Transition animations in mobile applications

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Thesis submitted for examination for the degree of Master of Science in Technology.

Espoo 23.5.2017

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ABSTRACT OF THE
MASTER'S THESIS

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Title: Transition animations in mobile applications

Date: 23.5.2017 Language: English Number of pages: 7+63

Department of Computer Science

Professorship: Software and Service Engineering

Supervisor: Prof. Tapio Takala

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The purpose of this thesis is to study how different transition animations influence people's ability to build a cognitive map of a mobile application, navigate and find information and to find out what kind of transition animations people are the most satisfied with.

Three transition design approaches were chosen based on how well they take advantage of the cognitive benefits of animation. The first approach uses custom transitions that are spatially planned to reflect a virtual three-dimensional environment, the second uses native platform animations with two dimensional planning and the third contains only simple dissolve animations. The three approaches were applied to two application context, resulting in total six prototypes.

The prototypes were tested with 18 participant in a user study which contained three tasks. The results of the study did not reveal statistically significant differences in navigation performance or in a cognitive map construction task. Therefore, based on the obtained result, it is not possible to say how different transition animations influence navigation performance or ability to build a cognitive map of a mobile application. Nonetheless, in one application context people rated the prototype with dissolve animations clearly less satisfactory than the other two versions. The result suggest that simple dissolve animations are not sufficient for producing great user experience in some contexts.

This thesis did not reveal statistically significant differences between the three transition animation approaches except in satisfaction ratings. The number of participants was low and in future research it is recommended to use more participants in order to reveal the possible differences.

Keywords: animation, transition, user-interface, user-experience, cognitive map, navigation

AALTO-YLIOPISTO
PERUSTIETEIDEN KORKEAKOULU

DIPLOMITYÖN
TIIVISTELMÄ

Tekijä: Tuukka Kantola

Työn nimi: Siirtymäanimaatiot mobiilisovelluksissa

Päivämäärä: 23.5.2017 Kieli: Englanti Sivumäärä: 7+63

Tietotekniikan laitos

Professuuri: Software and Service Engineering

Työn valvoja: Prof. Tapio Takala

Työn ohjaaja: TkT Teemu Kinnunen

Tämän diplomityön tarkoitus on tutkia animaatioita mobiilisovelluksissa selvittämällä, miten erilaiset siirtymäanimaatiot vaikuttavat kognitiivisen kartan muodostumiseen sekä kykyyn navigoida ja etsiä tietoa. Lisäksi selvitetään, minkälaisista animaatioista pidetään eniten.

Tutkimusta varten valittiin kolme animaatioiden suunnitteluperustetta sen mukaan, miten hyvin ne huomioivat animaation kognitiiviset vaikutukset. Ensimmäisessä lähestymistavassa hyödynnettiin animaatioita, jotka on suunniteltu virtuaaliseen kolmiulotteiseen tilaan. Toisessa lähestymistavassa käytettiin mobiilialustan omia animaatioita. Kolmas lähestymistapa rakentui ainoastaan häivytysanimaatioiden varaan. Kaikkien kolmen lähestymistavan mukaiset animaatiot toteutettiin kahdessa käyttöliittymäkontekstissa, jolloin tutkimuksen kohteena oli kuusi prototyyppiä. Prototyypit testatiin 18 osallistujan käyttäjätutkimuksessa, joka sisälsi kolme erilaista tehtävää. Saadut tulokset eivät paljastaneet tilastollisesti merkitseviä eroja navigoinnissa eikä myöskään kognitiivisen kartan rakentumisessa. Siksi tulosten perusteella on mahdoton sanoa miten erilaiset animaatiot vaikuttavat navigointiin tai kykyyn muodostaa kognitiivinen kartta mobiilisovelluksesta. Toisessa käyttöliittymäkontestissa osallistujat arivoivat yksinkertaiset häivytysanimaatiot selvästi vähemmän tyydyttäviksi kuin kaksi muuta versiota. Tulos viittaa siihen, että häivytysanimaatiot eivät ole riittäviä tuottamaan hyvää käyttäjäkokemusta tietyissä käyttöliittymäkonteksteissa.

Tässä diplomityössä oli ei tullut esille tilastollisesti merkitseviä eroja erilaisten siirtymäanimaatioiden välillä muissa kuin tyytyväisyysarvioissa. Osallistujien määrä oli pieni, ja jatkotutkimuksissa on syytä käyttää suurempia koehenkilömääriä, jotta mahdolliset erot saadaan esille.

Avainsanat: animaatio, siirtymä, käyttöliittymä, käyttäjäkokemus, kognitiivinen kartta, navigointi

Preface

First of all, I want to thank my instructor, Doctor Teemu Kinnunen, for helping me to formulate the thesis topic, for providing excellent advice and improvement suggestions and for helping me with statistical analysis.

Secondly, I would like to thank my supervisor, Professor Tapio Takala, for providing valuable instruction during the work. I would like to also thank my employer, Futurice Oy, for the trust and freedom to allow me to choose the topic I am most interested in, for providing me time and support for writing and the environment for conducting a user study.

Finally, I greatly appreciate the help of my colleague Erich Grunewald with english grammar and I'm thankful for all participant who volunteered to took part to the study.

Berlin, 23.5.2017

Tuukka Kantola

Contents

Abbreviations

UI	User Interface
UX	User Experience
HIG	Human Interface Guidelines
App	Application
SUS	System Usability Scale
EI/EO	Ease-in / Ease-out
MOT	Multiple object tracking

1 Introduction

1.1 Motivation

Animation has its roots in hand-drawn cartoons where it was used for entertainment purposes. Disney animators pioneered this traditional approach and created the fundamental principles and techniques of cartoon animation [28]. Since then, animation has been applied to user-interfaces to increase enjoyment and, more importantly, to enhance functionality. In 1984, Apple used animations for opening and closing windows in the Macintosh operating system. This kind of animation provided a continuous transition from one state of the interface to another, and has become an essential part of a modern user-interface. As users, we are now expecting animated interfaces and their absence can even feel distracting.

Animation has been researched in the context of user-interfaces for several decades, and the results show that it has significant potential for enhancing user experience, from helping people to orient themselves better [3] and making applications more natural and engaging [17] to enabling people to complete tasks faster [18, 20]. On the other hand, animation has also been shown to possess dangerous ability to distract and irritate if used incorrectly [2, 4]. Therefore, it is important for a designer to understand how animation can influence the user experience.

Previous research about animation is focused almost entirely on desktop computers and a few specific contexts such as information visualisation applications. The amount of research is particularly scarce for mobile interfaces. Although the findings mentioned previously have influenced animation design of mobile applications and provided great insights, many of the findings might not be applicable in a mobile context, for the simple reason that mobile and desktop interfaces differ fundamentally from each other in terms of interaction methods and available screen estate. Touch screen interaction has its own unique properties which differ greatly from keyboard and mouse interaction. The method of interaction is one major factor that determines what kind of animation feels natural and is the most efficient. The other difference – limiting physical form factor – forces mobile interfaces to be split into multiple separate views. This division increases the importance of the type of animation used, as it can smooth out the visual change that occurs when a view transitions. In mobile applications, the transition animation are still more important, because navigation involves constant movement between views.

There are many different ways of designing a view transition. New information can be introduced to the screen along the horizontal and vertical axes or from the depth axis. It is also possible to build complex custom transitions where individual user interface (UI) components move independently. Apple's Human Interface Guidelines [12] and Google Material Design Guidelines [10] provide some guidance for designing effective transitions. However, these guidelines are limited and do not offer enough information for deciding which kind of transition works best in a particular situation.

Currently, animations are often misused, probably due to a lack of guidance and because adding animations to applications has become considerably easy. All major mobile platforms (iOS, Android and Windows phone) include ready-made implementation of several view transitions, meaning they can be added to an app with very little development effort. Also, each new mobile device has enough processing power to display complex custom animations.

There is clearly a need for more thorough animation research especially targeting mobile devices. Further research would allow the creation of better design guidelines, principles and patterns for mobile interfaces which in turn would help designers craft more effective and enjoyable animations.

1.2 Objectives and Scope

The purpose of this thesis is to research *how different transition animations influence the user experience (UX) of mobile phone applications*. Because user experience is a very broad term, referring to a person's entire experience using a particular product, this research is limited to measuring only a few aspects of the UX: the navigational aspect and the user's subjective satisfaction related to it.

Specifically, this research aims to answer the following research questions (RQ) through a user study:

- **RQ1:** *How different transition styles influence people's ability to build a cognitive map of a mobile application?*

  Cognitive map (discussed in section 4.2.2) explains peoples behaviour in spatial environment and how well they can memorise its structure.

- **RQ2:** *How different transition styles influence peoples' ability to navigate and find information in a mobile application?*

  While this question is partly covered in the RQ1, the main measure for this question is the performance in navigation tasks.

- **RQ3:** *How different transition styles influence people's satisfaction of a mobile application?*

  This question complements the functional approach of RQ1 and RQ2 with subjective satisfaction rating. The satisfaction rating can potentially reveal the emotional impacts of animation and show if there is a connection between navigation ability and satisfaction.

The literature review in this thesis discusses animation in broad context including traditional cartoon animation. This is important for understanding common animation techniques, principles and terminology also used in user-interface design. The user study part is limited to transition animations since they are the most common and crucial type of animation in mobile interfaces. Other types of animations, such as progress animation or purely entertaining or educational animation are left outside of this work. Moreover, this work targets touch based smartphones, not tablets or desktop computers.

1.3 Structure of the thesis

This thesis is organised in seven chapters. After this introduction, chapter 2 discusses animation in context of user interface design and traditional cartoon animation, presenting previous research, design guidelines and principles. Next, chapter 3 explains the design considerations and implementation of the prototype applications used in user study. After that, chapter 4 describes methods used for researching animation and all relevant factors related to planning and conducting the user study. All data collected in user study are presented and analysed in chapter 5. Next, chapter 6 discusses the overall results and impact of this work and gives suggestions for future work. Finally, the last chapter concludes the thesis.

2 Animation in interface design

"It seems crazy to me that more people don't think about interfaces with respect to the dimension of time. Motion can provide so much information! Maybe the tools to create prototypes are too complicated for most designers?" – Pasquale D'Silva, Animator [32]

2.1 Contextual Background

2.1.1 Animation

The Disney animators Thomas and Johnston [34] define animation as a way of creating an illusion of motion. The illusion arises when still images are shown successively with high enough speed (around ten to twelve images per second) [35]. This speed, however, produces very jagged experience. 60 images per second is considered the sweet spot above which most people will not perceive much smoother motion although no theoretical limit has been proven [35].

Animation defined as motion suits well for the traditional cartoon animation but in the computer context animation is not always motion. For example, the change of an object's opacity from fully opaque to transparent is not seen as motion. These kind of motionless animations are common in user interfaces.

According to Chang [23], there are also two other fundamental differences in cartoon and user-interface (UI) animation. The first fundamental difference is that cartoon is a passive medium while UI is interactive. Cartoon animations are preplanned whereas interface animations respond to user input. The second distinction is their goals. The first goal of traditional animation is to entertain [28], while for UI animations it is to enhance functionality, such as navigation, directing attention and providing feedback. Prioritising entertainment at the expense of functionality results in compromised outcome. Still, traditional animation techniques have their space in helping to design more engaging and enjoyable animations for applications.

This work regards animation in the UI context meaning that animation is not always motion and that interactive and functional aspects are prioritised over entertainment. Still, traditional animation is explored from the affective[1] perspective, since it is an important aspect of user experience.

2.1.2 Animated transition

In this work, a transition is referred to as the change in a user interface from one visual state to another. Transition happens, for example, when a user interacts with a button after which a screen is filled with new content. The change from one state to another can be smoothed out using an animation. Animated transition displays consecutive images that gradually progress from the initial UI state to the final, connecting the two states visually over a short period of time.

Figure 1 illustrates a simple animated slide transition built in the Apple iOS operating system. The transition starts from the initial state which then smoothly

[1] The term affective refers to features that influence people's feelings and emotions

animates to the final state with a sliding overlay from the right side. The sliding animation is just one of the infinite possibilities of animating a transition.

How a transition should be designed depends on many factors, including which mobile platform it is made for, which interaction is used to initiate a view change, the context and content. The most common properties that need to be considered when designing a transition are discussed in chapter 2.2.

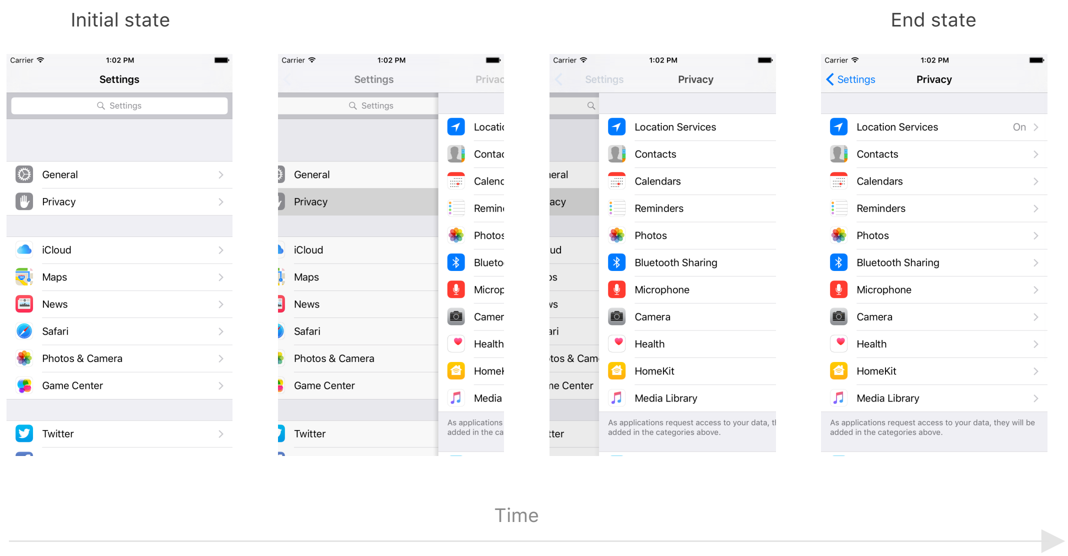


Figure 1: Timeline of a slide transition in Apple's iOS operating system. The initial state gradually progresses to the final state connecting the two visually over a period of time.

2.2 Properties of animation

Visual UI elements have multiple attributes which can be animated programmatically. These attributes include element's position, size, rotation, opacity and color, among others. The animation of an attribute is controlled through several animation properties which can be tweaked in animation software or with code. This chapter presents three important animation properties and summarises previous research related to each property.

2.2.1 Easing curve

Easing curve, also called a timing function, defines the speed at which an animated attribute changes at any point in time between the start and the end of an animation. Easing curve has also been referred to as temporal distortion because the chance of animation speed can be thought as distortion of time [41]. Because the speed of change is rarely constant, an easing curve also determines acceleration and deceleration of the change. For instance, when an object's position attribute is animated, the easing curve controls how fast the object reaches its maximum speed and how long it takes to stop. An easing curve can be applied to almost any attribute of a visual element, for example, to colour. Figure 2 illustrates common easing curves.

Linear easing (Figure 2:1) is the simplest possible curve and it adjusts an attribute value with a constant speed. At the start and end of an animation, a linear curve causes infinite acceleration because the speed changes between zero and the constant value instantly. Since infinite acceleration is not physically possible, a linear easing often feels unnatural.

In the real world, nothing moves completely linearly from one point to another. Objects accelerate and decelerate smoothly meaning that their speed and acceleration changes continuously without discrete steps. When we open a door, it starts accelerating smoothly, reaches its maximum speed around the middle of the movement and gradually decelerates until it is again stationary. An easing curve which smooths out the acceleration at the beginning of animation is called ease-in (figure 2:2). Similarly, a curve which smooths out the acceleration at the end is called ease-out (figure 2:3). Combining these two results in a curve called ease-in/ease-out (figure 2:4) which smooths both the start and end of an animation.

The ease-in/ease-out (EI/EO) curve has been advocated and found useful by several researchers [23, 41, 42, 17]. In one object tracking experiment Dragicevic et al. [41] compared the EI/EO with other alternatives in an application similar to a scatterplot data visualisation. They found that the EI/EO performed better than other easing curves. There are two main arguments for using the EI/EO. One is physical realism which contributes to making an animation natural and pleasing. Another argument is that the EI/EO curve helps a user in anticipating the beginning and ending of an animation. Dragicevic et al. explain that "In particular, if the user is not expecting the animation to happen in the first place, a slow and gradual start will help the user to detect that the animation is starting and to adjust to the tracking task accordingly."

Even though the EI/EO has been shown to be effective, the research regarding it is limited to desktop applications and particular contexts. There are also other easing curves such as Spring and Bounce (figures 2:5 and 2:6) which are widely used in mobile applications. Choosing which of the many possibilities to use depends a lot on the context. For example, Google Material design guidelines (chapter 2.4.3) advocate certain easing curves for particular situations. However, based on the current research alone it is not possible to create thorough context based guidelines for easing curves.

The easing curve is a complex property which allows communicating many different things, such as brand attributes, mood, personality, mass, softness and emotions. The easing of animation relates closely to many Disney cartoon animation principles (see chapter 2.4.1). Animator, Val Head, states that "The principles of Timing, Spacing, Follow-through, Anticipation, and Exaggeration can all potentially be expressed with the easing you choose for an animation" [11]. Therefore, the easing curve contributes significantly to how an animation makes users feel.

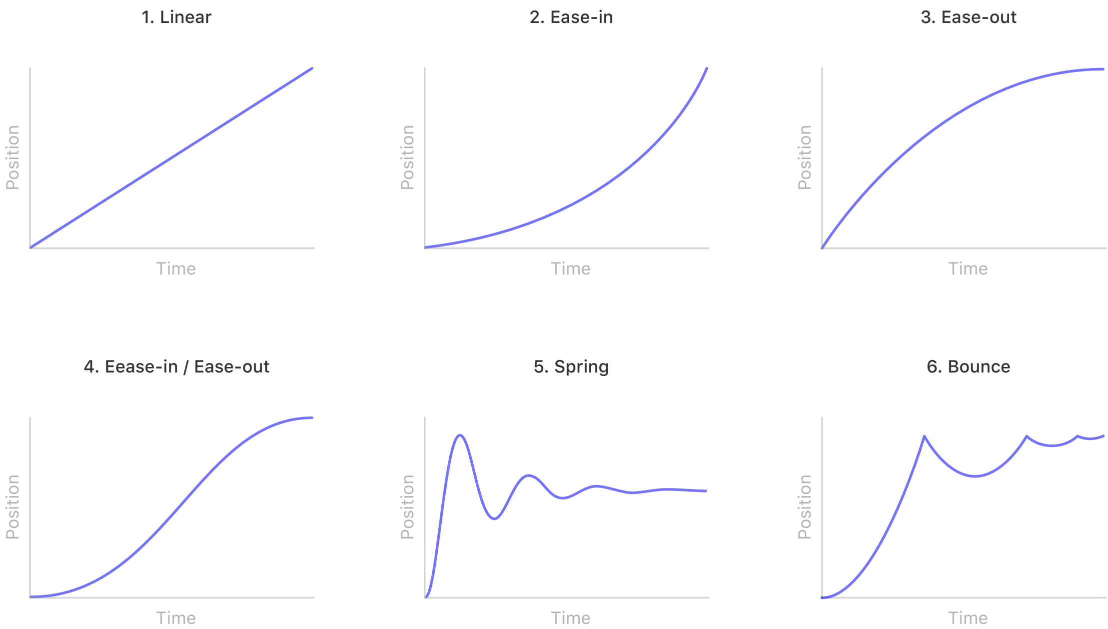


Figure 2: Examples of common easing curves applied to position attribute. The y-axis denotes the position of animated element in a screen, e.g., along the horizontal axis of a phone screen.

2.2.2 Duration

One drawback of animation is that it takes time. There is always a trade-off between time of animation playback and time spent using an interface. At one extreme, animation is too short to be visible. According to Nielsen [39], a visual change that takes 100 ms or less is perceived as instant. This short animation does not offer any benefit over a non animated version simply because 100 ms animation is basically invisible. Although without animation, users don't have to wait for it to be finished, they still need to spent considerable amount of time to adjust to the new information and make mental connections to the previous view [1]. In other words, the cognitive benefits of animation do not emerge with very short durations.

At the other extreme, an animation is so long that it wastes user's time. In mobile applications long transitions become easily frustrating because of the constant need to navigate between views and, therefore, even a slightly too long transition can cause negative experience. For example, when Apple's iOS 7 operating system came out with redesigned transitions, people were complaining that the transitions were too long [29]. Later, in the next iOS version, Apple acknowledged the problem and shortened the animations. Nielsen states that about one second is the limit for the user's flow of thought to stay uninterrupted [39], and this can give suggestion of the upper limit of an effective animation.

To maximise the benefits of animation, finding a balance between the two extremes is essential. Optimal duration, however, depends on multiple factors, including task type, data, expectations, attentiveness, user's perceptual abilities and previous experience, as is suggested by several researchers [3, 31]. For example, Klein et al. [8] found that 300–500 ms animation worked best for simple scrolling transition, whereas for more complex 3D transitions several second duration was ideal [40]. Particularly for mobile applications, an animator Val Head [55] recommends a duration ranging from 200 ms to 500 ms. She states that transitions with small amounts of change work best with the 200–300 ms range, and transitions with larger motion or motion that uses complex easing need around 400–500 ms.

There is one exception when a longer animation can be beneficial. Many applications spend several seconds to load or process data and filling this gap with an animation is not likely to harm productivity because users would have to wait anyway. Displaying a progress animation can even create a perception that time goes faster [30].

2.2.3 Motion path

When animation is applied to an object's position attribute, the object moves along a certain path. Typically, the path is a straight line because it is the default behavior in mobile platforms and does not require any extra implementation effort. However, in real life most movement is influenced by gravity and thus follow a slightly curved path [28]. Using a curved path makes movement more realistic as is described by Disney cartoon animation guidelines in a principle known as Arcs 2.4.1. UIs also benefit from the realism achieved with curved paths. An exception to the rule is movement which is naturally restricted to y-axis, for instance, when an object falls straight to the ground [28]. Since this kind of movement is common in UIs, curved paths should be used carefully and reserved for a movement which has a horizontal component.

When multiple objects are moving at the same time, the question of what is the most efficient motion path becomes more complex. Paths of objects might intersect causing one object to cover another, or objects might move very close to each other making tracking of their identities difficult. These kind of issues have been investigated in multiple object tracking (MOT) studies which reveal how our visual system performs under various conditions. Perhaps the most important factor affecting tracking performance is the spacing between objects. When there is plenty of space, we can track around 7 to 8 objects, but the number decreases when the spacing is reduced [50]. Another factor impacting performance is occlusion which makes the tracked object momentarily invisible since they become covered by other elements. However, a brief occlusion does not seem to impair performance [52].

Despite the extensive MOT studies, it is difficult to generalise their finding for creating general guidelines for motion paths in mobile applications. MOT studies focus on complex tracking exercises under laboratory settings which are not common in mobile phone usage. In mobile app transitions only a few objects are moving at the same time and, therefore, the spacing is rarely an issue. Furthermore, transitions happen quite fast and possible occlusions are very brief. Du et. al. [49] experimented with a technique in which movement trajectories were 'bundled' for a group of objects that are close in spatial locations and share similar moving directions. They found out that their technique improved tracking performance in complex situations, but surprisingly in simple tracking tasks the performance was actually worse.

In a summary, the careful planning of multiple motion paths unlikely bring noticeable cognitive benefits for mobile applications users because mobile apps have rather simple transition animations. Still, curved paths offer a way to increase the realism of movement and thus make movement feel more natural.

2.3 Cognitive and affective functions of animation

2.3.1 Maintain object connectivity

When a user navigates from one app view to another, new content might be introduced, some content might be removed and common content between the views might be rearranged or modified. Without animation, the change happens instantly and the user have to form a mental connection of how the new visual state relates to the old one. In contrast, if the change is smoothed out with an animation, user can visually track the content transformation. Visual tracking shifts some of the user's cognitive load to the human perceptual system and after the animation is completed, no time is needed for making mental connections. [1]

The automatic perceptual tracking which maintains connectivity between objects is one of the greatest benefits of animation as is shown in numerous studies [6, 1, 40, 23, 33] For example, Shanmugasundaram et al. [1] investigated how people can maintain connections in a node-link diagram when the visualisation undergoes a transition. They found out that participants made significantly less errors and completed the task faster when fast and smooth transitions were used instead of slow or nonanimated transitions.

The perceptual tracking system has been examined in multiple object tracking (MOT) studies. These studies have revealed several factors which influence tracking performance. First, there is a limit of the number of objects which can be tracked simultaneously. Initially, studies indicated that the limit was four objects [54] but more recent research showed that tracking eight objects was possible by changing test settings [53]. Second, tracking capability is reduced when objects move faster [53]. Third, spacing between objects has significant impact on performance [50]. Tighter spacing decreases and looser spacing increases performance. Franconeri et. al. even argues that the object spacing is the most important factor limiting tracking performance [50].

While the MOT studies have produced extensive results, drawing conclusions of them for mobile animation design is challenging. MOT studies are done in laboratory settings where participants are required to exercise intense concentration which is not typical for mobile phone usage. Furhermore, MOT tasks are considerably more complex than tracking tasks in mobile apps. It seems that object spacing could potentially impair performance in mobile apps since the screen space is limited. It might be good to limit the number of simultaneous moving objects to around four to maintain sufficient spacing. Multiple similar objects could be grouped and treated as a single entity, if tracking their indetities is not important.

2.3.2 Convey structural relationships

Besides helping to maintain the connectivity of individual objects, animation can aid in forming a mental image of larger structures. Two studies [3, 1] described below have shown that smooth transitions increases peoples' ability to form and maintain structural and spatial relationships in situations where only a sub part of the whole can been seen at a time. It seems that animation assists people in understanding how smaller parts constitute a bigger structure. These findings indicate a major benefit of animation for mobile apps since in mobile apps only a small part of content is visible at a given time.

Bederson and Boltman [3] conducted a study in 1999 to investigate whether animation help people to build a mental map of spatial information. The researchers built two versions of a desktop computer application for browsing family trees, one version with animated transitions and one without. Each family tree contained nine people and only one person was visible at a time. In one task, subjects had three minutes to explore a three after which they were asked to reconstruct the tree on a paper from their memory. The study revealed that animated transitions clearly improved peoples ability to reconstruct the trees.

In another study, Shanmugasundaram et al. [1] investigated whether smooth transitions influence peoples ability to recognise entire structures of tree-graphs. The researchers constructed two types of trees, shallow and deep, and asked participants to navigate the trees using a desktop computer. The test system only showed one branch of the whole tree at a time, and clicking on a move button a new subpart entered the viewport. After seeing all parts of the tree, participants were presented with four complete trees and asked to select the tree which corresponded to what they saw earlier. In other words, participants had to remember each substructure as well as they can so that they could recognize the entire tree. The study revealed that smooth transitions clearly increased participants' accuracy compared with a non animated version.

2.3.3 Direct attention

Motion is a highly effective tool for attracting attention. It is always the first element which captures users' attention in a display [15]. Bertram et al. [4] studied the effectiveness of animated icons and found that animation works as a notification mechanism. Authors stated that animated graphics were significantly better than static colour and shape in attracting users' attention, especially on the periphery of visual field. Therefore, animation can be used to draw attention to important areas of a user interface such as a notification message.

The ability of animation to capture attention also has high potential for abuse. Using animation to draw attention to something that is irrelevant to users' needs or task, often leads to distraction and irritation. Zhang [2] studied how animation effects information seeking performance. The author found that irrelevant animation can reduce the performance of information seeking because it distracts users' attention from the main content. Similarly, Bartram et al. [4] concluded that "...animated banners and popping images are not comfortable visual elements on a screen where one is trying to work but are effective if one, in fact, wants to dominate the user's attention."

2.3.4 Convey information

The information content in an animated graphic is distributed along a time axis which makes it possible to pack a lot of information into a single animated graphic. An animation can contain more information than a static image simply because an animation is made of numerous individual images. The high information density makes animation a great tool for communication in mobile user-interfaces where static images would require too much space to achieve the same goal. In UIs, animation is generally used for many communicative purposes such as hinting at affordances, demonstrating how certain features work, indicating problems and showing system status [55].

An example of animation's communication abilities is shown in a research done by Beacker et. al. [24]. They used icons for demonstrating the functionalities of drawing tools in an image editor application. The researchers compared the animated icons with static ones, and discovered that people understood the functionalities of each drawing tool better when they were presented with animated icons. Beacker et. al. described that in every case where static icons were not understood, the dynamic icons were successful in conveying the purpose of the tool.

Besides the UI context, animation has been researched in study environments [56, 57, 58] where researchers have claimed that animation facilitates learning. However, Trevsky [27] has critiqued the previous research saying that the comparison between static and animated content has not been fair. Trevsky argues that "[...] many of the so-called successful applications of animation turn out to be a consequence of a superior visualization for the animated than the static case, or of superior study procedures such as interactivity or prediction that are known to improve learning independent of graphics. [...] Thus, most, if not all, of the successes of animation seem to be due to advantages in extra information conveyed or additional procedures, rather than the animation of the information per se."

Trevsky might be right in his critique, however, using static images with the equivalent information of animated graphics is often impossible in mobile apps because of limited space. With the help of an animation, a designer can effectively communicate a lot of information in small space and consequently create more elegant UI solutions.

2.3.5 Express emotions and brand

Interface animation often focuses on purpose and utility more than the affective aspects such as engagement and storytelling. However, a merely functional approach is not enough to provide a great user experience. In highly competitive mobile app markets, it is important to consider how a product makes people feel. UI animations can be intentionally taken further and crafted to resonate on a deeper emotional level and to work in harmony with other aspects of design such as brand communication.

Generally, researchers have found that people find animated UIs more engaging and fun to use than non-animated versions [22, 22, 17, 8]. Studies also suggest that people prefer animated transitions even though they are not directly associated with any gains in efficiency when completing certain tasks [59, 60].

In order to create UI animations that are engaging and fun, animation properties (discussed in chapter 2.2), such as easing and duration, must be carefully chosen. With the selection of parameters, designer can communicate feelings of different kind, such as which materials UI elements are made of. For suggestions how to choose the animation parameters the Disney cartoon animations principles (chapter 2.4.1) offer some guidance although not all of the principles are relevant in UI context. Unfortunately, there exists no clear scientific research of how the selection of different parameters effects emotions.

Park et. al. [51] tried to understand how different animation properties influence the affective quality of animation using the Laban effort system which is a method and language for describing and interpreting the movement of a human body. They examined the relationship between the effort factors from the system and three motion properties: path curvature, duration and acceleration. However, the researchers did not find a significant link between the system and animation properties stating that "it would be wrong to directly adopt the parameters taken from the movements of the human body in order to design motion in user interfaces."

2.4 Animation principles and platform guidelines

This chapter presents Disney cartoon animation principles and animation guidelines provided by Google and Apple for their mobile operating systems. These principles and guidelines help designers to make decision regarding transition animations.

2.4.1 Disney cartoon animation principles

Animators at Walt Disney studios were masters at communicating emotions and feelings for viewers. They introduced the twelve principles of animation in a book Illusion of Life [34]. The principles were built upon, among other things, the observations of real world motion of people and animals, consequently reflecting the laws of physics [28]. The physical realism allowed animators to produce a better illusion of living characters. The twelve rules illustrate how to communicate effectively with animation and they offer great vocabulary for discussing details of animation. The twelve principles are summarised below [34].

1. **Squash and Stretch**

   Squash and Stretch gives objects a sense of mass and flexibility by making them momentarily longer or flatter. The effect can be applied to almost any object, from boucing ball to a human face. It is important to keep object's volume consistent when squashing or stretching in order to maintain realism.

2. **Anticipation**

Anticipation is used to prepare a character for an action in order to give an audience a hint what is going to happen next. This is achieved by preceeding each major action with a smaller move that builds anticipation. For example, before a man starts running he can lean back to another direction gathering momentum.

3. **Staging**

   Animation is divided into separate stages which happen after each other. The timing of individual stages are set so that the events in animation are not competing for attention, and therefore, viewer can focus on one element at time.

4. **Straight Ahead and Pose to Pose**

   Straight Ahead and Pose to Pose are two techniques for drawing an animation. Straight ahead means drawing a scene frame by frame starting from beginning and gradually progressing to end. Pose to pose, on the other hand, means starting with a few key frames and later filling the area between them.

5. **Follow-through and overlapping action**

   Follow through means that when an object comes to a stop its loosely tied parts continue moving beyound the point where the object stopped and the parts keep oscillating back and fort until they reach the final position. Overlapping action means that parts of the main object should move at different speeds.

6. **Slow In and Slow Out**

   Movement in real life starts slowly, builds speed and finishes slowly. Constant speed is not natural because objects need time to accelerate and decelarate. In cartoon animation this effect is achieved by adding more drawings near the beginning and end of an action.

7. **Arcs**

   Most natural movement follow an arched path because of gravity. Using this principle for animation adds realism.

8. **Secondary action**

   Secondary action is a gesture that supports the main action by adding more life and character to it. For example, when a person walks her hands might swings independently. Secondary action only emphasizes the main action and doesn't take attention away from it.

9. **Timing**

   Timing refers to the number of drawing inserted between each main action and it greatly affects personality and nature of an animation. Adding more drawings makes movement more detailed and faster while less drawings make it slower and less detailed. Detailed movement is not always desired because it can feel too smooth, especially in slow movement.

10. **Exaggeration**

    In cartoons, perfect simulation of reality can look dull and uninteresting. Disney encouraged animators to exaggerate important aspects of an animation while still remaining true to reality. If a charater is sad it should be made sadder or if it is worried it should be more worried.

11. **Solid Drawing**

    Solid drawing means making objects feel like they are in three-dimensional space and by esuring that they have certain properties such as volume, weight, balance and shadows. The principle also advocates avoiding "twins", that is, a drawings that have mirrored left and right sides since identical sides make characters look dull.

12. **Appeal**

    Appeal means that each character must have some charismatic aspects and that they are interesting to look at. Even villains or monsters should be appealing in a way that they feel real and interesting.

Even though cartoon animation is theatherical and thus very different from UI animation, certain Disney principles have been researched and used successfully in UI context [23, 17, 61]. The principle of Slow-in and slow-out (also known as ease-in/ease-out, see Chapter 2.2.1) is widely used in mobile operating systems and advocated by several researchers [23, 41, 42, 17]. Similarly, the principle of Arcs is extensively implemented in transitions in Google's Android operating system although it seems that they do not offer other benefits than to contribute in achieving more realistic movement.

The principle of staging has been researched in the context of information visualisation by several researchers. Heer and Robertson [22] investigated the effectiveness of three different transition styles (static, normal and staged) in statistical data graphics, such as bar charts, pie charts and scatter plots. There was evidence that users made less errors with staged animation although the difference was not very big. Moreover, staged animation was significantly preferred by users over direct animation in most cases. In another research, Guilmaine et al. [43] compared four animation techniques for smoothly animating changes in a radial tree visualization. Their hierarchically staged animations significantly outperformed other two solutions for certain type of changes in a user test.

Current research suggests that staged animation provides certain benefits. However, Chavalier et al. [14] warns that the potential improvements are easily outweighted by the drawbacks of staging, namely a loss of predictability in motion start times, and increased animation playback time. Similarly, Heer and Robertson [22] suggest using simple and short staging, and avoiding complex multi-stage transitions because they take too much time.

Moreover, Chang and Ungar [23] encourages using the principle of exaggeration. They state that "Employing exaggeration to the behavior of user interface objects makes that behavior more understandable, more "realistic," and thus makes the user interface more engaging.” Also, Thomas et al. [17, 9] built an image editor with cartoon inspired animations which included an exaggerated transform effect when moving objects, in which object resisted movement. The editor was shown to be effective and enjoyable for users. However, there is a danger in using exaggeration for UIs. If the effect it is overdone, animation loses its impact and becomes merely distracting.

Cartoon animation is very different from UI animation and the Disney principles are created mostly for character animation. Therefore not all of the principles are relevant in UI context. Chavalier [14] states that many recommendations derived from cartoon animation principles are too general to effectively guide the design of animated transitions.

2.4.2 iOS Human-Interface Guidelines

Apple provides Human Interface Guidelines (HIG) for all of its platforms, including iOS, macOS, tvOS and watchOS. The iOS is Apple’s operating system for mobile phones, and its guidelines [12] highlight several aspects to be concerned when adding animations.

The guideline warns about the dangers of animation, and suggests that animation must be added cautiously. Excessive or gratuitous animation can obstruct app flow, decrease performance, and distract users from their task. Apple emphasises that the use of motion should be purposeful and restraint, and that the results should always be tested. Additionally, the guide gives some suggestions regarding custom animations. Custom animations should be comparable and consistent to built-in iOS animations. Also, strive for realism and consistency with physical laws are encouraged, otherwise users might feel disoriented.

The consistent use of animation throughout the whole app is also emphasised. According to the guidelines, consistency helps users form a mental model of an application and to build on the previous experience: “For example, if you reveal a view by sliding it down from the top of the screen, you should dismiss it by sliding it back up because doing so helps users remember where the view comes from. If you dismiss the same view by sliding it down beyond the bottom of the screen, you break the user’s mental model of a view that’s available above the top of the screen.”

While Apple’s HIG guidelines for iOS offer useful advice for animation design, they are still very general and sparse. A lot of judgement is left for a designer since no specific use cases, context or even examples are provided. The iOS HIG reflects current literature pretty well. Dangers of animations are taken into account and the use of realistic, physicality based animations are in-line with Disney cartoon animation principles. Interestingly, the effect on a cognitive map is also acknowledged although it is discussed only in terms of consistency and not in spatial relationships.

2.4.3 Google Material Design Guidelines

Material design [10] is Google’s visual language for its operating systems and apps. Unlike the Apple’s approach of separate design languages for different devices, the Material design principles are uniform across platforms and device sizes. Thus, material design guidelines cover the much broader spectrum of devices than Apple HIG for iOS discussed above.

The material design is based on the studies of physical objects such as paper and ink. Consequently, it gives a great importance for physical motion, meaning that UI elements demonstrate mass and weight by reflecting physics laws. Abrupt starts, stops or changes in direction must be avoided because they appear unnatural and draw unwanted attention. Also, acceleration and deceleration should be smooth, otherwise movement feels mechanical.

For transitions, the guideline gives three principles: visual continuity, hierarchical timing and consistent choreography. Visual continuity states that transitions between views should be clear, smooth and effortless. Creating visual connections between transition states through colour and persistent elements are encouraged. Additionally, ways of directing users' attention must be explored: what elements should be emphasised or de-emphasised through the transition?

With Hierarchical timing principle, the hierarchy of different UI elements in a certain view can be communicated when transitioning from another view. Motion is used to indicate what the most important content is by creating a path for the eye to follow. The most important object reaches its full size first, while the least important item last. However, the guide acknowledges that the design of a transition isn't always easy: "It's not a simple formula in which the most important thing moves first and the least important last. The timing of transition elements should flow smoothly and avoid feeling disjointed."

The last principle for transitions, Consistent choreography, emphasises coordinated movement of UI elements across transition. The path elements move along should make sense, and overlapping paths should be avoided. The guide states that "when transitioning elements are coordinated, it aids user understanding about the app." Furthermore, reinforcing spatial relationships between elements with consistent incoming and outgoing motions is considered important. A method of judging the success is offered: "If all moving elements traced their paths on screen, would it look beautiful and organized? Does it create a clear picture of where to look?"

2.5 Implications for mobile transition design

The previous research shows that animation applied to desktop applications provide clear cognitive benefits for users. The benefits most likely apply to mobile context as well since there are currently no reason to assume otherwise. However, the past research regarding animation parameters such as easing curve or duration is not likely directly applicable to mobile context because of the fact that animation is highly context sensitive in terms of content, screens size and interaction mechanism, among other things. Furthermore, based on the previous research, it is not always clear how to take advantage of the benefits of animation in mobile interfaces. For example, animation's impact on attention is like a double edged sword which can enhance experience or cause major harm.

The mobile platform guidelines try to solve this problem with examples and recommendations of how to incorporate animation into apps. Especially Google

Material Design guidelines (Section 2.4.3) provide elaborated examples for choosing easing curve, duration and motion path for certain situations. It is impossible to make such recommendations based on the current research alone. Google's guidelines are not built upon the public scientific research and might be based only on the subjective views of UX specialists, and therefore lack scientific validity. Still, the platform guidelines are the best instructions we have in the situation of limited mobile specific research.

The previous research has also shown that animation has an affective influence and thus can increase satisfaction and engagement in specific contexts. Yet again, because the affective qualities are very context dependant it is difficult to draw conclusions from desktop research to mobile applications. The same style of animation that feels right in desktop application can feel distracting in mobile context.

Another limitation in the previous research is that it doesn't take into account how people's perception of an animation changes over time. A flashy exaggerated transition can feel interesting and impressive during a short user study but when the same animation is shown over and over again in a real use context it becomes easily frustrating. For example in a user study by Thomas et al. [17, 9] people liked exaggerated animations in an image editor. However, no professional image editor has such animations. The platform guidelines also advocate subtle transitions which clearly conflicts with the findings of the study.

Furthermore, people's overall taste regarding animation might change gradually over longer periods of time. What felt right a few years back can now feel dated. This phenomenon happened in the visual design field where designers used UI elements that mimicked real world objects in photorealistic manner. Nowadays this style, known as skeuomorphism, is rarely used since it does not feel right anymore. To put it another way, people's preference and taste regarding the visual style of UI has changed over time. The same can happen to UI animation as well.

In a summary, previous research and platform guidelines provide a direction for creating effective UI animation, although their help is limited. Also, it still remains unclear how to craft the affective side of animation since current research does not reveal how animation influences emotions an feeling. Therefore, designers have to rely on their intuition to get animation feel right.

3 Mobile prototypes

Researching animation often requires building specifically tailored prototypes because it might be the only way to focus on the particular context or properties of animation. This thesis also employs prototypes which will be described in the following chapters.

Chapter 3.1 first presents two UI concepts which form a base for prototypes. After this, chapter 3.2 describes three transition frameworks which guide transitions design, and finally chapter 3.3 explains the technical implementation and limitations of the prototypes.

3.1 Application concepts

The two application concepts were designed for this study: a music application and a news application. An application concept is here referred to as the main idea of an application, its features, visual look and feel and structure. Practically an application concept includes the whole user interface excluding animation. Both application concepts were designed for iOS.

The music application (Figure 3) provides playlists curated by artist and DJs. Each playlist has multiple tracks with cover artwork and detailed information. A user can save favourite tracks to a personal playlist and check which songs are currently trending. The application also shows upcoming concerts nearby. The music application doesn't have a traditional bottom navigation bar or a hamburger menu (also known as a drawer menu). A user can navigate by swiping in different directions (up, down, left and righ) so there are not always visual cues indicating possible navigation options.

The news application (Figure 4) offers news articles with several categories, including, sports, culture, economy and politics. A user can save news articles to a reading list for later reading. Morever, the application includes a two week weather forecast, three comic strips and a setting for choosing a preferred text size. The main navigation element in the news application is a bottom tab bar which almost always stays visible.

The rationale for choosing the two concepts is that they are likely already familiar to a participant. Thus, it is not necessary to provide extensive instructions for understanding the content and functionality in the applications. Furthermore, the two concepts allow creating ealistic applications with real content and sufficiently complex navigation structure. Because the concepts are different, results obtained with them are not directly comparable.

Animation research within two application concepts instead of just one offers two benefits. One benefit is that two concepts provide a broader benchmark for evaluating the effectiveness of transitions. Because the effectiveness depends on context, using only one UI would produce limited understanding. Second benefit is that two concepts allow collecting more data from a single test session because one participant can complete tasks with both concepts. Using the same concept twice for a single participant is not possible without a significant learning effect.

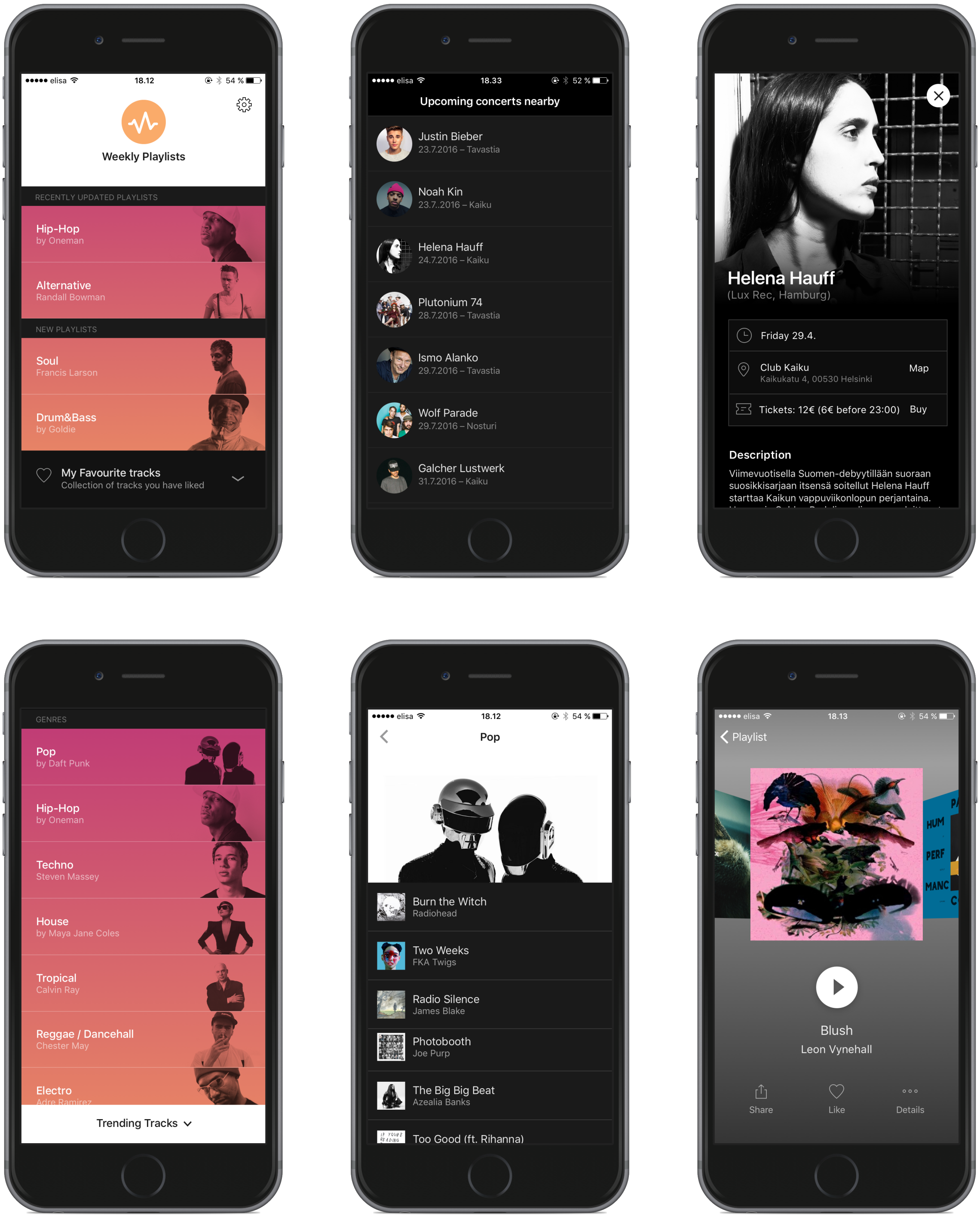


Figure 3: Screenshots of the music application concept. From top left: Home view, upcoming concerts, concert details, playlists, single playlist, track details

3.2 Transition design frameworks

Three different transition design frameworks, denoted here as Framework A (FA), Framework B (FB) and Framework C (FC), were composed for this study. A

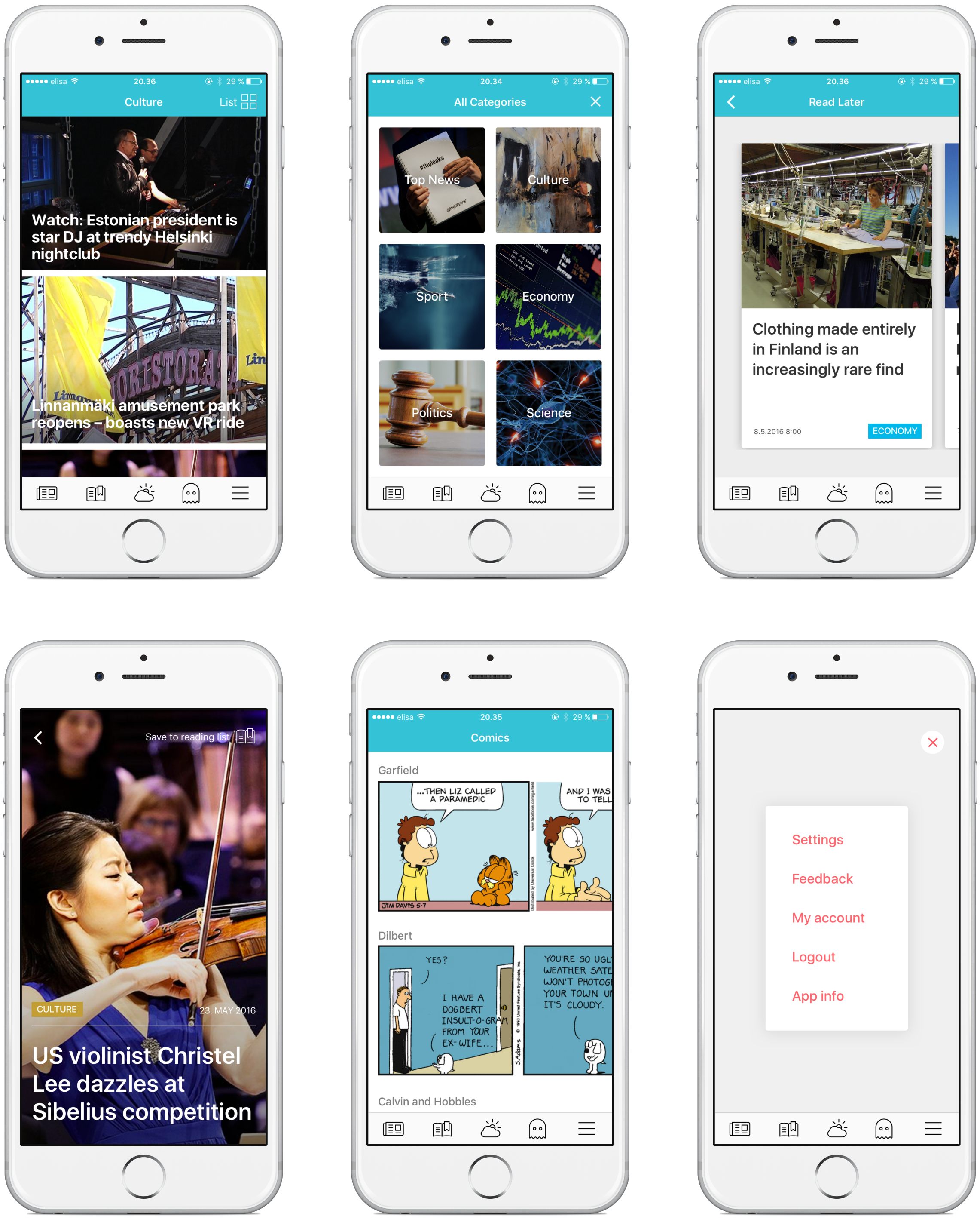


Figure 4: Screenshots of the news app concept. From top left: Landing screen, category list, read later list, news article cover, comics, secondary menu

framework consists of a set of principles which are followed when designing transitions. Each framework was applied to both application concepts, resulting in six prototypes. The main idea was to form the best possible version (FA), a very simply one (FC), and a version which lies somewhere between those two (FB).

The three frameworks share a few common design principles. First, they follow general advice regarding animation duration (Section 2.2.2) by keeping transitions relatively short, around 300–400 ms to avoid wasting too much user's time. Second, they keep transitions smooth and subtle to avoid the drawbacks of animation such as attracting too much attention or distracting users from their main task (Section 2.3.3). Additionally, all frameworks use straight animation paths because the prototyping tool Flinto does not support curved paths.

The frameworks differ from each other mostly in terms of how they take advantage of the object connectivity (section 2.3.1), convey structural relationships (section 2.3.2) and also what kind of affective influences they have (section 2.3.5). The level of object connectivity varies among the frameworks in terms of how the common content between views is animated and the communication of structural relationships between views is controlled by how well the animations are planned spatially. Characteristics of each framework are summarised in table 1 and discussed in detail in the following chapters. It is unclear exactly what kind of affective influences each framework exhibits.

	Framework A	**Framework B**	**Framework C**
Spatial design	X,Y,Z	X,Y	none
Common content	connected	not connected	not connected
Transition styles	custom & built-in iOS	built-in iOS	dissolve only
Workload	high	low	low

Table 1: Summary of the characteristics of three transition design frameworks used in this work. Spatial design refers to the number of dimensions used in the design of transition, common content describes whether the shared content between views is animated or not and workload refers to the design and development effort required for creating an application in accordance with the framework.

3.2.1 Framework A

Out of the tree frameworks, the FA is the most advanced approach for transition design and it follows the best practices of animation suggested by previous research (when applicable to mobile context) and the iOS Human interface guidelines (Section 2.4.2).

In the FA, the object connectivity is utilised whenever possible. The common content between the initial and end states of a transition is connected visually using a smooth animation. Figure 6 illustrates a transition which is designed according to this principle for the music application. The picture and name of an artist are smoothly resized and transformed to a new location maintaining the connections during the transition. Maintaining object connectivity is not possible without creating custom transitions since mobile platforms do not have a built in solution for this task. Therefore, creating animations according to the FA requires more design and implementation effort compared to the animations based on the other two frameworks.

The structural relationships between UI views are paid extra attention in the FA. The structure of the UI is planned spatially by placing all UI elements into a virtual 3D space according to an information hierarchy of the UI concepts. A simplified version of the spatial model used for the music app is illustrated in figure 5 which shows how UI views are positioned in space. For simplicity, individual UI components are not shown in the figure even though they can have their own position and are not necessarily tied directly to the views. Generally, hierarchically same level content is placed on the XY-plane, whereas the Z-axis is used indicate how specific the content is.

All transitions in FA are built according to the spatial model and thus communicate the structural relationships between UI views to a user by revealing spatial cues during transitions playback. For example, the figure 7 describes a transition in the news app which utilises Z- and X-axes. A new view slides in from the right while the current view slides to the left with a slower speed. Together these movements create an illusion of depth. The Z-axis is also present in a zoom-in and zoomm-out transitions which are used for opening more detailed or more general content of a particular section and. These animations are similar to what is used in zooming interfaces [18].

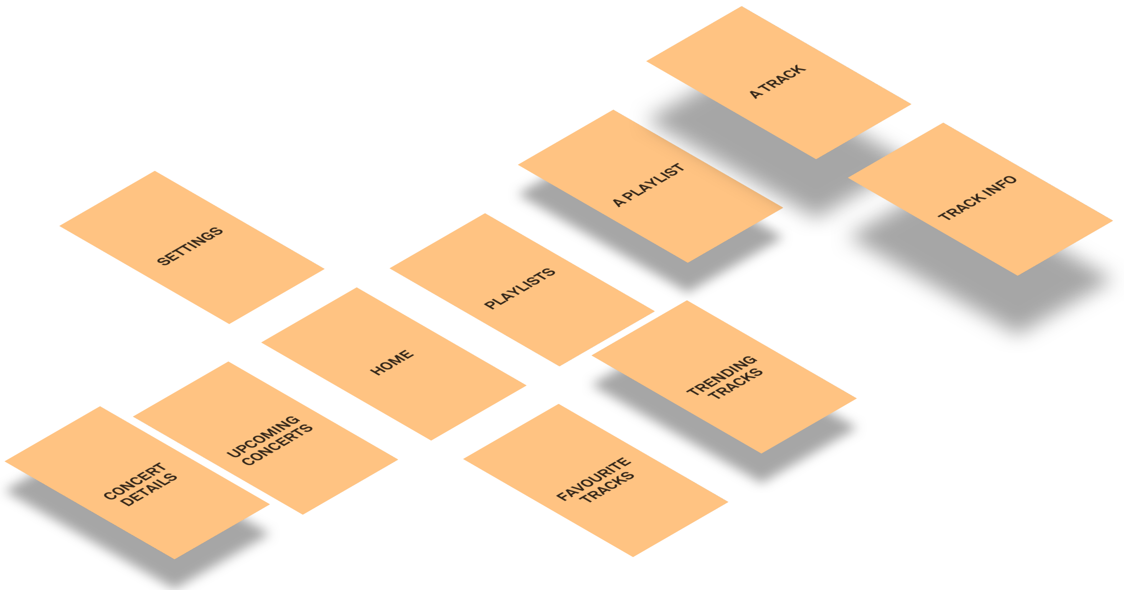


Figure 5: A simplified version of the spatial model used to design transitions for the Music application. The model shows how UI views are related to each other along X, Y and Z axes.

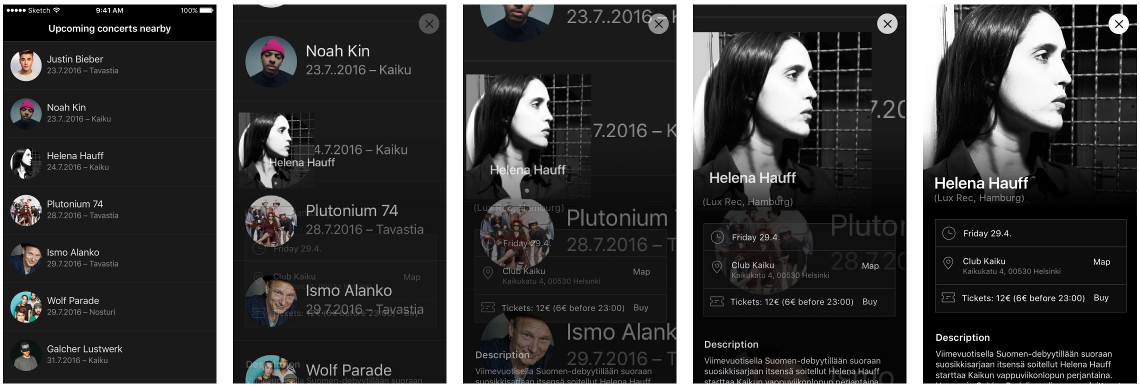


Figure 6: A transition designed according to the framework A for music application. The transition smoothly animates the common content shared between views.

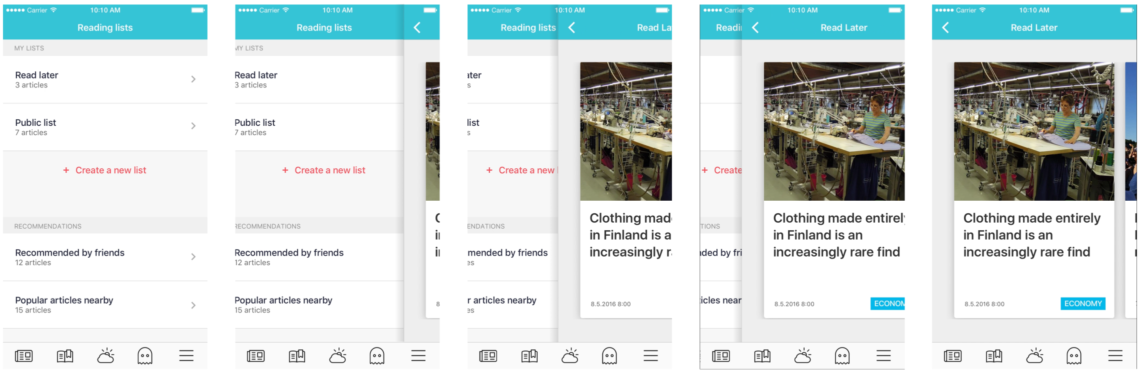


Figure 7: A transition designed according to the Framework A which takes advantage of the Z-axis. A new view slides in from the right side while the current view slides to the left with a slower speed. Together these movements create an illusion of depth.

3.2.2 Framework B

The framework B is somewhat less sophisticated approach to transition design than the FA. The FB uses only transitions which are included in the iOS operating system. Because custom transitions are not allowed, the object connectivity is not utilised meaning that the common content between UI views are not connected during a transition.

Similarly to the FA, the use of transitions in FB is planned spatially but only in the XY-plane. The missing Z-axis design means that the used transitions can communicate physically impossible relationships between UI views in 3D-space. This happens because some of the built in iOS transitions (for example the slide animation in figure 1) reveal spatial cues along the Z-axis which might conflict with each other.

Creating transitions according to the FB requires little design and development effort since the built-in transitions are rather easy to include in an app. Therefore, FA and FB offer an interesting comparison and might provide insight whether the extra work effort of FA brings justifiable benefits. There is also a potential advantage in using default iOS transitions. Default transitions might perform better than custom ones because people are already familiar with them and have formed expectations on how a view change happens.

3.2.3 Framework C

The Framework C uses only simple dissolve animations for all transitions except for scrolling. A dissolve animation gradually increases the opacity of a new UI view which eventually covers the initial view. With a dissolve animation it is not possible to maintain object connectivity or convey structural relationships because a dissolve animation does not contain any movement and therefore does not suggest UI element's spatial position related to other elements. Prototypes made from the FC perspective act as control versions and do not represent a realistic case of transition design in modern mobile applications.

3.3 Technical implementation and limitations

Available tools for building the prototypes were evaluated from the perspective of the best compromise between animating capabilities and workload required to build the prototypes. An animation prototyping software Flinto [48] was chosen for the task because it allows creating rather complex prototypes using a visual editor without writing code. Other alternative software was also considered, such as Principle, Framer and Origami, but they were not really suited for creating a multi-view prototypes at the time of writing this thesis. Moreover, the option of coding real applications was abandoned because of the very high work effort required, even though the option has the most flexible possibilities for animation.

Flinto can create custom transitions, animate multiple elements individually and animate several parameters such as opacity, position, size, rotation and colour. It also provides easing curve controls with built-in iOS UIKit easing functions and delay control. Flinto prototypes can only be installed to iOS.

While Flinto has rather extensive animation features, it also has limitations. One limitation is that the timing of multiple parameters applied to a single object can not be controlled individually. For example, when the size and the colour properties of a single button are animated they share the same easing curve, delay and starting and ending times.

Another limitation is that the motion paths of moving objects are always linear. An object moving from one place to another travels across the shortest path. Therefore, it is not possible to fully follow the Material design guideline (Chapter 2.4.3) regarding motion paths, since the guideline advocates non-linear paths for certain types of transition. This limitation unlikely has an impact on the results since the use of curved paths is not associated with cognitive benefits although it makes animations look more physically realistic.

Yet another constraint in Flinto (and generally in all animation prototyping software) is that content can not be generated dynamically or fetched from other sources (i.e, from internet). An initial and end state of a transition have to be constructed from images. Consequently, the prototypes used in this work, only a part of the UI is functional because creating a complete app would have required drawing hundreds of screens.

4 User Study

This chapter presents methods which are used to find answers to the research questions and the rationale for choosing these particular methods. This is followed by learnings from pilot tests. After this, participants' backgrounds are presented. Finally, this chapter describes test procedure and settings.

4.1 Methodology for animation research

The effects of animation are most often studied by conducting a user test where a group of people complete certain tasks under varying conditions. Common tasks include tracking objects [22, 14, 62, 1], estimating changing values [22, 16], navigating or finding information [3, 24, 25, 18, 7, 40] and recalling information from memory [3, 21]. Participants' performance is then measured with objective performance indicators such as error rate [18, 20, 22], task completion time [18, 20], tracking accuracy [62, 22] and ability to memorise and recall information [3].

Many studies complement the objective approach with subjective ways to measure the impacts of animation. Preference surveys or questionnaires are often used to rate satisfaction or usefulness [19, 63, 21, 22, 18] and additionally many studies ask subjective comments from participants after the main tasks [63, 20].

4.2 Selection of methods

The user study in this thesis is influenced by the research done by Bederson and Boltman in 1999 [3]. They investigated if animation help people build mental maps of spatial information. Their study is unique as it seems that nobody else has examined the connection between animation and mental map in academic literature.

The researchers [3] built two versions of a desktop computer application for browsing a family tree, one with animated transitions and one without. Subjects were asked to perform three tasks with the prototypes. In the first task, the subjects were presented with a series of nine statements and asked to navigate a family tree and determine if the statements were true or false. In the second task, the subject was given three minutes to explore a tree freely, after which the tree was hidden and the subject was presented 10 multiple choice questions about the tree. The third task involved reconstructing the previously seen family tree from memory using a stack of nine photographs of the family tree members. Besides the tree tasks, participants' subjective satisfaction was measured with a survey.

Bederson and Boltman found a statistically significant finding in the reconstruction task in which the reconstructions made of the animated version had fewer errors. However, as a surprise to the researchers, there were no statistically significant differences in the other tasks or subjective satisfaction survey.

Like the study of Bederson and Boltman, this thesis compares various prototypes made with different animation styles with the help of navigation and mental map construction tasks. The major difference is that this study focuses only on mobile context and not the desktop computers. Another clear difference is that the construction task in this thesis is more challenging because it is done purely from memory without the help of pictures and because app UI is more complex than a family tree.

4.2.1 Navigation task

Navigation tasks done with prototype applications are commonly used in animation research [40, 3, 7, 3]. This study also employs a navigation task in order to find out how different transition styles influence peoples' ability to navigate and find information (RQ1). The task created for this study consists of statements which are presented to a participant one by one from a laptop computer. A participant has to find out whether a statement is true or not by navigating the prototype application installed on a mobile phone and to provide an answer to the statement using the laptop. The laptop records time spent answering each statement.

The specific set of statements in the navigation task guide participants only to certain parts of the UI. This approach is wanted because the app prototypes are not complete and thus do not contain every screen and functionality. Allowing free exploration would cause confusion since a large part of the UI is not functional because large part of the content is missing.

In additition to measuring navigation performance, the navigation task creates a requisite for the following task, cognitive map construction. During the navigation task participant has to visit every screen which is implemented into the prototype in order to answer the statements. This procedure ensures that all participants share similar baseline information before continuing to the next task.

The procedurement for the navigation task used in this work is summarised below:

1. A statement is presented from a laptop screen
2. Participant explores the application to find answer to the statement
3. Participant enters his/her answer using the laptop application
4. Next statement is presented

The application for presenting the statements and for recording task completion times is implemented with jsPsych javascript library [65] (see figure 14). The application runs on a web browser and shows the statements one by one to a participant. When participants find an answer, they choose answer between 'true' and 'false' and press a 'submit' button. The statements used for Music and News application contexts are presented in appendix A1 and appendix A2 respectively. The statements for both application contexts contain one more complex task which involves preforming a certain interactive procedure which must be completed before it is possible to answer the statement.

4.2.2 Cognitive map construction

Edward C. Tolman, an American psychologist, introduced the term cognitive map (also known as a mental map) after studying how rats find their way in mazes in two studies he did in 1930 [36] and 1948 [37]. In the second paper [37], he argued that rats, and similarly humans, store a mental representation of spatial surroundings to their brain in a form of a map-like construction, called a cognitive map. Tolman stated that cognitive map contains routes, paths and environmental relationships which help animals to navigate in their environments.

After Toman's experiments there has been debate about what the cognitive map actually means. The term *map* seems to be a major cause for the confusion since researchers don't agree on what the actual internal mental structure is in the brain where spatial information is stored. Some researchers think that the mental structure is just like a cartographic map, while others argue that the structure has no real connections to the concept *map*, as we understand it [38]. Because of the controversy, the general acceptance of the term is a bit more abstract: cognitive map is *"an internal mental representation which we use to understand and know the environment"* [38]. In other words, the cognitive map is a model in the brain which plays a major role in the thinking of the everyday spatial environment and is important tool for us because it explains and influences our spatial behaviour. Cadwallader suggests that cognitive map affects at least three types of decisions and Garling et al. add one more (quoted directly from Kitchin [38]):

1. The decision to stay or go
2. The decision of where to go
3. The decision of which route to take
4. The decision of how to get there

User interfaces can be thought as digital versions of real world environments where people navigate to different places and make decisions about routes they take. Therefore, it is reasonable to assume that humans build a cognitive map of user interfaces as well, and that the cognitive map influences human's ability to navigate and find information also in this context. Moreover, the study by Bederson and Boltman [3] indicates that animation enhances people's ability to form the cognitive map in a digital environment.

Because it is not possible to study a cognitive map directly, a specific method must be used to extract individual's cognitive map information. Methods used in previous research include observing subject's behaviour, analysing an external representation or asking subject to reconstruct a map using artefacts [64] as is done in the study by Bederson and Boltman [3]. This thesis takes the approach of analysing an external representation which in this case means that participants' spatial knowledge is obtained by asking them to draw a map of an UI from memory. Initially, the plan was to use the same approach as Bederson and Boltman, but a pilot test revealed that providing UI printouts made the task too easy and, therefore, the pure memory based approach was chosen.

The drawing task, referred in this work as a cognitive map construction, includes two parts. First, participants are asked to draw the whole application UI on to printed phone frames (see A1) from their memory as thoroughly as possible. Participants draw a single UI view on to a single phone frame and write a descriptive name for each. Specific drawing symbols for text, images and buttons (appendix A1) are used in order to make the task and analysis more straightforward. In case there are multiple identical views with different content, only one view is needed. For example, the music app has a player screen for each music track so it is necessary to only draw the player view once.

In the second part, a participant places the finished drawings on a whiteboard using magnets and connects them to each other with a marker indicating the possible navigation paths inside the application. Indicating a link to one direction is enough and thus no back links are required. A constantly visible navigation element (e.g., bottom navigation bar) is a special case for which participants are instructed to draw only the links from a single screen. At any point of the task participants are allowed to add and draw more frames if they feel something is missing. The task has no time limit and it ends when a subject annouces that he or she is ready.

4.2.3 Subjective Survey (SUS)

In this work, a System usability scale (SUS) survey (table 2) is used to measure participants' subjective satisfaction of prototypes, and consequently to answer the research question RQ3: *How different transition styles influence peoples' satisfaction of a mobile application?* The SUS was chosen because it is one of the most used surveys in the usability field and it has shown to produce reliable results [45]. Creating a survey with a new set of questions would have required additional testing and would have been outside the scope of this work.

SUS consist of ten statements on which respondents rate their agreement with five point likert scale. The final SUS score is calculated from individual answers and it ranges from 0 to 100. Even though the final score seems like a percentage, it can not be treated as such since on average the SUS produces a score of 70 points, meaning that the distribution is skewed towards higher scores [47]. Bangor et al. [47] analysed SUS sores from 273 studies and created an adjective rating scale for scores which is shown in figure 8. The scale shows, for example, that around 73 points is needed for a grade "Good".

In the original SUS, half of the questions are worded positively and half negatively. Sauro and Lewis [46] compared the original SUS with an all-positive version, but they didn't found any major difference in mean SUS scores between the two versions. However, in their review of 27 SUS surveys, they found that 11% of the datasets were miscoded by researchers and 13% of questionnaires contained mistakes by users. Therefore, in this work, an all-positive version of SUS is used to avoid possible errors.

This work also uses a 7-point likert scale instead of the usual 5-point scale in order to produce more accurate results. The five-point scale could potentially be too limiting for some users because of the short range. For example, some participants might think that the right answer would lie somewhere between the values 2 and 3. Kraig Finstad [44] compared five- and seven-point versions of the SUS and found that participants using the five-point version were significantly more likely to use interpolations than those using the seven-point scale. Finstad found that about 3% of the answers were interpolated on the five-point scale, while on the seven-point scale there were no interpolations.

Furthermore, the survey was arranged so that a moderator didn't see the participants's responses when they were filling the survey. Research has shown that people tend to give more positive answer if they think that their answer is not anonymous [66]. This phenomena is called social desirability bias and occurs as a tendency of a participant to give an answer that will please a moderator [45].

ID	Question
1	I think that I would like to use the application frequently.
2	I found the application to be simple.
3	I thought the application was easy to use.
4	I think that I could use the application without the support of a technical person.
5	I found the various functions in the application were well integrated.
6	I thought there was a lot of consistency in the application.
7	I would imagine that most people would learn to use the application very quickly.
8	I found the application very intuitive.
9	I felt very confident using the application.
10	I could use the application without having to learn anything new.

Table 2: Questions in System Usability Scale survey. An all-positive version is used instead of the original version where half of the questions are worded negatively.

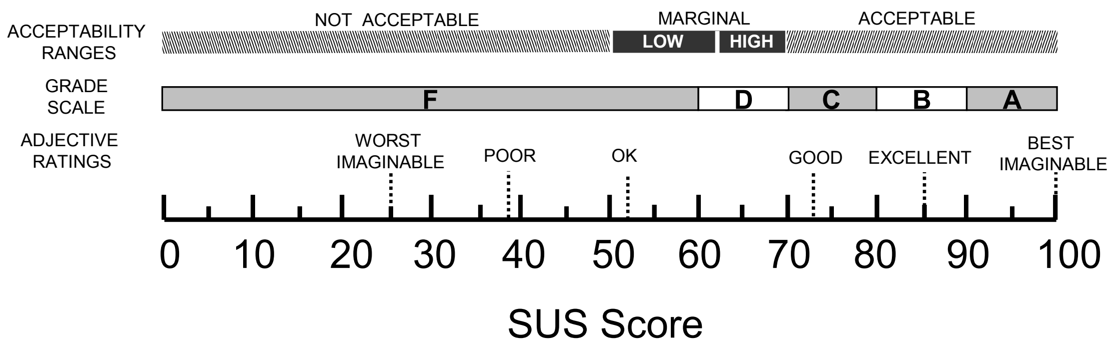


Figure 8: Several ways of interpreting a SUS score. Researchers have created rating scales for final SUS score because the distribution of results is skewed toward the higher end. The scale used in this work is the adjective rating created by Bangor et al. [47]

4.3 Pilot test

Four pilot test were arranged in order to reveal potential problems with test design. After each pilot test, several iterative improvements were made to the prototypes, test procedure and test settings. Only after the emerged issues were fixed and the test ran smoothly, the actual user study was started. People who participated in the pilot test were not included in the actual study.

The pilot revealed several problems with the mental map construction task. One of the problem was that the instructions were not comprehensive enough. This was easily fixed by providing better instructions. Another issue was that the task was too easy. Initially, users were provided printed UI views of the application and asked to visualise how they can navigate in the app by connecting the views with a marker. This was rather easy assignment because the printed UIs contained too much visual cues, such as text labels and icons. Therefore, the pre-printed UIs were abandoned and participants were asked to draw a map of the whole application structure from their memory.

Several improvements were also made to the application concepts based on the pilot test. It was noted that the navigation and mental map construction tasks were considerable easier to complete with a news application than a music application prototype. In order to make the application concepts more equal, more content and functionality was added to the news application prototypes.

A few more observations were made during the pilot test. It seemed that the two pilot testers who used Android had no problems completing the test even though the prototype applications were designed for iOS. Another observation was that none of the participants were able to tell whether there was a difference in animations between the versions they tested. This fact indicates that the designed animations were realistic and didn't draw too much attention. On the other hand, one participant commented that the navigation tasks took all her focus and that it would have been nice to explore the application freely without completing tasks. Despite this, the navigation task was not altered because allowing free exploration would have required programming real test applications.

4.4 Participants

User study participants were required to have prior experience with touch based smartphones and basic understanding of written English text because the prototype applications were implemented in English.

The pre-requisites and other relevant background information about each participant were checked in a background survey. The survey collected data which could influence the results, including age, occupation, experience with common mobile operating systems. Besides, the survey measured participants's familiarity with applications similar to the application concepts used in the actual test.

Total of 18 people (11 male, 7 female) participated in the experiment and each of them were rewarded with a 20 euro gift card. Participants were in their twenties or thirties, with an average age of 27 years (SD = 2,91) (figure 11b). Six people were students and the rest were working in various fields (table 3), including engineering, art, design, commerce and customer service. All participants qualified the pre-requisites with good to excellent Eglish skills (figure 9).

Participants were frequent users of music applications with their mobile phones

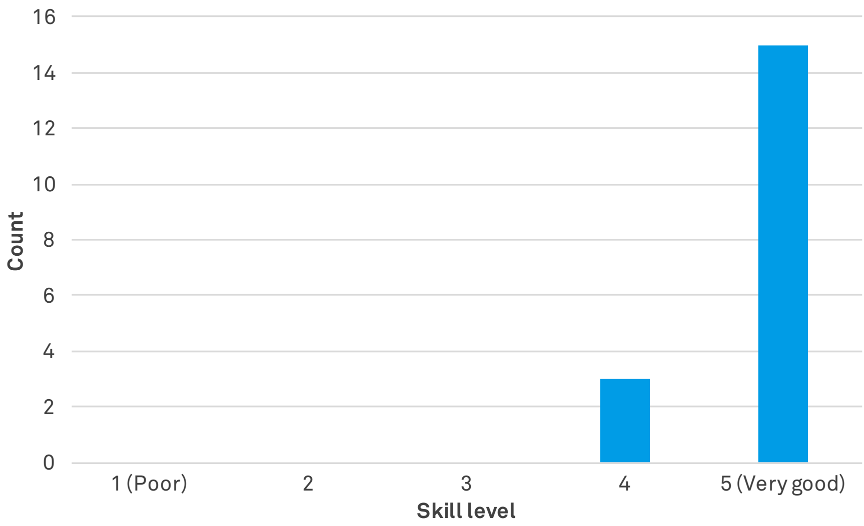


Figure 9: Participants's understanding of written English text

(Figure 12). 12 people used music applications daily, 4 people multiple times a week, and only one did not use any at all. Usage of news applications, on the other hand, was not that popular (figure 13). While there were people who used news applications frequently (5 daily, 4 multiple times a week), approximately the same amount of people used them rarely or not at all (3 have tried, 5 never).

Remarkably, iOS was the most familiar platform among participants (figure 10). 15 people reported at least one year experience with iOS. In comparison, Android had only 5, and Windows Phone 3 people with the same level of experience. Furthermore, every participant had tried iOS and there were people who had never used Android or Windows Phone. The high experience with iOS indicates that the sample of participants does not fully represent general population, since currently Android is clearly the most popular mobile operating system.

4.5 Experiment setup

4.5.1 Test Planning

The experiment is designed so that a single participant completes tasks with two prototypes, a Music app prototype and a News app prototype. This approach allows collecting more data from a single test session and therefore minimises the number of required participants. However, as a downside this approach introduces potential learning effect which could bias the results. After the first round of tasks participants have gained experience which can result in increased performance for the second round of tasks.

In order to minimise the learning effect, specific arrangements were implemented. First, the order in which the app prototypes are presented is changed after every test session. For example, the first participant (P1) started with the Music app which

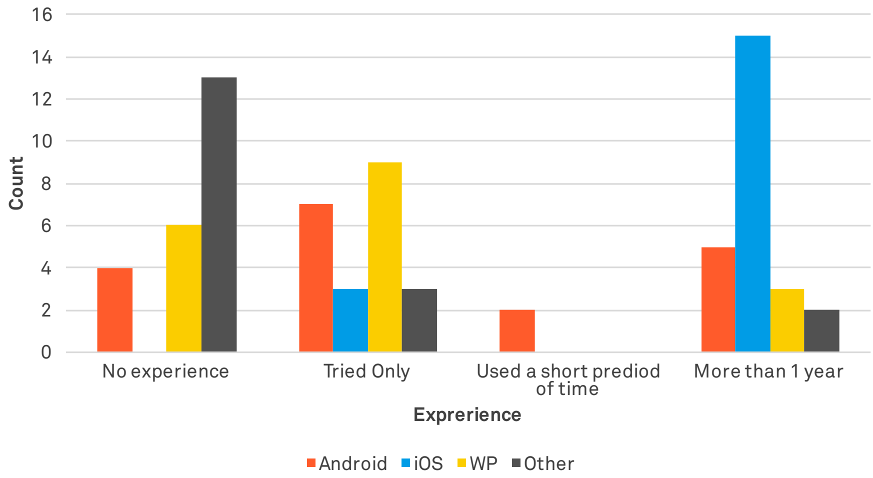
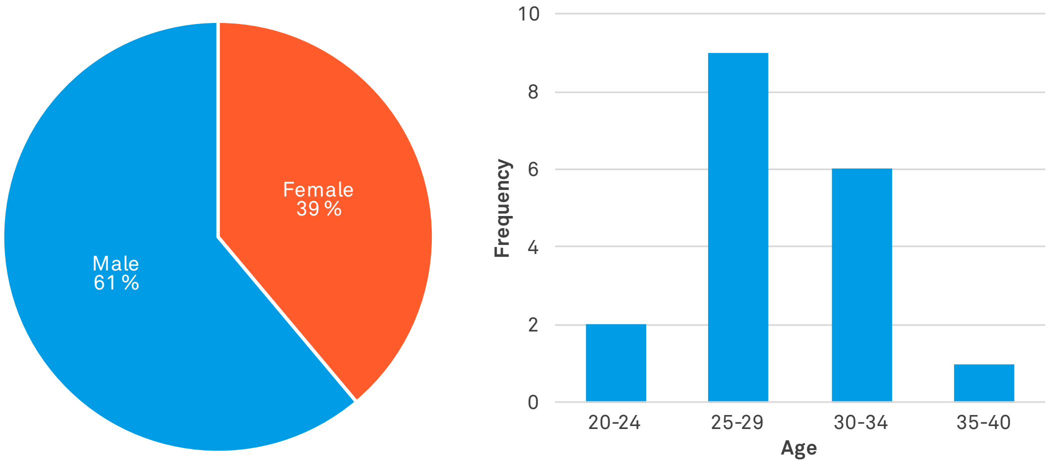


Figure 10: Participants's experience with the most common mobile operating systems.

ID	Age	Gender	Occupation
P1	29	M	Film director
P2	24	M	Cafeteria worker
P3	24	M	Culture producer
P4	31	M	System specialist
P5	30	M	Student (commerce)
P6	28	M	Student (commerce)
P7	29	M	Sales associate
P8	29	M	Communications officer
P9	30	M	Solutions Consultant
P10	27	F	Account executive
P11	37	F	Designer
P12	28	F	Project engineer
P13	26	F	Student (design)
P14	31	M	Student (design)
P15	29	F	Student (design)
P16	29	F	Designer
P17	31	M	Account manager
P18	30	F	Student (engineering)

Table 3: List of all user study participants (excluding pilot users) with their age, gender and occupation. M = Male, F = Female.

was followed by the News app, while for the P2 the order was reversed. Second, the application UIs were designed to be very different from each other so even though participants can memorise the UI they first see it doesn't bring any performance benefits. The prototypes a single person uses during a test session are built using a different transition design framework (see chapter 3.2). Table 4 illustrates the order



(a) Gender (b) Age

Figure 11: Age and gender distribution of the participants

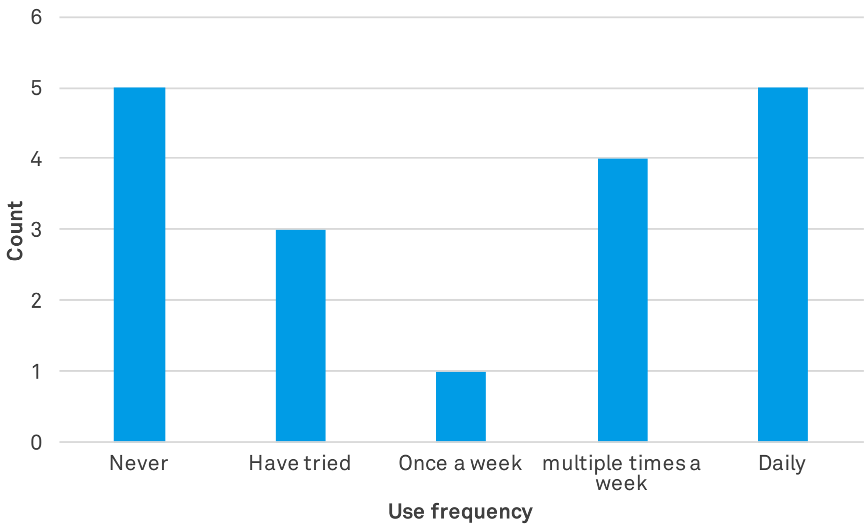


Figure 12: How often participants use news apps with their mobile phone

in which the prototypes were tested.

Besides, the purpose of the study was not revealed for the participants in advance to avoid directing their attention to animations. Subjects were only informed that the study is about testing mobile app prototypes. Furthermore, the nature and order of the tasks were not revealed in advance because there is a danger that if the subjects expect that the second round has identical tasks they might be able to gain performance advantage by planing their actions.

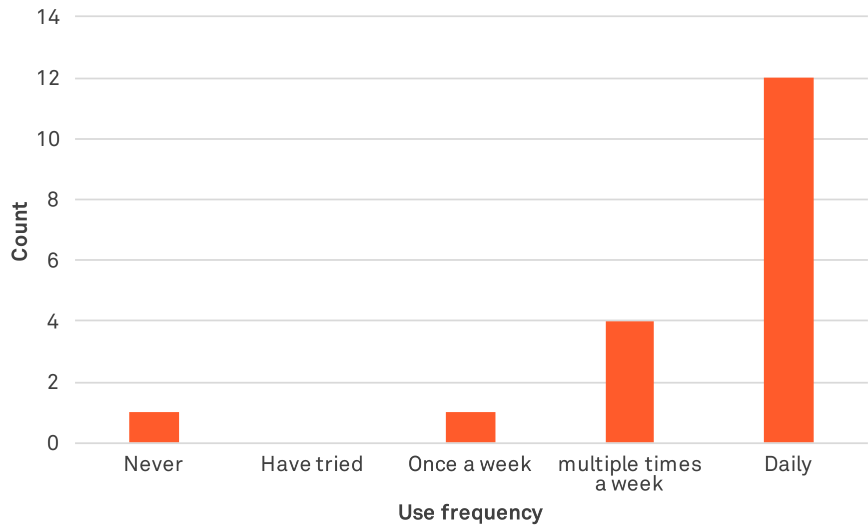


Figure 13: How often participants use music apps with their mobile phone

4.5.2 Environment and equipment

Two similar office meeting rooms equipped with a table, chairs and a whiteboard were chosen for the experiment and each test session was conducted in one of the two rooms. The reason for using two separate rooms was due to a limited availability of the rooms.

A 15" MacBook Pro laptop was used for collecting the answers of the background information and SUS surveys through Google Forms service. The laptop was also used in the navigation task to present the statements, collect answers and record task completion times. In order to make this possible, a special helper application was implemented using jsPsych [65] framework (see figure 14). The benefit of the application is that it automates several moderator tasks and thus reduces potential errors.

All prototypes were installed on an iPhone 6S which was switched to an airplane mode with all notifications turned off in order to minimise distractions during the experiment. The test phone was connected the whole time to the laptop with a cable in order to collect the video and audio recordings of the navigation task for later analysis.

After the cognitive map construction task, the final whiteboard drawing was captured with a camera. Furthermore, after the tasks were completed, the most important points from the open discussion were written down.

4.5.3 Produre

At the beginning of a test session participants were instructed to sit on a chair in front of a table and read a written consent form with general information about the experiment. After participants had read the paper, they were asked if they had

ID	Music A	Music B	Music C	News A	News B	News C
P1	first				second	
P2		second				first
P3			first	second		
P4	second				first	
P5		first				second
P6			second	first		
P7	first				second	
P8		second				first
P9			first	second		
P10	second				first	
P11		first				second
P12			second	first		
P13	first				second	
P14		second				first
P15			first	second		
P16	second				first	
P17		first				second
P18			second	first		

Table 4: The order in which the app prototypes were tested. Letters *A*, *B* and *C* denote the animation design framework. *ID* shows the participant identification number. The text *first* indicates the prototype a participant started the experiment with and the the text *second* indicates the second prototype which participant used after the first one.

any questions. When everything was clear, participants answered the background information survey using a laptop. After this, the actual experiment began.

The test proceeded so that participants first completed all tasks with one prototype, and following this, the same tasks with another prototype. Participants were not told anything about the upcoming tasks of the experiment prior to the actual task.

Participants were first read instructions from a paper for the navigation task after which they performed the actual task. This was followed by instructions for the cognitive map construction task. The construction task involved participants to draw all UI screen on paper and give each screen a descriptive name. Next, they were guided to attach all screens to a whiteboard using magnets and draw the navigation paths between each screen.

Following the construction task, participants were instructed to answer the subjective survey using the laptop. Participants were told to give an honest answer and the moderator moved to other side of the room so that the participant could answer the question anonymously.

Next, the same procedure followed with another prototype except no instructions were given any longer for the tasks. Finally, when participants had completed all tasks for the second prototype, they were told that the experiment is over. This

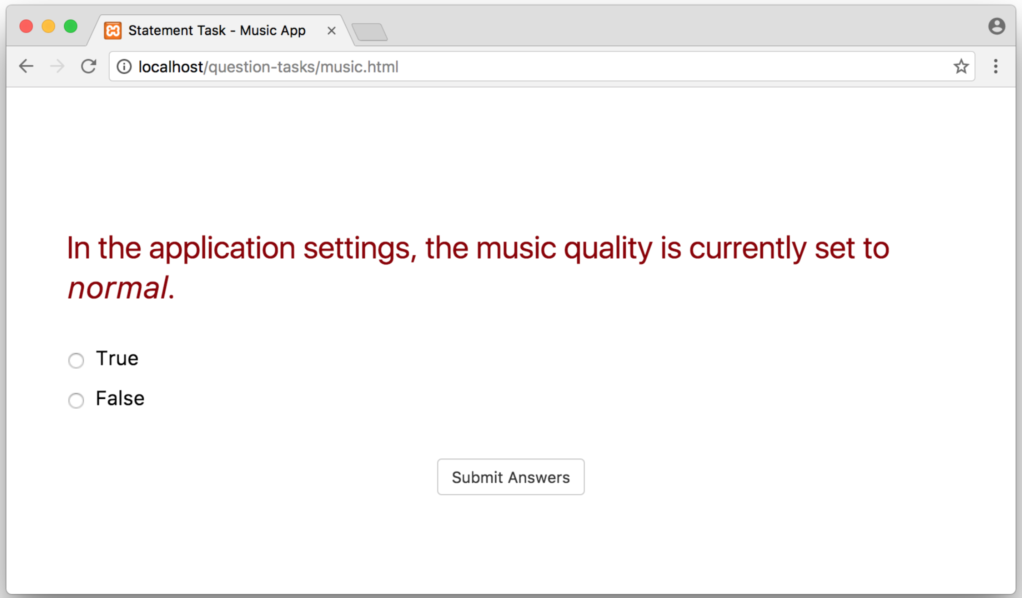


Figure 14: Screenshot of the web application which presents statements, collects answers from the participant and records task completion time in the navigation task.

was followed by a casual discussion about the experiment. The whole procedure is summarized as follows:

1. Handing out introduction and consent form paper
2. Asking if there are any questions
3. Background information survey
4. Instructions for navigation task
5. Proto X: Navigation task
6. Instructions for cognitive map construction
7. Proto X: Cognitive map construction
8. Instructions for subjective survey
9. Proto X: Subjective survey
10. Proto Y: Navigation task
11. Proto Y: Cognitive map construction

12. Proto Y: Subjective survey
13. Casual discussion about the experiment

5 Results

This chapter presents the results of the user study. Red color is used for Music application concept and blue for News application concept.

5.1 Navigation task

Figure 15 presents average times spent on the whole navigation task. In 15a the three animation versions for music application are compared, and similarly, 15b compares the animation versions for news application. In both charts, the average value is calculated from six measurements. According to single factor ANOVA, there are no statistical differences between the three animation versions in music application (p=0,818) or in news application (p=0,523). The results seems to suggest that differently designed transition animations do not have a visible influence on total navigation time.

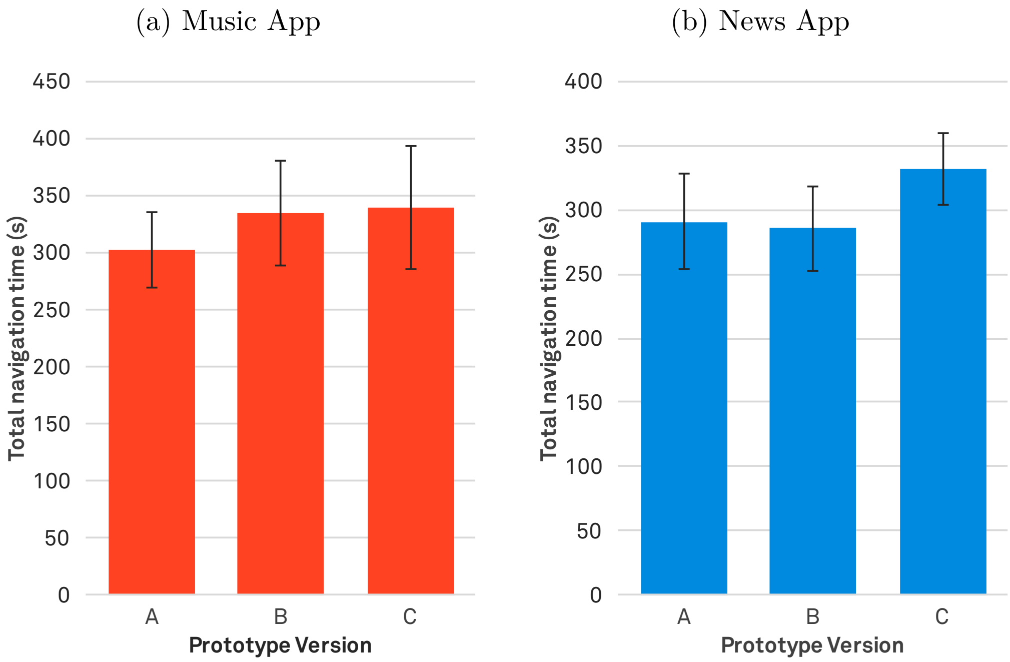


Figure 15: Average of total time spent on navitation task for each prototype version.

Average completion times of individual tasks for the music app are depicted in Figure 16. Overall, there are no major differences between animation versions, except in task 4 and task 6 (see the task descriptions in appendices A2 and A1). In the task 4, participants spent clearly more time with animation version C than the other two. The task 4 involves navigating by swiping multiple times and it looks like the version C impairs users' ability to do that. In the task 6, the version A stands out with considerably low completion time. Versions B and C have clearly higher, almost double, the time of version A.

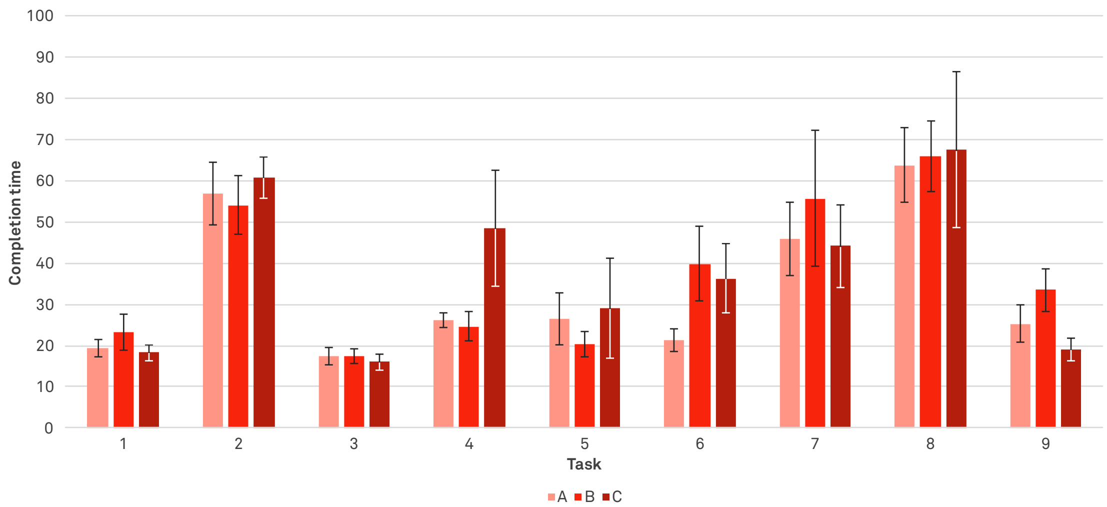


Figure 16: Music app: Average of task completion times (seconds) in navigation task for each prototype version

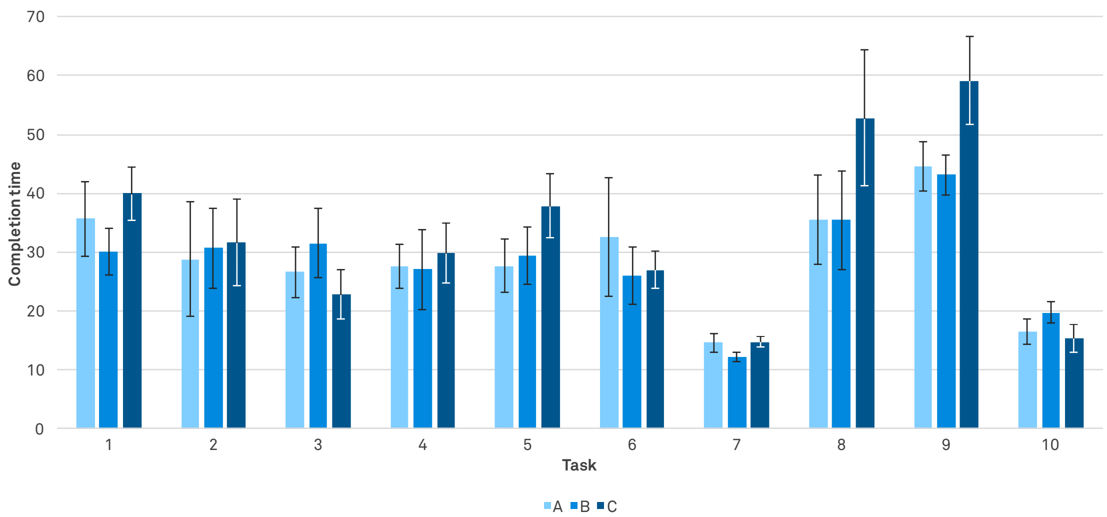


Figure 17: News app: Average task completion times in navigation task for each prototype version

Individual average task times for news application are similarly presented in Figure 17. Again, there are no major differences overall besides for the task 9 and also for the task 8 although the difference is not that large. The task 9 is more complex than the rest and it involves saving a news item to a reading list and after that navigating to the list.

5.2 Cognitive map construction

The drawings from the cognitive map construction task were analysed from three perspectives: the level of detail contained in the drawings, the number and validity of the navigation links between the views and the number of screens drawn. The detailed scoring criteria for each perspective are described in table 5 and an example drawing from one participant is shown in figure 18. Each drawing was evaluated against a model answers which are included in appendix A2 and A3.

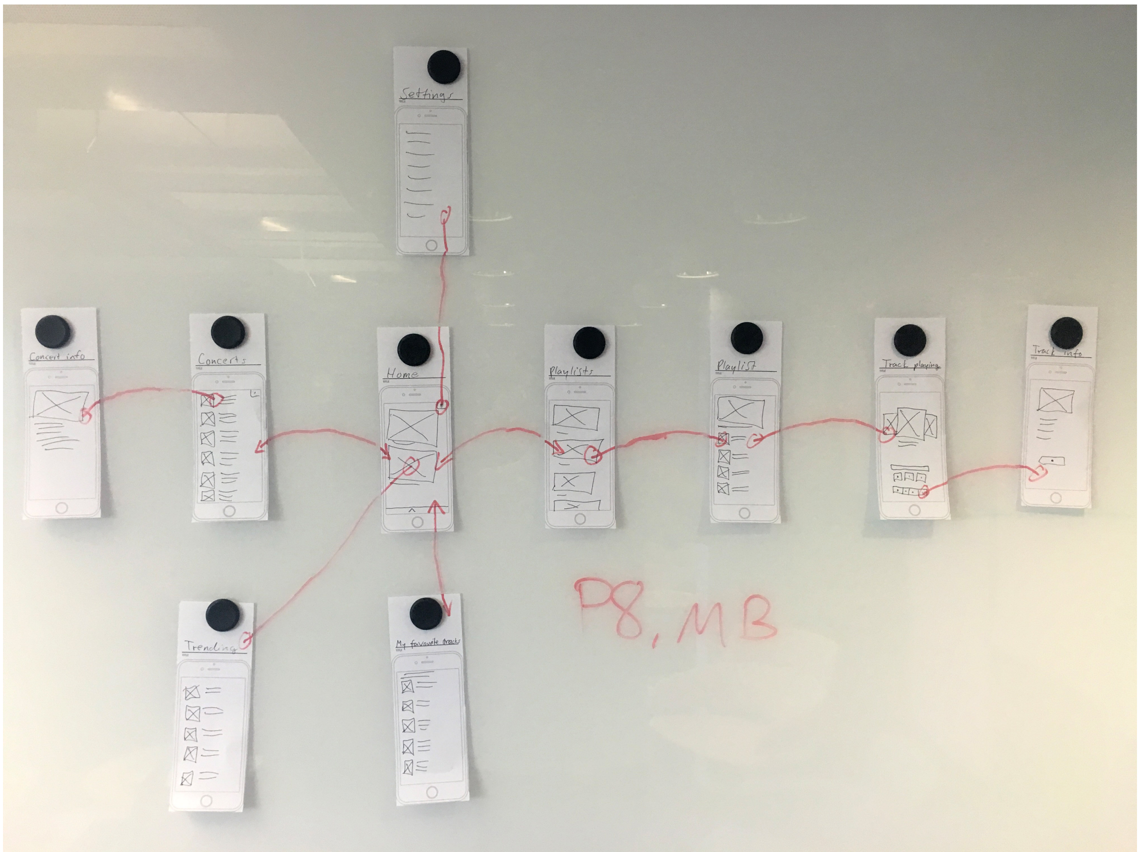


Figure 18: En example drawing from the cognitive map construction task done by a single participant.

The final scores from the details, links and number of views perspectives are shown in figures 19, 19 and 21, respectively. The differences between animation versions are small and do not show any statistically significant differences. In the music app ANOVA shows p-values of 0,499 (links) 0,912 (details) and 0,688 (number of screens). The corresponding p-values in the news app are: 0,889 (links) 0,675 (details) and 0,830 (number of screens).

Table 5: Scoring criteria used to rate a single UI view drawing from three perspectives: level of details, connecting links and count of views.

Details score	
1	The view contains all details defined in the model answer.
0,5	The view contains at least one detail defined in the model answer.
0	The view contains none of the details defined in the model answer.
Links score	
1	The link connects two UI views together as is defined in the model answer.
0,5	The link connects wrong screens together but there is only one navigation step between the connected screens.
0	The link connects wrong screens together and there are more than one navigation steps between the connected screens.
Number of views score	
1	The view has at least one of the following: a descriptive name, 0,5 or higher details score.
0	The view do not have a descreptive name and it has details score of zero.

(a) Music App (b) News App

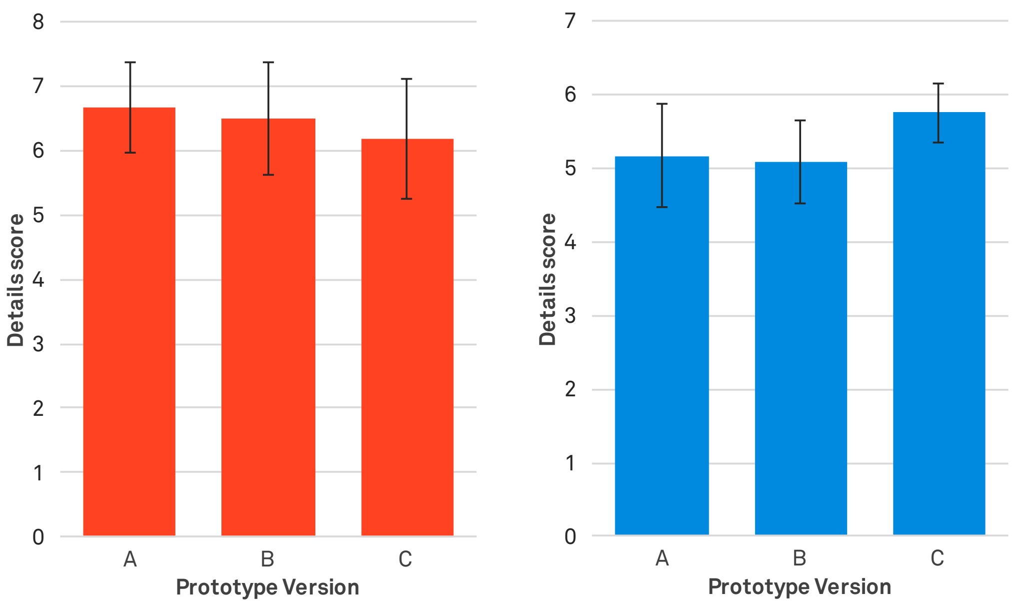


Figure 19: Score for how well participants were able to draw details from the prototypes. A bigger number is better.

(a) Music App (b) News App

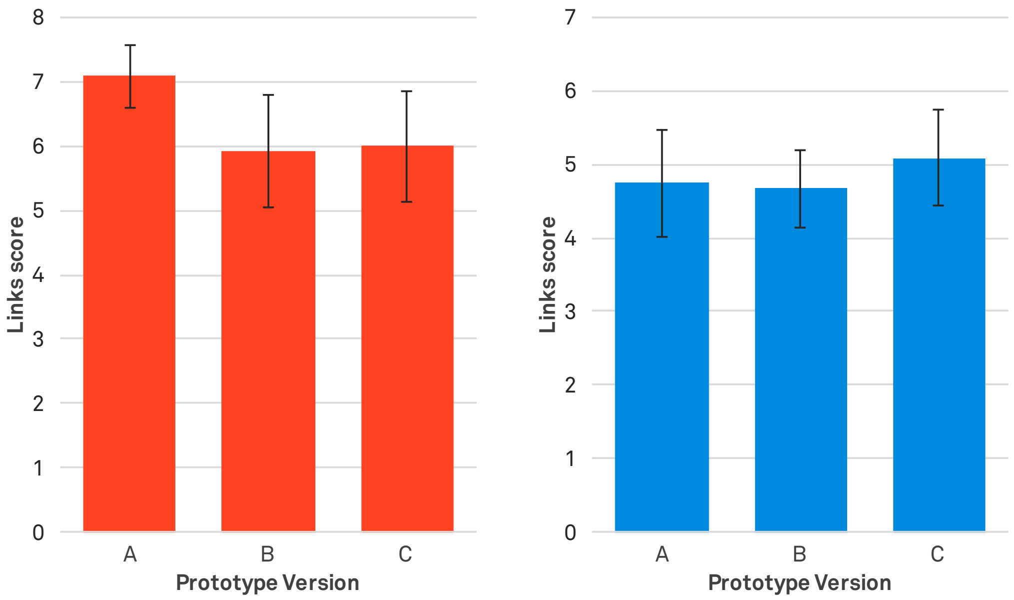


Figure 20: Score for how well participants were able to link the possible navigation paths of screen to each other. A bigger number is better.

(a) Music App (b) News App

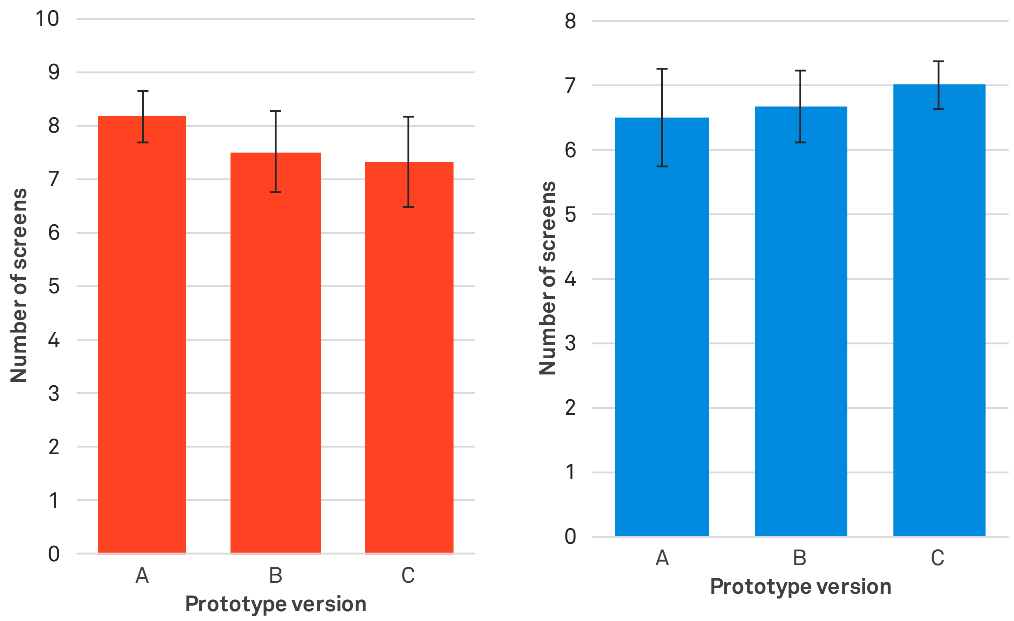


Figure 21: Scre for how many screens participants were able to remember score. A bigger number is better.

5.3 Subjective survey

Figure 22 shows average SUS scores for the music app (a) and for the news app (b). Single factor ANOVA indicates that the result for the music app is statistically significant (p=0.045), while for the news app this is not the case (p=0.75). Each average is calculated from six participants.

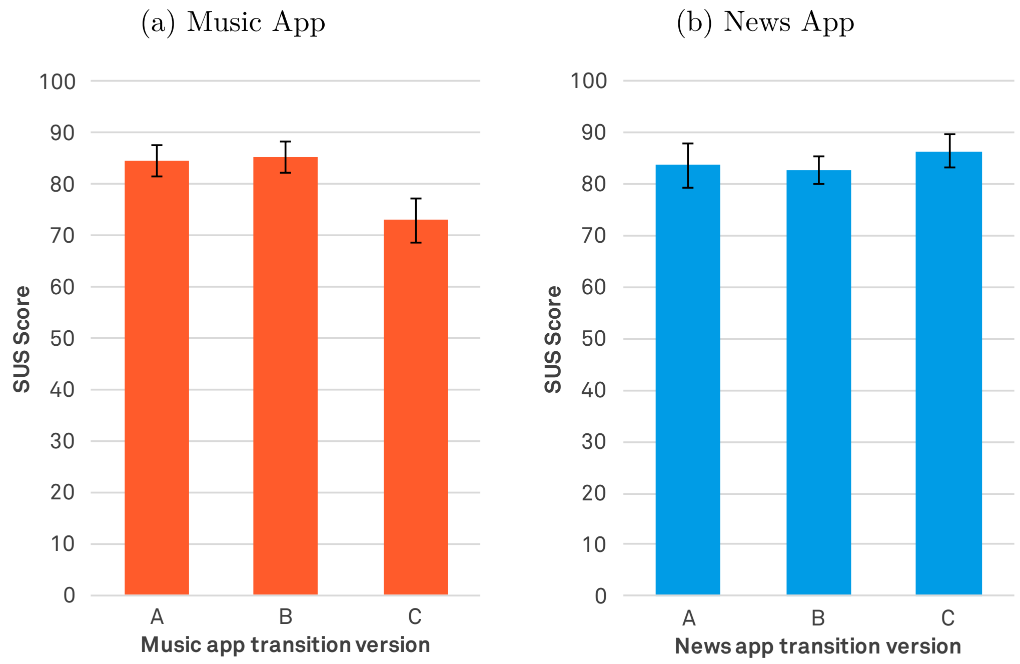


Figure 22: Average SUS Scores for news and music applications. Music app: A: 84,4, B: 85,3, C: 73,1. News app: A: 83,6, B: 82,8, C: 86,4

In the music application SUS survey 22a, the animation version A (84,4 points) and B (85,3 points) score equally while the version C (73,1 points) has more than 11 points lower score than others. According to the adjective rating scale (see figure 8), versions A and B receive a grade *excellent* while the version C receives a grade *good*.

Looking at the individual questions, the C scores the lowest in all of them. There are three questions in which the C version scores considerably lower than the other two: Q1: I think that I would like to use this application frequently, Q8: I found the application very intuitive and Q10: I could use the application without having to learn anything new. Scores of these questions are illustrated in the figure 23.

Results for news application (Figure 22b) don't reveal difference between animation versions (A: 83,6, B: 82,8, C: 86,4). Averages of all versions are very close to each other within 3,6 points of difference and correspond to grade B in the SUS grade scale. Moreover, there are no statistically significant differences in individual SUS questions.

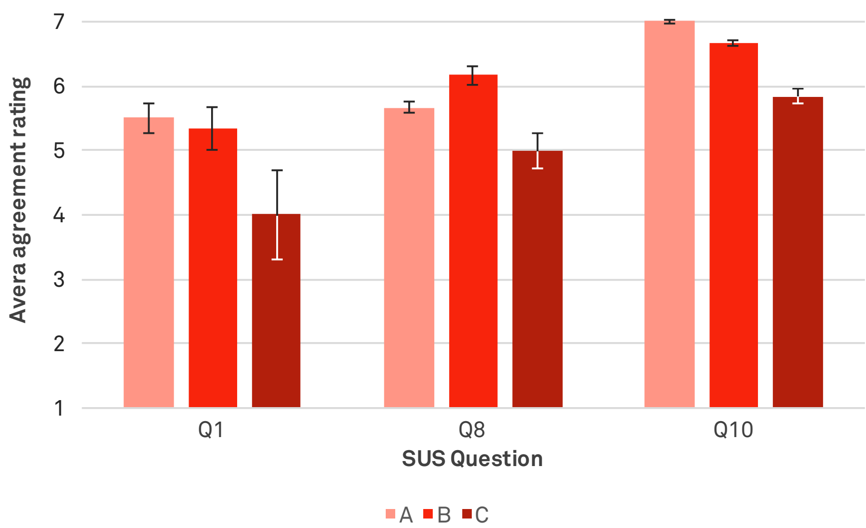


Figure 23: The survey data of tree SUS questions which show clear difference between animation versions in the music application. Y-axis denotes the average rating from strongly disagree (1) to strongly agree (7). Q1: I think that I would like to use this application frequently. Q8: I found the application very intuitive. Q10: I could use the application without having to learn anything new.

5.4 Subjective comments

After completing all tasks, participants were asked two questions about the experiment: 1) "Do you have any comments about the experiment?" and 2) "Did you notice any difference in the animations between the two apps you tested?".

Several participants commented on the features and the look and feel of the applications: *"I liked that I can see the upcoming concerts near me"*, *"The visual style of the news app looks more trustworthy [compared with the music app]"*. When discussing the cognitive map construction task, a few individuals commented that the structure of the news app was easier to memorise. Furthermore, one participant commented that *"The task [cognitive map construction] was easy for me because I have good visual memory"*. Around one third of the participants explicitly said that they did not notice any difference in animations and a few answered that there was some difference but they could not describe what it exactly was. One participant was able to state that *"the music application had more popping animations"*.

During the experiment, several participants made spontaneous comments right after being introduced to the construction task second time. They noted that they kind of expected to be asked to repeat the construction task for the second prototype although at least some of them seemed not to pay extra attention to memorise the stucture. *"Oh, I kind of expected to do the same thing again. I should have paid more attention [to the navigation task]"*. However, one participant told that she intentionally paid extra attention to the second navigation task because she expected to do the construction assignment again.

6 Discussion

6.1 Influence of transition animations

6.1.1 Influence on cognitive map

The results of the cognitive map construction task did not show that animation has influence on people's ability to build a cognitive map of a mobile application. This outcome is different from Bederson and Boltman's [3] observation that animation helps people to form a cognitive map of a family tree. The different outcome can be a result of a low number of participants (see Section 6.2) or caused by several differences in the experiment setup.

One difference is that the premises for building a mental image of the prototypes were not fully comparable. Both studies had same the amount of total navigation time (around five to six minutes) but the navigation tasks were somewhat different. In this thesis participants formed their cognitive map solely during a statement based information finding task while Bederson and Boltman [3] used the same task but in addition allowed three minutes of free exploration. The free exploration allows participants inspect a prototype in relaxed manner without a constant pressure to answer questions and, therefore, might facilitate memorisation better than the more stressful statement task. Moreover, the free exploration allows participants to visit all views multiple times while in the statement task the views at the edges of a navigation structure will be likely visited only once. In this work, the number of visits people made to each screen varied from one to five, depending which navigation path was chosen. Only one visit might not be enough to make mental connections between views for some people.

Another distinction in the experiment setup is the construction task arrangements. Bederson and Boltman [3] provided participants printouts of family tree members along with names to assist in the construction while in this work participants were asked to draw the UI map purely from memory. Initially, the plan was also to provide simplified UI screen printouts but the pilot study revealed that the printouts made the task too easy and, therefore, the memory based approach was chosen.

One drawback of the purely memory based task is that it does not provide any visual cues for participants while they do the sketch drawings. This makes the construction task demanding because participants have to recall a lot of visual details. When we navigate in digital apps or in real world environments, we see visual cues such as landmarks which we use for making decisions where to go. The visual landmarks allow us to compare our model with what we see and orient ourselves accordingly. The lack of visual cues in the drawing task might make connecting views more difficult than it would be in the real use situation. Therefore, analysing maps drawn from a memory does not necessarily tell the whole truth about people's ability to navigate in an app. In this sense, the artefact based reconstruction task which Bederson and Boltman used could reflect real navigation ability better.

The scores from the construction task might give some indication whether the experiment was too difficult or if there was enough exposure for learning to happen. Although the construction task scores had a lot of variation, two people were able to construct the music app with nearly perfect score. This suggests that there was sufficient exposure to the screens to form a cognitive map. On the other hand, nobody scored the full points with the news app which might indicate that the time spent exploring the interface was too short or, alternatively, the interface was too complex to memorise.

6.1.2 Influence on navigation

The user study results did not reveal any noticeable influence of animation on navigation performance. The finding is consistent with what Bederson and Boltman observed [3]. In their work participant's navigation time was equal in animated and non animated interfaces.

The reason Bederson and Boltman did not observe difference in navigation performance could be that they used one second long transitions. The past research has shown that long durations diminish the benefits of animation in navigation performance [1, 60, 25]. For example, in a study by Shanmugasundaram et. al. [1], there were no differences in participant's navigation performance between prototypes with long animations and no animations at all, while a prototype using short animations resulted in the best performance. In this thesis, however, transition durations were almost identical in all animation frameworks and, therefore, can not explain the equal performance.

The transitions in the animation Framework A (and partly in B) were designed to reflect the overall structure of an application and thus to assist people in building a mental image of the application (see chapter 2.3.2). In addition to the structural connectivity, the prototypes took very little advantage of other cognitive benefits of animation, such as maintaining object connectivity 2.3.1. Therefore, the possible gains in navigation performance in this work are primarily caused by the animation's ability to assist in understanding structural connections. This is different from the majority of information visualisation studies where most gains in performance are caused by the object connectivity (chapter 2.3.1).

One explanation for the equal result is that the experiment setup did not provide sufficient premises for animation's benefit of understanding structual relationships to emerge. It is unclear how many transition events people have to be exposed to before there is a measurable increase in the navigation performance. Obviously, at the beginning of the navigation task, participants do not have any understanding of the application structure and, therefore, can not navigate any better with animations than without. At the end of the task participants might have gained some benefit in understanding the whole compared with a non animated interface, but at that point the navigation task is already over. This means that the benefit might have only a minimal influence on the results in this work.

6.1.3 Influence on satisfaction

According to the SUS survey, the prototypes designed with the animation Frameworks A and B had equal user satisfaction ratings in both application contexts. While the result suggests that the two approaches produce equal satisfaction, it is possible that the nature of the SUS survey and the amount of participants caused possible differences remain hidden. SUS survey is not particularly sensitive in revealing the influence of animation because it measures the satisfaction of a whole application. Attributes such as visual style, functionality and usability together have a lot bigger impact on the final score than animation alone.

Despite the limitation of SUS, the prototype based on the Framework C had significantly lower satisfaction rating than the prototypes built according to the Framework A and B in the music app context. Interestingly, in the news app context, the Framework C based prototype had equal score to the other two versions. The varying performance of the Framework C prototypes is likely caused by the differences in the navigation structures of the applications. The music app is built around a swiping navigation mechanism and does not have a constantly visible bottom navigation bar found in the news application. This means that animation plays a bigger role in helping to communicate the application structure to a user in the music application. In the news app, the bottom navigation bar already indicates the structure well without animation. The dissolve animations in Framework C simply do not support understanding the application structure in the same way as the animations of the Frameworks A and B do and thus result in lower satisfaction in music app context.

The SUS results suggests that if there is some difference in the overall satisfaction between prototypes designed with Frameworks A and B, it is rather small. Hence the extra work effort required to build animations according to the Framework A instead of using built-in platform animations might not be always justifiable. Also, the built-in animations have the benefit that people are already familiar with them. Furthermore, simple dissolve transitions are less satisfactory than more complex transitions which contain movement. This is not a surprise because dissolve animations can not realise the many possible cognitive benefits of animation. Therefore, simple dissolve animations should be avoided, unless the app is tab bar based, and in this case a simply non animated interface likely produces equal satisfaction.

6.2 Limitations

There are several limitations in this work that are addressed here. First limitation is that 18 participants are likely too little to reveal statistically significant results. The user study used two different application contexts and three animation design frameworks and a single participant tested two of the context-framework combinations. This means that each combination contained data only from six participants. Furthermore, the cognitive map construction task is highly susceptible to participant's cognitive abilities. One participant mentioned that he has excellent visual memory and therefore the drawing task was easy for him. The different level of cognitive abilities, among other things, can easily skew the results when there are a small number of participants.

Second, the prototypes used in the navigation task were missing some functionality. In order to make the test as smooth as possible, the statements were designed so that people will not likely navigate to the broken parts of the UI. Also, people were told that the prototype applications are not fully functional. Still, some participants were a bit slowed down because of the broken parts of the UI. For example, they tapped a button a few times, until they realised that it is not functional.

Finally, the test setting was rather complex because a single participant completed the tasks with two different applications. Using two applications introduces learning effect which likely has influence on the results although the effect was minimised by changing the order of the context after every experiment. Still, it would have been better to test only one prototype with a single participant to eliminate the learning effect. Another limitation in the test setting was that participant might have oriented themselves differently to the tasks since they were not told that their task completion times were recorded. Thus, some participant might have taken the test more relaxed manner while others might have guessed that the time will be recorded and therefore tried to perform as fast as possible. The time spent in the navigation task likely also has an impact on the cognitive map construction task. Furthermore, some people made comments about the app's content and functionality since participants were not instructed to be quiet during the task. This might also have caused some variations to navigation task completion times.

6.3 Future research

It still remains unclear what kind of transition animations work best for particular UI contexts in mobile application because this work did not reveal significant differences between the tested approaches. Thus, it would be important to conduct further study in mobile context with more participants to better understand the influence of different types of transition animations. Such findings would allow creating more thorough animation design guidelines for mobile applications. Moreover, it would be interesting to study the advanced spatial design approach used in this work (Framework A) in more detail and find out whether it results in better performance than using only built-in platform animations (Framework B). If the differences are subtle, considerable amount of participants is needed to achieve statistically significant results.

During this study, I made two learnings which I suggest to take into account in the future research. First, the cognitive map construction method has a few drawbacks which make it less attractive for studying the influence of animation. The method requires giving participants very careful instructions and the analysis of the drawings is complicated. Furthermore, it is unclear what kind of practical implications can be made from the memory based drawing task.

In order to the construction method to be beneficial in practice, the level of detail in people's UI drawings must sufficiently correlate with navigation performance. This is not necessarily true because drawing a UI from memory is a totally different task than navigating in a mobile app. While people draw a UI they have a lot of time to think whereas when navigating a UI people can constantly see visual cues and rather use trial and error approach. In the end, the navigation performance might be the measure which tells most about the effectiveness of a transition, not how people can construct an UI on paper. To summarise, a cognitive map construction task might just add unnecessary complexity and likely does not bring additional benefits over pure navigation performance measurement if transition times are fast enough. Thus, studying only a navigation performance might be a better alternative.

Second, one limitation of the previous research is that it does not take account how people's navigation ability changes over time. When people start a navigation task, they don't have yet build a mental model of an application structure and therefore animation can not have influence on the navigation performance at the beginning of a such task. This is why it would be interesting to build an experiment with two navigation tasks and a time break between the tasks. In the second task, the learning happened in the first navigation task could be more visible.

7 Summary

Currently, there exists little animation research specifically tailored for mobile applications and, therefore, the understanding of animation in this context is limited. Also, findings from the animation research done for desktop applications are not necessarily applicable to mobile context because mobile apps are unique in terms of available screen estate and interaction mechanisms. This thesis aimed to expand the animation knowledge in mobile context by studying how different transition animations influence people's satisfaction, ability to navigate and form a cognitive map of a mobile application.

Firstly, this thesis presented the relevant findings of previous animation research related to digital user interfaces. In this context, animation has shown to have cognitive and affective functions such as assisting people to maintain object connectivity, helping understand structural relationships, focusing attention and conveying information. Animations also have an affective function meaning that it can influence emotions and thus assist in brand communication. Moreover, this work discussed the choice of animation parameters, what previous research says about them and examined the existing animation design principles and guidelines.

Secondly, this thesis described the design and implementation of prototype applications which were built for the user study. The prototypes were based on two application concepts, a music application and a news application, and on three approaches to designing transition animations. Combining the two contexts and three approaches resulted in six final prototypes. The most sophisticated animation design approach, Framework A, employed a spatial planning idea where transitions reflect a virtual three-dimensional environment. The Framework A was based on the hypothesis that spatial cues in animations help people to better understand the structure of a mobile application. This approach was complemented with two other versions, one with built-in platform animations and one with simple dissolve animations.

Thirdly, a user study with 18 participants was conducted to test how the prototypes were perceived and how people perform with them. The test contained two tasks which were influenced by a study of Bederson and Boltman [3]. The first task measured navigation performance by asking participants to find answers to statement questions by navigating a prototype app. The second task, called cognitive map construction, tested how thorough cognitive map participants built during the navigation. The task involved participants to draw the whole application structure from memory in to paper. In addition to the two tasks, participants' subjective satisfaction was measured with a SUS survey. During a single test session, a participant completed the three tasks in both application contexts.

Finally, the result of the user study were presented and discussed. Based on the obtained results it is not possible say whether animation helps people to build a cognitive map of a mobile application because there were no statistically significant differences between the scores from the cognitive map construction task. The outcome is different from the observation of Bederson and Boltman who saw increased construction ability from people who used animated interface. Based on the results it is not possible to make a conclusion about the influence on navigation performance either because of equal navigation times. Although this result is same as what Bederson and Boltman observed, other researchers have shown that animation enhances navigation performance in some context [1, 60, 25].

Despite the fact that the two aforementioned tasks did not reveal influence of animation, the SUS survey measured statistically significant difference between the music app prototypes. The simple dissolve animations (Framework C) scored clearly lower than the other two versions. On the other hand, all three prototypes had equal SUS score in the news app context. The result seems logical since music app has different navigation structure without constantly visible navigation elements and, consequently, benefits greatly from animated transitions. The result is in line with the previous research and seems reasonable since dissolve animations can not take advantage of the many cognitive benefits of animation.

Overall, this thesis did not reveal statistically significant differences between the three animation design approaches except in subjective satisfaction ratings. Still, this work makes a methodological contribution to mobile animation research by illustrating challenges and limitation of applying the chosen methods to mobile context. The learnings from this study, especially regarding the cognitive map construction method, can be utilised in the future research. In the future research it is important to consider whether the cognitive map construction approach brings additional value instead of just using navigation tasks. It is also important to use more participants so that the possible subtle influences of animation become visible.

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A User study instructions and model answers

#	Question
1	In the application settings, the music quality is currently set to normal.
2	A Ticket to Ty Dolla $ign's concert costs 13 euros
3	A Ticket to Helena Hauff's concert costs 23 euros
4	Daft Punk has curated a playlist for Pop music
5	The last track in the Pop music playlist is Hold up by Beyonce
6	The third track in the Trending tracks playlist is Tsunami by Told Sland
7	The track Too Good by Drake has been released on a record label called Cash Money Records. (Tip: The track can be found under the Pop playlist by Daft Punk).
8	TASK: Like the song Hold Up by Beyonce in the Pop music playlist by pressing the heart icon. Also like two consecutive songs after that. STATEMENT: The three songs you liked are now included in the My favourite tracks playlist.
9	The last track in the House playlist by Maya Jane Coles is Rpsts by S Olbricht.

Table A1: Statements used in navigation task for the Music application.

#	Question
1	The app provides the following news categories: Sports, Politics, Economy, Culture.
2	In the sport news caterogy, the title of the last news article is Comment: This shouldn't be possible.
3	The Comics section contains Garfield comic strip.
4	In the All Categories list, the Sport category has a swimmer as a background image (Tip: Press the list icon [IMAGE] to access all categories).
5	Stockmann sold its Hobby Hall online store to SGN Group.
6	The weather forcast says that it will be 21 degrees celcius on Thurday 7.7.
7	The text size is currently set to large in app settings.
8	The Sibelius violion competition winner, Christel Lee, was born in Washington.
9	TASK: Add the news item about the Sibelius violin competition to the reading list Read Later. STATEMENT: The read later list contains the article you added and three other articles.
10	The reading list section contains a list called Recommended by friends.

Table A2: Statements used in navigation task for the News application.

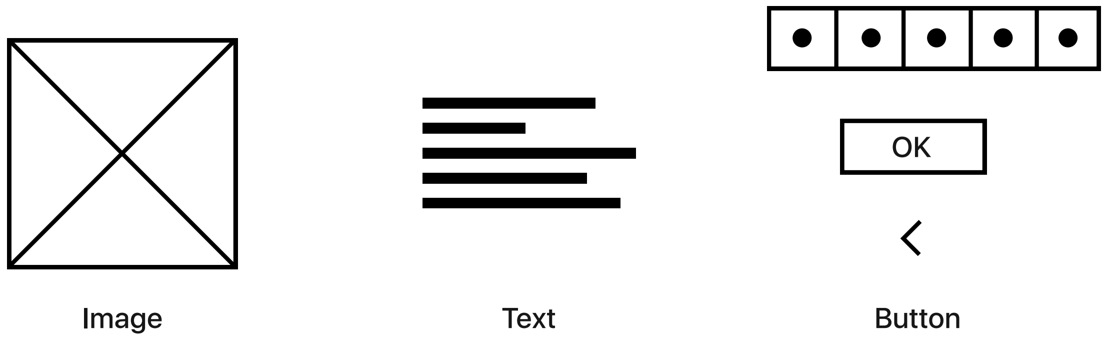

Figure A1: Drawing symbols for images, text and buttons used in the cognitive map construction task. These symbols are used in order to make the task less demanding for participants and also for making the analysis work more straightforward.

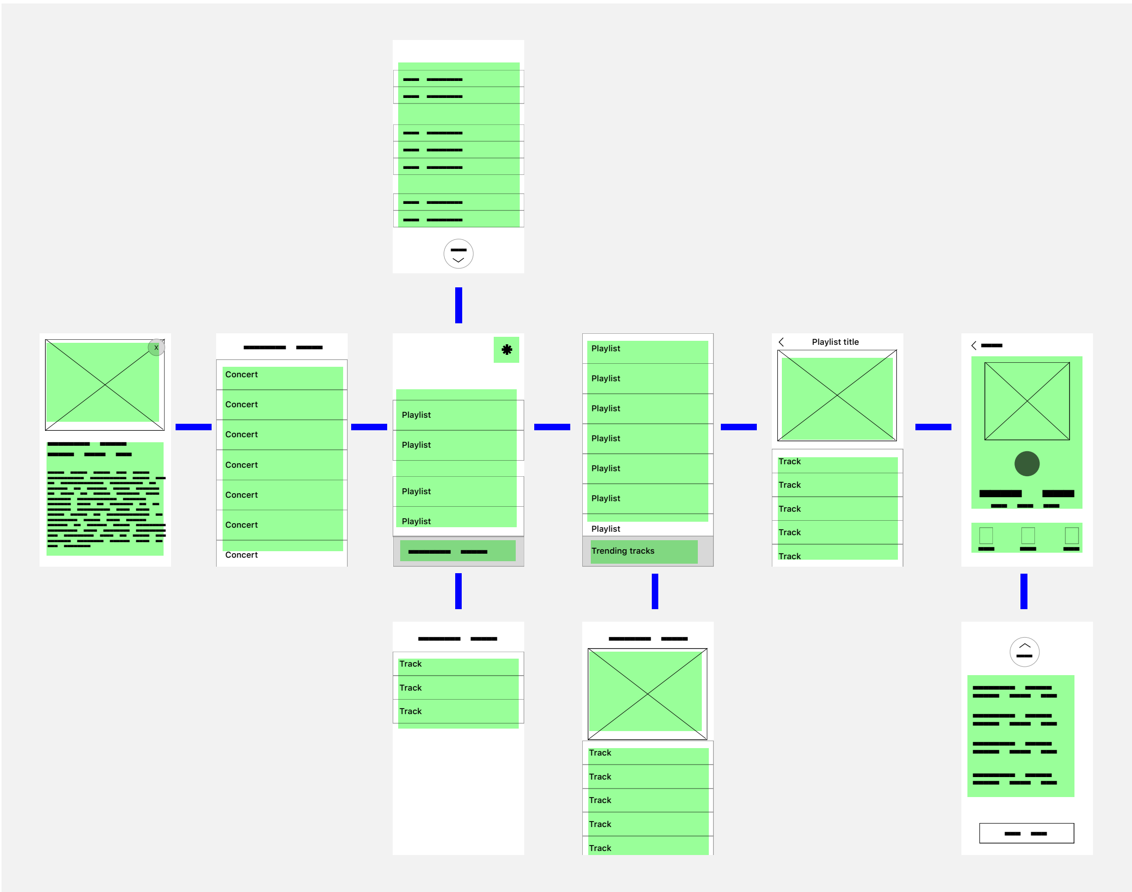

Figure A2: A model answer for scoring cognitive map drawings done in music app context. Green blocks indicate details for determining details score and blue lines indicate links between views which determine links score.

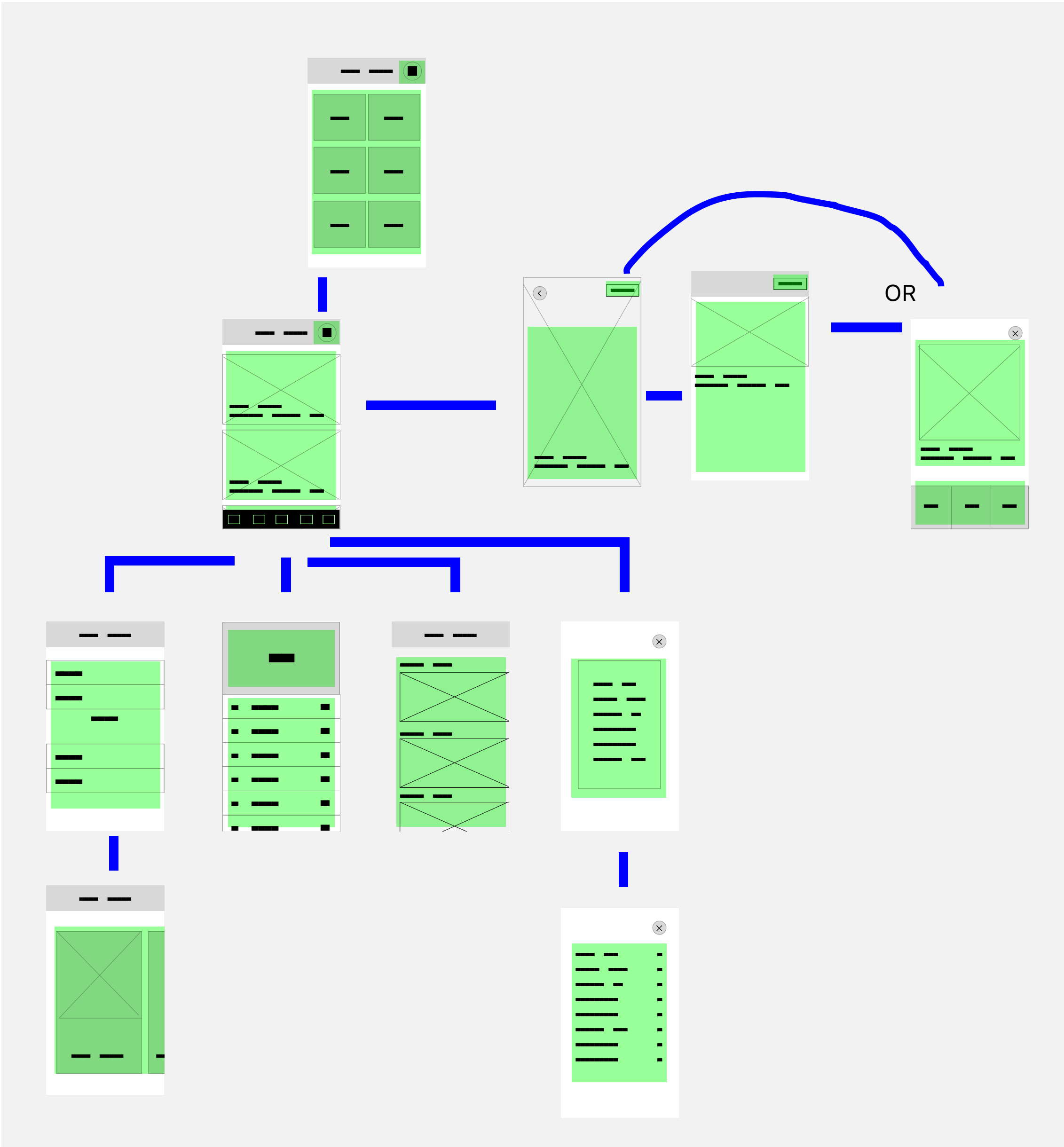

Figure A3: A model answer for scoring cognitive map drawings done in news app context. Green blocks indicate details for determining details score and blue lines indicate links between views which determine links score.