed resulted in an equivalent action pattern. Thus, changing the direction did not change the action pattern used with the blinking light, but affected the meaning. In the 2D and 3D conditions, the same action pattern was used, but the directional parameter was used to emphasize the meaning of each device message.

### 5.2.4. Study protocol

An online survey platform Qualtrics was used to perform the study. 90 subjects (48 female) with a mean age of 28.7 years (SD = 7.3) participated. The online survey was shared on social media such as Facebook and LinkedIn and mailing lists. Participants registered for the survey voluntarily. The study was conducted in Turkish, and all participants were native Turkish speakers to remove cultural and linguistic variables.

The online study started with a consent form and a brief demographics survey. Participants were then exposed to one of the videos and rated four states (Q1-Q4) individually on a 5-point Likert scale (1- strongly disagree, 5-strongly agree). Participants repeated this process for three videos. The order of the videos and questions in every video was counterbalanced to eliminate bias. After users viewed their videos, they answered a last question: “Could you briefly describe how you made these inferences?”.

## 5.3. Analysis and Results

### 5.3.1. Analyses

The data was analyzed by one-way ANOVA with the independent variable of *media* (1D, 2D, and 3D) for each question in each video. The dependent variable was the Likert scale ratings (1- strongly disagree, 5-strongly agree) in the questions answered by participants.

**Table 5.1:** ANOVA results of comparision 1D, 2D and 3D conditions. Significantly different results ($p < ,05$) are highlighted.

| | Complete | | Error | | Process | |
|---|---|---|---|---|---|---|
| | F | *p* | F | *p* | F | *p* |
| Q1 | 5,688 | ,005 | 9,405 | ,000 | ,299 | ,742 |
| Q2 | ,217 | ,806 | 1,338 | ,268 | ,808 | ,449 |
| Q3 | ,462 | ,632 | 1,456 | ,239 | 2,453 | ,092 |
| Q4 | 21,463 | ,000 | 5,005 | ,009 | 1,542 | ,220 |

**Table 5.2:** ANOVA results of comparision 1D and 3D conditions. Significantly different results ($p < ,05$) are highlighted.

| | Complete | | Error | | Process | |
|---|---|---|---|---|---|---|
| | F | *p* | F | *p* | F | *p* |
| Q1 | ,008 | ,929 | ,196 | ,659 | ,172 | ,680 |
| Q2 | ,033 | ,856 | ,972 | ,328 | ,119 | ,731 |
| Q3 | ,363 | ,549 | 2,183 | ,145 | 4,366 | ,041 |
| Q4 | ,196 | ,659 | ,008 | ,930 | 1,755 | ,190 |

### 5.3.2. Results

Participants completed the test in 5.3 minutes (SD: 3.1). Identical action patterns over different media were inferred similarly by participants. 8 of 12 device messages were understood similarly in the 1D, 2D, and 3D comparison (Table 5.1). There was significant difference was caused by the 2D condition. When the 1D and 3D conditions were compared, only Q3 in the *process* video was found to be significantly different (Table 5.2). 11 of 12 device messages expressed via blinking lights and the body movements of the device were understood identically by participants. Comparison between 1D - 2D, and 2D - 3D conditions were the same as the 1D, 2D, and 3D comparison. Answer frequency (1 – strongly disagree, 5 – strongly agree) also showed correspondence with mean scores (Appendix E).

The differences between the three media were found in the *process completed* and the *process failed* messages (Q1 and Q4) in the *complete* and *error* videos. Therefore, the design of the *complete* and *error* videos may have affected the results. In the *complete* video, mean scores of the *process failed* (Q4) messages were low in 1D (M=1.50), and 3D (M=1.93) conditions for the *complete* video. In contrast, 2D actions had a low mean score for Q1 (M=2.53) and a high mean score in Q4 (M=3.40) for the *complete* video. Participants who viewed 1D and 3D conditions agreed on the expected device messages at a mean score of Q1 higher than other device messages. In the 2D condition, the circle moved in a round path, and when it reached the bottom it moved to the top in two steps like a check mark. As some users mentioned in the last question, they defined this motion as *complete* and rated it five on the Likert scale. However, other users who rated it with the lowest score, described the *complete* video as being unable to infer any meaning from the motion pattern. These participants also commented that completing a full circle as being related to process completion, so they believed that to complete the process the circle should have gone back to its start point by completing its circuit. Thus, the design of the expressive action affected the meaning interpretation. They may have interpreted the *complete* video as error in the 2D condition because completion of the circle was interrupted by moving back to the top in the middle of its round. The results also showed in the mean score of the error message (Q4) being higher than the complete (Q1) in the *complete* video for the 2D condition. In the *error* video, participants who saw the 2D condition agreed on the expected device message (Q4) with a higher mean score (M=3.97) than other device

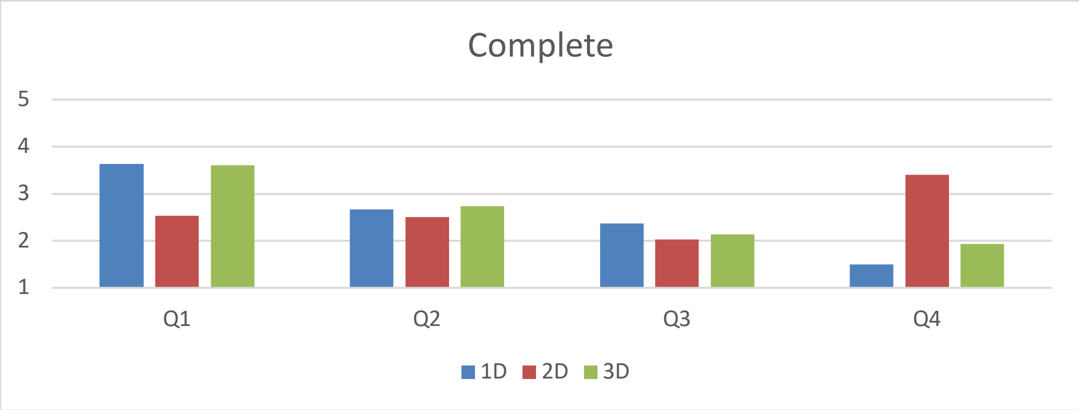


**Figure 5.2:** The mean scores of 1D, 2D and 3D conditions in *complete* video.

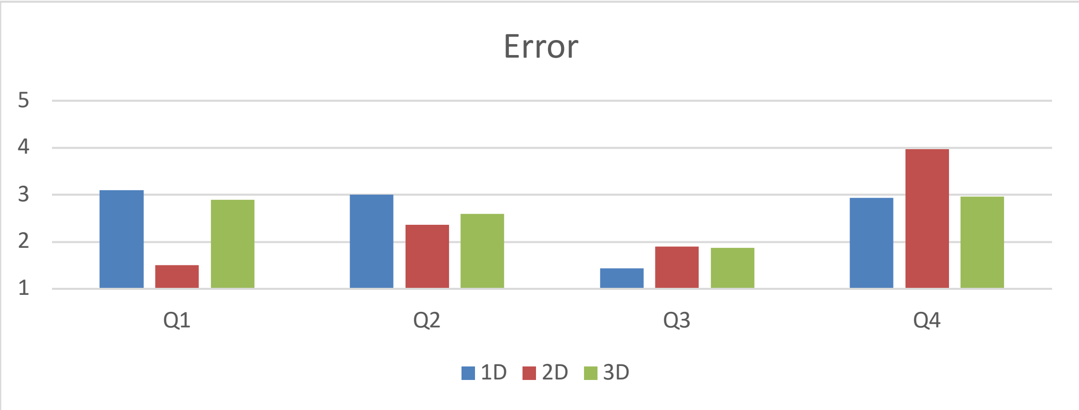


**Figure 5.3:** The mean scores of 1D, 2D and 3D conditions in *error* video.

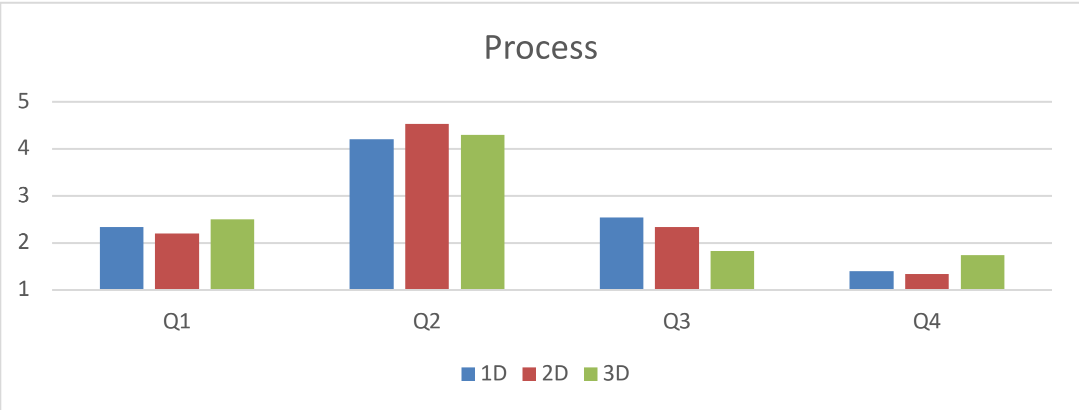


**Figure 5.4:** The mean scores of 1D, 2D and 3D conditions in *process* video.

messages. In contrast, in the 1D and 3D conditions, mean scores for Q4 were M=2.93 and M=2.97, respectively, and these mean scores were not higher than the responses to other questions. The mean scores of the *process failed* messages (Q4) were not quite the least agreed upon device message for the 1D and 3D conditions. However, users were not certain whether video was *process completed*, *processing* or *process failed* as all these device messages had a similar mean score around three (Figure 5.3). Thus, participants neither strongly disagreed nor agreed about these device messages in the *error* video. In the *error* video of the 1D condition, two participants mentioned that because the blinking light was white, they could not relate it to an error message. As most of the participants interpreted the expressive actions from previous experience, they expected to see the red light most commonly used to express error messages in consumer electronics. In the 3D condition, one participant noted that the sharp movements related to a process failed or completed. Another participant's comment supported this idea with the following: "Sudden and attention-grabbing gestures evoke a more successful or unsuccessful action because the device is expecting a response from the user. Quiet and swinging movements indicate an ongoing process or a device's resting / waiting state". In the 2D condition, participants stated that the action of the circle is as if it is stuck and cannot move. A similar action was used in the 3D condition in which the object was bending to the front and then shaking back as though it could not move further. However, the *stuck* meaning might be easier to understand from the 2D motion as the circle was actually moving by changing its place while the object in the 3D condition only bent and turned in the same spot. So, motion design in the *error* video might have affected results as in the *complete* video as well. Although all actions occurred in the same timeline and key frames in different media, the direction and the paths of the actions were not transferred to the other media. The point light did not have a direction parameter, and in 2D and 3D conditions they had different axes of direction. Only the time and intensity of actions were identical in all conditions. The direction parameter was used to support the design of the action patterns.

The *process* video was interpreted as *processing* in 1D (M=4.20), 2D (M=4.53) and 3D (M=4.30) conditions. Of the three videos, the *process* video was the most agreed upon video with high mean scores for the *processing* message (Q2) and low mean scores for other device messages. There was no significant difference between 1D, 2D and 3D conditions for the four device messages. However, there was a significant difference for the *sleep/standby* message (Q3), when 1D (M=2.53) and 3D (M=1.83) conditions were compared. The higher mean score on Q3 for the 1D condition than the 2D and 3D conditions seemed to have been caused by the previous experience of users. As the blinking light is one of the most common non-verbal feedback modalities in consumer electronics, participants have the most experience with blinking light actions in interpreting device messages. In most consumer electronics, a point light is fully lit while the device is on and blinks during a pause mode. In the study, a breath-like blinking animation was used to emphasize the *processing* message. Therefore, the mean score of the *sleep/standby mode* (Q3) message was higher in the 1D condition than the others. A similar result was found in the first user study as the mean scores for the *status and notification* messages were highest in the *process* video, especially for the dishwasher condition.

### 5.4. Discussion

The results showed that action patterns in point light, graphic animation and body movement could be transferred into different modalities to express the same device message, but the design of these actions influenced the perceived device message. Although participants were exposed to the same action patterns with identical timing and frequency of motion, the design of the action patterns affected the meanings due to direction and path of motion. These results were important in understanding whether the same action patterns can be applied to different communication methods to express the same device message. As a result, it should be possible to create an *action pattern dictionary* useful to interaction designers for different modalities and a variety of devices. In addition, patterns defined in previous studies can be applied to other media. For example, light behavior definitions for connectivity features (Liu et al., 2017) can also be used in the body movements of a robot or drone. Because participants explained the action patterns based on their previous experiences with devices, these abstract messages could be more understandable if users are exposed to similar patterns in various products. Thus, the applicability of action patterns across different media can increase the learnability and usability of user interfaces. The comments of the participants have been analyzed to understand these results in detail.

When users were asked to describe how they had made these inferences from the videos, they mentioned several topics which helped in understanding the results better. Most of the users mentioned that they made these comments based on their previous experiences. 12 of 30 participants who saw the 1D condition referred to their "previous experiences", "owned products" and several devices such as game consoles and computers in their responses to the last question. Considering that the last question was optional and not all participants answered it, a majority of participants explained the action patterns through their experiences with other products in the 1D condition. 7 Participants referred to previous experiences for the 2D condition and 4 participants for the 3D condition. Participants viewing the 1D condition mentioned their previous experiences and owned devices more than participants who saw the other conditions. First, these results indicated that in all conditions users tend to describe action patterns with expressive patterns from devices they have used before. Second, previous experiences were mostly mentioned for the condition with point light as it is the most typical communication method in devices among all the tested conditions. So, participants interpreted the meaning of the action patterns based on their previous experiences more if they had had similar feedback before. They related these action patterns directly with the existing expressive lights from another device.

In the 2D condition, movements of the object were most often comprehended differently compared to the other conditions. Specifically, they mentioned "path", "start and end point", "full round", and "circular path". Participants also noted their previous experiences with web pages, mobile devices and other interfaces for the 2D condition. In all conditions, the word "movement" ("hareket") was mentioned by 41 participants and "time" ("süre") was mentioned by 12 participants. Additionally, they mentioned several action related terms to explain how they inferred meaning from these videos such as "fast", "sudden", "speed", "rhythm", "frequency", and "continuous". Therefore, users understood feedback through the movements patterns highlighting how frequently the action was repeated, how fast it occurred, and whether the action was continuous or not. "Movement" was mentioned by 17 participants in the 2D condition and 20 participants in the 3D condition. These results indicated that in graphic animation, respondents referred to movement properties such as speed, direction, and continuous motion more than for the 1D conditions. Users might simply not be as familiar with graphic animation in user interfaces as point lights. Thus, respondents interpreted the action patterns as properties of motion rather than directly relating it to immediate feedback from a user interface. Although many participants noted movement in the 3D condition too, they mostly mentioned it in relation to the movement of human actions rather than the movement parameters of time and speed referred to in the 2D condition.

In the 3D condition, 7 participants considered these actions as "human" or "animal" actions and also mentioned "body language" and "emotional state". One participant noted, "When I think of the product as a human being, I think that when the top of the product is spinning, it was focused on its thoughts, showing that it was busy calculating an operation." Thus, many users interpreted the body movements of the device both with regard to the motion properties and body language in the 3D condition. In summary, these results indicated that users defined the three different media through the following mindsets:

1D: Direct relationship to communication in existent devices

2D: Interpretation based on the motion properties of time and speed

3D: Interpretation of motion properties and direct relationships to human behavior

In the 1D and 3D conditions, other than one device message, the results were similar. Although participants who saw the 1D condition referred to existent expressive light patterns, and participants who saw 3D condition referred to body language, both respondents gave similar answers to the device messages. This result supported the *action pattern* hypothesis. Even though different referents were mentioned, these patterns were perceived as identical device messages. The varying approaches to interpretation of the three different media are also significant to understanding the parameters of action patterns. The main findings of this study are that patterns in point light, graphic animation, and body movement can be applied to each to express the same device message, but the design of each action pattern influences the meaning. Besides applying the same time and frequency in another media, the action should be refined for the specific media to represent the same device message. In other words, the action pattern should be *fine-tuned* based on parameters such as *direction* of action while transforming it to another media. For example, moving a 3D object to towards or away from users may create alternative meanings (Harris & Sharlin, 2011). There is no *direction* parameter in point lights, therefore while transferring the action pattern to body movement, these parameters should be considered in order to design the correct motion to express any device message. This study revealed the relationship between different expressive actions and how users perceive different non-verbal communication on a device. In further studies, other parameters such as direction and intensity of action could be investigated to develop guidelines for designers. Moreover, visual communication methods such as light, graphics, and physical movement have been examined in the study, but the relationships between visual, auditory and even tactile feedback methods should be examined to include them within the *action pattern* hypothesis.

# 6. DISCUSSION AND CONCLUSION

## 6.1. Discussion with the Research Questions

The main hypothesis of the thesis was that actions in user interfaces influence user perception and comprehension of device messages independent of product type or communication method. Two user studies showed that action patterns can be transferred to different devices, and they can be expressed through different media via light and physical movement. However, the findings of these studies show that it is difficult to determine whether the hypothesis was true or false. User studies in the thesis showed that identical patterns can be applied to different products and different media to reveal the same device messages, but there were several variables that affect the results. In this section, the results have been briefly discussed regarding the research questions.

### 6.1.1. RQ1: classification of device messages

Although the device messages were not the focus of the thesis, it was important to generalize and present the analogy of device messages to better define the expressive patterns accordingly. Previous studies had not presented systematic analysis of device messages, rather they discussed the device messages within the scope of their studies. In this thesis, device message definitions have been grouped into *complete and confirm*, *error and unable*, and *processing* and *status and notification* groups. The user studies were conducted based on these device message categories. The aim of the action pattern hypothesis was to generalize non-verbal feedback in devices. While each device has unique features and expresses various information, it is hard to define abstract expressive actions for every single feature. Moreover, grouping similar device messages may reduce the cognitive load of users. For example, if the same auditory icon is used in a device for similar functions, users would simply need to learn one beep pattern instead of different sounds representing whether the device is connected, a feature is on, or a command is received. Otherwise, there will be hundreds of different sounds which will be neither feasible for designers to create nor easy to understand or follow for users. Thus, grouping device messages is not only useful in conducting future user studies but also important in allowing users to follow the iconic meanings of action patterns in user interfaces. Action patterns are basically abstract metaphors that create meaning in user interfaces. So, users first perceive an iconic meaning from the action and then relate this meaning to a feature of the device. For example, a breath-like blinking can be understood to mean a device is in a standby mode because it is the regular state of humans, and this slow, repeating pattern exhibits a calmer state. This meaning can be equated to the language of device being *in stand-by mode*. Designing unique metaphors and actions patterns for each feature would be exhausting. Thus, the taxonomy of common device messages in the thesis may provide a basis from which researchers can conduct further studies in HCI and help designers to define the communication and interaction of device messages in user interfaces. The device messages were grouped based on typical feedback and device states in consumer electronics. In further studies, the taxonomy of device messages can be extended to more specific device messages of different products.

#### 6.1.2. RQ2: identical action patterns in different products (dishwasher vs. mobile phone)

The action pattern hypothesis claims that the applicability of patterns in different types of expressive media to reveal an identical device message across user interfaces. In the second research question, the aim was to examine the applicability of the same patterns on different products. If users are exposed to similar patterns in different products, it could be easier for users to understand the non-verbal communication from a device they have never used before. Therefore, the applicability of action patterns over different products was examined via point light on two different products. The results indicated that participants perceived similar device message in the *complete* and *process* videos, but in the *error* video only 3 of 8 device messages were perceived identically in the dishwasher and mobile phone settings. The primary finding of this study was that action patterns can be applied to different products to express the same device message when the products have a similar user flow. For example, a dishwasher turns on, starts its process and completes that process, while since a mobile phone is always on and it can process multiple tasks simultaneously, the user flow of these two products were too different. While participants inferred the error message in the dishwasher condition, they disagreed about other device messages such as the *error* message in the *error* video in the mobile phone condition. Participants did not expect the see a warning message via point light instead of through the screen of a mobile phone. In this study, distinct products were chosen on purpose to examine products with different features and user scenarios or contexts. The transferability of action patterns between devices with the same working logic such as washing machines, ovens, and coffee machines might be easier. In further studies, the effect of similarity between user flows of devices could be examined.

The study showed that identical action patterns can be inferred as similar device messages in different products, and presented the criteria for transferring the same action pattern to different devices. Technology has been advancing rapidly, and emerging technologies have been affecting products and experiences. For example, with the emergent trend of the IoT, many devices are coming out with connectivity features which are bringing about many new device messages such as *onboarding*, *device is connected*, and *device is disconnected*. Thus, it might be just the right time to discuss and decide on how to effectively communicate these novel functions and states to their users. Every new device message also establishes novel metaphors with which to communicate. If different products use similar action patterns for identical features, it will cultivate familiarity in users and help them understand new device messages with greater ease. Since this work demonstrates that the same light behavior was inferred similarly, transferring action patterns to various other products could assist in the creation of a universal dictionary for action patterns.

### 6.1.3. RQ3: identical action patterns across different media (point light vs. graphic animation vs. body movements)

The last research question and user study related to the above research question tested the *action pattern* hypothesis. As mentioned in the previous research question, the aim of the hypothesis was to examine whether a universal action pattern dictionary can be created. Previous studies also showed that interpreting motion cues are independent from age and culture (Barrett et al., 2005; Rimé et al., 1985). Therefore, instead of designing new motion patterns for each feature, product and media, it should be possible to define an inclusive level of human-computer communication. To this purpose, the applicability of identical action patterns to different methods of communication was raised in RQ3. The results of the user study showed that action patterns reveal the same device messages via point light, graphic animation and body movement.

Direction of actions also influenced the perceived device message across different media. Device messages in 1D and 3D conditions were shown to be more similar while comparison of all the conditions showed that 4 device messages were not perceived identically by respondents, this result was especially clear in the 2D condition. The results led to the conclusion that action patterns can be readily transferred between blinking point lights and body movement, but are less likely to be applicable to graphic animation. Based on the responses to the last question, motion design apart from timing and intensity affected the perception of users. In the *complete* video, the object in the interface followed a circle and then went up in two steps to mimic a check mark, which was intended to express completion. Although the user study was not intended to find the correct action patterns for specific device messages, motion was designed to express a specific message such as complete, error and process to obtain more accurate inference results from the study. The hypothesis could be tested with random action patterns without the intention of a specific device message, but participants would then be more likely to blindly guess the action patterns without any referents. Therefore, timing and the intensity of actions were designed based on point lights in the first study, and then after minor revisions based on expert reviews, they were applied to the graphic animation and body movements. While the *check mark* metaphor worked for 1D and 3D conditions in the *complete* video, participants interpreted the movement of the graphic differently than in the complete message. Participants pointed out that the discontinuous movement by the graphic expressed that the process had been interrupted, so the mean score of the *error message* was higher for the *complete* video. One of the more interesting findings of the study was that path and direction of a device can influence the inferred meaning of that movement. Basically, the path was defined by the changes in the direction, so *direction* became another parameter of action patterns along with *time* and the *intensity* of an action.

*Time* defines when a motion happens, ends, and the time between two movements. The *intensity* of actions was the brightness of light or the distance moved in graphic animation and body movements; it is the strength of an action. For example, if an object can bend, the scale of the intensity between the maximal degree to 0 degree that an object can bend, while in a tactile feedback the scale is between the maximum amount of vibration and no vibration. Moving an object up or down can also affect the meaning of an action as a *direction* parameter. In physical movements, there could be multiple directions based on an object's freedom of movement such as rotating along the X, Y, and Z axes. As the direction parameter is not available to one dimensional actions such as point light and vibration, direction can be used to emphasize meaning by designers while transforming an action pattern from point light to body movement. Similar parameters were also mentioned in previous studies (Laban & Ullmann, 1971; Novikova & Watts, 2014; Ross & Wensveen, 2010; Thomas & Johnston, 1981). A parametric definition of movement can assist in the design of actions. To define universal action patterns that can be used in different media, these parameters should be considered. Users also mentioned dynamic motion in explaining how they interpreted the action patterns including the speed, timing, and flow of motion. Since not all of the tested communication methods exhibit all the parameters (e.g. point light), defining actions based on the essential parameters of time and intensity was a useful method also used in this study. However, while transferring action patterns to other media, specific parameters such as direction should be included to express device messages.

The hypothesis hoped to reveal the relationships between different communication methods. It does not claim to be a strict rulebook for non-verbal feedback, but simply advises that the design of any action could be referred to the action of another device in representing the same message. The study was conducted by transferring the exact timeline to three media to test the hypothesis. If a designer believes time, intensity, or direction need to be fine-tuned for a specific product, medium, or feature, then the pattern of another product or medium should not be duplicated. This study does not restrict designers to copying existent actions from interfaces, but rather supports their design of device messages by providing characteristics of actions. While designing the patterns and during the evaluation of these action patterns with interaction design experts, most of their comments were based on feedback from current devices and body language. Users also interpreted actions through previous experience and human movement. Therefore, designers should consider these metaphors in defining action patterns.

To summarize all the research questions, the device messages were classified based on previous studies and the contexts of device messages depending on if they were instant feedback to user actions or showed the state of a device devoid of user action (RQ1). Users inferred the same device message from identical action patterns in different products, but the use flow of the products affected interpretation (RQ2). Users also inferred the same device messages from identical action patterns from different media. Although the timing and intensity of the actions were the same for all conditions, direction of motion also affected the perceived device message (RQ3).

### 6.2. Main Contribution and Application Areas

User studies and discussions in the thesis touched on several topics. The thesis intended to contribute to the design and HCI fields by classifying device messages, revealing relationships between different non-verbal communication methods, discussing the parameters of motion design to express a device message, and analyzing how users interpret non-verbal feedback.

Non-verbal communication of device messages may be one of the most understudied topics in HCI. If one considers the human-computer communication as language, action patterns are its vocabulary and this vocabulary needs to be extended through continued work. Currently, the abstract vocabulary of action patterns is limited to just a few actions, such as on, off and blinking light behavior (Harrison et al., 2012). Although several studies have discussed iconic representation of messages in various media such as auditory, tactile and visual icons, "how to design action patterns for products with different features and usage" was presented in the thesis.

Today we are surrounded by numerous devices and the number will increase to 35 billion devices by 2020 (Camhi, 2015). How these devices will communicate with users to increase their life quality without frustrating them and without demanding too much effort and attention is an important issue in HCI. At first, there was one computer for many users, then with the rise of personal computers, there was one computer for each user. Now, users have a computer, a tablet, a mobile phone, and a smart watch, often times more than one each. In the future, we will have more devices with which we interact and it will require a higher cognitive load to process so much information. Therefore, we should focus on more intuitive interaction methods. Technology should not be placed at the center of our lives, instead it should be near invisible, blending in with its environment without demanding too much attention (Case, 2016; Weiser & Brown, 1996). Recently, innovation has become technology driven. As designers, we should bring a more human-centric perspective to innovation by making technology intuitive, natural and invisible.

Users should become informed while needing a minimum amount of attention and more intuitive feedback methods would be useful for users who are under high workloads. Demanding only a minimum amount of attention while doing a focused action such as driving a car is important. It could be easier to recognize an action pattern, be it visual, auditory, or tactile than to read text on a screen amidst focusing on the road, other cars, and pedestrians. In such cases, users simply do not have time to examine feedback, but instead must make quick, vital decisions. Non-verbal communication in user interfaces is not only useful for users with a high cognitive load but also provides more natural and intuitive interaction for all users.

Animation art is a magical experience. Understanding the personality of Alaaddin's magic carpet just through its movement is fascinating (Clements & Musker, 1992). Our ability to create meaning from abstract motion, enables animation artists to bring even inanimate objects to life. As previous studies in HCI have shown, while an algorithm runs in the background of the machine, we still believe that it has intentions and emotions. Outside usability issues, non-verbal communication methods can be applied the design of emotional aspects of products. As previously mentioned, humans tend to prefer familiar things, so giving personality to devices not by transforming human appearance but human behavior through expressive interfaces might help create emotional bonds with products. Carrying on human-like behavior instead of human appearance (e.g. face and limbs) is important for not to falling into the *uncanny valley* caused by realistic human appearance in robots (Mori, 1970). When body movement animations were shown to my friends, they became excited and began commenting on the personality of the product. So, the appealing experience of animation should be transferred to user interfaces to create more attractive products with character.

Expressive action patterns have a variety of application areas. The point light is already one of the most common type of feedback in devices with or without screens. Today, we also see it in emerging technologies such as home assistants, wearable devices and similar products. Body language have been used in social robots to interact with users, not only for humanoid robots but also robot assistants with abstract forms such as ElliQ (https://elliq.com/) and Jibo. There have also been studies on the body movements of drones to exhibit their intentions (Sharma et al., 2013; Szafir, Mutlu, & Fong, 2015). Beyond robots and drones, tangible user interfaces are increasing and even kinetic user interfaces that interact with users' physical movements have been discussed in HCI (Parkes, Poupyrev, & Ishii, 2008; Togler et al., 2009). In the future, body movement could be used as an interactive modality with daily objects as much as with robots and drones. Action patterns already have various application areas in existing products and will develop further in future technologies. To use them efficiently in user interfaces, we should continue to explore the as yet undiscovered areas of non-verbal communication.

### 6.3. Limitation and Future Work

The user studies did not result in the expected results for all questions for every condition without flaw. Although most of the device messages were inferred similarly in both studies, there were a few unexpected results, and actually these results helped in understanding the dynamics of the applicability of action patterns through different products and media. In this thesis, a novel term for HCI was proposed and tested through user studies. However, it is still only a hypothesis needing to be supported by further study. Mainly, to extend the *action pattern* hypothesis, other non-verbal communication methods such as auditory and tactile icons should be examined to understand whether users perceive similar device messages from both visual and non-visual patterns. The user studies should be repeated with a wider variety of products, especially comparing products with similar user flows might support the findings of the first user study.

In the second user study, *timing* and *intensity* parameters of the action patterns were identical in every condition. Because *direction* also affected the perceived device message, it should be examined in future studies along with timing and intensity. Moreover, point light, graphic animation and body movement inherently have different degrees of freedom. For example, a point light has intensity, graphic animation has intensity and direction along the X and Y axes, while body movement has intensity and direction along three axes. One of the biggest challenges while designing the action patterns was to create same meaning across different media. In addition, while comparing media in different dimensions, all conditions were expressed within a computer environment on 2D screens. The 3D object was displayed with an indoor background to emphasize its physical movements, but the perception of users might differ if they were to experience these actions in real physical space.

In further studies, a user study could be conducted giving tasks to participants and observing their interpretations of non-verbal communication because the context and state of a device also influence the perceived device message. The same actions might have different meanings when a device is in standby mode, off or working. Participants in the second study mentioned that sudden movements were more related to the *process completed* or the *error message* because the device was warning the user to take some kind of action. An action pattern with urgent movements could be interpreted as *something is wrong* in standby mode though while the device is working, it could be inferred as either *process is completed* or *failed*. For example, with a breath-like blinking light, based on the user scenario and the features of the device, a user may relate this action to mean a shaver is charging, or a washing machine is paused. Thus, the same action pattern can have different meanings even on the same device depending on its context and state. Therefore, action patterns can be tested with different media and different products in a user scenario with tasks in further studies instead of showing these actions through a single scene on a screen.

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**APPENDICES**

**APPENDIX A**

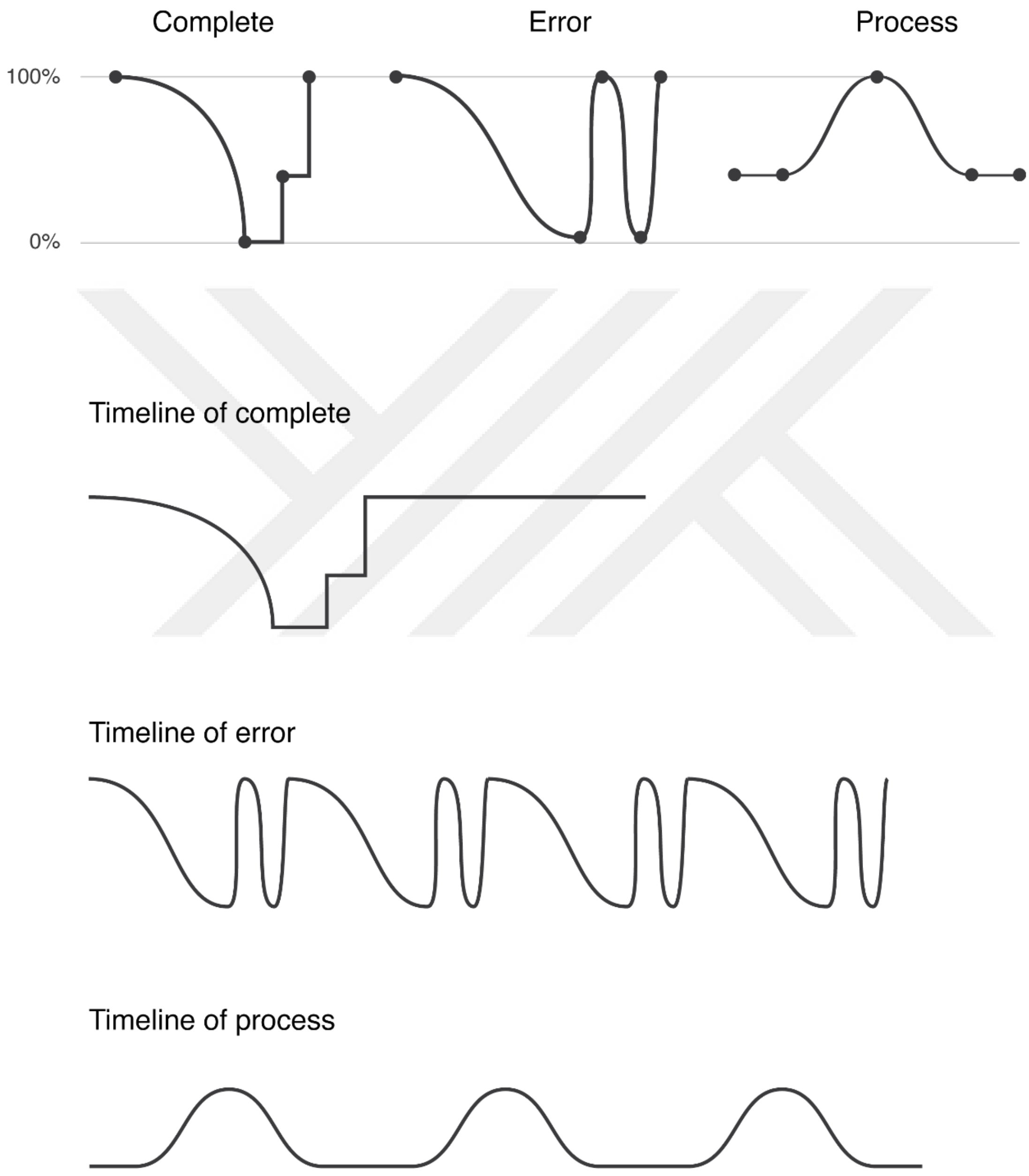



**Figure A.2:** Motion design of actions


**Figure A.2:** Sequences in the first user study

APPENDIX B

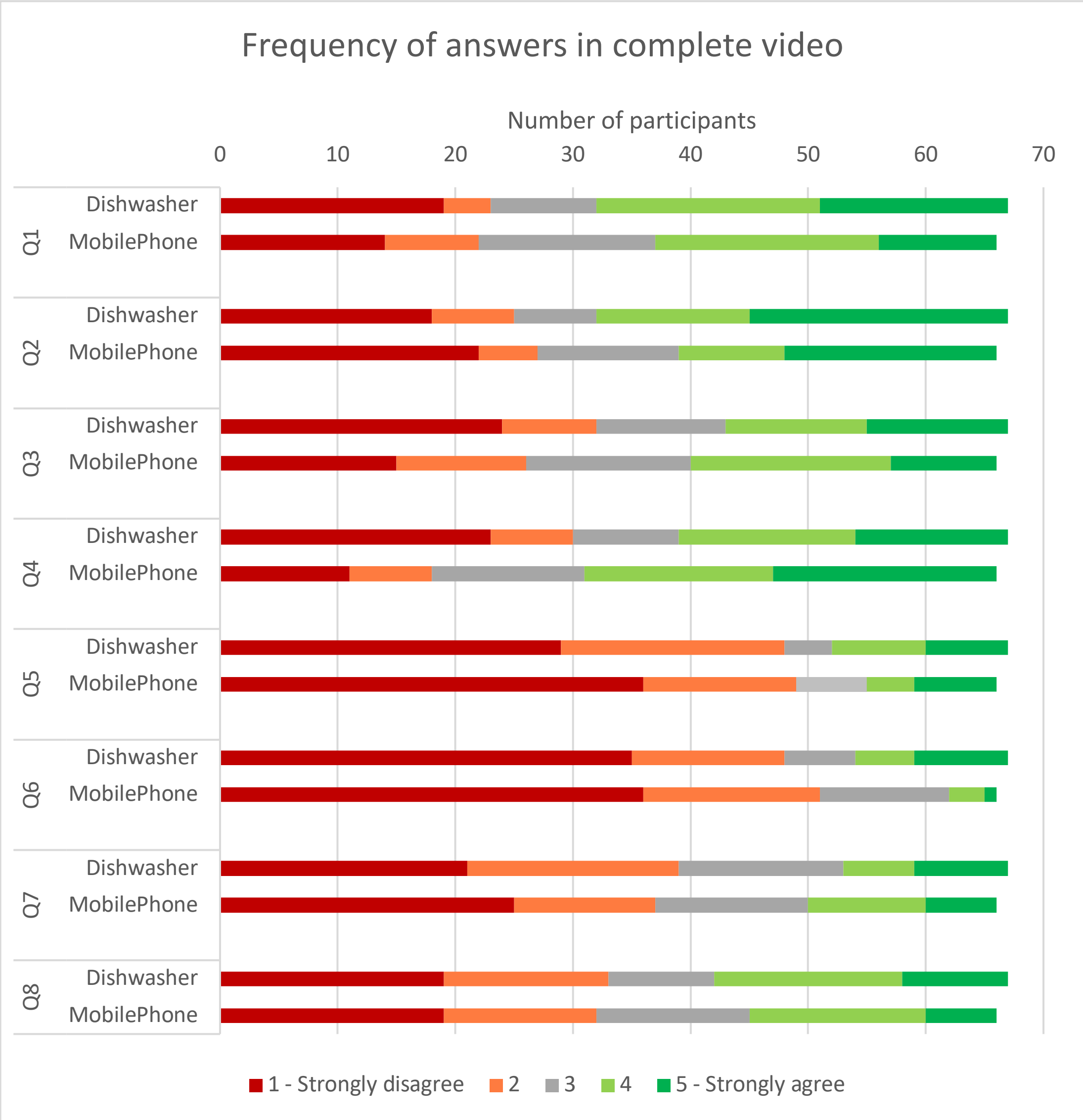



**Figure B.1:** Frequency of answers in complete video in the first study

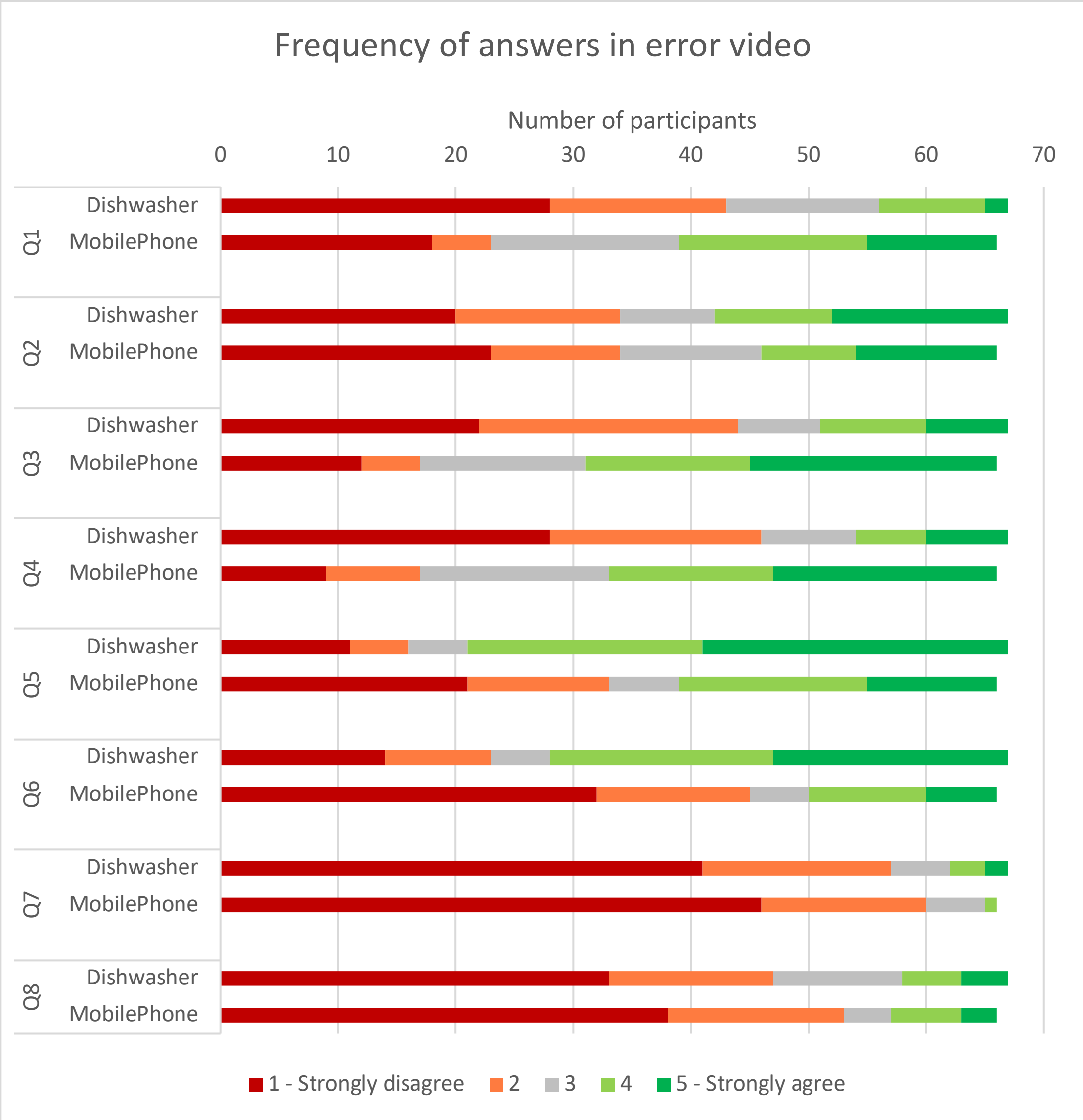



**Figure B.2:** Frequency of answers in error video in the first study

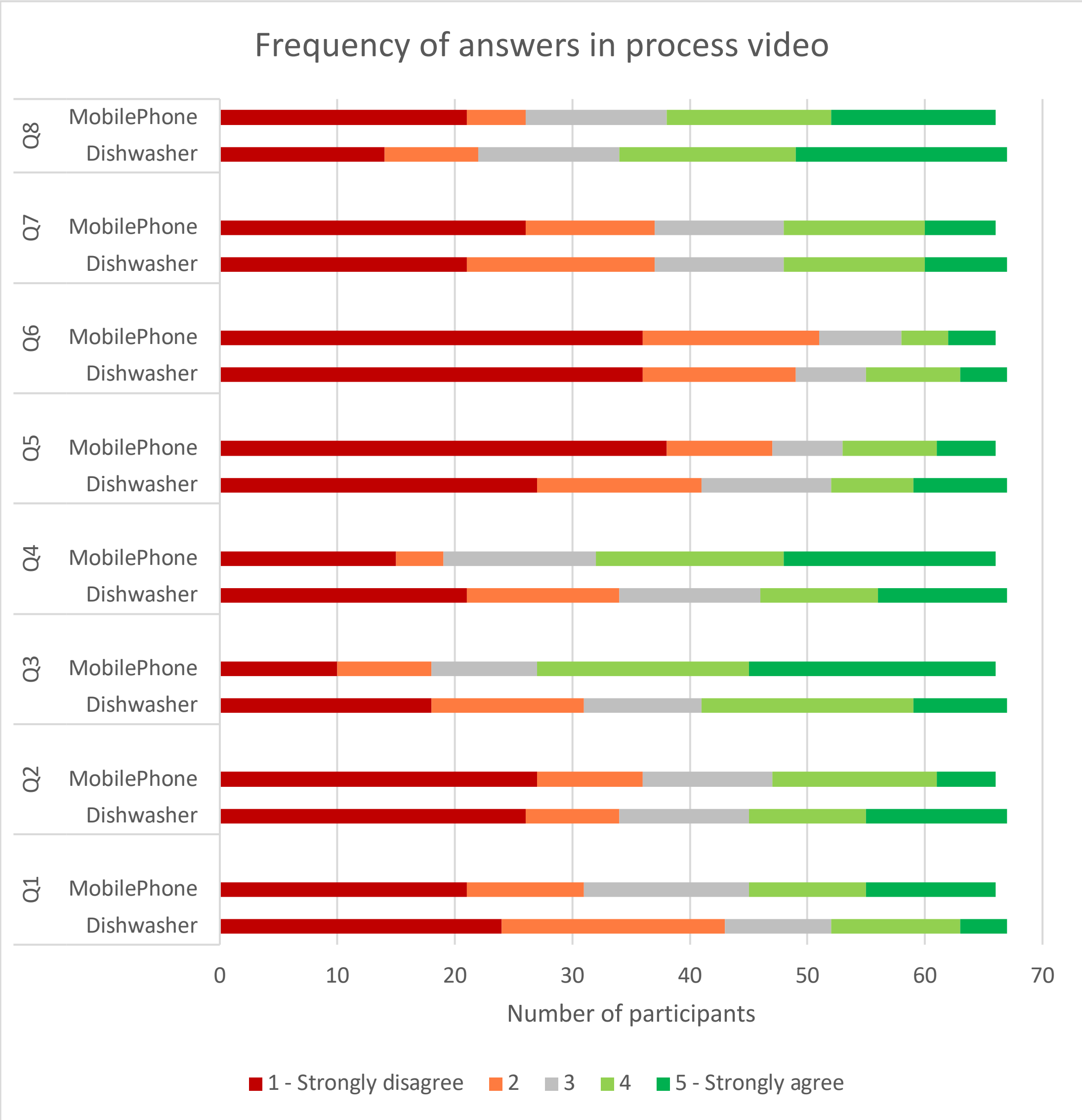



**Figure B.3:** Frequency of answers in process video in the first study

**APPENDIX C**

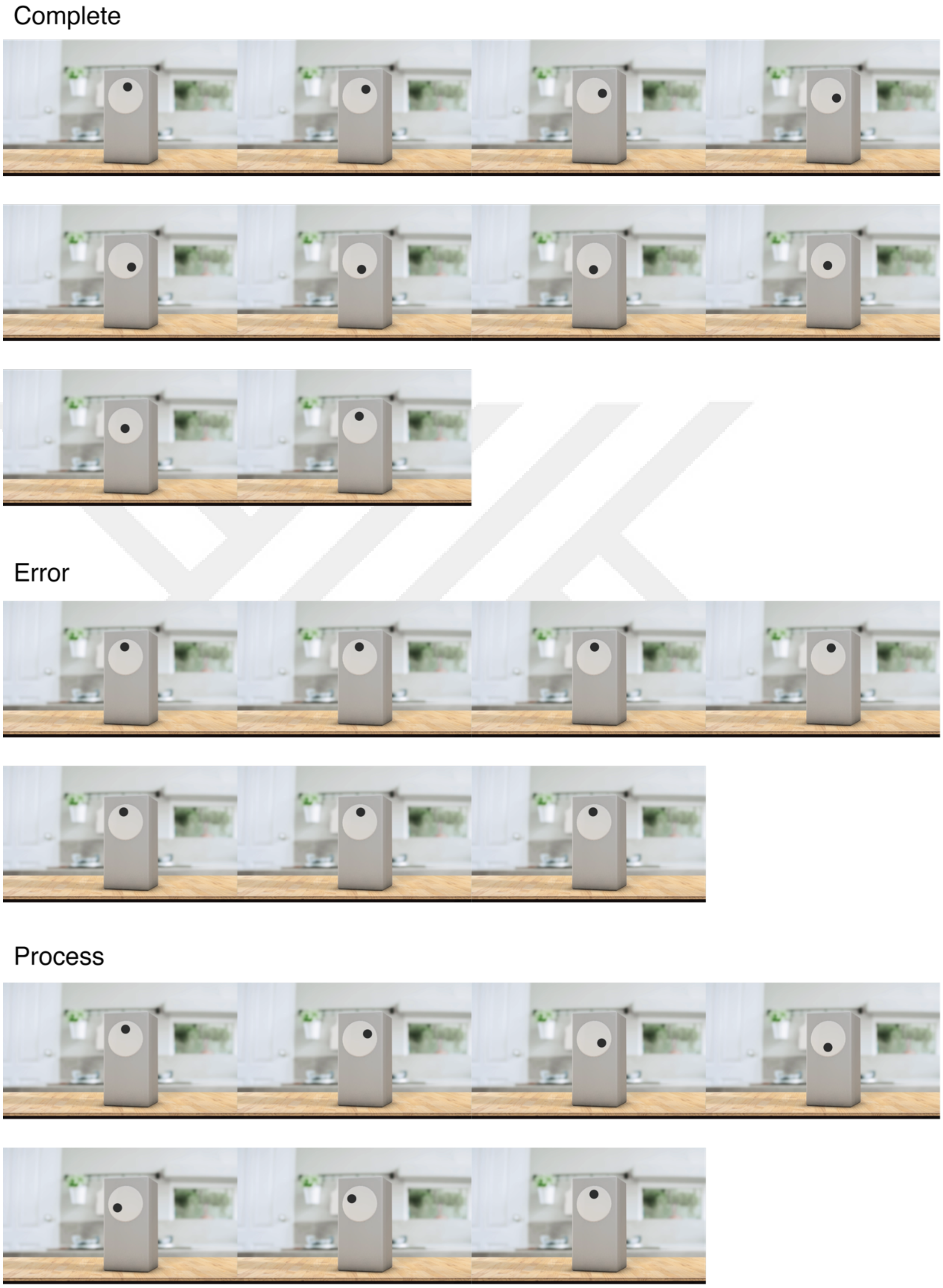



**Figure C.1:** Sequences of graphic animations

## APPENDIX D

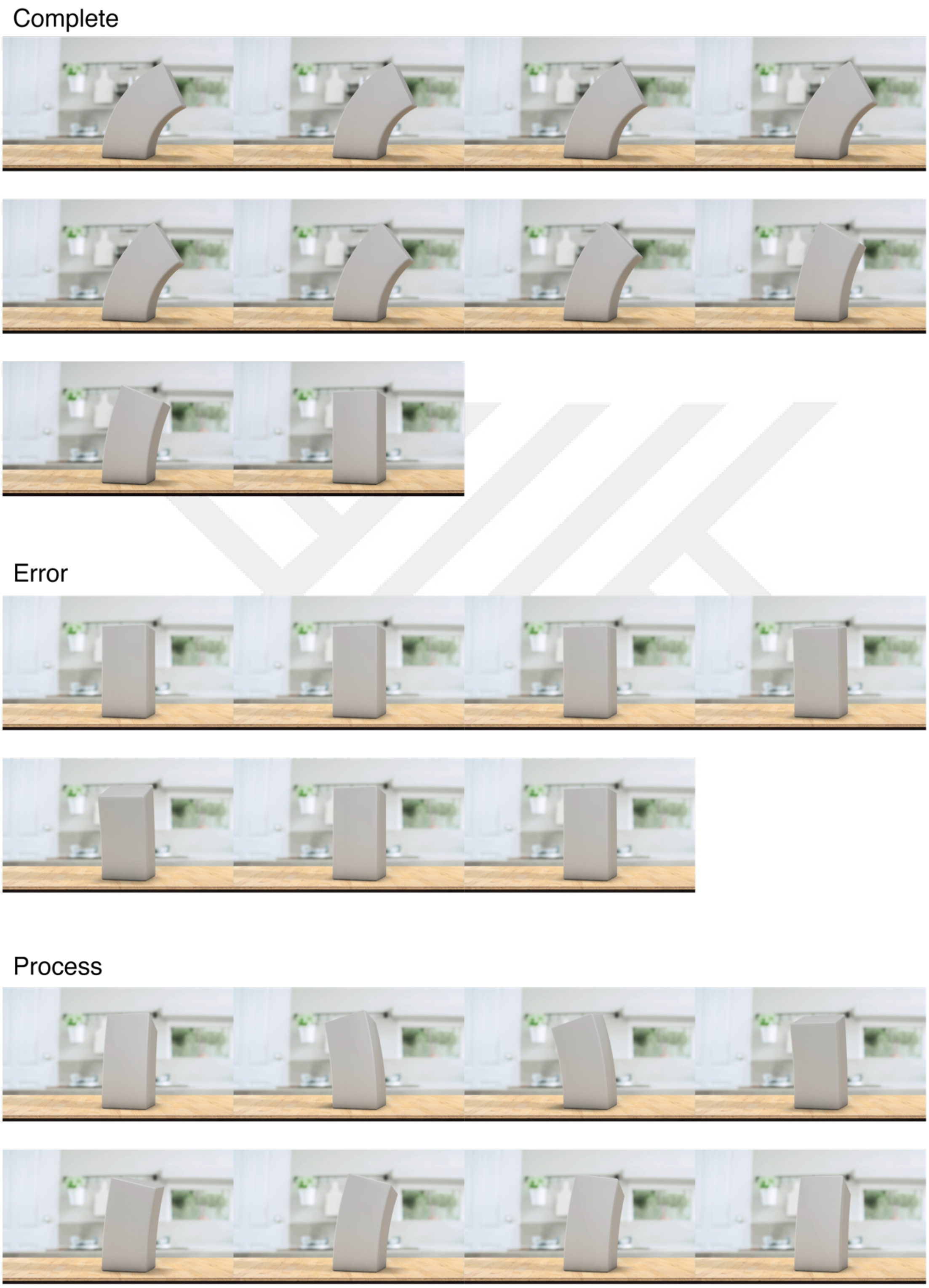
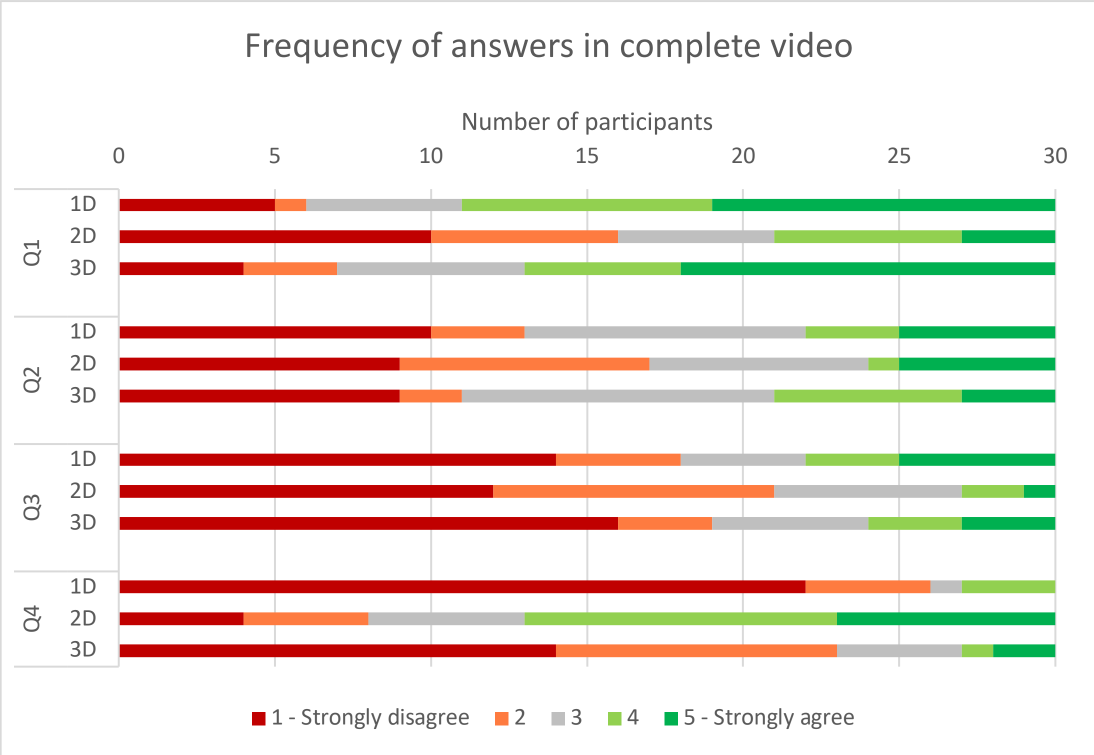



**Figure D.1:** Sequences of body movements

## APPENDIX E



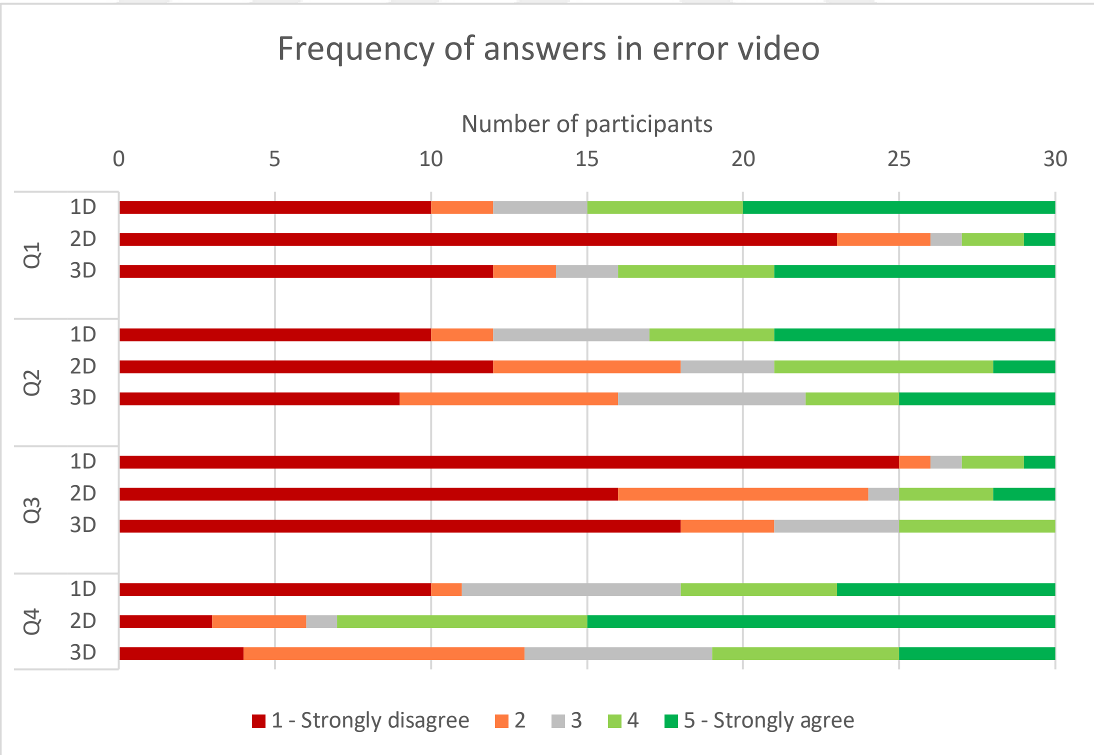




**Figure E.1:** Frequencies of answers in complete (above) and error (below) videos in the second study

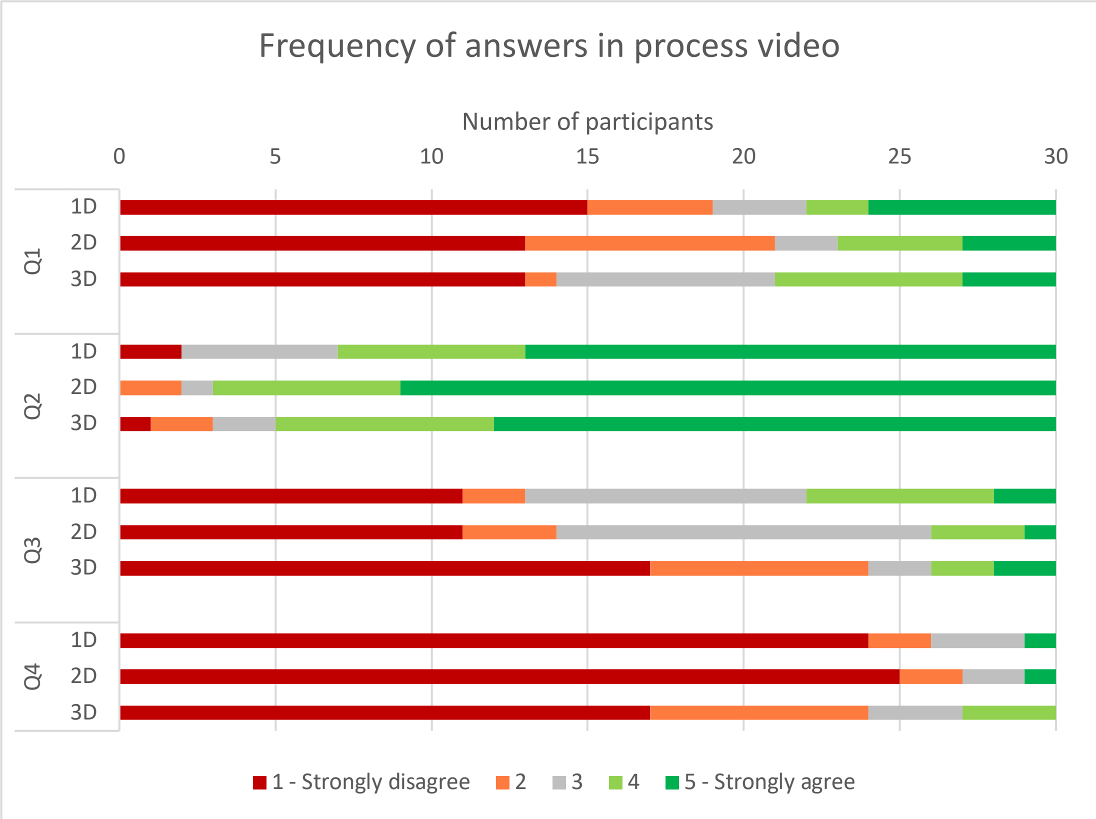



**Figure E.2:** Frequencies of answers in process video in the second study

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