UNDERSTANDING ANIMATION USE ON MOBILE INTERFACES

by

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This thesis is dedicated to my father: Hobbin Wang. Thank you for providing this chance for me to study abroad to gain knowledge that I am really interested in. Thank you for all the supports and encouragements.

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ABSTRACT

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Animations are playing an important role in today's user interface design. To investigate the animation usage on smart phone interfaces, in this study, I inspected 428 animation videos from five smart phone apps to answer the question: "How does the animation change on interfaces from 2008 to 2017?". By comparing the parameters such as frequency and duration based on the context from the historical perspective, the results can provide insights for both the HCI and UX community. The findings on the key markers laid a foundation for researcher to understand the animation use specially on interfaces in the industry overtime, also providing insights for practitioners to improve the user experience by looking into the animation use.

CHAPTER 1. INTRODUTION

This chapter provides an overview of the thesis study, introducing the background and the main focus in the area, establishing a stage for the research. The researcher will describe the scope of this study to show the reasonable boundaries. The following sections explore the background, the purpose of the research, theoretical framing, research scope, research question associated with this thesis.

1.1 Background

The promotion of the use of animation for user interface design by Chang and Ungar (1993) has brought the animation from cartoons to the interfaces. 20 years passed, animation has become an essential part of user interface design due to the advancement of the development tools such as HTML 5 and CSS 3 as well as the fast development of the processing power, and designers with increasing numbers are integrating animation in the app design on smartphone for richer experience. Animation can serve to focus attention and maintain continuity, respecting and reinforcing the user as the prime mover (Google, March 2017). The roles of animation were evaluated and organized in five categories: keeping in context, teaching aid, improving user experience, data encoding and visual discourse (Chevalier, Riche, Plaisant, Chalbi & Hurter, 2016). Moreover, the wide use of mobile phone has made the experience on mobile interface more important than ever before, as the overall Internet usage by both the mobile and tablet devices exceeded desktop usage for the first time in 2016 (StatCounter, 2016). Nowadays, animation has become an integral part of the user interface. It has become a key feature in design guidelines of leading software companies, providing design languages for designers to learn and use. Google stressed the role of the animation in Google Material Guidelines by calling on the cooperation of animators and other roles to further the creative dialogue and push the boundaries of technology. Unlike Apple's Human Interface Guidelines, Material Design considers animation as one of the core features of the user interface, which is more critical than other interface element such as color and the typography (Liddle, 2016). Google provides a more comprehensive section to set a standard for motion for designers, following three general principles: informative, focused and expressive. At the same time, many UI frameworks and

libraries are created like Motion UI and Velocity, helping designers to create CSS transitions and animations on apps.

While animation has been around for a long time and enjoyed a wide range of use in entertainment and film industry, to take interactivity into account, animation in HCI can be defined as:

> *a series of varying images presented dynamically according to user actions in ways that help the user to perceive a continuous change over time and develop a more appropriate mental model of the task (Gonzalez, 1996).*

Under this definition, animation, animated transitions and motion are all within the range of my topic. Since Chang and Ungar (1993) proposed 3 general animation principles (solidity, exaggeration, reinforcement) that can be applied on the interface, which were drawn from the twelve basic principles of animation in the book *The Illusion of Life: Disney Animation* (Thomas, Johnston & Frank, 1995). People have seen a significant change of animation use on mobile over time due to many external factors such as the changing social world and interaction styles, especially after the first smartphone was launched in 2007. For example, the unlock transition animation for iPhone changed a lot. In the times when people use swipe-to-unlock gesture as the way of interaction, the clock and the slide bar moved away at the same time with the clock moving out to the top and the slide bar to the bottom of the screen. The acceleration of the speed of this animation is the move partial transition. While when the interaction changes from swipe to a new feature called "Rise to Wake", which uses sensors to detect in iOS 10, the unlock transition changes to be faster and the sense of acceleration has disappeared.

Throughout history, we can identify lots of similar patterns across many products: functions proliferate, products become more portable and touch-screen based. However, many more things have been changed. To further understand the changes and the development, many historical analyses have been done in the field of HCI. For instance, Engholm (2002) used the concept of style as a means of classifying and understanding the graphic design on the internet in a historical context; Buur and Stienstra (2017) examined the interaction style in IT product design through a historical analysis; Chen (2016) inspected the aesthetic evolution of websites by curating them into the design periods.

The concept of style which originates from architecture and design has been used to describe the artworks. Similarly, for better naming and comparison, the concept of “periods” is

defined and frequently used by designers and artists to help critics to compare works based on the particular shared qualities (Thomas, 2016). Unlike fields such as architecture and design where people can explain the historical inheritance and comparing alternative design expressions through the well-defined style periods, HCI, as a relatively new field, is facing changes in a more dynamic environment with different artefacts and media coming out every day. However, not so much attention has been given to the topic of how things change and evolve, especially the ones on mobile device platforms. For user experience designers, just like Buur and Stienstra (2007) said, "a challenge much greater than simply creating 'user-friendly' interfaces: to convey expression through form and interaction". Animation, which plays an important role in both the interaction and the form on interface, is worth examining from a historical perspective.

1.2 Purpose of the Research

The goal of this study is to identify how animation change and evolution on smartphone interfaces through comparing the frequency and duration, thus enabling a first step towards the understanding of animation style period on smartphone interfaces in the last decade. By investigating this topic from the historical perspective, a better understanding of the development of animation usage in interaction and interface design can be gained. For researchers in the HCI community, a more comprehensive perspective on animation use can provide a foundation for further research; For practitioners in the UX community, designers can learn animation more efficiently based on the insights gained from this research; Additionally, more design opportunities may be found based on an understanding and comparison of past designs.

1.3 Scope of the Research

The scope of this thesis study is animation use on mobile interfaces rather non-mobile platforms. There are three reasons as follows. First, the limited and small screen size of the mobile interface pushes the content within the mobile interface as less as possible, on the other hand, the functionalities in the mobile application are increasing, which makes the interactions more challenging, the use of transitions and animations are more in need (Nielson, 2012). Second, the attribute of the touch screens provides more space of interaction on mobiles. Distinguished from the WIMP (windows, icons, menus, pointer) style which is the key feature of

desktop applications and websites, the touch screen holds a different system language. For example, the menus in mobile applications usually display as icons before clicking it. Thus, there are more challenges and possibilities on the mobile interfaces. Third, most of the research in this area has focused their attention within desktop applications such as the 3D computer animation or a specific element like the progress bar on desktop (Trapp and Yasmin, 2013; Lasseter, 1987).

1.4 Theoretical Framing

In this section, three theoretical frameworks used in this study are presented. These frameworks cover the key elements in my topic: (1) How to describe animation; (2) How to describe animation usage on interfaces; (3) What is the mindset like when doing research from a historical perspective. These three frameworks are: principles of animation (Chang & Ungar, 1993), rhetorical functioning of interface (Sosa-Tzec & Siegel, 2014) and humanistic HCI (Bardzell and Bardzell, 2015).

1.4.1 Principles of Animation

Researchers have been devoted a lot in exploring and identifying the animation types and principles on interfaces. The framework that still significantly influences today's design and laid a solid foundation for the field is the principles proposed by Chang and Ungar in 1993. Before this proposal, the static presentations are the normal standard. They first introduced the animation from cartoons to the user interface and presented 3 groups of principles that can be used on interfaces. They are solidity, exaggeration and reinforcement. 8 principle types are introduced under these principles: solid drawing, motion blur, dissolves, anticipation, follow through, slow in and slow out, and arcs. Some names of these principles like arcs and follow through are drawn directly from the excellent work on cartoon animation: *Disney animation: the illusion of life* (Thomas, Johnston & Thomas, 1995), however, they give them new meanings in the new context. After that, several influential researches have been done to further investigate the application of the animation on user interfaces. Thomas and Caulder (2001) focused on direct manipulation, trying to figure out the animation which can be used to reinforce the direct manipulation. Additionally, Novick, Rhodes & Wert (2011) attempted to enrich and improve the general principles by connecting types of animation with corresponding communicative

functions. Harrison et al (2007) explored animation use in progress bars, taking the user's perception of time into consideration and using it as a way to improve the overall user experience. Trapp & Yasmin (2013) have created a systematic vocabulary which classifies the animation into 21 types, serving to better communicate animated transitions in mobile storyboards. And in the newest edition in Google Material Design Guideline (Google, 2017), several techniques are provided under the main principles, such as fading and stagger.

1.4.2 Rhetorical Functioning of Interface Elements of Animation

Sosa-Tzec & Siegel (2014) provide an approach for evaluating the user interfaces using visual rhetoric. It challenges and extends the original notion of visual rhetoric by focusing on the notion of function. This approach focuses on the possible meaning and implication to users. The evaluators need to know about the system and its purpose, in addition to the audio, visual and physical component of the interface. In such case, designers can get a wider perspective, taking account the experiences, communication, and meaning into consideration.

Animation, as an element of rhetoric on the mobile interface, also going closely with the functions taking into account as the context of the use. As to this research, it can be beneficial to evaluate and compare animation which performs the same function. So, three dimensions will be taken into consideration for comparison when examining animation on the interface: the types, the form of the interaction and the function.

1.4.3 Humanistic HCI

Computing goes beyond the individual work settings, expanding and merging its branches into a larger social context (Wyche, 2006). In the meantime, a wide variety of approaches from the third paradigms have been emerging which fit poorly the models from either human factors or cognition revolution (Harrison, Tatar & Sengers, 2007). Lots of disciplinary perspectives are introduced to better guide the design, engaging humanistic topics, theories, and methodologies from the field of philosophy, literature or history to expand and enrich the body of knowledge in HCI (Bardzell and Bardzell, 2015). These humanistic theories and methodologies have contributed a lot to the HCI community although Humanistic HCI did not come to its own until the early 2000s. Among these major contributions such as critical

theory and historical genealogies, the historical perspective is the one that researchers in Humanistic HCI expect the researchers and designers pay attention to.

In fields such as art and architecture, scholars can have a chance to critique and explain things based on the past designs and periods defined by artists. By taking the historical accounts into consideration, which includes the interpretation of past events and traditions, considerations regarding the revolution process including how it developed and started, researchers can re-establish their knowledge from a systematic way and give them a solid background (Bardzell & Bardzell, 2015). While when it comes to history and tradition, HCI as a new and inter-disciplinary field can be quite different compared to some well-established fields such as architecture, fashion design as well as graphic design. Despite the well-known three paradigms accepted widely in the community (Harrison, Tatar & Sengers, 2007), historical accounts of single types of artefacts or media are quite limited.

According to Bardzell and Bardzell, "Humanistic HCI refers to any HCI research or practice that deploys humanistic epistemologies (e.g., theories and conceptual systems) and methodologies (e.g., critical analysis of designs, processes, and implementations; historical genealogies; conceptual analysis; in service of HCI processes, theories, methods, agenda-setting, and practices" (2015, p. 55).

One important contribution the Humanistic HCI made is to provide the historical consideration. It enables researchers to reconstruct their knowledge of the original act of language, styles, genres, and historical details.

1.5 Research Questions

RQ1: What animations are present in smartphone apps from 2008 to 2017?

a. What are the frequency and duration of each animation type?

b. What are the functions of the animations?

c. What user action triggers each animation type?

RQ2: How has animation use changed from 2008 to 2017?

CHAPTER 2. LITERATURE REVIEW

In this chapter, two areas of literature will be presented. The first section explores the approach to animation in the user interface design. Under this section, the animation principles, animation-focused design guidelines as well as the criticism and rhetorical evaluation are introduced. The second section discusses the approach to conduct the study from the historical perspective, including three parts. The first part introduces the evolution of HCI history in general by addressing the paradigms, which sets a stage for the topic. The second part anchors into how the concept of style periods in art and architecture helps people understand and build the field. The third part focuses on how the researchers in HCI conduct the historical analysis and draw insights from the cases.

2.1 Approaches to Animation in User Interface Design

In the following sections, the literatures related to the knowledge of animation on interface are introduced, including the animation principles, animation-focused design guidelines, criticism and rhetorical evaluation functioning.

2.1.1 Animation Principles

Researchers started to define how animation works and tried to figure out the principles on interface since long ago. Chang and Ungar (1993) proposed 3 general animation principles (Solidity, Exaggeration, reinforcement) that can be applied to the interface. Then Thomas and Caulder (2001) introduced the principle of attachment, reluctance, smooth as well as anticipation to enrich the existing principles.

Table 1 Animation Principles (Chang & Unger, 1993, p52)

	Principle	Example from Self interface
Solidity	Solid drawing	Objects move solidly
	Motion blur	Stippled region connects old and new locations of a moving object
	dissolves	Object dissolve through one another when changing layers
Exaggeration	Anticipations	Objects preface forward movement with small, quick contrary movement
	Follow through	Object come to a stop and vibrate into place
Reinforcement	Slow in and slow out	Object move with slow in and slow out
	Arcs	Objects travel along gentle curve
	Follow through	Object do not come to a sudden stop, but vibrate at the end of motion

Thomas and Caulder (2001) take the instances of direct manipulation to demonstrate how these principles work in reality. Attempting to provide valuable supplement to the general principles, Novick et.al (2011) constructed a similar set of models by making the connections between the types of animation and different communicative functions as shown in Table 2:

Table 2 Animation Types and Communicative Functions (Novick, 2011, p77)

Animation Types	A change of place
	A change of size
	A change of shape
	Gesture
	Rotation
	A change of color
	Blur
Communicative Functions	Signaling different context
	Signaling different value
	Signaling different status
	Signaling importance or urgency
	Signaling a change in function
	Signaling a referent
	Signaling salience

Bederson and Boltman (1999) found that animated changes of viewpoint help users with the process of constructing their mental maps, thus they can have a better special sense of

information. To be more specific, three out of four of the participants emphasized the contribution animation did to assist them with the understanding of the relationships between the data. Besides, a set of systematic vocabulary describing animated transitions in mobile storyboards was created by Trapp and Yasmin in 2013 to help the designer to deeply understand the animation types. They defined 21 animated transitions, as shown in Table 3.

Table 3 21 Animated Transitions (adapted from Trapp & Yasmin, 2013, p727)

#	Animated Transition	iOS 5	Windows	Android
1	Fade	✓	✓	✓
2	Cross-dissolve	✓	✓	✓
3	Move	✓	✓	✓
4	Move Partial	✓	✓	✓
5	Push	✓	✓	✓
6	Push Partial	✓	✓	✓
7	Zoom	✓	✓	✓
8	Buttons Fly	✓		✓
9	Carousel	✓		✓
10	Fade Sequential		✓	✓
11	Stretch in/Stretch out		✓	✓
12	Curl	✓		
13	Curl Partial	✓		
14	Flip	✓		
15	Iris	✓		
16	Genie	✓		
17	Fly By		✓	
18	Flip Partial		✓	
19	Turnstile		✓	
20	Turnstile Feather		✓	
21	Rotate			✓

2.1.2 Animation-focused Design Guidelines

The Design guideline is a living document that will be updated as we continue to develop the tenets and specifics of designs. Several leading software companies such as Google and Apple developed their own design guidelines, unlike Apple's human interface guideline, Google Material Design Guideline promotes an animation-focused strategy. As it puts in its newest edition, "There are times in our creative process when we need to branch out of our UX comfort zone and simply animate to test out new concepts and technology. Designers, animators, and engineers need each other to further the creative dialogue, create new interaction patterns, and push the boundaries of our technology." (Google Material Design, 2016). Animation becomes a standard design language for people to use in interface design. Liddle examined the various animation design guidelines created by leading software companies such as Apple, Microsoft, and Google in 2016 to understand the current animation use by comparing them with the principles proposed by past studies, which includes solidity, exaggeration, reinforcement, anticipation, attachment, reluctance and smoothness. From the comparison, he found that some of the principles such as exaggeration and reluctance were rarely discussed, while some other topics emerged such as the timing, the mass and the weight. We can also see that Google's guideline covers most of the principles. In conclusion, from Liddle's research, we can see that different guidelines tend to have different focuses in terms of animation principles, while we can also see some shared trend of animation use, for example, the reinforcement and smoothness are principles that all guidelines agree with. Table 4 shows the result of the comparison.

Table 4 Guideline Comparison (adapted from Liddle, 2016)

	iOS Guideline	UWP Guideline	Material Design Guideline
Chang and Ungar, 1995			
Solidity	Tangentially discussed "In general, strive for realism"	Tangentially discussed "Animation is a tool for creating a physical ecosystem to live inside and manipulate through touch."	Discussed Motion in the Material Design should embrace the familiarity and real-world behavior of the physical objects."

Table 4 continued

Exaggeration	Not discussed	Not discussed	Not discussed
Reinforcement	Discussed "In general, strive for realism" and "immersive experience"	Discussed "Animation is a tool for creating a physical ecosystem to live inside and manipulate through touch."	Discussed "Upon and input event, the system provides instant visual confirmation at the point of the contact."
Thomas and Caulder, 2001			
Attachment	Tangentially discussed "…Enhance the sense of direct manipulation"	Tangentially discussed "The quality of the experience depends on how well the app respond to the user"	Discussed "…Material can lift up when touched, indicating an active state"
Reluctance	Not discussed	Not discussed	Tangentially discussed "Lighter or smaller objects may move faster because they require less force, and larger objects need more time to speed up"
Smoothness	Tangentially discussed "In general, strive for realism"	Discussed '…the impression of enhanced performance…."	Discussed "Changes in acceleration or deceleration should be smooth across the duration of an animation."
Anticipation	Discussed "…users visualize the results of their actions"	Discussed "…drawing analysis from tasks the user is already familiar with."	Tangentially discussed "…acknowledge input immediately and animate in the ways like direct manipulation."
Topics not covered by traditional design principles			
	Consistency, caution	Consistency; personality; elegance; enhanced performance	Mass and weight; exploration; pressure; continuity; timing; choreography; delight

Among the three, Google has a more comprehensive document, stressing the importance. "In the Material Design Guidelines, motion plays an integral part to the overall feeling and functionality of the design framework", said by Sharon Correa and John Schlemmer in 2016. Within the basic principles like informative, focused and expressive, google material guideline provides a number of guidelines and techniques on how to use motion appropriately. They also

provide some dimensions which can be used to customized to express and describe the style, including the speed, movement and the sequencing. Thus, designers get more language to describe the animation based on these dimensions. Under the speed section, easing and duration are introduced. And under the movement section, things like motion path, overshoot, oscillation, stretch and elevation are mentioned, giving a more specific guidance to either describe or use animations. For example, motion path, both the linear and arc motion are introduced, and the arc motion is better to use be used when transitions that require a large adjustment to the aspect ratio of a surface.

Not only the leading companies set the guidelines for animation principles, but also designers in the industry create guidelines online for reference. Figure 1 shows a set of principles provided by Willenskomer in 2017. He proposes these principles based on the 12 principles of Disney animation, transforming and creating the new ones to fit into today's context.

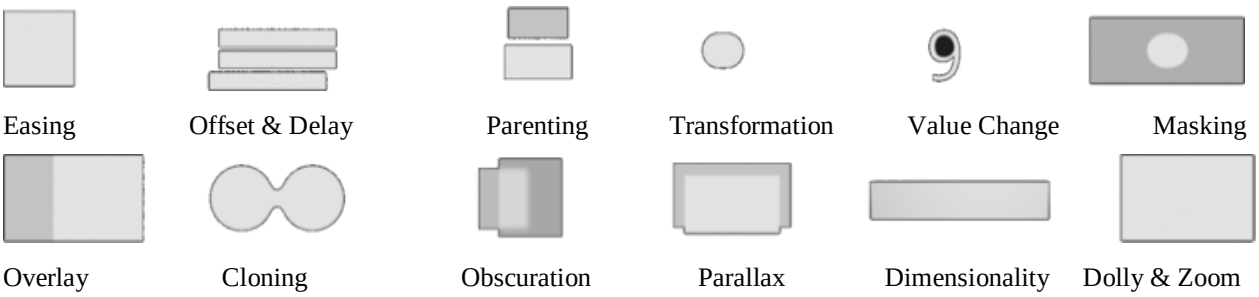


Figure 1 The 12 Principles of UX in Motion (Willenstomer, 2017)

2.1.3 Criticism and Rhetorical Evaluation as an Approach to Interface Aesthetics

With a special focus on the notion of function, rhetorical evaluation connects the rhetoric perspective and user experience (Omar and Martin, 2014). Basically, there are two criteria. The first is to inspect the apparent function, in other word, to align the interface with the user goals and the purpose of the interactive system, the second is the inspection of the functions performed by certain components. Components and interactions are analyzed as a whole as a means to comprehend their impact on the user. Rhetorical evaluation pays attention to the forms of the interaction and cares how they relate to the UI components including the visual, audio and the

physical. As a rhetorical element on the interface, animation can be described by taking the purpose/goal and the function into consideration, thus, a wide perspective of interface aesthetics can be gained by both the scholars and designer. It entails reflection since interacting with the system is the principle mean to comprehend the possible meaning of the user interface.

The interface criticism aims to provide an approach for designers to analysis the aesthetics on interface which are based on the media aesthetics. As introduced by Bertelse and Pold (2004), "designers can analysis the interface through identifying the use of standards and the conformance to tradition, considering various genres in the interface".

2.2 Evolution of Design Style

2.2.1 Shift of Paradigms in HCI Practice

There are three paradigms in HCI practice. The first paradigm places an emphasis on engineering and human factors, seeing interaction as a form of man-machine fit; While the second paradigm emphasized the information processing as a joint effort from both the mind and the computer without looking at it separately. The third paradigm then shifts the focus to the meaning making and context (Harrison & Sengers, 2007). In a word, a clear shift from the function and utility to the aesthetic and the felt experience can be seen throughout the history.

2.2.2 The Concept of Style in Architecture and Design

The concept of style has been the focus of much conversation within all genres of art, from museum and arts to architecture. Style has been used for different goals, to classify products and systems, but also to serve as an inspiration to create a specific look and feel (Engholm & Salamon, 2005). In the field of interaction design, it can provide designers with strong visions and a sense of direction in designing new user interfaces. And in history of architecture and design, the style labels often come from the style discourse of period, for instance, Dada, Art Deco. Periods provides an opportunity for people to critique designs according to their shared qualities. By defining a period, techniques, styles, tools as well as vocabulary are better organized and constructed, making it easy for people to develop and build-upon. For instance, romantic music is built-upon the impressionist music (Thomas, 2016). As of art periods, there are generally six large periods, including Renaissance, Renaissance to

Neoclassicism, Romanticism, Romanticism to modern art, and Contemporary art. And these periods are divided into several periods respectively. Take one period of time in history for example, in the times of Renaissance (c.1300-c.1602), there are roughly three art periods: Italian Renaissance, Renaissance Classicism and Early Netherlandish painting. In the period of Early Netherlandish painting, the art works shared a common international Gothic style.

From a linguistic perspective, Enkvist (1983) has mentioned that the basis of the style is that all experiences of style arise from comparison. The comparison can depend on the function and usage or connections in time and space. And according to Enkvist (1983), people can identify style markers through the comparison.

2.2.3 Historical Perspective in HCI Research

In HCI, several attempts have been made to examine designs from the historical perspective which is promoted in the humanistic HCI. By taking the historical account into consideration, different researchers hold different goals and methodologies. For example, Jacob and Marcelle's (2007) seeks to preserve qualities of interaction which are lost in history through understanding the development of interactive products while Wyche's (2006) goal is to identify new design spaces by understanding how household technologies change over time employing historical analysis approach. In this section, 4 examples are provided to show the process on how to do a study which sees from a historical perspective.

Øritsland and Burr's (2000) study aims to understand the change of the style and thus seeks to transit periods of style in the past to new expressions by focusing on physical products which have small functional displays. In order to identify different interaction style periods, the first step of the research team is to figure out what properties would influence the changes of the style. In agreement with Ylimaula (1992), The research team decides to analyze and define the periods through looking at technological innovations, company spirit as well as societal trends. With the 3 properties in mind, the research team in this paper defines the periods through the analysis of the product from a single company through a team visit to the Danfoss Museum, where display the products since 1933. As a result, the team generates 4 major style periods, which are *Machine Cowboy Epoch, Analog Professional Epoch, Digital Hacker Epoch, Molly Epoch.*

Chen and Crandall's (2016) research aims to understand the evolution of web designs by drawing inspirations from the notion of design periods. To realize this goal, the researchers need to compare the qualities of periods over time, to define period names, and to figure out the factors that drives shifts from one period to another. By asking the expert to critically interpret the poster, drawing on their experience to identify and group together designs that shared similar qualities. The follow-up interview questions were used to allow experts to give the key markers, information architecture, visual flavor, media composition) that lead to the change. With these makers, the researchers asked the experts to explain these markers. Finally, experts were asked to reflect on the whole critique session and their thoughts were categorized into 4 design periods: *Rudimentary, Simplicity, Informational period; Chaos, Gradient, Light, or Rise of the Image period; Formative or Cinematic period; Condensation, Sci-Fi, or Flat period*.

Wyche (2006) focuses his research on figuring out how the method of historical analysis help the overall understanding of the domestic environment from a design perspective. Wyche got started by reading the documents and the searching of the patents to know about the technology themes and the design spaces. Then, the research team integrated some qualitative research methods such as interviews to gather insights from older people. By employing the historical analysis, the understanding of activities is gained and therefore, providing more design spaces for technology design in the domestic environment.

Through the literature review, it's clear that historical analysis can help them either get inspirations on new design spaces (Wyche, 2006) or increase their sensitivity and push the boundaries of the design (Buur & Stienstra, 2007), deepening the understanding of the development process through defining the periods (Chen & Crandall, 2016). By taking historical perspective into consideration, we mean to view a discipline or a specific artefact and medium from the rather longtime frame, trying to understand its development process and even design the future with the past. Such perspective allows researchers and designers to open up new design spaces as well as to better use the concept based on the accurate understanding of its origin and development path.

Across many types of products, some shared features of the historical developments can be seen: such as the increasingly complex functions, faster computing speed. While HCI, as an interdisciplinary with the fast development speed, it is of great importance to examine the

artefact or a specific trend from a historical perspective to see if some of the direction is still on the right track and reflect constantly if we have new opportunities.

CHAPTER 3. METHOD

In this chapter, the general introduction of the content analysis method will be introduced. Also, according to the context of my study, a pilot study will be presented to show the potential process of data collection and analysis.

3.1 Content Analysis Approach in the New Media Age

According to Neundorf (2016), "Content analysis may be briefly defined as the systematic, objective, quantitative analysis of message characteristics (p.1)". Content analysis is a research method for studying text documents as well as communication artifacts, which can be texts of different formats, pictures, audio or video (Bryman & Crame, 2011). While in the new interactive media age, emerging media is dramatically changing the way how people receive the information. The emergence of Web 2.0 platforms enables the users to generate the content in an easier and fast way. As Neundorf (2016) stated: "The Internet has swelled to contain literal libraries of information, and not just of printed content, but of audio and visual material as well (p.203)". As Facebook become the leading hub where user generate large amount of content in 2017, YouTube is becoming another platform where new video content generated by the users showing up constantly every day. Though the shifting nature of the media makes the content analysis difficult to code with moving and sometimes fluid content, there are a lot of shared qualities and methods between past and the new content analysis with the same goal towards generating knowledge and implications through categorizing the content (Neundorf, 2016).

In general, conventional content analysis, directed content analysis and summative content analysis are three approaches to be used to conduct the content analysis (Hsieh, H. F., & Shannon, S. E, 2005). The major difference among these approaches is how to generate and develop the initial codes. Different from the conventional content analysis, the researcher chooses to develop the initial coding scheme employing the existing theory as a foundation before starting the analyzing process (Kyngas & Vanhanen, 1999). And one difference between the summative content analysis and the other two is that the text is usually analyzed in words rather than viewing them as a whole.

3.2 Data Collection

The Web 2.0 platform is constantly generating thousands of contents by users, including blogs and the mass media content (Neundorf, 2016). Also, content is becoming more accessible. In this study, the data was generated through one of the biggest interactive media video sharing platforms: *www. youtube.com* due to the limited accessibility to the old versions of the apps and the fluid nature of the animation interactions. The apps on smartphone will be examined through the video which can demonstrate the animation on smartphone clearly.

3.2.1 The Type of the Content

According to Neundorf (2016), there are generally three types of content in the new media age: user-generated content, user-selected content, and interactive media output. In terms of this study, the researcher analyzed the video created by users on the internet, and the media source is either the user of the product or the creator of the product. In this case, the researcher was looking for two types of videos: the official marketing video which contains the presentation of animation features, or videos created by the users on the YouTube which show the feature of the apps on iPhone, for example, it can be a tutorial.

3.2.2 Sampling Strategy

Due to the accessibility and availability of the video resources, in this study, the researcher follows the criteria below to help with the data collection based on the total number (approximately 500) of apps in app stores launched in 2007.

1. The video must contain at least three minutes of content.
2. The video must have a clear resolution with the standard of 360p and easy for people to see and recognize the key features.
3. The video must show the interactive features of the apps instead of static images.
4. At least one function of the app is shown completely.
5. At least four years' data per app can be found on YouTube from 2008 to 2017.

With these criteria in mind, the researcher has found 5 apps that meet the criteria, covering five different categories from tools to reading app. They are New York Times app,

photo app, maps app, wallet (previously named as passbook) and podcast app. All the apps are on the iOS to make sure the consistency when analyzing the data. For each app, 4 videos are collected from different years. So, there are in total 20 videos. Below shows the number of videos in each year and it's worth mentioning that there isn't any data in 2011 since all the video can be found in this year cannot meet the requirement stated above.

Table 5 Number of Apps in each year

2008	2009	2010	2012	2013	2014	2015	2016	2017
1	1	1	3	2	1	5	2	4

3.3 Data Analysis

In this study, to identify the animation type and usage on smart phone apps, there are general ways of doing the content analysis, while the specific steps might vary when answering different research questions.

Generally speaking, there are 3 major steps of conducting the content analysis: preparation, organizing and reporting (Holsti,1969). In the preparation phase, the researcher defined the goal and the unit of analysis based on their own research questions, also, the context of the study needed to be identified in this stage. And in the organizing stage, the researcher started with making sense of the data through observation, making sure whether it is an inductive or deductive research, then came to the initial coding, during initial coding, researchers were allowed to record all the relevant information either on the coding sheet or the margins of the data source. "Initial Coding is breaking down qualitative data into discrete parts, closely examining them, and comparing them for similarities and differences" (Strauss & Corbin, 1998, p. 102). And the goal of Initial Coding is "to remain open to all possible theoretical directions indicated by your readings of the data" (Charmaz, 2006, p. 46). When the initial coding was done, the researcher started to abstract the information and group them into categories. Finally, a report was made to demonstrate the results and findings.

This data analysis process for each research question is presented below to show the research procedure and how the researcher reach the results.

Q1: What animations are present in smartphone apps from 2008 to 2017?

In the preparation stage, the researcher first started to identify the unit of the analysis as the animation types. In the organizing stage, the researcher started to make sense of the data by looking through the video several times without stopping. In the initial coding process, all of the types identified were written down as the video was playing, in this case, all of the types were recorded as the descriptive language, they could be either a sentence or a few words. This process was repeated four times so that all of the types could be recorded. In the meantime, the start time and the end time of each animation were recorded. Moving forward, with all those types written down, the researcher started to group them into categories, for example, moving upward and moving downward can be grouped into "move". In this stage, the inductive method was used rather than the deductive to group the data. While in order to get a sound classification of the animation types, the researcher needed to align the current categories with the types summarized in the literatures. The researcher created a codebook of animation types based on the frameworks in the literature. In this stage, the research is more like the deductive process. Through comparison and grouping, some of the types were changed into new types, however, there were still some types that could not align with any established categories such as the page turning animation. In this case, the researcher picked the name based on the common language being used on the internet. In the next step, the researcher began to transfer the types into well-defined names based on the animation type frameworks, trying to be in a high-level summary. Finally, in the reporting stage, a report was created with all the type names.

Table 6 Codebook of Animation Types

	Animation Types	**Definitions**
1	Arc	Move with a curving trajectory (Thomas, Johnston & Frank, 1995)
2	Change of color	the color change (Novick et al., 2011)
3	Dissolve	Object dissolve through one another when changing the layers (Chang & Ungar, 1993).
4	Drop	Going downward suddenly (Keynote, 2017)
5	Ease in and Ease out	Motion that starts slowly and accelerates is "ease in," and for motion that starts quickly and decelerates is "ease out (Material Design Guideline, 2017).
6	Flip	Turn an object upside down (Trapp & Yasmin, 2013)

Table 6 continued

7	Follow Through	To continue a motion to the end of its arc (Wikipedia, 2018)
8	Glow	To shine with low light
9	Move	The position changes from one place to another (Trapp & Yasmin, 2013).
10	Loading	Processing
10	Overshoot	Animating an element past its resting position, as though propelled by a great force (Material Design Guideline, 2017).
11	Paper shredding	Animation that mimic the way the mechanical device used to cut paper into either strips or fine particles (Wikipedia, 2018).
12	Pages turning	An effect shows the state of turning the pages (bryphi77, 2016).
13	Parallax	Elements close to the viewer move faster than those further away (Material Design Guideline, 2017).
14	Push	A movement that follows a liner path (Trapp & Yasmin, 2013).
15	Rotate	Changing the direction of an object (Trapp & Yasmin, 2013).
16	Scale	Elements that grow larger appear to raise in elevation (Material Design Guideline, 2017).
17	Scale-in-down	Elements that shrink in size appear to recede (Motion UI, 2017).
18	Solid Drawing	A technique that makes the drawing looks three dimensional and believable with volume, weight and balance (Chang & Ungar, 1993).
19	Stagger	Applying temporal offsets to a group of elements in sequence, like a list. Stagger creates a cascade effect that focuses attention briefly on each item (Material Design Guideline, 2017).
20	Stretch	Stretch refers to increasing an element's size along a single axis (Material Design Guideline, 2017).
21	Transformation	A thorough or dramatic change in form or appearance (Willenskomer, 2017).
22	TV turn off effect	An effect that mimic the way showing the state of TV turning off (Daesongguree, 2013).
23	Zoom	Adjust the distance so that the image seems to be smaller and farther away (Trapp & Yasmin, 2013).

According to the definition of the codebook, the researcher also created a visual reference to demonstrate the meaning of each animation type for better interpretation.

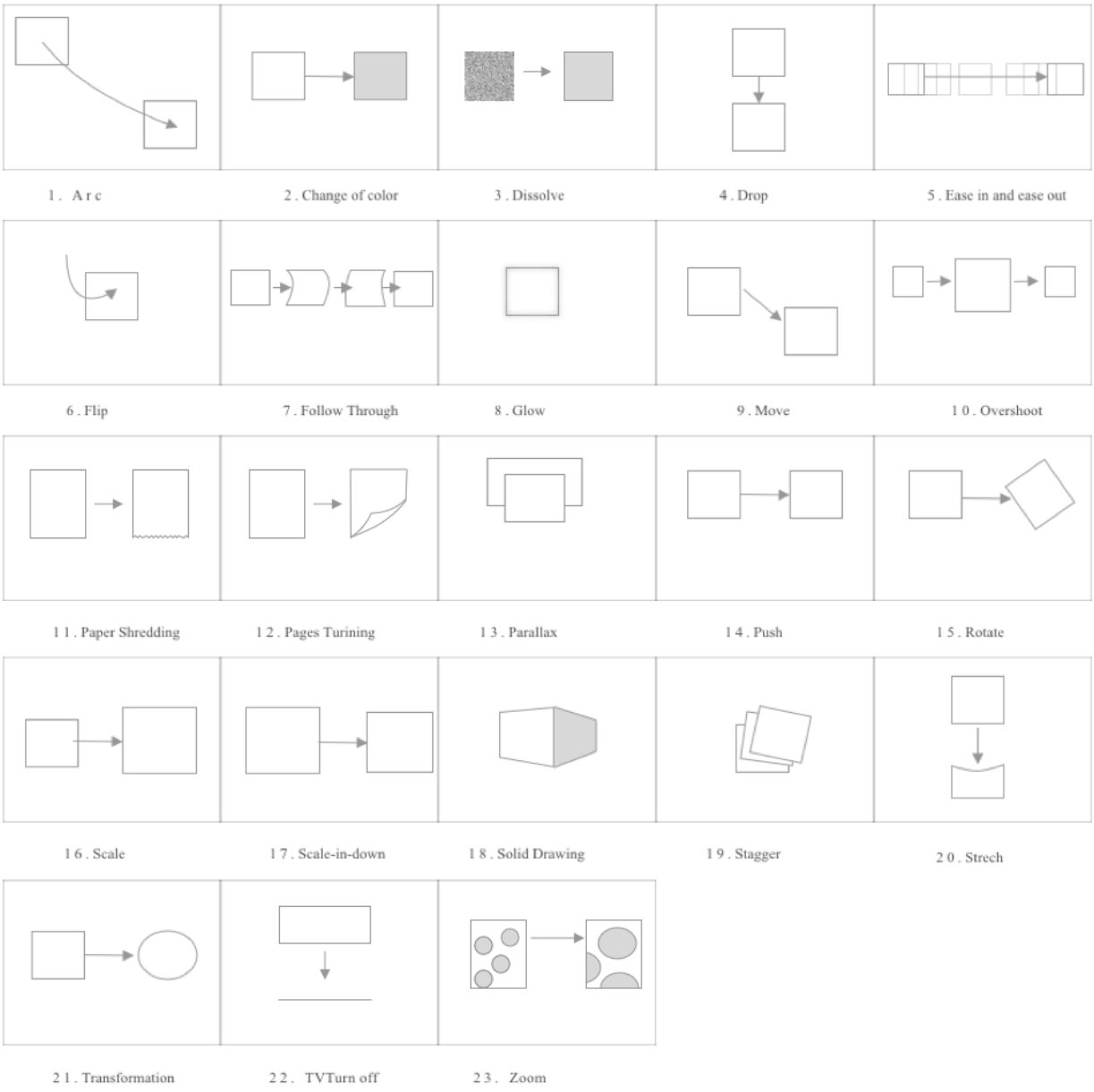


Figure 2 Visual Reference of the Animation Types

Sub question (1): What's the frequency and duration of each animation type?

In this research, after masking sense the animation types existing on the mobile interface, it's important to figure out the usage of change based on some key features: frequency and duration. The researcher used a tool to help with the timing task, and this online tool was called: http://www.watchframebyframe.com. Researchers could view the video in centi-second to

capture the start and the stop time for a higher degree of accuracy, since the normal YouTube video only allows second as the unit. Below is the screenshot of how this tool works.

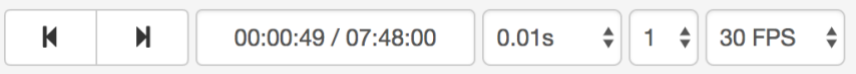


Figure 3 The Timing Tool

And in this study, the researcher finally got 428 video clips in total with 80 video clips/app on average. So, for a specific year, there were around 20 videos for each app. The screenshot blow are two examples of these videos.

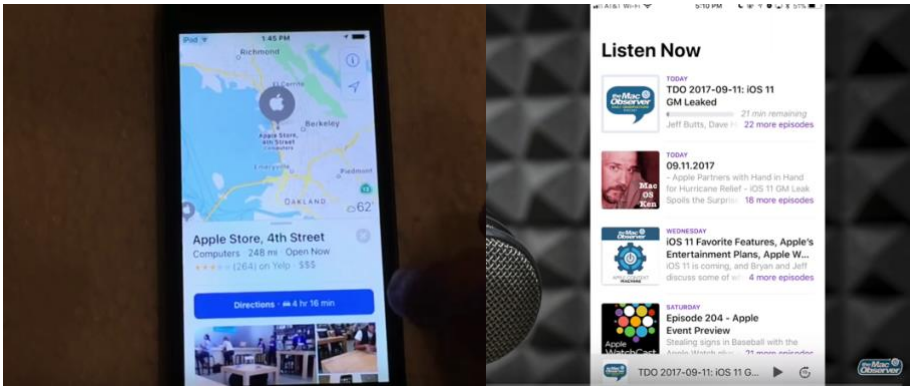


Figure 4 Example Screenshots of Videos

Sub question (2): What are the functions of the animations?

Sosa-Tzec and Siegel (2014) extended the original notion of visual rhetoric by focusing on the notion of function, so that one can inspect the elements on the interface from a broad perspective, taking into account the meaning and context. To understand what's exactly happening as the animation proceeds, there are also three stages. In the preparation stage, it was necessary to identify the unit of analysis as the function, in other words, what the user was going to accomplish at the moment. In the organizing stage, the researcher went through the video again, writing down the function of each animation in descriptive language based on the start and end time of the animation. And after the initial coding, the researcher began to group the function name with the similar meaning to a same name. Since some of the names could not be integrated into a same type as they serve different purpose in nature, the researcher needed to refer to the

codebook to figure the function of the animation. In the reporting stage, the function name as well as the frequency of each function were presented.

Table 7 Codebook of Functions of Animations

	Function	**Definitions**
1	Add	Adding an element to existing content
2	Browse	Reading the content by scrolling up and down
3	Control	Manipulating the play media with controls
4	Crop	Removing part of the image
5	Delete	Removing the whole content
6	Load	Waiting the content to be fully loaded to view
7	Edit Settings	Changing the displays by editing
8	End of Scrollable Content	Indicating the end of the content
9	Input	Texting using the keyboard
10	Locate	Showing the location using the pin
11	Navigate	Showing the route on the map
12	Open Webpage	Reading the content in another window
13	Pause	To stop the media player
14	Play	To start the media player
15	Receive	Accept the items sent from others
16	Return	Going back
17	Scan	Reading the content in the camera
18	Search	Inspecting and looking for a content
19	Select	choosing a specific option
20	Share	Sharing the content in the social media
21	Sort	Re-arranging the list of contents
22	Subscribe	Making a subscription to a content
23	Switch Mode	Changing from one display mode to another
24	Verify Identify	To ensure the safe use of the app
25	View	Bringing new content onto the screen

Sub question (3): What user action triggers each animation type?

To fully understand the context of each animation type, the user interaction was also recorded. After identifying the unit of analysis as the interaction, to be specific, the gesture, the researcher wrote down the interaction in descriptive language as the initial coding. Then, the grouping work was done to integrate similar statements. After that, the codebook was written based on Apple's Human Interface Guideline where detailed introduction of gestures were introduced. However, gesture like double tap is not in this guideline so plain language is needed to describe. The interaction was refined according to the codebook afterwards. Some interaction

names were deleted such as scan, since it was not in any literature. The interaction was recorded based on the start and end time of the animation.

Table 8 Codebook of the User Actions

	Actions	**Definitions**
1	Double Tap	User can be directed to more controls.
2	Drag and Drop	With a single finger, a user can move or duplicate selected photos, text, or other content by dragging the content from one location to another, then raising the finger to drop it (Apple, 2017).
3	Pan	Panning allows users to move expansive surfaces in any direction (Google, 2017).
4	Scroll	Users scroll vertically through content in a list (Google, 2017).
5	Swipe	When performed with one finger, returns to the previous screen, reveals the hidden view in a split view controller, reveals the Delete button in a table-view row, or reveals actions in a peek (Apple, 2017).
6	Tap	Activate a control or selects an item (Apple, 2017)

Q2. How has animation use changed from 2008 to 2017?

In order to answer this question, the first step was to identify what to be compared and the second step was to figure out what statistic attribute could be used to describe the result. In this study, the researcher used frequency and duration as the unite to compare. And for each one, several aspects were compared as listed below.

As to frequency, several things were compared:

- The number of categories of types occurred in each year
- The total frequency of each type
- The occurrence of animation types in each year
- The type with the top frequency in each year

As to duration, several things were compared:

- The average duration of all types in each year
- The average duration of each type in each year

- The minimum and maximum duration in each year

And for the statistic, in this study, four major attributes were recorded: Maximum and minimum, average, and the standard deviation. The first three were essential for describing what the data look like and the last one indicated the extent of deviation for a group as a whole. One thing worth noting was the need of normalizing when comparing the attributes based on the years since the number of videos varied between years. Therefore, when it came to the number of animations per video and the number of categories per video between years, the researcher needs to normalize the data first.

The whole data analysis process was conducted in Excel for better comparison and calculation. Each video was marked with a number and the researcher could compare the data by using the filter. Below are the screenshots that demonstrate how to filter the data and how 428 video clips organized.

Further, to get a deeper sense of how the animations changed, it's better to compare the animation based on contexts. To achieve this goal, the researcher started by classifying the animations according to the function. Take the passbook app for example, to serve the function of "view", animations used were quite different throughout years. After getting the animation which serves the same function, the researcher began to visualize the animation on a timeline. The benefit of doing that was to easily compare attributes such as the sequence, duration, the combination of types being used. Finally, the findings and insights acquired by comparing the data on timeline were integrated into the report. Below is a screenshot of the sequence timeline, animation serving for the same function was intercepted from the timeline.

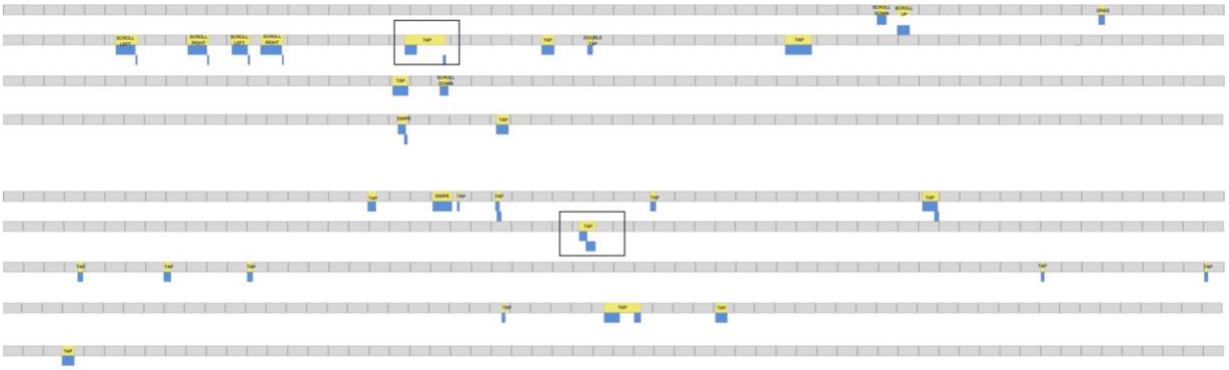


Figure 5 The Sequence Timeline

3.4 Limitations

There are several limitations for this study. The first one is the small sample size. Due to the limited access to the videos in the past, there are only five samples, which is not enough to generalize to a larger population. Second, the quality of the video might not apply the same standard, some of the video might have a low processing speed. Third, there are no data in the year of 2011, which may cause the difficulty when analyzing the data as a whole. Finally, the recent features of animation which emerge in the newly built apps cannot be inspected.

3.5 Validity

According to Maxwell (2012), one of the threats to the validity of one research is the researcher bias. In this study, two methods were used to reduce the researcher bias. The first strategy used was collecting rich data (Maxwell, 2012). In order to get detailed data on animation, I collected data from various angles to ensure information related to animation were all collected, including the start/end time of the animation, the actions and the functions. As to the duration, I used an online watching tool to record the time which can have higher degree of accuracy. The second strategy I used in this study was Comparison (Maxwell, 2012). During the phase of identifying the animation types, I watched and recorded the video for three times and compared the results in three rounds to see whether some data was missing or repeated. Additionally, investigator triangulation was used in this study to check the result. I asked a researcher for help to write down the types according to the codebook to ensure the accuracy of data after comparison.

CHAPTER 4. RESULTS

4.1 What animations are present in smartphone apps from 2008 to 2017?

To answer this question, there are three sub questions included for better understanding what's happening on the interface. The first question focuses on the animation types per se, while the second and the third answer the question by digging into the context of the animation to provide a wide source of information closely related to the animation.

4.1.1 What's the frequency and duration of each animation type?

There are in total 24 animation types investigated from the 20 videos of 5 smart phone apps. The frequency as well as the average time (duration) of each type/overall are presented in Table 9 and Table 10 below. From Table 4, it shows that the average animation duration is 512.32 ms, with a standard deviation of 245.65. We can see that there is a huge difference between the maximum and the minimum: 2220 and 160. Regarding the animation types, the top 3 types that show up most frequently across all years are: Push, follow though, and change of color.

Table 9 Frequency and duration of each animation type

	Avg.	**SD**	**Max.**	**Min.**	**Median**
Frequency	18.91	29.3	124	1	14
Duration	512.32	245.65	2220	160	333

Table 10 Descriptive statistics of animation types across years

	Animation Types	**Frequency**	**Avg. Duration (ms)**	**SD Duration**
1	Arc	4	297	120.13
2	Change of color	67	125	180.5
3	Dissolve	2	390	98.99
4	Drop	10	105	139.52
5	Ease in and Ease out	39	754	100.5
6	Flip	12	410	293.89
7	Follow Through	58	333	112.3
8	Glow	2	326	42.42
9	Move	31	268	199.83

Table 10 continued

10	Loading	4	325	120.3
11	Overshoot	14	170	381.34
12	Paper shredding	1	2220	N/A
13	Pages turning	4	670	73.13
14	Parallax	4	895	74.38
15	Push	124	290	210.4
16	Rotate	2	365	332.34
17	Scale	21	280	102.45
18	Scale-in-down	11	291	98.74
19	Solid Drawing	1	1320	N/A
20	Stagger	17	160	86.49
21	Stretch	1	720	N/A
22	Transformation	2	290	410.12
23	TV turn off effect	3	468	309.24
24	Zoom	6	394	124.37

4.1.2 What are the functions of the animations?

Table 11 Frequency of animation functions across all years

	Function	**Frequency**
1	Add	5
2	Browse	49
3	Control	4
4	Crop	2
5	Delete	13
6	load	1
7	Edit Settings	20
8	End of Scrollable Content	33
9	Input	2
10	Locate	9
11	Navigate	5
12	Open Webpage	1
13	Pause	1
14	Play	3
15	Receive	1
16	Return	28
17	Scan	1
18	Search	4
19	Select	4
20	Share	7
21	Sort	1

Table 11 continued

22	Subscribe	1
23	Switch Mode	2
24	Verify Identify	1
25	View	76

Among all of the 20 videos, 25 functions were identified. View is the most frequently used function with 76 occurrences. It's obvious from the table above that most animations are closely tied with the functions like: view, return, and browse. While there are 8 functions that appear only one time.

Table 12 Descriptive statistics of frequency of animation functions across all years

	Avg.	**SD**	**Max.**	**Min.**
Frequency	11.25	18.44	76	1

4.1.3 What user action triggers each type of animation?

To get an overview of the user action usage, Table 13 and Table 14 present the frequency of each user action as well as the statistics across all years.

Table 13 Frequency of each user action

	User Actions	**Frequency**
1	Double Tap	1
2	Drag and Drop	3
3	Pan	5
4	Scroll	62
5	Swipe	18
6	Tap	66

Table 14 Descriptive statistics of frequency of user actions across all years

	Avg.	**SD**	**Max.**	**Min.**
Frequency	25.83	30.18	62	1

Regarding user actions, in total 6 user actions were identified among all 428 video clips. It's not surprising to see that Tap is the most frequently used action which triggers lots of

animations in different contexts. Also, the popularity of the touch screen makes the gestures like scroll and swipe become prevalent too.

4.2 How has animation use changed from 2008 to 2017?

In order to identify how animation use has changed in the last decade, it's good to see the frequency of each animation in different years first. The grey cell in Table 15 gives an idea of when this type first occurred.

Table 15 Frequency of each animation type in each year

	2008	2009	2010	2012	2013	2014	2015	2016	2017
Arc					3		2		1
Change of color	2	1		4	10	5	16	8	14
Dissolve			1				2		
Drop				3			7		
Ease in and Ease out	7	5	2	2		3		2	6
Flip				5	5		1		1
Follow Through	4	7		18	1	2	14	4	7
Glow				1	1				
Move		1		8	3		8	4	8
Loading	1	2	1						
Overshoot				2		2	1	3	6
Page shredding				1					
Pages turning				4					
Parallax				4					
Push	2	2	12	12	18	6	29	13	30
Rotate					1				1
Scale			1	3		2	2	4	7
Scale-in-down		1					2	4	4
Solid Drawing				1					
Stagger				5	3		6		2
Stretch				1					
Transformation							1		1
TV turn off effect					2				1
Zoom				1				2	3

The left part of Table 16 presents the number of the animation showing up per video in each year, the result has been normalized so that it can be compared between years. The right side shows the results on duration for each year.

Table 16 Descriptive statistics of frequency/video and duration in each year

	Frequency/video				**Duration (ms)**			
	Avg.	SD	Max.	Min.	Avg.	SD	Max.	Min.
2008	16	N/A	16	16	584.75	239.84	1960	190
2009	19	N/A	19	19	577.83	149.9	1380	300
2010	23	N/A	23	23	515	233.61	1002	100
2012	24	4.24	30	21	599.82	500.98	2220	50
2013	22.5	2.5	25	20	400.8	224.83	1001	100
2014	20	N/A	20	20	430.67	283.91	1770	50
2015	20.4	4.41	25	13	363.31	262.46	1330	70
2016	22	2.0	24	20	381.44	139.68	1350	40
2017	22	4.7	30	18	383.21	171.91	890	40

Table 17 Descriptive statistics of SD and avg. of duration of each type in each year

	2008		2009		2010		2012		2013		2014		2015		2016		2017	
	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.
Arc									120.13	297			88.3	555				470
Change of color	205.06	685	N/A	330			255	323	201	355	171.93	236	121.4	294	99.9	290	110.2	238
Dissolve					N/A	460							76.5	320				
Drop							280	183					30.1	34				
Ease in and Ease out	376.9	877	287.3	672	301.5	581	399.8	700			420.4	985			284.55	305	280.5	755
Flip							320.5	746	402.7	469			N/A	1103			201.3	280
Follow Through	200.5	382	490.3	545			244	310	190.6	180	399.9	420	322.9	323	120.5	222	288.7	341
Glow							N/A	360	N/A	300								
Move			N/A	570			378	384	487.6	814			255.0	428	297.5	480	200.4	411
loading	N/A	495	86	415	N/A	288												
Overshoot							299	205			97.9	240	N/A	40	123.7	230	200.9	213
Page shredding							N/A	2220										
Pages turning							103	606										
Parallax							99.9	556										
Push	387	595	458	780	99	439	489.9	440	320.6	402	439.6	418	320.9	385	290.8	345	199.6	289
Rotate									N/A	130							N/A	600
Scale					N/A	310	86.9	217			200.5	285		280	100.4	351	299.4	212
Scale-in-down			N/A	570									77.9	355	148.7	585	186.5	585

Table 17 continued

Solid Drawing							N/A	1320										
Stagger							289.3	367	295.6	306			1504.3	388			184.6	321
Stretch							N/A	720										
Transformation													N/A	210			N/A	340
TV turn off									131.5	755							N/A	180
Zoom							0	540							320.5	585	246.5	460

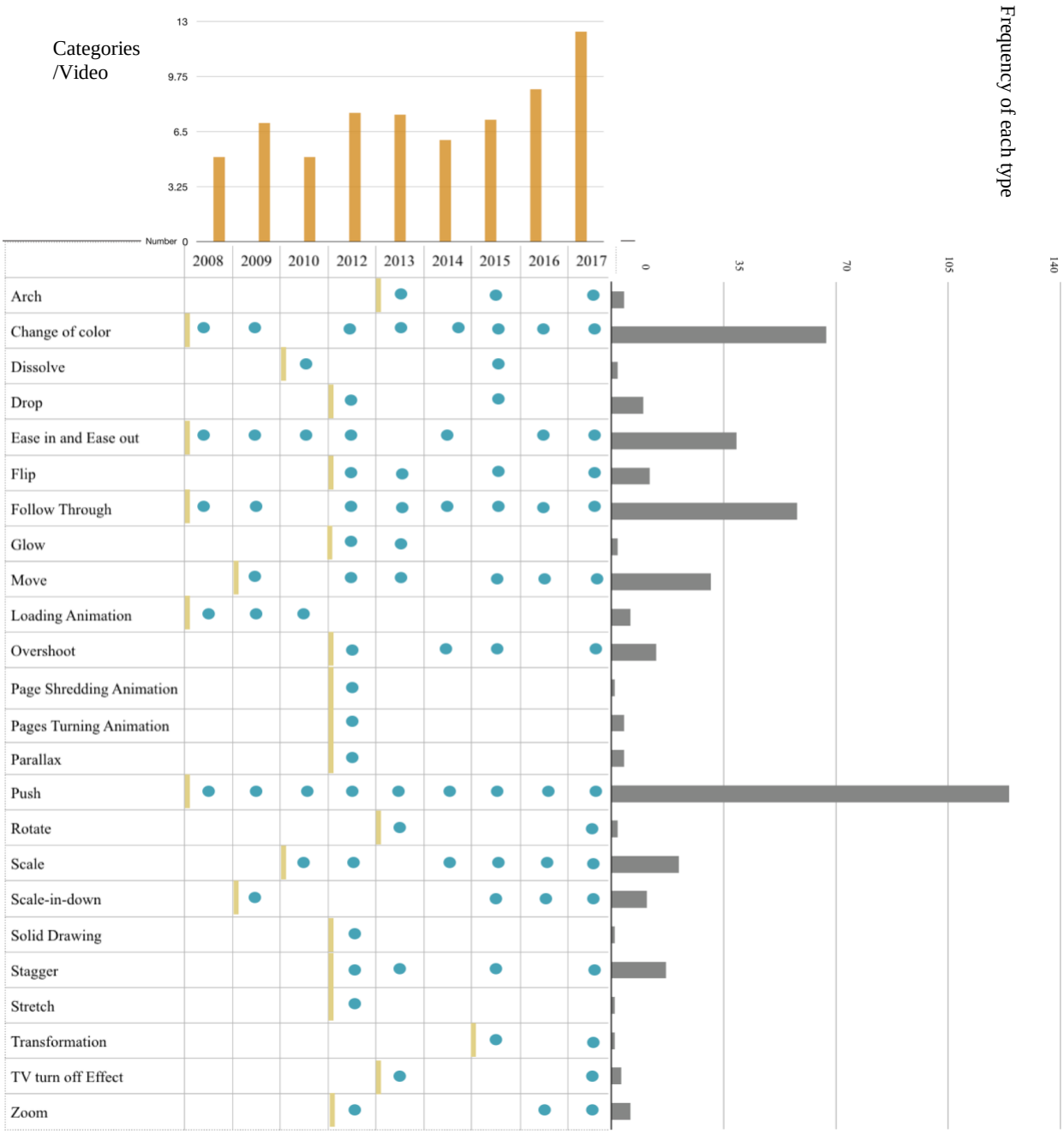


Figure 6 The number of categories and frequency of each type

The figure above shows the frequency of occurrence in the last decade, number of the categories in each year and total frequency of each type. The blue dots stand for the animation appears in that year, and the yellow line means when the animation first appear.

As of the amount of the categories per video, since the number of videos is not evenly falling in each year, so the researcher normalized the data before comparison. For example, there are five videos in the year of 2015, which is a lot. And the amounts of categories of each video is: 8, 7, 7, 9, 5, so the result for that year is the total number of categories of all video divided by 5. After the normalizing process, we could see an upward trend of categories per video in the past decade. And in 2017, the amounts of categories per video reach the top.

As to the frequency, there are two findings. First, among all of the types, push is the most frequently used in the last decade. Change of color and Follow through is the following. Second, there are several types showing up only once and then disappeared, such as the stretch, paper shredding and solid drawing.

Regarding frequency of occurrence, there are basically three phases as of when the animation first showing up. In the first phase, five types show up in the year 2008; In the second phase, most types appear between 2008 and 2012; Three types show up after 2013.

It's worth mentioning that Push is the animation that shows up all the time according to the five sample apps, and Push is also the type of the top frequency in six years with the numbers increasing over the years. Push is not only a frequently used transition, but a good navigation animation.

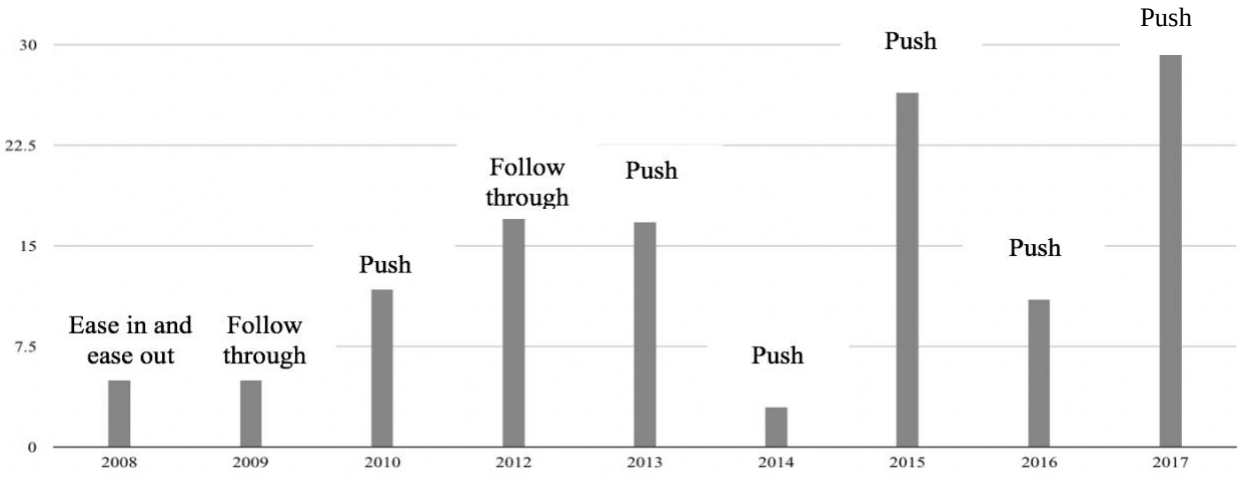


Figure 7 The top frequency types

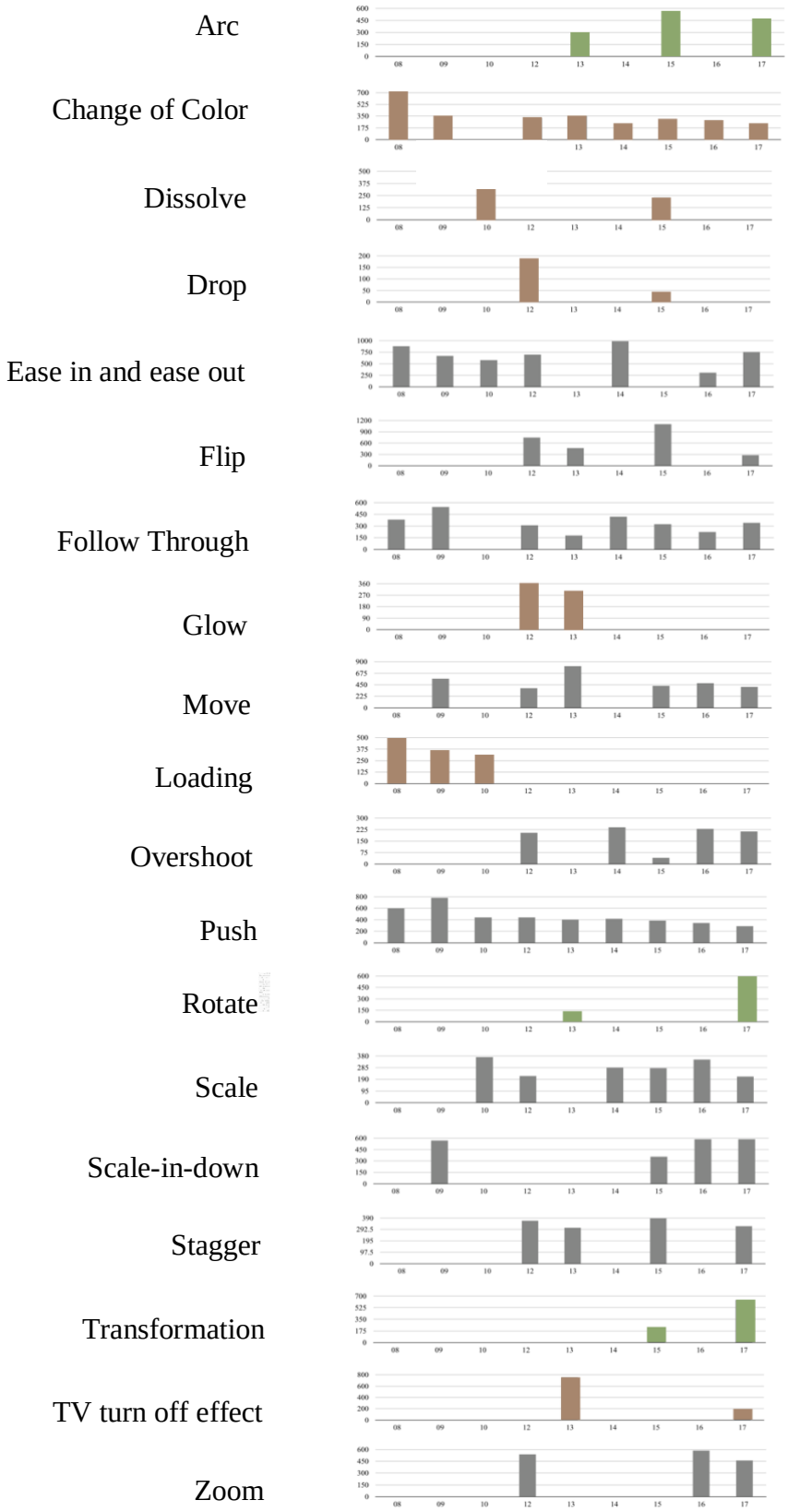


Figure 8 Results on average animation duration of each type

Figure 10 shows the average duration of each animation type in the last decade. It's hard to see general patterns due to the limited data points for some years, but it can be grouped into three groups in general: increasing, decreasing and oscillating.

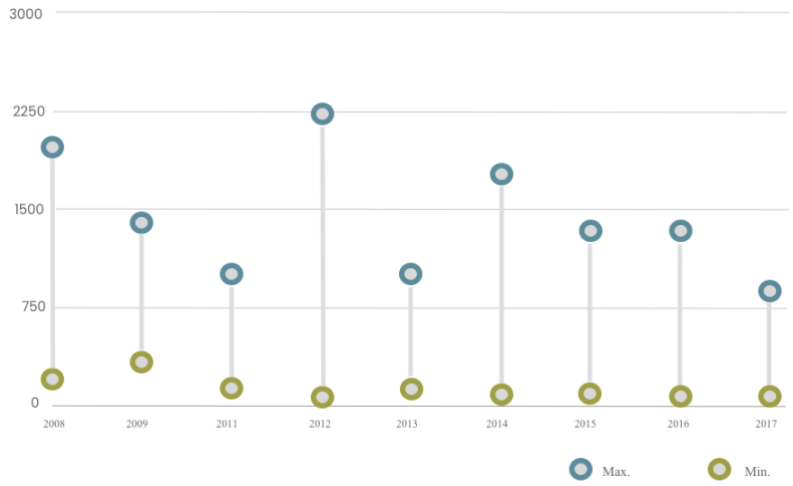


Figure 9 Maximum and minimum of average duration in each year

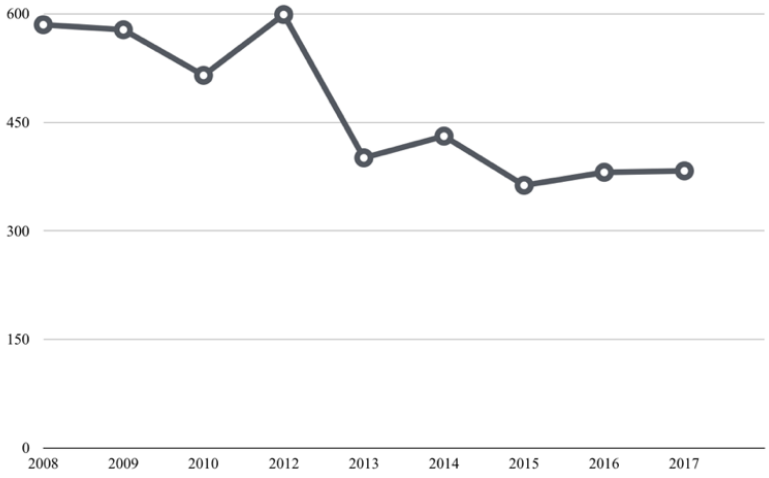


Figure 10 Average duration in each year

Figure 11 and figure 12 provides an overview of the average duration across all years. From figure 11, it can be seen that the gap between the maximum and minimum varies throughout the year, the smallest gap appeared in 2017, while the largest gap appeared in 2012.

From figure 12, we can see the longest average duration occurs in the year 2012 since several types with long duration appeared such as paper shredding and solid drawing.

In summary, the findings presented above illustrated how the animation change in last decade from two major areas: the frequency and the duration.

In the next paragraph, more findings were identified when comparing attribute including types, sequence, duration and user actions in the same context. To understand how animation used differently when serving the same function, firstly, animation types were identified in each year. Secondly, the duration of each type was also recorded. Thirdly, the user action provided more information on what's happening on the interface. Finally, in order to perform a function, several types were usually used together or as the combination, therefore, the sequence and the use of combination of each type has become another important attribute to describe the animation usage on the interface.

After making sure what attributes need to be compared, the next step was to select functions that the animation served. Among 25 functions previously identified in the code book, 10 functions were chosen with the criteria that at least three years of data can be found to compare. They are: Return, view, delete, edit the settings, control, browse, locate, the end of the scrollable content, locate and sort. It's interesting to find that the usage of animation varies a lot when serving a same function both within and across the apps.

Table 18 below shows these attributes based on the Return function. And for each app (Photos app, Podcast app and Passbook app), three years of data from 2008 to 2017 were presented to be compared.

Table 18 Results based on the Return Function

App	**Metrics**	**2008**	**2009**	**2010**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Photos	Sequence									
	Types							Scale-in-down	Scale-in-down	Scale-in-down
	Duration							420	680	470
	Action							Tap	Tap	Tap
Podcast	Sequence									
	Types						Arch	Push		Push
	Duration						290	190		200
	Action						Tap	Tap		Tap

Table 18 continued

Pass book	Sequence									
	Types				1.Push 2.Move 3.Follow through	1.Push 2.Move 3.Follow through		1.Move 2.Move 3.Stagger		1.Push 2.Stagger
	Duration				730	730		540		810
	Action				Swipe	Swipe		Swipe		Tap

Note:  The width of this rectangular shape demonstrates the duration for each type.

The Return Function here refers to going back. As to Podcast App, there is a general trend of shorter durations. While when it comes to Passbook App, the amount of type decreased with the disappearance of follow through to emulate the real-world movement, which may due to the increasing content on one interface.

Table 19 Results based on the View Function

App	Metrics	2008	2009	2010	2012	2013	2014	2015	2016	2017
NY Times	Sequence									
	Types	1.Change of color 2.Push 3.Loading	1.Change of color 2.Push 3.Loading	1.Change of color 2.Push						1.Change of color 2.Push
	Duration	1260	900	640						360
	Action	Tap	Tap	Tap						Tap
Photos	Sequence									
	Types						1.Scale 2. Overshoot	1.Scale 2.Overshoot	Move	Transformation
	Duration						430	340	420	340
	Action						Tap	Tap	Tap	Tap
Podcast	Sequence									
	Types				Flip, Solid drawing	Flip		Flip		1. Change of color 2. Flip
	Duration				1320	620		510		390

Table 19 continued

	Action				Tap	Tap		Tap		Tap
Pass book	Sequence									
	Types				1.Move 2.Move 3.Follow though 4.Stagger	1.Move 2.Move 3.Follow though 4.Stagger		1.Move 2.Move 3.Follow though 4.Stagger		1.Push
	Duration				960	980		820		380
	Action				Tap	Tap		Tap		Tap

The View function might mean differently across apps, while for the comparison purpose, they all serve a same goal which is to bring the new content to the screen to read. The diverse content would lead to different interactions and the animation usage.

As of NY TIMES App, there are some interesting findings. First, the types have changed with the loading animation disappeared in the year of 2009. And the loading animation change from the progress running bar to the circle one. This change might be made due to the increasing processing speed, and it shows that people do not need the loading animation anymore to wait for an article to be ready. Second, when combining the sequence and the duration together, there is a tendency of shorter duration with a more compact sequence, which means one comes not until the former one fully gone. For instant action such as Push, it's obvious that the durations become shorter throughout the 10 -year-period to provide a much smoother experience. Below are the screenshots of NY TIMES app ranging from 2009 to 2010.

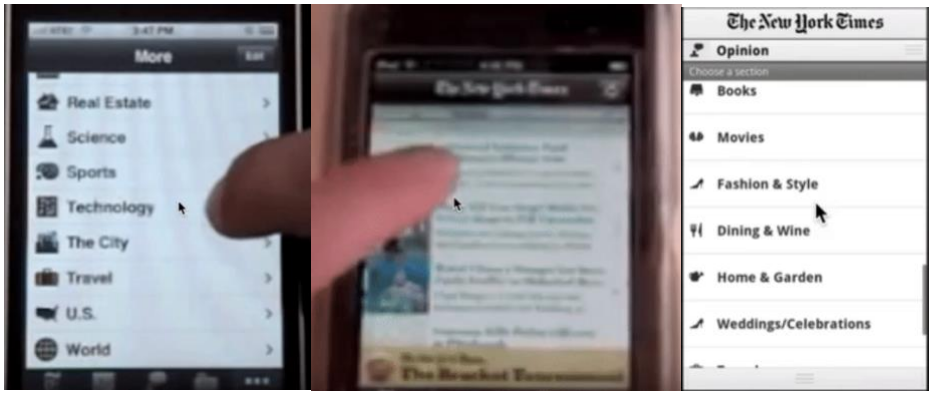


Figure 11 The screenshots of NY Times App in the year of 2008, 2009 and 2010

As of the Photos App, it's worth noticing that the types become more diverse when viewing a photo or memory. With a purpose of providing a sense of real-world movement in 2004 and 2005, overshoot and scale are successful of achieving this goal; While the purpose changes to bring a clearer information architecture since the increasing amounts of photos there in 2017, animation like Transformation is added.

Podcast App have also gone through some changes. As for the types, to open a new podcast, flip is being used throughout the times. However, the use of solid drawing emulating the real material of tapes disappeared in 2012, which is a symbol demonstrating the skeuomorphism. This change might due to the changing dominant design language: skeuomorphism vs. flat design.

Similarly, this change applies to Passbook app too. Passbook uses a combination of follow through and stagger to mimic the real-world movement and material with a purpose to have the experience just like the physical wallet. While they disappeared in 2017 with a shorter duration. This change might also due to the increasing content, in this context, the card. The purpose changes to a bit towards a more effective and quick experience. Below are the screenshots of Passbook app in the year of 2012, 2013, 2016 and 2017.

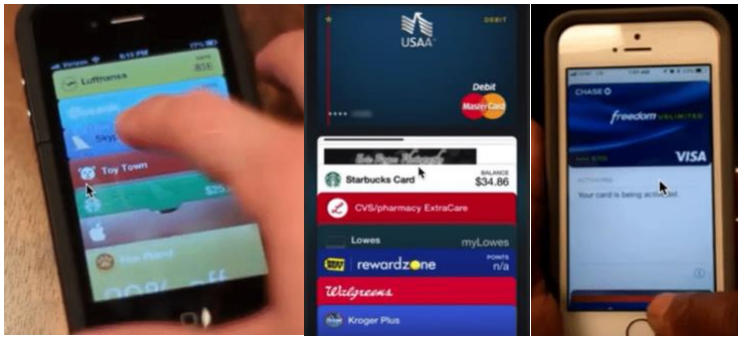


Figure 12 The screenshots of Podcast App in the year of 2012, 2013, 2016 and 2017

Some general findings based on the View Function:

- The disappearance of the animation with skeuomorphism attributes.
- Shorter duration of animations with compact sequence triggered by the instant actions.
- Combinations with diverse animation types are used to articulate the information architecture as the content growing.

Table 20 Results based on the Delete Function

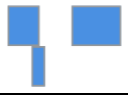
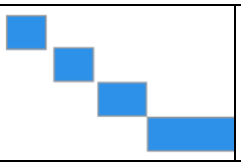
App	**Metrics**	**08**	**09**	**10**	**12**	**13**	**14**	**15**	**16**	**17**
Podcast	Sequence									
	Types				1.Push 2.Follow though 3.Push	1.Arch 2.Push 3.Rotate 4.Push				1.Push 2.TVoff
	Duration				1330	2180				1070
	Action				Swipe+Tap	Tap+Swipe +Tap				Swipe+Tap

Table 20 continued

Pass book	Sequence									
	Types				1.Push 2.Change of color 3.Flip 4.Shredding	1.Change of color 2.Flip 3.TVoff				1.Change of color 2.push 3.TVoff 4.Stagger
	Duration				4270	1780				1670
	Action				Tap	Tap				Tap

As for the Delete Function, it basically means the same thing as removing a content from a list across different apps. For Podcast App, it takes multiple actions to finish the action of deleting. The combination of types changes with the changing combination of interactions.

Passbook performs the Delete Function also quite differently. Shredding as a featured element of skeuomorphism disappeared in 2012, while it's interesting that the TV off animation is showing all the time. The number of the types has decreased. Below are the screenshots of Passbook and podcast app in the year of 2012, 2013 and 2017.

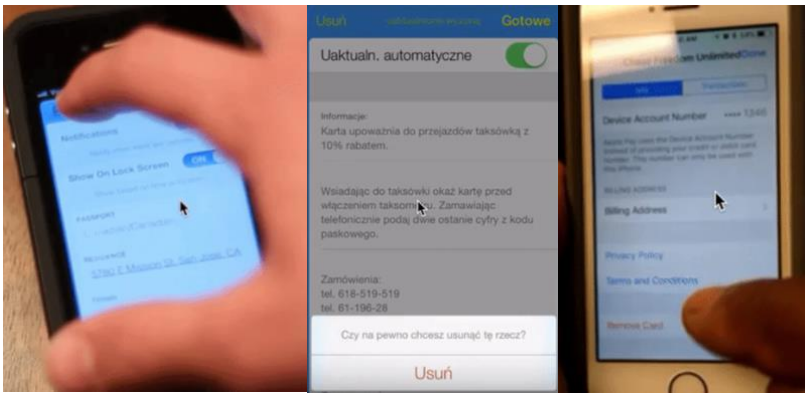


Figure 13 The screenshots of Passbook App in the year of 2012, 2013 and 2017

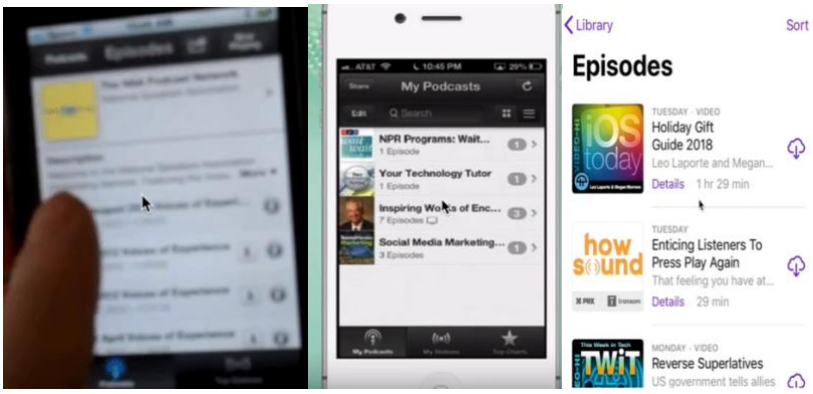


Figure 14 The screenshots of Podcast App in the year of 2012,2013 and 2017

Some general findings based on the Delete Function:

- The disappearance of the animation with skeuomorphism attributes
- Shorter duration of animations to delete.
- The decreasing number of types to achieve the shorter total duration
- Buttonless interfaces lead to simple actions, which causes the decreasing number of types

Table 21 Results based on the Edit Settings Function

App	**Metrics**	**08**	**09**	**10**	**2012**	**2013**	**14**	**15**	**16**	**2017**
Maps	Sequence									
	Types				1.Pages Turning 2.Follow though			Push	Push	Push
	Duration				1900			670	990	590
	Action				Swipe			Tap	Tap	Tap
Pass book	Sequence									
	Types				1.Glow 2.Flip	1.Change of color 2.Flip		Flip		Push
	Duration				1300	1160		1030		840
	Action				Tap	Tap				Tap

As to the Edit Settings Function, the changes appear to be similar in Maps App and Passbook App. The skeuomorphism animations such as Pages turning animation and Glow have disappeared in 2012, flip, as an animation with longer durations, has been replaced by Push. Below are the screenshots of Maps app in the year of 2012, 2015, 2016 and 2017.

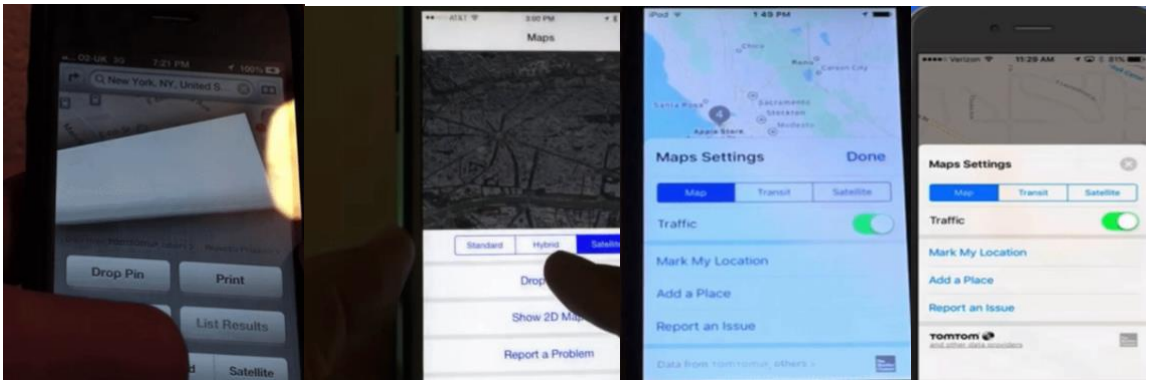


Figure 15 The screenshots of Maps App in the year of 2002,2015, 2016 and 2017

Some general findings based on the Edit Settings Function:

- The disappearance of the animation with skeuomorphism attributes.
- Shorter duration of animations with compact sequence triggered by the instant actions.
- The disappearance of the animation with long durations like flip.

Table 22 Results based on the Control Function

App	Metrics	08	09	10	12	13	14	15	16	2017
Podcast	Sequence									
	Types				Push	Push				1.Change of color 2.Scale, arc 3.Overshoot
	Duration				290	190				630
	Action				Double-tap	Tap				Tap

Control Function means to control and edit the podcast that's playing now. The skeuomorphism feature with a special gesture of double-tap disappeared in 2012, as the

replacement, the push triggered by tap shows up. While in 2017, the single gesture push is replaced by a combination of three types for a purpose of a clearer hierarchy and real-world movement with longer total duration, which may due to the reason that this function is the key feature and not the instant actions used quite frequently. Below are the screenshots of Podcast app in the year of 2012, 2013 and 2017.

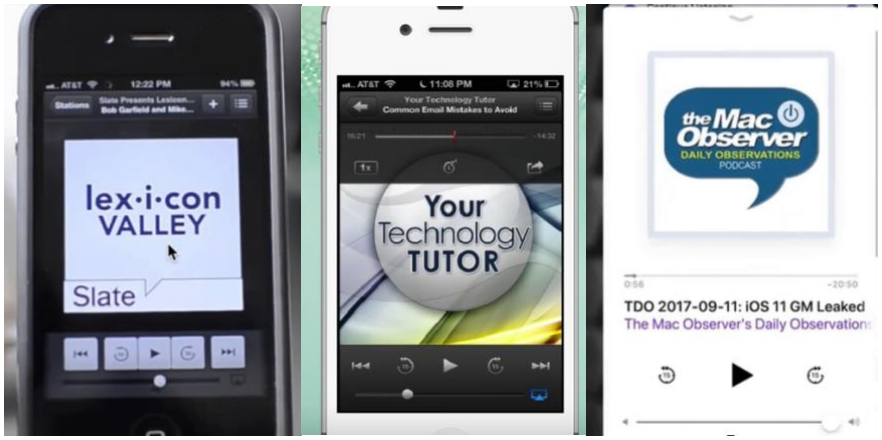


Figure 16 The screenshots of Podcast App in the year of 2012, 2013 and 2017

Some general findings based on the Control Function:

- The disappearance of the animation with skeuomorphism attributes.
- Increased number of types being used to serve more purpose with longer durations when it's a core feature and not used frequently.
- Animation was applied on a group of animation rather than a single element.

Table 23 Results based on the Browse Function

App	Metrics	08	09	10	12	13	14	15	16	2017
Podcast	Sequence									
	Types				1.Paralax 2.Follow through	1.Ease in and out 2.Follow through		1.Ease in and out 2.Follow through		1.Ease in and out 2.Follow through
	Duration				910	1020		930		900
	Action				Scroll	Scroll		Scroll		Scroll

Browse Function here generally stands for reading the content by scrolling up and down. As to the types, the parallax animation appears in 2012 with a purpose to emphasizing the depth of the content and having a clearer information architecture. While this animation disappeared with the simpler app information architecture. As to the duration, the general trend is the shorter duration of Ease in and out, the longer duration of the follow through. This makes a lot of sense since the browsing experience becomes more and more smooth so that it takes shorter time as one scroll. Also, the users have an increasing sense of control especially for the feedback, thus people get more space and time to get the feedback when scrolling to the end of the content.

Some general findings based on the Browse Function:

- The disappearance of the animation that facilitating a complex information architecture.
- The duration becomes shorter for the browsing per se. and becomes longer for getting feedback and control over the content.

Table 24 Results based on the Locate Function

App	Metrics	08	09	10	12	13	14	15	16	2017
Maps	Sequence									
	Types				1.Drop 2.Follow through 3.Scale 4.Overshoot			1.Drop 2.Follow through 3.Scale 4.Move	1.Push 2.Push 3.Move	1.Push 2.Zoom
	Duration				850			650	1170	940
	Action				Tap			Tap	Tap	Tap

According to the Maps App, the Locate Function means showing the location information using the pins. As for the types, the number of the type decreased during the four years, which might due to the situation that with increasing locations added, it is hard to show each one in a rich way. While it's interesting to note that the gap between two animation types is increasing. One benefit of doing so is to emphasize the information of the location by delaying the showing up time. Below are the screenshots of NY Maps app from 2015 to 2017.

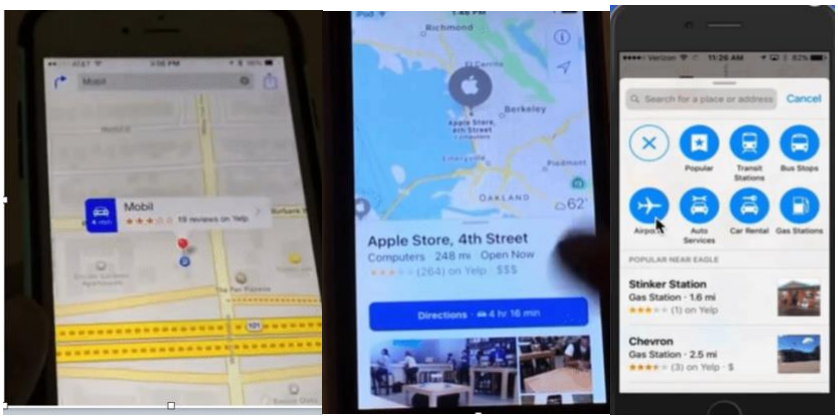


Figure 17 The screenshots of Maps App in the year of 2015, 2016 and 2017

Some general findings based on the Locate Function:

- The sequence and timing play an increasing important role in emphasizing elements
- Decreased number of types since the features evolve to be combined.

Table 25 Results based on End of the Scrollable Content Function

App	Metrics	08	09	10	12	13	14	15	16	2017
Maps	Sequence									
	Types				Follow through			Follow through	Follow through	1.Follow through 2.Move
	Duration				540			620	840	1010
	Action				Scroll			Scroll	Scroll	Scroll

The follow through in this context gives the user a feedback as the end of a scrollable content. The content would continue moving as they reach the end. As for the types, the combination of follow through and move appear in 2017 as a mean to provide more space of control: the content would move done a bit to give a stronger feedback as scrolling down the content. As for the overall duration, it becomes longer to provide a stronger sense of reaching the end.

Some general findings based on the End of the Scrollable Content Function:

- Increasing number of types and longer duration to allow stronger sense of feedback and freedom of control over the content.

Table 26 Results based on the Sort Function

App	Metrics	08	09	10	12	13	14	15	16	2017
Podcast	Sequence									
	Types				Scale				1.Change of color 2.Push 3.Move	1.Change of color 2.Push 3.Move
	Duration				320				820	820
	Action				Drag and drop				Tap	Tap

The Sort Function here refers to re-arranging the content by specific rules. In the Podcast App, the type of animation changes with the action changing from dragging and dropping to simply tapping. With the growing amounts of podcasts in the list, it's hard to manually drag each one.

Figure 18 The screenshots of Podcasts App in the year of 2012 and 2016

General findings based on the Sort Function:

- Increasing number of types as the content grows.

Except for the findings gained above, it can be found that the amount of animations that trigger by each action varies over time, and the combinations that includes at least two animations becomes more. The table below shows the results on the number of combinations in each year.

Year	**2008**	**2009**	**2010**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Three animation	0	0	3	13	5	4	10	6	9
Two animation	5	4	4	11	8	6	12	6	19

Figure 19 The number of combinations

CHAPTER 5. DISCUSSION

This chapter includes two sections. The first section provides the implications and insights on the animation use on mobile interfaces for the HCI community, interpreting and synthesizing the results presented in the last chapter. The second section outlines the limitations and the future work.

5.1 Implications of the Results

In order to figure out how the use of animation has changed in the last decade, the researcher investigated this topic by looking at the animation types with two aspects being evaluated: the frequency and duration. Also, more parameters like sequence and type combinations are compared based on the interaction context: functions and user actions. Some key markers are gained as evidence to show how the animation has changed over time. The implications are drawn from theses results.

1. Findings regarding animation types

- **Animation types emerge with diverse goals to achieve**

Among the 24 animation types identified in this study, 5 animation types remained the same as the types which were first introduced by Chang and Ungar in 1993. They are: ease in and out, follow through, dissolve, solid drawing and arc. These animations have one thing in common that the goal is to mimic the physical movement in the real world. While the types emerging afterwards appear to serve a broader range of goals. For example, the goal of transformation appeared in 2014 is to provide a smooth user experience and add some element of playfulness; Parallax, scale and Stagger first appeared in 2012 are aiming to provide the focus and attention; Change of color and glow are providing feedback; Push is to facilitate navigation. They appeared closely with the development of the information architecture and user actions on the interface.

2. Findings regarding animation durations:

- **The disappearance of skeuomorphism animation**

Animations that mimic the real-world material like Paper shredding, page turning, solid drawing, and glow haven't shown up since 2012, among which there is a common feature that the duration all exceeds 1000ms. Also, motion blur introduced by Chang and Ungar in 1993 does not appear in this study probably due to a limited use scenario.

Implications: The benefit of using skeuomorphism animation is to provide a real-world material layer to the interface, sometimes even can add a sense of playfulness to the interface, however, the long duration may cause frustration for the users. The skeuomorphism design still can benefit the user experience and serve purpose if the duration can be reduced.

- **The decreasing duration with smaller gaps between each for animations triggered by an instant action**

  As to the Push animation, which is triggered by an instant action, the duration becomes shorter over years. Instant actions here are defined as no more than 100ms according to the research from Neilson Norman Group. It's also worth noting that the median of the duration is in this study is 333, which matches the research of the book: *engineering* usability wrote by Nelson in 1993. In his research, 100ms is considered as instant, while 1000ms is seen as the limit of the user's flow of thought to be uninterrupted. So that means 100ms to 1000ms keeps user feel connected as a feedback for a user action. And it's been said by Nelson that 200ms to 500ms is a good range to start with for interface animations.

  Implications: For frequently used functions like view and add that are triggered by the instant action, animations with short durations seem to make more sense. Similarly, as to change of color animation used to provide feedback, it's also good to have short duration to enable quick response. The recent trend is that the next animation showing up not until these animations gone.

3. Findings regarding the sequence and gaps:

- **The gaps between animations are playing a functional role**

Generally speaking, it's clear that the gap between two animations becomes shorter and shorter. While it's also obvious that the gap tends to change from evenly spreading to combining short and long one. For example, in 2015, three animations occurred merely at the same time, following with the last one occurred after about 100ms. The delayed occurrence of elements helps focus the user's attention and emphasizes important information.

Implications: As combinations become more, it's more likely to see several animations triggered by one action showing up together or in a specific sequence. In this case, the sequence and the gap between the animation begins to serve the purpose, most times on focusing attention and emphasizing. While the tricks regarding the gaps and sequence can benefit the experience, it's not wise to use them frequently.

4. Findings regarding the number of categories and frequency of types

- **The increasing categories of the type being used**

  As the feature on the interface proliferating over time, more types emerged to support the complex information architecture and features being added. For example, stagger emerged in 2012 to support the growing content of a list. By adding temporal offsets to a group of elements in sequence creates a cascade effect that focuses attention briefly on each item (Google, 2017). Similarly, transformation and parallax support the interface in other aspects like articulating the relationship and emphasizing the depth as the information architecture becomes more and more complex. The number of categories changed from five in 2008 to fifteen in 2017. And compared with the animations presented from Chang and Ungar (1993), only five animation types are discussed in 1993. Types like motion blur and anticipation discussed in 1993 were not showing up since 2018.

  Implications: Responding to the increasing elements on the interface, new types emerge. It's also important to note that the animation needs to apply on a group of elements rather than the single one, in such situation, animation to each element in a group needs to behave slightly different. Take the arch animation for example, the animation applied to

each element in a group could have different curves so that they look as a whole, since different shapes and size can lead to different parameters to look consonant.

Besides, the trend of buttonless user interface also affect the type being used. Take Deleting function for example, after three times of Taps were replaced by a single action of Swipe in 2017, animation types were changed accordingly. Thus, the types being used can be affected greatly by the gestures like swipe and span which are popular on buttonless interfaces. The micro-interactions show up with these gestures need to take close attention.

- **The increasing number of the animation used as combinations**
  For most animations, especially the ones that support the key features and not used that frequent like Push, there is a trend of increased amount of the animation occurring triggered by an action. In 2008, animation seems to occur one by one, while in 2017, it's normal that four animation appear together as a combination to serve more purpose at a time.

  Implications: When the use of combination becomes commonplace, it's worth paying attention that for a series of consecutive animations, the gap between each element can serve some functional purpose like navigating and focusing attention. Also, the combination of animation needs to apply to all the elements on the interface with different parameters responding to different size and shape.

For the HCI and UX community, these implications provide both of them some insights. For researchers in the HCI community, these implications definitely help eliminate the gap between the knowledge in the academia and industry. Researcher can form a clearer understanding of animation use in the market from multiple angles, such as the frequency and duration. For practitioners in the UX community, unlike some general knowledge regarding timing of animation, the work has been done in this study offers some perspective to further craft the skills of animations on the interface, such as the attention to the gaps between animations, and the combination of animation being used. Additionally, the results in this study might help

designers create new animation and forms based on the understanding of the patterns identified in the past decade. For example, although there is a general trend of the downward duration, animations with longer duration are also popular, in this case, there might be some opportunities for motion graphics or animations with some gaming or playful attributes. Excepting for creating new design opportunities, these markers provided in this study could also help UX designers improve the current animations on the interface. For instance, the duration of animation that is triggered by the instant actions needs to be within a relatively short range within 100ms.

5.2 Limitations and Future Work

There are some limitations and opportunities for future work. First, the animation data is collected from five smart phone apps encompassing 428 video clips, however, this amount of data is not enough to generate insights that can stands for the situation in today's app market. The validity of the results may be influenced by the loss of data in some years. Thus, research in larger data set might need to be done in the future. Second, many parameters come into play such as number of stages, speed and the mapping of the animation, much research is needed to figure out how they evolve over time so that a more comprehensive picture can we get. Third, just like this paper, the researcher combines the animation with the function and user action as a context, it's also interesting to identify how animation can complemented by other things such as the narrations (Mayer & Anderson, 1991). Fourth, the data in this paper did not involve the animation beyond the graphical user interface like tangible interfaces. Although it goes beyond the scope of this paper, I hope there could be some work done in the future research regarding animation usage on different media.

CHAPTER 6. CONCLUSION

The purpose of this study was to see how animation usage has changed on smartphone interfaces in the past decade. The researcher approached this question by first answering: "What animations are present in smartphone apps from 2008 to 2017?". And in order to do the comparison, two main aspects of animation were evaluated: frequency and the duration.

After inspecting 20 videos collected from the internet, the researcher identified in total 24 animation types. These 24 types were generated through integration of the principles in the past literature and the modern design guidelines. And it's worth mentioning that some interesting types were also identified such as the TV turn off animation and page turning, which were not recorded in previous literates. More importantly, 6 implications for animation use were summarized in this study which can provide solid insights for HCI and UX community.

For researchers in the HCI community, after Chevalier et al. (2016) investigated the evolution of animation from the roles, uncovering three new roles of animation including improve the user experience and support discourse, the importance of animation use has drawn lots of attention. While this paper responds to this call through evaluating the animation use specially on the mobile interfaces, bridging the gap of the knowledge in the research and the industry. For designers in the UX community, the patterns found in this study can definitely gain some insights both in creating new animations or improving the current user experience on digital interfaces from the animation perspective.

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