Enriching navigation on media tablets applying direct multi-finger gestures to enhance engagement by translating the expression of user action to device function

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Engineering Psychology
Master's Thesis

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Abstract:

Current media tablet interfaces lack interaction possibilities regarding navigation in the operating system. It seems like the media tablet interface is designed primarily for single-touch elements, where a precession touch in a given area, is needed to activate the function of interest. The problem addressed in this paper concerns how the interaction on media tablets can be enriched by adding multi-finger gestures, which are not tied to a specific position. The specific media tablet, investigated in this study, was the Apple iPad, since it was the most mature platform found on the consumer market.
First a technological analysis of the iPad was made, to see if the were technical limitations in implementing multi-finger gestures, then a psychological analysis of different user aspects were explored, to design an experiment application. An experiment with 20 test subjects was conducted, to examine how the multi-finger interaction method would perform compared to a traditional single-touch approach, within the experiment application. It was concluded that the multi-finger interaction method could not outmatch the traditional single-touch approach. Though, it was seen that the five-finger gesture corrupted the experiment in such a degree, that removing this gesture, would provide significant better results in favor on the multi-finger interaction method.

Preface

This study is the result of the Master thesis written by group 1071 studying Engineering Psychology at Aalborg University under the School of ICT.

All references in these paper are written according to the Harvard referencing method, though sometimes with added information, e.g. a page number. The attached CD in the back of this paper contains electronic appendices.

The authors of this study would like to thank Moten Bøgh for helping with making the experiment application for the iPad and the 23 test subjects that participated in the pilot studies and in the experiment.

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CHAPTER 1

Introduction

1.1 Motivation

This project is based on experiences with, and observations, of media tablets and their operating systems - especially the iPad made by Apple. Authors of this study are experienced users with the iPad. During long time use of the iPad, a lack of interaction possibilities regarding navigation in the operating system have been experienced. Furthermore, a great part of the interaction is accomplished with an intermediary which prevents the user's expressiveness in the touch input. An iPad user is forced to use software buttons to make a step back in the information hierarchy in e.g. the built-in browser Safari. The same goes for the calender, where it is impossible to shift between month unless the user taps the month-line in the bottom of the screen. It is also impossible to shift between applications unless the user double tap's the round physical button on the front of the iPad and chooses another application from the multitasking bar to be run. There are more examples of interaction possibilities that could have been implemented to support more freedom of interaction for the user and thereby provide an enrichment of the interaction. It is experienced that the iPad can be operated physically with more than two fingers, so this study wonders why three-, four- and five finger gestures are not implemented into the interface?

Why do iPad users have to utilise dedicated software buttons to navigate in the operating systems and its applications, when a hand full of fingers can be used for simple navigation tasks, such as backward and forward? It seems like the iPad interface is designed primarily for single-touch elements, where precession touch in a given area is needed to activate the function of interest - illustrated by red markings on Figure 1.1 on the following page. This type of interaction is henceforth referred to as local area interaction. There are other cases in the interface, where the position of the input is less important and the input movement is directly translated - e.g. when exploring a web page where swiping and dragging can be utilised at any position on the page illustrated by the green marking on Figure 1.1 on the next page. This type of interaction is henceforth referred to as global area interaction. Furthermore, the expression of the input movement is translated into the output movement of the web page content. That is, when a user can express himself in the interaction with the device, it seems like a more enriched interaction. The initial problem is then:

> *Is it possible to enrich interaction with an iPad by adding global area interaction that are not tied to a specific position on the touch screen?*

Figure 1.1: Illustration of local and global interaction areas in safari on the iPad.

1.2 Defining the media tablet

The iPad belongs to product category of media tablets. In the following a general overview of media tablets will be given. To explore the product category of media tablets it is necessary to define the characteristics of them. Media tablets can in general be defined as:

> *" ... tablet form factor devices with 7-12in. color displays. They are currently based on ARM processors and run lightweight operating systems such as Apple's iPhone OS and Google's Android OS (operating system). This distinguishes them from tablet PCs, which are based on x86 processors and run full PC operating systems. Media tablets do not include built-in hardware keyboards but use a stylus/pen or finger for navigation and data input. They provide a broad range of applications and connectivity, differentiating them from primarily single-function devices such as ereaders." [IDC, 2010]*

The media tablet market exploded in 2010, starting with Apple's launch of the iPad sale in April. Since the launch of the iPad other tablet manufactures have emerged on the market, and in 2010 at least 15 million media tablets were sold [Apple Inc., 2011*a*]. The sale of media tablets in 2011 is projected to 44-55 million units [IDC, 2011; Gartner, 2011], and is predicted to surpass 208 million units in 2014 [IDC, 2011]. The predicted sale of media tablets in 2014 insinuates, that the user group for media tablets cannot be defined as only tech-savvies, young people of the Facebook generation, early adopters and Apple enthusiasts - the user group is highly differentiated. iPad buyers range from travel companies who buy iPads for their passengers to loan as entertainment in flight travels, to two year old children drawing, and students in 7^{th} grade in elementary school who have been bought iPads to save money on paper books [Iceland Express, 2011; Mike Wilson, 2011; Arhus kommune (Aarhus council), 2011].

Given that the same operating systems are used on tablets and smartphones, users who already have a smart phone might adapt relatively easy to how the media tablets are operated. Though, the need for a device as the media tablet can be difficult to understand for at novice user, as the iPad is said to be a large iPod Touch as the users have the same possibilities on both devices; and laptops have alot more powers, larger screens, and a real physical keyboard. The media tablets are just in between smart phone sized devices and laptops. When Apple introduced iPad to the public, the said purpose of the device was:

> ... *browsing the web, reading and sending email, enjoying photos, watching videos, listening to music, playing games, reading e-books and much more. [Apple Inc., 2010*a*]*

There was nothing new to it compared to the iPod Touch except for the size. The larger form factor though could be why media tablets have become so popular. The larger screen allows for more text to be shown at a readable size, which can be a problem on smartphones, the virtual keyboard can be larger compared to smart phones, and thereby make them easier to use. As the media tablets are instantly on, just like smart phones, there is no waiting time for the device to start up. This means that the user can e.g. browse and check emails immediately.

It can be concluded that the number of tablet users will grow and the new form factor of media tablets are interesting for HCI researchers because it starts to make multi-touch interaction a more common interaction form. This generates a need for methods to convert a lot of the traditional interfaces made for mouse interaction to interfaces optimised for multi-touch interaction e.g. web pages, drawing application, and writing applications.

CHAPTER 2

Analysis of the media tablet platform

2.1 Gestures terminology used in research

This section defines the terminology of gestures used in the project. Gesture research is divided in two directions; Human-to-Human communication and HCI. The terminology used to separate different types of gestures, differ from taxonomy to taxonomy. To make the needed description of gestures it is required to look into different contributor's work to the gesture area, in order to select a terminology used further on in the project.

Wexelblat [1998] has summarised the terminology of four major taxonomies of gestures, in the article partly based on work from Wexelblat's master thesis [Wexelblat, 1994]. Efron [1941] is one of the first to to make a taxonomy for human gestures based on experiment or systematic observation. The initial work for a general theory of speech and gesture by Efron [1941] is later used as groundwork by McNeill and Levy [1982], Rimé and Schiaratura [1991], and Kendon [1986] in their gesture research. Even though each one of these three researchers has focused on their own approaches for there gesture research, the fundamental classification of gestures has not changed substantially from Efron [1941]. It is thereby possible to compare the terminology of the taxonomies by mutual identifying characteristics of the classifications. Wexelblat [1998] has made a rough comparison of his findings, described by the identifying characteristics. These findings can be found in Table 2.1.

Kendon	**McNeill and Levy**	**Rimé and Schiaratura**	**Efron**	**Identifying Characteristics**
Physiographic	Iconic	Physiographic	Kinetographic	Picture the content of speech
Ideographic	Metaphoric	Iconic	Ideographic	Portray the speaker's ideas, but not directly the speech content
Gesticulation	Beats/Butterworths	Speech marking	Baton	Marking the rhythm of speech
Autonomous gestures	Symbolic	Symbolic	Symbolic/Emblematic	Standardized gestures, complete within themselves, without speech
None	Deictic	Deictic	None	Pointing at thing/area; space around body used

Table 2.1: Gesture taxonomies found in a review of the literature done by Wexelblat [1998].

The table shows that the four authors use different terminology for the classification of a gesture with the same "identifying characteristics". Furthermore, it is seen that pointing gestures are not described in Kendon's and Efron's taxonomies. The different terminology and missing descriptions indicates a lack of consistency in the gesture research area. This is a problem when describing gestures in general and can lead to confusion if there are no agreement of the definition for the terms used to classify different gestures types.

Wexelblat [1998] argues that the problem with a comparison of the four taxonomies, is the lack of concrete rules on how to classify a gesture. Wexelblat [1998] gives an example of a new approach for classifying gestures: “One could distinguish gestures initially into two classes: speech-related and self adjusters (tugging one’s collar, fixing one’s hair). Symbolic gestures would then be separated from a class of coverbal gestures. The rules used to make these divisions are clear: does the gesture relate to the speech; does it co-occur with words or in place of them, etc.” Wexelblat [1998] then argues that gestures could be divided in to a top level of three classes: self adjusters, speech-replacing, and coverbal. Instead of the flat taxonomic with groupings of gestures, Wexelblat [1998] would prefer something like a decision tree to guide our understanding of gestures more systematically. The overall problem that Wexelblat [1998] points out is that the taxonomies reviewed are inadequate for designing and categorising gestures to be applied into a computer interface.

To avoid further confusion on the terms used to classify different gestures types in this study, it is decided to employ a taxonomy already developed for human computer interactions by Karam [2006], rather than develop an additional taxonomy by ourselves. The reason for using Karam [2006] is that it is focused on HCI as opposed to Efron [1941], McNeill and Levy [1982], Rimé and Schiaratura [1991], and Kendon [1986] which focuses on human-to-human interaction. Maria Karam’s PhD thesis “A framework for research and design of gesture-based human computer interactions” [Karam, 2006] is based on the work by Quek et al. [2002] and an extensive review of existing literature on the subject. Karam [2006] suggests a taxonomy with five categories of gesture styles: Deictic, Gesticulation, Manipulative, Semaphores, and Sign Language.

2.1.1 Gesture definition by Maria Karam

The section will provide a description of gestures, based on the literature reviewed by Karam [2006]. The classification of the gestures used in her framework is primarily referring to work by McNeill [1996] and Quek et al. [2002] and applying it to a framework specifically for designing HCI using gestures.

Deictic

Deictic gestures are used for pointing to a spatial location or establish the identity of an object. They are also referred to as pointing gestures in some literature [McNeill, 1996]. Deictic gestures can be similar to the direct manipulation input of a mouse [Karam, 2006], but can also be used in combination with speech like in the “Put-that-there” interface, created by Bolt [1980]. Here, the users point at a large screen display to select an object and adds a voice command to execute an action on the object.

Manipulative

Quek et al. [2002] define manipulative gestures as: "those whose intended purpose is to control some entity by applying a tight relationship between the actual movements of the gesturing hand/arm with the entity being manipulated". In comparison with direct manipulation e.g. drag and drop, the manipulative gestures involve more complicated interactions that require interpretation to determine what action is required [Karam, 2006]. Manipulative gestures are typically aided by visual, tactile, or force-feedback from the object both in the virtual and real world [Quek et al., 2002].

Semaphores

The definition of semahporic gestures used by Karam [2006] is provided by Quek et al. [2002]

> *"Semaphores are systems of signalling using flags, lights or arms [Brittanica.com]. By extension, we define semaphoric gestures to be any gesturing system that employs a stylised dictionary of static or dynamic hand or arm gestures...Semaphoric approaches may be referred to as "communicative" in that gestures serve as a universe of symbols to be communicated to the machine."*

In human communication semaphores are used to replace words with symbols like thumbs-up, the OK-sign or waving. These signs are not always interpreted the same, in all cultures [McNeill, 1996]. Semaphoric gestures are often discussed in the HCI literature, in spite of them being the least used types of human gesturing [Wexelblat, 1998; Quek et al., 2002]. The semaphoric gestures can be a practical method of providing distance interactions and enabling eyes-free interactions [Karam, 2006]. Stroke gestures like flicking a pointing device back and forth to navigate within a web browser, marking or pie menu selections is also considered semaphores [Karam, 2006].

Gesticulation

Gesticulations are also referred to as Coverbal gestures [Kettebekov, 2004; Bolt and Herranz, 1992]. Gesticulations are considered one of the most natural forms of gesturing and commonly considered for use in multimodal speech interfaces [Karam, 2006; Wexelblat, 1998; Quek et al., 2002]. The gesticulations are in close relationship to the semantic content of speech and are often used almost unconscious as a way to clarify content in a sentence [McNeill, 1996]. For instance: "The fish was this big!" the speaker is showing the length of the fish by holding the hands fare apart in front of him. Iconic gestures and pantomime also fall within this category [Karam, 2006].

Sign Language

The sign-language gestures are linguistic-based and: "require the collective interpretation of multiple, individual hand signs that combine to form grammatical structures" [Karam, 2006]. The finger spelling in sign language can be considered semaphores but when finger spelling is used in a conversational interfaces, it is needed to interpret a series of signs to make a meaningful string, which make finger spelling more like gesticulation [Karam, 2006].

2.1.2 Gestures applied on media tablets

In the context of a media tablet where the user need to touch a glass surface to make gesture inputs, some gesture types apply better than other. It seems like that Semaphores, Gesticulation and Sign Language is better suited for movements in free space, and would be hard to apply via touch in a surface in two dimensions like a media tablet. Semaphores and Sign Language also has the problem that if the semantic meaning of the gesture can be different depending on cultures, it can thereby cause incongruence and doubt to the meaning of the gesture. This make Semaphores and Sign Language less useful for universal communication on a media tablet.

Deictic and Manipulative appear to be better suited to used for interaction with a media tablet surface. By restricting the use of gestures to Deictic and Manipulative gestures the interaction will be tied to direct psychical movement and not so much to gestures that are symbols of a linguistic nature with semantic content.

In this project the term gesture will henceforth refer to touch inputs on media tablets. As the gestures are only performed with one's fingers on capacitive multi-touch screens, a more specific definition can be put forth:

> *A gesture is of a deictic or manipulative nature, and by that, a touch or a movement of one or more fingers, made on a screen surface, with the intention of executing a given action.*

2.2 Overview of gestures in other technologies

The terminology in Section 2.1 on page 4 indicates a large diversity in the gesture research area. From semaphore gestures used in free air to deictic gestures that can be used on the iPad. This section illustrates the diversity of gestures applied in, more or less, commercial "products". The illustrated technologies are quite different and it can be argued that e.g. Sci-fi is not a technology. This is possibly true, but Sci-fi movies have, nearly always, been a look into the future from the directors' point of view. An example of this will be shown below. The smartphone- and media tablet branches are collapsed, as they are elaborated in Section 2.4 on page 11.

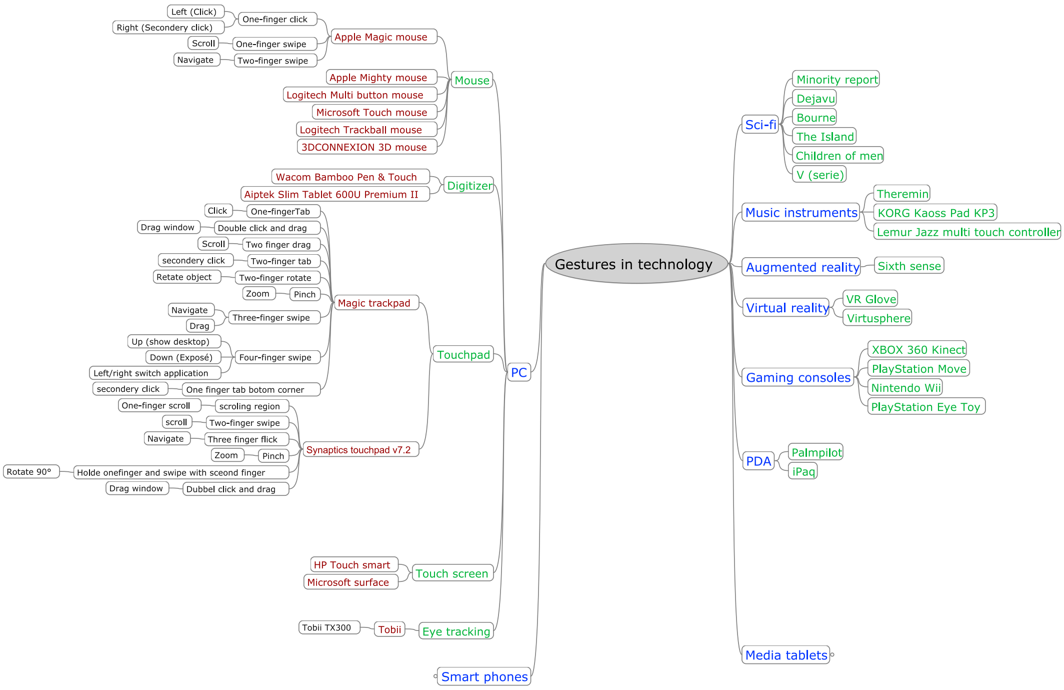

Figure 2.1: Gestures in technology

In the PC branch the touchpads can be found. Gestures on touchpads can be compared to gestures used on media tablet, as the physical attributes are often the same. Though, the big difference is, that there is no visual feedback in the same location as one's fingers. Furthermore the gesture set often consists of more complex gestures. Two-, three and four finger gestures can perform different actions depending on the direction of the gesture. The Sci-fi branch is important, because the movies often visualise how humans think the future of technology and how human-computer interaction may evolve. For instance the movie Minority Report [IMDB - The Internet Movie Database, 2002] is often said to have been an inspiration for Sony Playstation Move and Microsoft XBOX 360 Kinect. The PADDs (Personal Access Display Device) from the Star Trek series, were often operated by the fingers, and may have been an inspiration for the media tablets seen today. Figure 2.2 and Figure 2.3 show two PADDs from Star Trek Deep Space Nine (1993 - 1999).

Figure 2.2: A touch navigated PADD from Deep Space Nine [Memory Alpha, 2011].

Figure 2.3: Another PAD from Deep Space Nine [Memory Alpha, 2011].

The Music instruments and Augmented reality branches are included to illustrate the spectrum of gestures. The Virtual reality branch and Gaming consoles branches can be compared as the gestures are of a semaphoric nature. The gestures are e.g. used to provide touchless distance in the interaction, which is the key component of the Gaming consoles branch. The PDA branch encompasses pen-gesture based devices, which can be said to be a precursor to the multi-touch devices.

It can be concluded that a variety of technologies have implemented gestures. Specifically the touchpads have implemented fairly complex gesture sets.

2.3 Multi-touch gesture research review

To gain an overview of the research conducted in the area of Multi-touch gestures a review was made. The aim of this review was to look into if there has been conducted any studies, that treat the issue of enriching interaction on a multi-touch surfaces.

The criteria for choosing a paper is that it must deal with touch-screen interaction. A extensive literature review of gesture research conducted by Karam [2006] was used as inspiration to pick out some of the papers.

The papers reviewed are categorised by the type of study, if user evaluation has been made, and if the issue of enriching interaction has been addressed. Only the studies dealing with enrichment of the interaction is described further. The categorisation can be seen Table 2.2.

Author	Title	Type of paper	User evaluation?	Enriching interaction
Minsky [1984]	Manipulating simulated objects with real-world gestures using a force and position sensitive screen	Proof of concept	no	no
Rekimoto [1997]	Pick-and-drop - a direct manipulation technique for multiple computer environments	Proof of concept	no	no
Rekimoto [2002]	Smartskin- an infrastructure for freehand manipulation on interactive surfaces	Proof of concept	no	no
[Wu and Balakrishnan, 2003]	Multi-finger and whole hand gestural interaction techniques for multi-user tabletop displays	Prototype	yes	yes
Pastel and Skalsky [2004]	Demonstrating information in simple gestures	Proof of concept	no	no
Bragdon et al. [2010]	Gesture Play: Motivating Online Gesture Learning with Fun, Positive Reinforcement and Physical Metaphors	Ab-test	yes	somewhat

Table 2.2: List of multi-touch research papers reviewed

2.3.1 Mike Wu - 2003 - Multi-finger and whole hand gestural interaction techniques for multi-user tabletop displays

Multi-touch tabletop with a multi-user application for room planing. They use a gesture set of eight gestures, see Figure 2.4 on the following page, plus a pie-chart menu, see Figure 2.5 on page 11.

User evaluation:

- Five participants.
- Participants were assisted by a researcher during the test.
- Participants were instructed in each of the interaction techniques and function.
- Only qualitative data from participants was gathered.

Conclusions:

- The participants required practice to learn the gestures but were able solve the tasks in the test.
- Occlusion Issues when operating the pie-menus.
- Users desired additional functionality

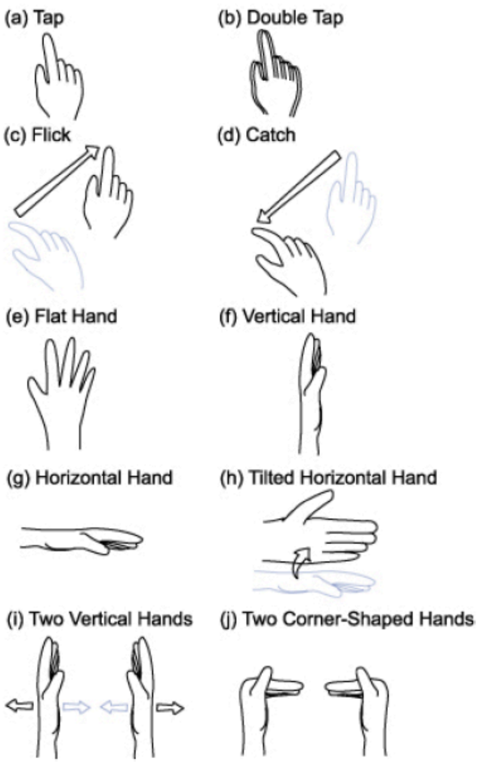

Figure 2.4: Gesture set used for multi-user tabletop displays . (a) Tap: single point touch. (b) Double Tap: single point touch-release-touch. (c) Flick: quickly slide single point away from self. (d) Catch: quickly slide single point toward self. (e) Flat Hand: lay hand flat on surface. (f) Vertical Hand: side of upright hand touches surface in a vertical manner. (g) Horizontal Hand: side of upright hand touches surface in a horizontal manner. (h) Tilted Horizontal Hand: tilt top of horizontal hand away from self. (i) Two Vertical Hands: symmetrically slide two vertical hands together or apart. (j) Two Corner-Shaped Hands: each hand makes a corner. [Wu and Balakrishnan, 2003]

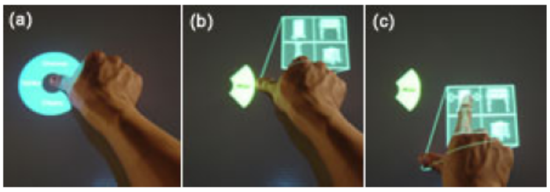

Figure 2.5: FurniturePalette tool. (a) A double tap on the table brings up a context-sensitive menu. (b) Sliding the finger in one of the four directions causes a corresponding toolglass to be attached to the finger. (c) A second finger is used to make a selection within the toolglass [Wu and Balakrishnan, 2003]

2.3.2 Summary of the Multi-touch gesture research review

Most multi-touch gesture research focuses on the technology of the multi-touch interface. Very little research was found that deals with enrichment of the interaction method. To the knowledge of the authors of this study there seems to be a gap between the research in technology of multi-touch interfaces and the research in user interaction with multi-touch interfaces that is not fully described. In this study it would therefor be of interest to try to build a bridge between the technology of media tablets and the psychology of user interaction. In the following section a study of multi-touch used on smartphones- and tablets will be conducted to gain an overview of the technology

2.4 Multi-touch used on smartphone- and tablet operating systems

To gain a overview of which gestures can be made on media tablet, it is necessary to investigate the light weight mobile operating systems controlling the media tablets. This section will investigate possible gestures across different mobile platforms, to see how much the gesture sets stand out from each other. A gesture set is simply the whole group of gestures, which can be used on a specific platform. Gestures which only can be performed in specific applications or on platforms other than media tablets are not of interest to this study.

In Figure 2.6 on the following page an overview of the different operating systems is shown. The listed operating systems are not a complete record of every available mobile systems, but these are the most frequent used on smartphones and media tablets today [Canalys, 2011]. The upper half of Figure 2.6 contains smartphone operating systems. There are no specific smartphones listed, since most of these operating system can be found on many different phones. The lower half of the Figure contains operating systems running on different media tablets. Since the tablet market has just started to develop (cf. Section 1.1 on page 1) the number of different tablets using the same operating system are limited. Therefore, the listed operating systems are combined with a media tablet using the specific system. Not all of the different gestures found across the platforms, could be found in official papers from the manufactures. Information regarding the gestures, was therefore also gathered across several “tech” sites and web stores selling the products.

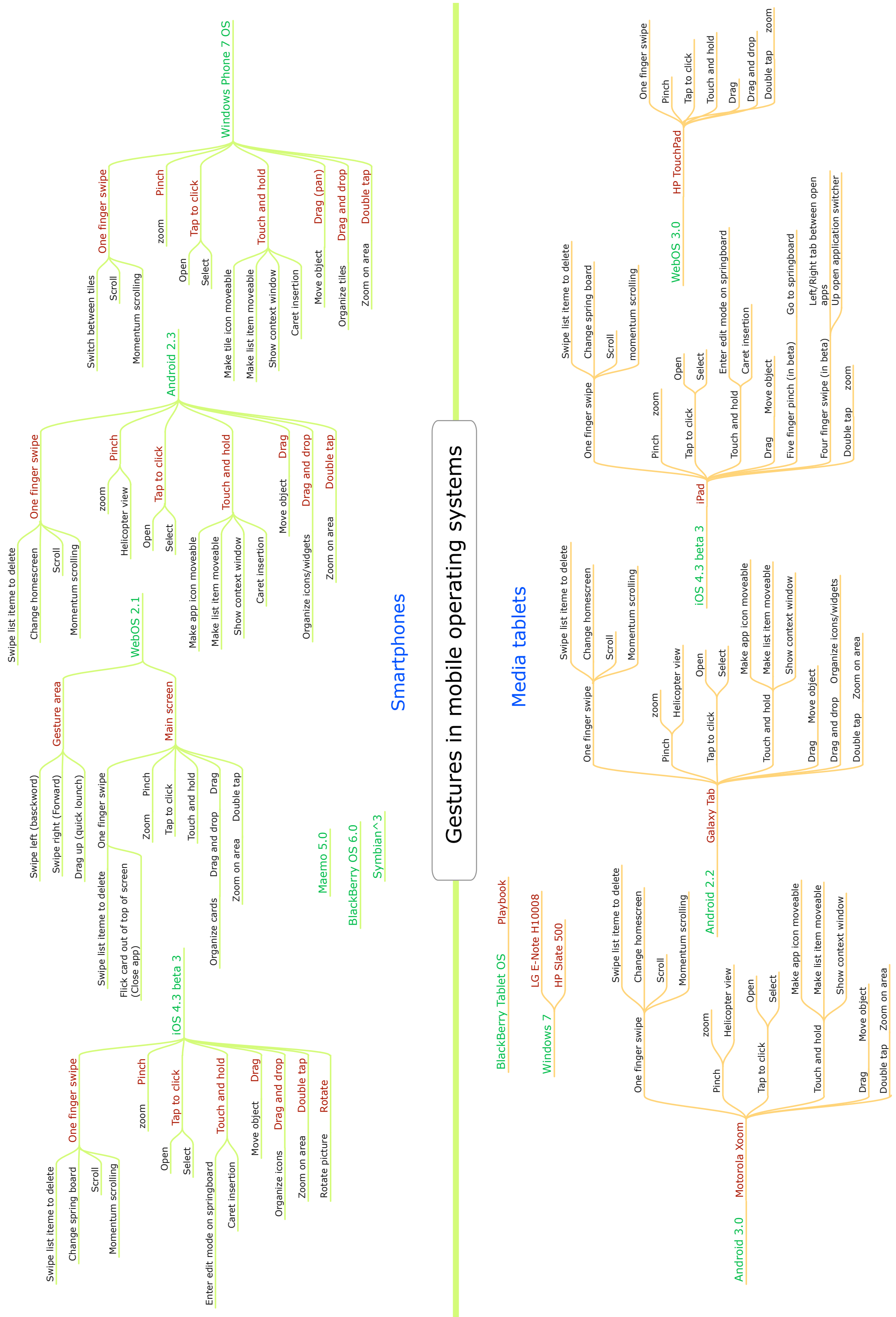

Figure 2.6: Map of gestures which are implemented on smartphones and media tablets.

The gestures from Figure 2.6 on the facing page are summarised in Table 2.3. The gestures are as follows: one finger swipe, pinch (open/close), tap to click, touch and hold, drag, drag and drop, double tap, rotate, four finger swipe and five finger pinch. Whereas four finger swipe and five finger pinch can only be used in iOS 4.3 beta 3.[1]

Operating system	Android 2.3/3.0	iOS 4.3beta 3	WebOS 2.1/3.0	Windows Phone 7
One finger swipe	Android	iOS	webOS	Windows
Pinch (open/close)	Android	iOS	webOS	Windows
Tap to click	Android	iOS	webOS	Windows
Touch and hold	Android	iOS	webOS	Windows
Drag	Android	iOS	webOS	Windows
Drag and drop	Android	iOS	webOS	Windows
Double tap	Android	iOS	webOS	Windows
Rotate		iOS		
Four finger swipe		iOS		
Five finger pinch		iOS		

Table 2.3: Android, iOS, WebOS and Windows Phone compared to each other regarding possible touch inputs.

The gestures from Table 2.3 are illustrated in Figure 2.7 on the next page. The gestures inputs can be categorised after their physical attribute. In this context the categorisation are the number of fingers being used in the specific gesture. In Table 2.4 it is seen that only pinch, four finger swipe and five finger swipe utilises more than one finger. Whereas the four finger swipe and five finger pinch are only available for developers.

Number of fingers	1	2	3	4	5
One finger swipe	•				
Pinch (open/close)		•			
Tap to click	•				
Touch and hold	•				
Drag	•				
Drag and drop	•				
Double Tap	•				
Rotate		•			
Four finger swipe				•	
Five finger pinch					•

Table 2.4: This table shows how many fingers are use in the specific touch inputs.

In Section 2.2 on page 7 it was seen that e.g. three- and four finger gestures are possible on touchpads. Touchpads are often smaller than the screen on multi media tablets, but it is still physical possible to conduct multi-touch gestures. Seen from a physical side it should be possible to enrich the multi media tablet interaction with three and four finger gestures. Before investigating this postulation further the origin of the tablet OS will be examine in the following.

The operating systems running on smartphones and media tablets very alike. The newest Android tablets have Android OS 3.0, where as smartphones running Android OS have 2.3.

[1]It should be mentioned, that the final release of iOS 4.3, does not have four- and five finger swipe from default, but can be activated in developer mode.

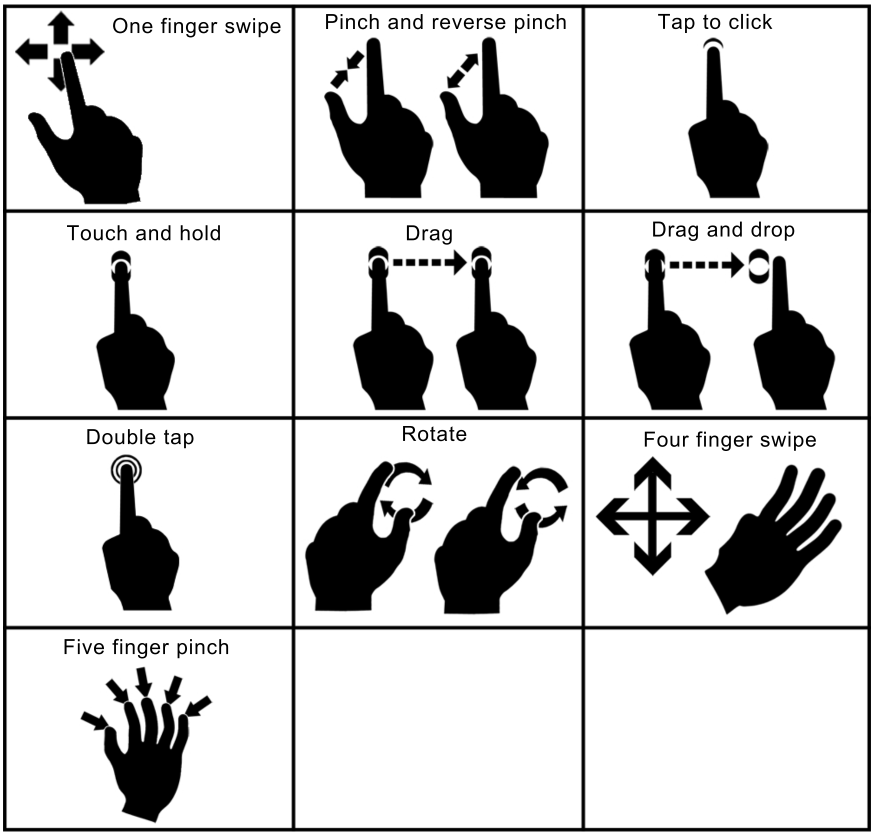

Figure 2.7: Illustration of the different touch inputs. With inspiration from Gesturecons by Ryan Lee [2011].

The iPhone 4 and iPad 1 and 2 have the same operating system (currently iOS 4.3 [Apple Inc., 2011*b*]), but have some differences in the interface, to make the best use of screen real estate[2]. Both Android OS and Apple iOS were orginally designed to smartphones, which have relatively small screens compared to media tablets - cf. the definition of media tablets in Section 1.1 on page 1. The largest smart phone on the market is Samsung's new Infuse 4G, which has a 4.5 inch touch screen [Samsung, 2011]. The smallest smart phone in sale, with a capacitive touch screen, is the Sony Ericsson Experia X10 mini, which has a 2.55 inches large touch screen [Sony Ericsson, 2011]. Furthermore, the operating systems were in most aspects designed to be operated one-handed with the thumb as input due to the size of smartphones. In Figure 2.8 on the next page a HTC Hero GSM and an iPhone 4 are seen. The Figure shows how a smartphone can be held, and furthermore how the thumbs can reach the whole screen.

[2]The amount of space available on a display for an application to provide output to the user.

Figure 2.8: A HTC Hero GSM and an iPhone 4 held in one hand.

Given that the operating systems are designed to a one-finger interaction approach, the media tablets, with the same operating systems, have inherited the same one- and two-finger interaction approach. The question is then: is it viable to implement this one-finger interaction approach directly to a media tablet and anticipate that the work- and operating flow would be the same? To study this, a quick-and-dirty test was made to observe if there should be any physical limitations in making multi-touch gestures on the iPad.

It should be noticed that for the remainder of this project the iPad is used as the reference platform for media tablets. iOS is the most mature operating system on the media tablet platform at the moment. Moreover, an alternative media tablet as e.g. Motorola Xoom, has not been available in this study, as it cannot be bought on the Danish market at the time of writing.

2.5 An observational anthropometric/ergonomic study of a iPad

Even though the operating system running on the iPad is almost identical to the one running on the iPhone, the physical form factor differ. To examine what this physical difference has of impact on the interaction an anthropometric/ergonomic study of the iPad was made. This would give a answer to the physical side of the initial problem: Is it possible to enrich interaction with an iPad by adding global interaction that are not tied to a specific position?

2.5.1 How to physically operate the iPad

The study was primarily of an observational nature. One of the authors of this study held the iPad[3] in different postures trying to simulate every-day use situations. Both the authors's hands are fully functional and furthermore, to maintain the validity of this observational study, the authors's hand was measured and compared to hand anthropometry of British

[3]Apple iPad Wi-Fi (16 GB), dimensions (HxDxL in cm): 24.3x1.3x19, weight: 0.68 Kg

workers [Pheasant, 1996]. The author's hand was between the 5th- and 95th %ile hand and close to the 50th %ile hand. The measurements are seen in Appendix A on page 119. It was concluded that his hands can be compared to west European male adults.

The iPad can be used in landscape and portrait mode, since the display content automatically by default orientates it self. The project member is right handed and the iPad will be held in this hand in the one-hand navigation postures. In the other postures, the member's left hand will support the iPad, whereas his right hand will be used for the gestures. It should be noted that these observations are not providing evidence for all hand positions possible when holding a media tablet, but these are generalised positions and they can as well be used in different combinations. The observations from the study can bee seen below.

One hand navigation

It is seen in Figure 2.9 and Figure 2.10 that the thumb cannot reach the whole screen, which is required to navigate the iPad. The area marked with red in Figure 2.9 and Figure 2.10 is the maximum distance of reach when holding the iPad at the right side of the device. The marked area is 7 cm, whereas the area from the outer edge to the display edge is 2 cm. In the last-mentioned area touch inputs cannot be registered.

Figure 2.9: Right handed posture in landscape mode

Figure 2.10: Right handed posture in portrait mode

One hand navigation with the other hand as support

When using the left hand to support the iPad, at least five fingers are available to make gestures - see Figure 2.11 on the next page and Figure 2.12 on the facing page.

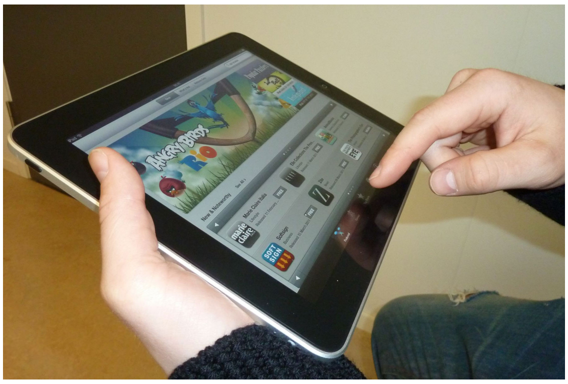

Figure 2.11: Two handed posture in landscape mode.

Figure 2.12: Two handed posture in portrait mode.

Two handed thumb navigation

In this posture the lower half of the display can be used with both thumbs at the same time including the virtual keyboard as seen in Figure 2.13 and Figure 2.13. The virtual keyboard will be shown, when tapping on a text field, which normally is found in the upper half of the display. Then the user can shift to the thumb posture to input text. The disadvantage of this hand posture is, when using the navigation buttons in e.g. Safari (iOS web browser) - see the red rectangle in Figure 2.13 - the user has to move his hand to the upper half of the screen and press the navigation buttons.

Figure 2.13: Two handed thumb posture in landscape mode.

Figure 2.14: Two handed thumb posture in portrait mode.

Object support

When supporting the iPad on other objects such as one's leg or a table - see Figure 2.15 and Figure 2.16 on the following page respectively - the user can use both his hands i.e. ten fingers to provide touch inputs.

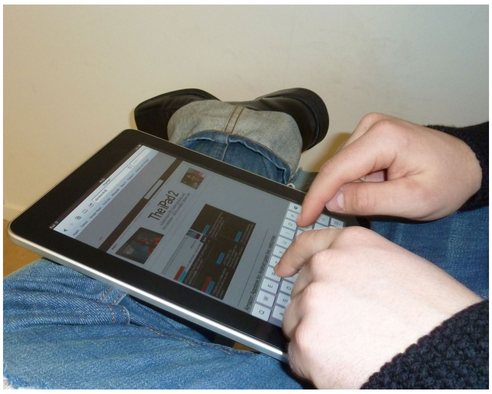

Figure 2.15: Supporting the iPad with one's leg

Figure 2.16: Supporting the iPad on a table. Furthermore, different iPad casings give the possibility of having the iPad angled to a more convenient viewing angle.

To conclude on this study, it was seen that the iPad is almost impossible to fully operate in one hand. Furthermore it was shown, when physically supporting the iPad, whether it is with one's hand or an object such as one's leg or a table, it is possible to use at least five fingers as input. This gives the opportunity to expand the gesture set on the iPad, from one- and two-finger gestures, to three-, four-, and five-finger gestures. It is thereby psychical possible to enrich interaction on the iPad. In the following an analysis of the iPad platform will try to give a more detailed answer to the initial problem.

2.6 Analysis of the iPad platform

This section will provide an overview of the iPad, to gain a technical understanding of how interaction can be enriched with the device. To provide this understanding it will be analysed how a user can interact with the interface, how the information hierarchy is structured, how the technology used for input is working, and how feedback on a user input is given. These aspects will provide a fundamental understanding of the iPad platform and point out areas in which a more enriched interaction can be achieved.

2.6.1 Interaction envelope

The interaction envelope for the iPad consists of user inputs and system output. The input side contains: Touches on the screen, sound, and rotation/acceleration of the device. These inputs can be processed to an output consisting of visual stimuli from the screen or auditory stimuli from the speaker on the device, see Figure 2.17.

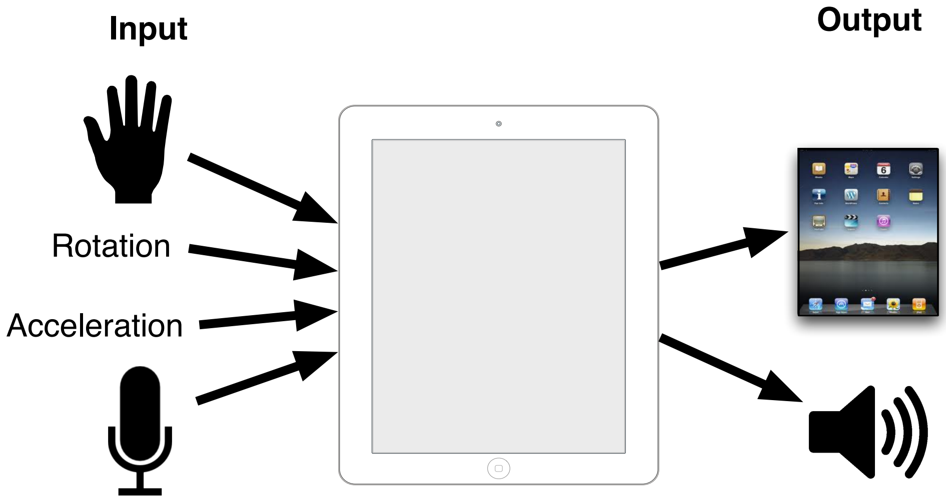

Figure 2.17: Input/output from the iPad

To gain a method of analysing a system like the iPad, a terminology for coupling input (action) and output (function) will be provided in the next section.

2.7 Coupling Action and Function through Feedback and Feedforward

This section will provide a tools and a terminology for analysing the iPad interface. This knowledge can then be used to point out how to enrich the iPad interaction.

To make a system where the action of making a gesture are naturally coupled with a function, it is important to provide the user with the right feedback and feedforward. Feedback is in this context thought of information about the users current action with the purpose of guiding the users further action. Feedforward is providing information about the consequences of an action to the user. Wensveen et al. [2004] addresses this issue of incoherence between user action and product function in electronic products in the paper “Interaction Frogger: a Design Framework to Couple Action and Function through Feedback and Feedforward.”

The design framework can help the designers to make a system that approach embodied freedom of interaction. The key idea of freedom of interaction is, according to Wensveen et al. [2004], to offer interaction that:

- “Takes full advantage of a person’s perceptual motor skill”
- “Offers a myriad of ways to achieve a product’s functionality”
- “Allows the person to act at multiple points at once”
- “Allows for easily reversible actions”

Freedom of interaction in not unlimited and it is important to realise that freedom of interaction does not equal freedom of action[Wensveen et al., 2004]. While unbounded action possibilities can make a system with freedom of expression, the system is useless if the system are not able to give proper reaction to avoid the user getting lost[Wensveen et al., 2004]. The rest of this section deals with how the user’s action and the product’s function can be coupled to produce this guiding information, while still allowing the user freedom of interaction.

Almost all mechanical products inherent a natural coupling between action and function, it therefore easy for the user to understands the coupling between action and function. This coupling is not naturally inherent in electronic products, where the user requires information to properly guide his actions towards intended product function [Wensveen et al., 2004]. To achieve this coupling between user action and product function, Wensveen et al. [2004] put forth a framework with the following six guidelines, in an attempt to unify action and reaction and thus making the interaction seem more naturally coupled. To explain the guidelines in a easy comprehensible way a example of the mechanical system of a scissor is used.

- Time - The product’s reaction and the user’s action coincide in time.
  Using a scissors, there is no delay between the user moving his fingers (action), the movement of the blades (reaction) and the cutting of the paper (function).
- Location - The reaction of the product and the action of the user occur in the same location.
  There is direct connection between location of the cut in the paper and where the blades of the scissors touches the paper. Thou the action of the hand is not at the same location but the scissor can be seen as an extension of the hand when cutting paper in accordance to Heidegger’s concept of “ready-to-hand” or “zuhanden” [Dourish, 2004]
- Direction - The direction or movement of the product’s reaction (up/down, clockwise/counterclockwise, right/left and towards/away) is coupled to the direction or the

movement of the user´s action.
The direction of the incision in the paper follows the same direction as the scissors. The user can make a deeper cut by moving the scissors forward.

- Dynamics - The dynamics of reaction (position, speed, acceleration, force) is coupled to the dynamics of the action (position, speed, acceleration, force).
The scissors cuts at a speed and length which is proportional to the movement of the users hand. Faster and longer movement results in faster and deeper cut in paper and vice versa.

- Modality - The sensory modalities of the product's reaction are in correlation with the sensory modalities of the user's action.
When the scissors blades cut through the paper it can seen, heard and felt by the user. In nature the relations between these different modalities are in natural and harmony. e.g. To object touching makes a sound and can visually be perceived.

- Expression - The expression of the reaction is a reflection of the expression of the action.
The user can express himself through the cutting of the paper. Slow and precise actions make a fine and precise cut, hurried and unfocused actions, makes a cut that is imprecision and rough on edges.

Purely mechanical products are in almost all cases bound to follow these six guidelines because the action and reaction are naturally coupled. This is not the case for electronic products that do not have to follow the tight coupling laws of the physical world [Wensveen et al., 2004]. This gives the electronic product many advantages over a purely mechanical product; we can listen to music without playing the instruments or talk with our uncle on the other side of the earth without need of travelling the distance, to name a few examples.

2.7.1 Feedback

Wensveen et al. [2004] considers feedback an essential part in interaction design, and further defines three degrees of feedback, which each have their uses. According to Wensveen et al. [2004] there is three division of feedback: Functional, Augmented, and Inherent.

Functional feedback
Functional feedback is defined as the information generated by the system, when the system performs its function. An examples of functional feedback is when you turn on a television and you can see picture on the screen and sound starts emerging. [Wensveen et al., 2004]

Augmented feedback
Augmented feedback is not directly related to function of the product but are an affirmation of the system having received a input. This kind of feedback appeals more to the cognitive skills of the user instead of the users perceptual motor skills. This is a way of ensuring the used that his input is register when there is a delay between action and functional feedback, e.g. when turning on a television a red light starts blinking before the you can see the picture emerging on television. [Wensveen et al., 2004]

Inherent feedback
Inherent feedback is the direct feedback from performing an action on a product. Inherent feedback is often motor-perceptual. When the user performs an action potential on the system, the movement will often provide a inherent feedback e.g The feeling of resistance from a button while pressing it down and also hearing it "click". [Wensveen et al., 2004]

2.7.2 Feedforward

Feedforward, the information provided by the system before the users action, has according to Wensveen et al. [2004] the shame three division as feedback:

Inherent feedforward
Inherent feedforward shows the action potential of the product to the user's motor-perception skills. It informs the user of what action can be carried out by pushing, sliding, rotating parts of the device. It also shows the user which body part must be use in order to work the function. Inherent feedback can be considered a limited form of interpretation affordance. [Wensveen et al., 2004]

Augmented feedforward
Augmented feedforward relates to the cognitive skills of a user e.g. words, pictograms or spoken words. It is information from an additional source to guide/help the user to an action possibility - or the purpose of it. An example of this is the display of a mobile phone guiding the user how to unlock the keypad. [Wensveen et al., 2004]

Functional feedforward
Functional feedforward provides more general information then the concrete action possibility of the product. Functional feedforward is more about the purpose and functions of a product i.e. If a screen and speakers are visible on the the product this feedforward audio visual capabilities. This can support the user's semantic understanding of the product. [Wensveen et al., 2004]

Through the rest of this study will the terminology form this framework be used to analyse the iPad interface to identify if the interaction can be enriched by strengthening the coupling between actions and functions. The next section will give a overview of the iPad user interface.

2.8 Applied gestures in the iPad user interface

As mentioned in the motivation an iPad user cannot navigate his iPad without using buttons. There are few exceptions though. Functions such as pinch-to-zoom, rotate images, and drag are used directly on page content and not a specific area. This section will provide context examples of the gestures possible in Apple iOS. The shown figures are screen shots of applications and functions available in stock iOS.

2.8.1 One-finger swipe

The one finger swipe is used in e.g. changing the home screens and scrolling in lists. This gesture is used for global area interaction, it can be applied anywhere on scrollable page content. The dynamics and to some extent the expression of the action are also translate to the scroll i.e. speed, acceleration, force. The one finger swipe in context can be seen in 2.18 and Figure 2.19.

Figure 2.18: One finger swipe, left or right, can shift between home screens.

Figure 2.19: One finger swipe, up or down, can bed used to scroll in lists.

2.8.2 Pinch (open/close)

The pinch gesture are utilised when a user has to zoom in or out on content in e.g. the Safari browser or on a photo. This gesture is also used for global area interaction and do also translate the dynamics of the action. Examples of zoom can be seen in Figure 2.20 and Figure 2.21 and in Figure 2.22 and Figure 2.23 on the following page.

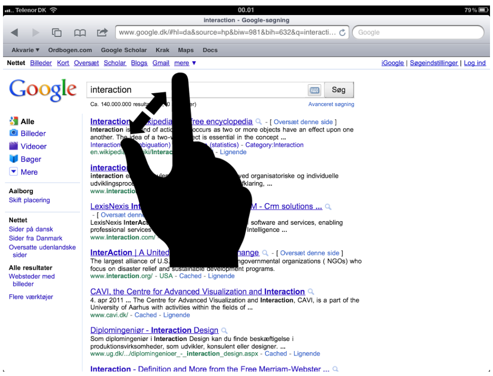

Figure 2.20: A pinch open gesture can be used in e.g. Safari, to zoom in on page content.

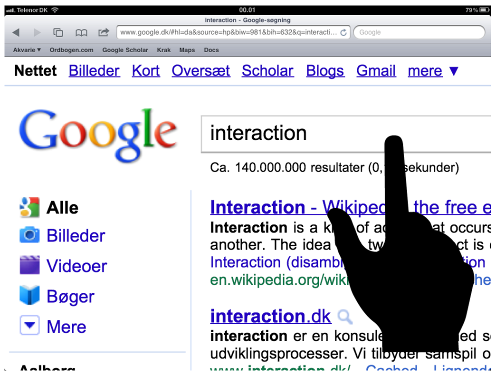

Figure 2.21: A pinch open to zoom in was made. The user can conduct a pinch close to zoom out again.

Figure 2.22: A pinch close gesture can be used on photos to zoom out.

Figure 2.23: The feedback from making a pinch close on a photo.

2.8.3 Tap to click

The tap to click gesture is used in the majority of navigation tasks, that can be made in iOS. The tap is a local area interaction, it require the user to hit a relative small area of the screen to execute the action. The tap do not translate dynamics or expression i.e. The iPad perform the same function whether the user taps hard or soft. Figure 2.24 shows the navigation buttons in top of the built-in Safari browser. When a user wants to make a step backwards, he has to utilise these buttons. This can be accomplished with a one finger tap. Another example of navigation that only can be conducted with a one-finger tap to click gesture is in the Calendar application on iOS - see Figure 2.25 on the facing page. The Calendar application contains a month line, where the user can tap on a specific month, or drag with one-finger, to shift between months. In the iPod application the same requirements are seen. Here, the only way to return to the artist layer, is to tap the Artists button - see Figure 2.26 on the next page.

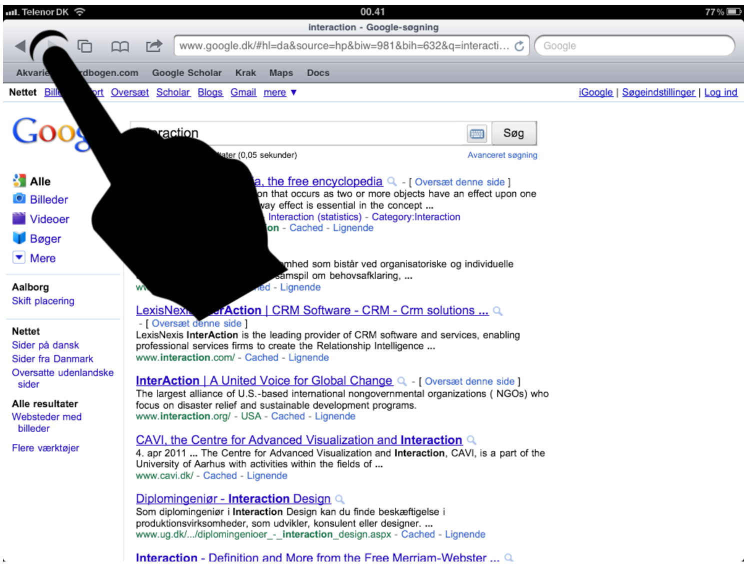

Figure 2.24: The user is forced to use the software buttons for navigating between the next or previous page.

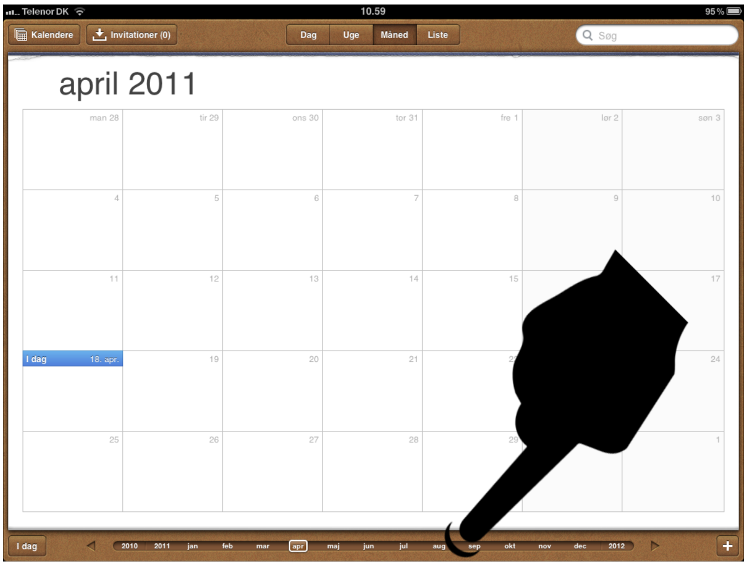

Figure 2.25: Changing the month in the iOS Calendar can only be accomplished by tapping on another month.

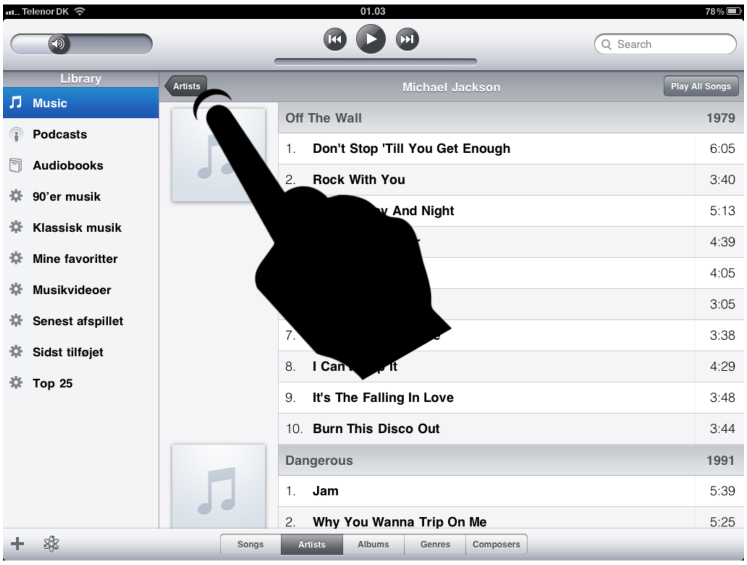

Figure 2.26: If a user wants to go to the previous artist layer, he has to tap the Artists button.

2.8.4 Touch and hold (long press)

The touch and hold gesture is e.g. used when a user wishes to enter the jiggle-mode on the home screens. Touch and hold is a local area interaction and do not translate dynamics or expression. To enter jiggle-mode the user has to touch an icon and keep the finger pressed against the display until the icons enters jiggle-mode. Hereafter the user can either drag the icon he made the gesture on, or move his finger to another icon to drag it to a new location. He can also choose to uninstall the application. An example of these scenarios can be seen in Figure 2.27 and Figure 2.28 on the following page.

Figure 2.27: In this Figure the touch and hold gesture is used to enter jiggle-mode, where the icons make a jiggle motion from side to side.

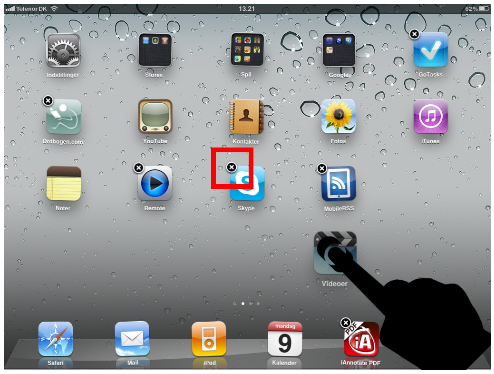

Figure 2.28: The user can after entering jiggle-mode either drag the icon or e.g release the touch and hold gesture and tap on the the X in the upper left corner on an icon to uninstall the application. The X is shown in the red frame.

Drag

A user can drag an icon on the home screen, after entering jiggle-mode, to move it to another location. A drag gesture can be used for local area interaction - see Figure 2.29 where drag is used on an icon. Drag can also be used as a global area interaction when drag is applied on page content e.g. Drag to switch between two home screens or drag to scroll a webpage in safari. The drag gesture translate the dynamics and expression of the action.

Figure 2.29: An icon on the homescreen is moved to another location. The hand at the left shows where the icon where located before the drag gesture. The hand at the right shows the current location of the drag gesture and icon.

2.8.5 Drag and drop

The drag and drop gesture implies the drag gestures described above. Drag and drop are used for local area interaction and it translate the dynamics and expression of the action.

When conducting a drag and drop gesture, the user picks up e.g. an icon, then dragging it to another location and dropping it of at the new location. This can be seen in Figure 2.30.

Figure 2.30: An icon is picked up at the left side of the screen and dropped of at the right side.

2.8.6 Double tap

The double tap gesture can be used for zoom in on content on a web page or for showing the multitasking bar in the bottom of the screen. Double tap is a local area interaction and do not translate dynamics or expression. To show the multitasking bar the physical home button must be double tapped - this can be seen in Figure 2.31, the home button is shown in the red frame.

Figure 2.31: The home button can be double tapped to show the multitasking bar.

2.8.7 Rotate

The rotate gesture is used for rotating e.g. a picture in the built-in photo viewer iPhotos. The rotate gesture used for global area interaction and it translate the dynamics and expression of the action. The gesture is seen in Figure 2.32 and Figure 2.33.

Figure 2.32: The user has to grab the picture as in the pinch gesture.

Figure 2.33: Afterwards the user can rotate his hand to rotate the picture.

2.8.8 Four-finger swipe

This gesture is only available in iOS 4.3 as a preview to developers. The gesture has two functions: switch to the next open application or opening the multitasking bar - left/right swipe and up/down swipe respectively. The Four-finger swipe gesture used for global area interaction and it only translate the dynamics and expression of the action switching to next open application. The left/right swipe gesture can be seen in Figure 2.34.

Figure 2.34: A four finger left swipe where the next open application is slided in from the right to come to focus.

2.8.9 Five finger pinch

The fiver finger close pinch is also, only available in iOS4.3 as a preview to developers. The Five finger pinch gesture used for global area interaction and it do not translate the dynamics and expression of the action. This gesture closes an application in the same manner as a single tap on the home button. The gesture can be seen in Figure 2.35 on the facing page.

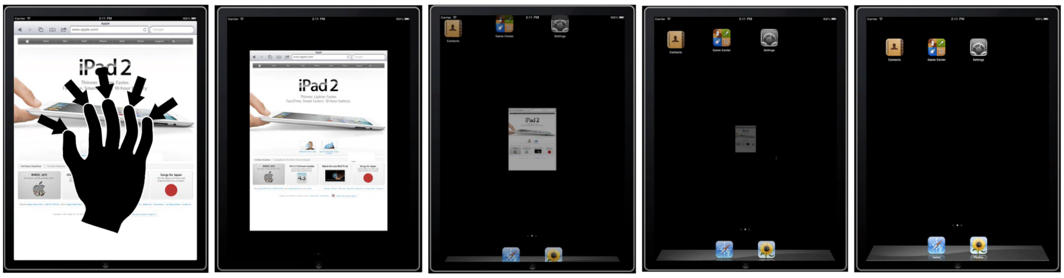

Figure 2.35: The five finger pinch close gesture, with the following transition.

From the above it can be concluded that graphical navigational elements such as the back-button or the month line in the Calendar application, are limited to control via one-finger gestures that uses local area interaction. Rotate and pinch are the only gestures that are conducted with two fingers. The software buttons requires local area interaction and do not translate the dynamics and expression of the action. The two finger gestures (including the four- and five finger gestures) can be conducted almost anywhere on the screen. By having the possibility to make gestures, that uses global area interaction, the user can focus on the task at hand e.g. locating a specific song, instead of being interrupted by the subtask of finding the back button.

The interaction with buttons does not translate the expression of the user's input i.e. if the user pushes harder on the back button this will have no effect. Furthermore the user needs to locate the button and to use precise movements to be able to hit the correct button. Rough movements will only decrease the chance of hitting the right button.

2.9 Levels of navigation in a tablet interface

The iOS operating system do basically only have one function, it can run applications. All functionality of an iPad is reached by running different applications. Applications for the iPad can be divided into three types: Utility, productivity, and games. Depending of the nature of the application, the application structure can be more or less complex.

2.9.1 Utility applications

Utility applications are simple one screen- and one task applications. These apps do not have any hierarchical information structure. An example of such an application could be Spirit Level - see Figure 2.37 on the next page or Calculater Pro - see Figure 2.36 on the following page.

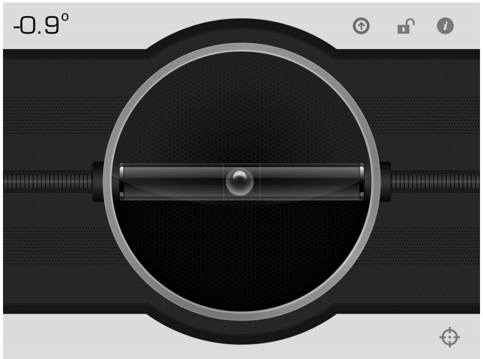

Figure 2.36: Screenshot of Spirit level application for iPad.

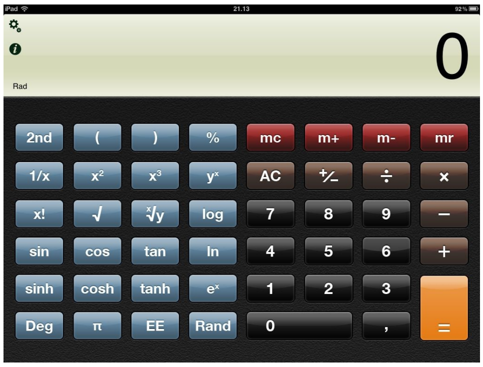

Figure 2.37: Screenshot of Calculator Pro application for iPad.

2.9.2 Productivity applications

Productivity applications are used to obtain and/or create information. The focus of these applications is to make information accessible, to the user, in a fast and efficient way. It is normal that a productivity application has more than one tab. Tabs can be seen as separate parts of an application that not necessarily have the same information structure. In most cases the information inside a tab is hierarchical. Here the user can browse in the hierarchical structure. An example of a productivity application, with a hierarchical structure, is the Safari web browser, where the user can browse the content of a homepage, see Figure 2.38. In this application the user can switch to the last viewed page with the back- and next button. The user can switch between nine open web pages opened in separate tabs, see Figure 2.39. The tabs-page in safari is a little atypical from other applications. Normally the tabs are available by separate buttons in the bottom of the screen.

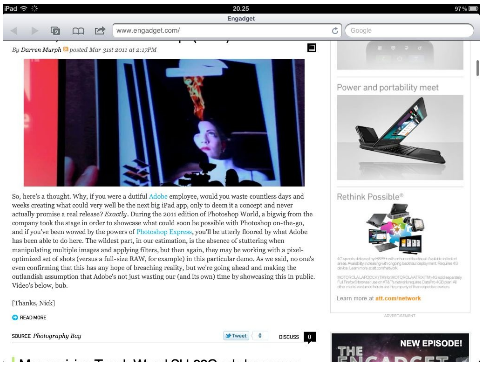

Figure 2.38: Screenshot of Safari application for iPad.

Figure 2.39: Screenshot of Safari with nine tabs open.

Another example of a productivity application is the Youtube application, where the user can browse video content. In this application the tabs are used to categorise and emphasise the content. The tabs are available at all time from buttons in the tabbar at the bottom of the screen, see Figure 2.40 on the next page. Each video page within a tab in the application has a number of related videos attached, which the user can browse between. The App store is a application used to acquire new applications to the iPad. This application also uses tabs to categorise and emphasise the content, see Figure 2.41 on the facing page.

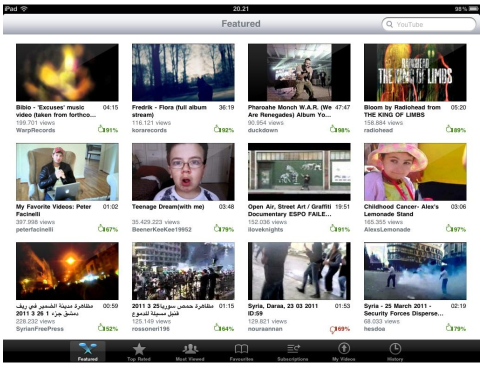

Figure 2.40: Screenshot of Youtube application for iPad.

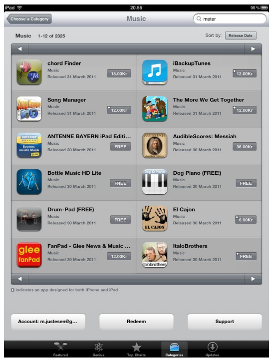

Figure 2.41: Screenshot of App store application for iPad.

2.9.3 Games

The last category of applications is games. Games normally use custom controls- and user interface elements, to give the user a unique gaming experience. An example of a game is Fruit Ninja HD where the user swipes the screen to cut fruit into pieces, see Figure 2.42, or Angry birds where the user shoots with birds from a slingshot, see Figure 2.43.

Figure 2.42: Screen shot of Fruit Ninja HD for iPad.

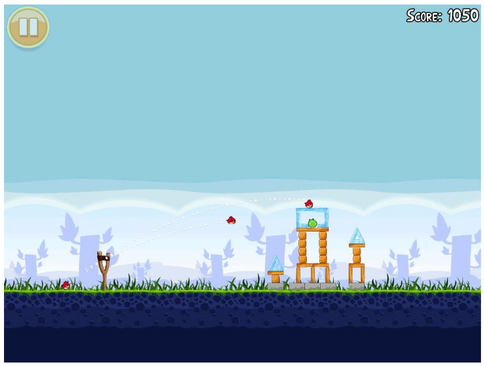

Figure 2.43: Screenshot of Angry Birds HD for iPad.

2.10 Overall App information structure on a iPad

To make a generalised model of the information structure on the iPad, the model must allow for the most complex application structures. The most complex information structure on a iPad is within the productivity applications, that can contain more than one tab with different hierarchical content in each tab. The content of a page can also extent besides what can be seen on the screen, which makes it necessary to be able to scroll and zoom within the page content. This provides a generalised model in five levels of information abstraction: page content, hierarchical structure of pages, tabs, switch between applications, and launch applications from home screen. A figure of this model can be seen in Figure 2.44.

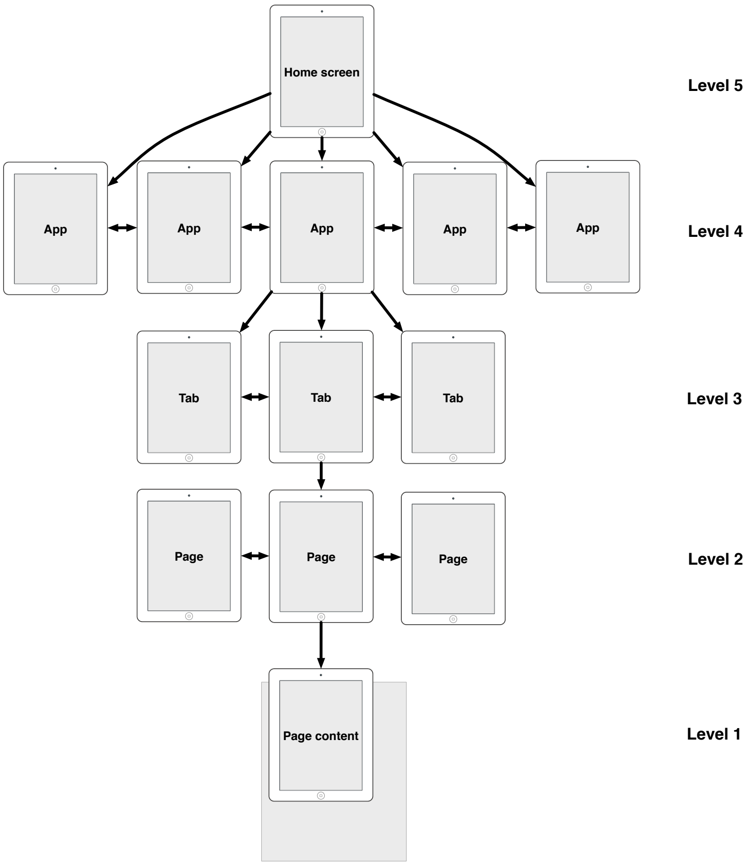

Figure 2.44: Model of the information structure of an ipad with applications.

2.10.1 Functions needed for navigating the information structure

To navigate this structure a number of navigation functions are required. A list of the functions can be seen in Table 2.5 on the facing page. It is only on the first level the iPad applies global area interaction with translation of dynamics and expression. Level 2 and 3 are navigated by local area interaction with taps on software buttons in the interface. Level 4 and 5 makes use of a hardware button for navigation. On level 1 the user manipulates the content directly with rich interaction, the dynamics and expression of the manipulation is translated into the navigation i.e. velocity, acceleration, and direction of the users finger is used as properties for the navigation. In this interaction there are no intermediary and the user have close to a one-to-one interaction with the content at level 1. Navigation on level 2-5 are accomplished by intermediary interaction, where the user pushes a button to have the iPad execute the order.

Navigation function	**Action on iPad**
Level 1 Pan in current application content	One finger drag
Scale current application content	Pinch open or close with two fingers or double-tap
Level 2 Move back in current application information hierarchy	Back button
Move forward in current application information hierarchy	Forward button
Level 3 Previous tab in current application	Tap button in tab bar
Next tab in current application	Tap button in tab bar
Level 4 Previous open application	Double-tap home button and tap application icon
Next open application	Double-tap home button and tap application icon
Level 5 Open new application	Tab home button and tap application icon
Close application	Tab home button
See list of open applications	Double-tap home button

Table 2.5: Functions and actions needed for navigating the information structure of the iPad

To gain a understanding of the technical possibilities for making additional global area interaction, that can help enriching the ipad interaction, the technology of multi-touch screen input will be examine in the next section.

2.11 Technology of multi-touch screen input

This section will describe how a multitouch screen detects input and how the gesture recogniser works in iOS.

The iPad uses a capacitive touchscreen. When a finger touches the screen this can be measured in a change in the capacitive field in a grid of sensing electrodes. It is thereby possible to determine the position and size of a number of touches on the screen. An illustration of the structure of the screen can be seen in Figure 2.45.

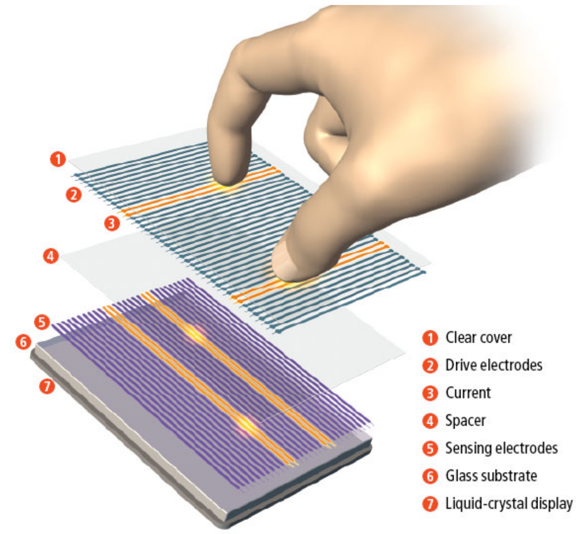

Figure 2.45: Illustration of the structure of the capacitive touchscreen.[Scientific American, 2009]

The touch information is then used by Apple iOS to determine the user's intention of the touch. In Apple iOS this is handled by a UI Event handler. This event handler features: error handling, determining what gesture the user is doing, tracking movement patterns, and what graphical element is touched on the screen.

In Apple iOS there is a standardise set of gesture recognisers which can be used to determine if the users is: Tapping (any number of taps), Pinching in and out (for zooming a view), Panning or dragging, Swiping (in any direction), Rotating (fingers moving in opposite directions), or Long pressing (tap and hold). [Apple Inc., 2010*b*, p.33]

To determine the action of a gesture there are configuration properties for each gesture type. With the use of different properties it is possible to target a large number of functions. In Table 2.6 on the facing page are the standard gesture recognisers and configuration properties described to give an overview of the possibility for different gestures that could be used in a gesture set.

Gestures	**Description**
Tapping	The tap gesture begins when the required number of tabs and the required number touches are recognised. The gesture ends when all fingers are lifted.
numberOfTapsRequired	The number of taps for the gesture to be recognised.
numberOfTouchesRequired	The number of fingers required to tap for the gesture to be recognised.
Pinching	The gesture begins when the two touches have moved enough to be considered a pinch gesture. The gesture changes when a finger moves (with both fingers remaining pressed). The gesture ends when both fingers are lifted.
scale	The scale factor relative to the points of the two touches in screen coordinates.
velocity	The velocity of the pinch in scale factor per second.
Panning or dragging	It begins when the minimum number of fingers allowed has moved enough to be considered a pan. It changes when a finger moves while at least the minimum number of fingers are pressed down. It ends when all fingers are lifted.
maximumNumberOfTouches	The maximum number of fingers that can be touching the view for this gesture to be recognised.
minimumNumberOfTouches	The minimum number of fingers that can be touching the view for this gesture to be recognised.
Swiping	The swipe is recognised when the specified number of touches (numberOfTouchesRequired) have moved mostly in an allowable direction (direction) far enough to be considered a swipe. Swipes can be slow or fast. A slow swipe requires high directional precision but a small distance; a fast swipe requires low directional precision but a large distance.
direction	The permitted direction of the swipe for this gesture recogniser, Right,Left,Up,Down can be used.
numberOfTouchesRequired	The number of fingers required to tap for the gesture to be recognised.
Rotating	Rotation is a continuous gesture. It begins when two touches have moved enough to be considered a rotation. The gesture changes when a finger moves while the two fingers are down. It ends when both fingers have lifted. At each stage in the gesture, the gesture recogniser sends its action message.
rotation	The rotation of the gesture in radians since its last change.
velocity	The velocity of the rotation gesture in radians per second.
Long press	The gesture begins when the number of allowable fingers have been pressed for the specified period and the touches do not move beyond the allowable range of movement . The gesture recogniser transitions to the Change state whenever a finger moves, and it ends when any of the fingers are lifted.
allowableMovement	The maximum movement of the fingers on the view before the gesture fails.
minimumPressDuration	The minimum period fingers must press on the view for the gesture to be recognised.
numberOfTapsRequired	The number of taps on the view required for the gesture to be recognised.
numberOfTouchesRequired	The number of fingers that must be pressed on the view for the gesture to be recognised.

Table 2.6: Description of gestures in UIGestureRecognizer. [Apple Inc, 2011*d*]

In Section 2.4 on page 11 it was described that the iPad only uses one- and two-finger gestures. With the use of the NumberOfTouches configuration property it is possible to extent the iPad gesture set to support more multi-finger gestures with the standard gesture recognisers. The next section will look further into the touch input interaction with the iPad.

2.12 Touch input

The iPad tracks two parameters form the user's touch on the screen, number of touches and position over time - see Section 2.11 on page 34. When the user makes an input, the iPad needs to determine the appropriate action to the input. The input can be divided into two categories: one that is reacted upon directly (Direct gestures) and another that first is recognised after an input performed (Symbolic gestures). An illustration of the time aspects of the gestures can be seen in Figure 2.46.

In the time domain the direct gestures have a one-to-one connection between action and function, whereas symbolic gestures have a delay in the connection. A further explanation is seen below.

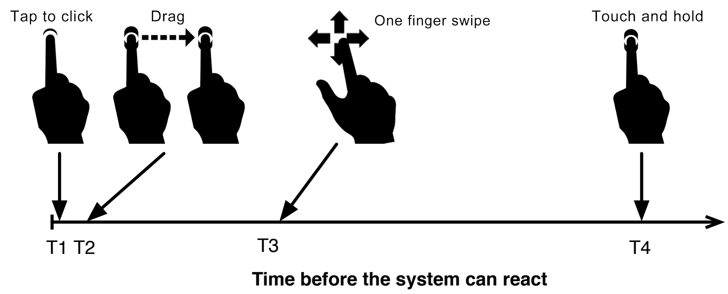

Figure 2.46: System reaction time: T1 = the time it takes to tap and lift the finger, T2 = the time it takes to touch and move a finger in a direction, T3 = the time it takes to touch and move a finger fast in a direction and lift the finger, T4 = the time it takes from the start of long press to a context menu appears. Note that the time line is only for an illustrative purpose and is not to scale.

2.12.1 Direct gestures

The characteristic of a direct gesture is that the system can react upon the input with no noticeable delay[4] for the user. These gestures are of a deictic and manipulative nature, i.e. pinch, tap, and drag and drop - see Figure 2.7 on page 14. By using multi-finger variations of these gestures it is possible to extent the gestures set without the need to sacrifice the direct connection between action and function in the time domain.

[4]The system has a response time. When a user e.g. taps on an item, the system has to use time for process, before an output is performed.

2.12.2 Symbolic gestures

The characteristic of a symbolic gesture is that the system needs to analyse a pattern of positions over time before being able to recognise the gesture. An example of three typical symbolic gestures can be seen in Figure 2.47. The system cannot determine a specific gesture before the gesture pattern is unique from the rest of the gesture set. While the user performs the vertical line (the red line), the system cannot distinguish between the three gestures. The user is required to draw more of the gesture pattern to provide a unique gesture. This introduces a delay between the user's input and the reaction from the system. If a gesture in a gesture set are lengthy to perform for the user, the system response will have a large delay.

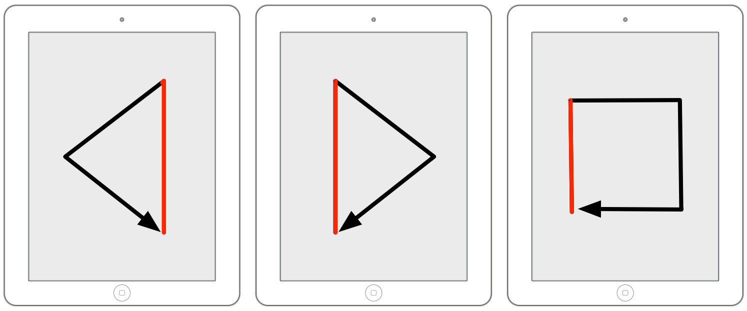

Figure 2.47: Example of three symbolic gestures that could be used to the back, forward, and home function.

The use of symbolic gestures on the iPad is limited to very simple symbolic gestures i.e. the touch and hold gesture, and the swipe gesture. The system response from the symbolic gestures on the iPad are provided with a very small time delay. The swipe gesture is a relatively fast flick on the screen with a nearly unnoticeable feedback delay that easily can be mistaken for a direct gesture. This is because the time it takes from start of the gesture to it is considered a swipe by the system can be very close to direct gestures like a tap.

and the default delay for touch and hold is 500 ms [Apple Inc, 2011*d*].

2.13 Screen output

Even though the ipad is just a flat two-dimensional screen, there is applied graphical effect that indicate that the content of a iPad extends to some kind of spatial room outside the boundaries of the screen. This section will give some examples of how the iPad interface try to indicate this room by the use of metaphors (metaphors is elaborated upon in Section 3.4.2 on page 49). The information provided from the interface to the user are static or dynamic. Examples of this can be seen below.

2.13.1 Static output

The static output contains information in the form of interactable content and non-interactable information content. An example of the static screen output can be seen in Figure 2.48. There are graphical effect applied to feedforward the action possibilities to the user. Almost all objects with rounded corners are tappable and the partly visible box in the bottom of the screen indicates that the is more content on the list further down i.e. occlusion. These effects can be seen as feedforward (described further in Section 2.7 on page 19), to indicate the current action possibilities in the interface user.

Figure 2.48: Example of the static output in the settings app on the iPad.

2.13.2 Dynamic output

Almost every transitions in the iPad interface are animated to guide the user's interaction and provide feedback and feedforward. These transitions are applied to make a metaphor of a spatial world of objects in the interface and feedforward the location of the objects. Examples of this can be seen in Figure 2.49, Figure 2.50, Figure 2.51, and Figure 2.52 on the next page. With these transitions it is shown to the user that when content is changed on the screen it do not disappear it is just moved away to a place outside the boundaries of the screen.

Figure 2.49: Transition between home screens. The metaphor used is that the home screens are placed continues along a horizontal line.

Figure 2.50: The multitasking bar contains a horizontal line of last used applications. The last six applications used are on the first screen. By dragging the bar to the left the list changes to applications prior to the first six. If the list are dragged to the left controls for music, sound and brightness appears.

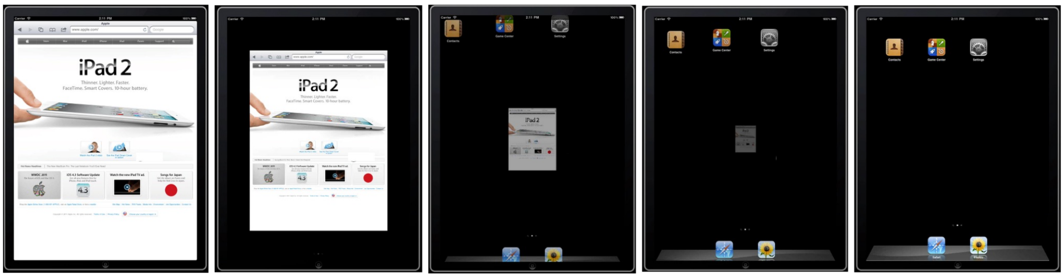

Figure 2.51: Close application metaphor: An application fades into the center of the screen and goes behind the other icons on the springboard which comes in from the top, bottom, left and right sides of the iPad edge. The transition is not telling that the application flies behind the background but tells instead that the application is behind the icons on the home screen.

Figure 2.52: The application switch metaphor: the applications changes place by flipping backwards.

These four examples contribute to the creation of a metaphor of spatial relation in the iPad interface. An interpretation of where content is moved when it is not visible on the screen can be seen in Figure 2.53. The story the metaphor try to tell can be interpret as the interface elements do not vanish when the leave the screen, they are just moved outside the field of view. This metaphor is analogous to objects in the real-world which also do not vanish when they leave our the field of view. The illustration can seem to be somewhat confusion, this is due to lack consistency in the interface metaphors and it is thereby not totally clear where interface elements are moved to when the leave the screen.

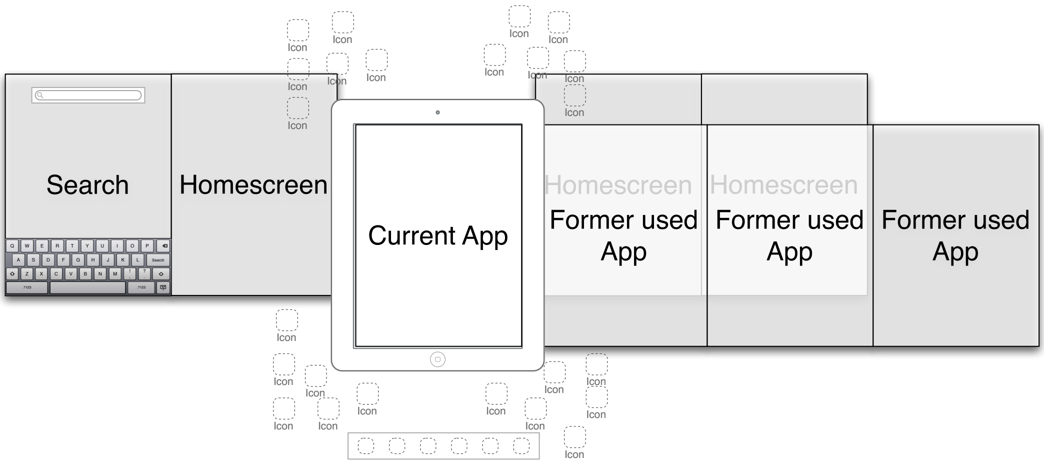

Figure 2.53: Model of the spatial metaphor generated by the transitions examples.

2.14 Findings of the analysis of the media tablet platform

This chapter has covered technical the aspects of the iPad. The following is a summation of the findings:

- There is no uniform terminology in the area of gesture research. The five gesture styles: Deictic, Gesticulation, Manipulative, Semaphores and Sign Language were chosen as a terminology.
- Eight different gestures where found across mobile operating systems, where only the pinch and rotate gesture are accomplished with more than one finger.
- Four finger swipe and five finger pinch are only available for testing to developers on the iPad.
- More complex gesture sets are used on other technologies e.g. computer trackpads utilise various one-, two-, three-, and four-finger gestures.
- The ergonomic study made with an iPad showed that, in every day use, five fingers are available most of the time. Furthermore, findings showed that the iPad cannot be operated one-handed with the thumb.
- The review of the Multi-touch gestures literature showed a majority of studies that focused on proof-of-concept of technical aspects instead of user tests. Studies that have been conducted to test user performance with multi-touch gestures, are, to the knowledge of the authors of this study, very limited.
- When navigating the information structure of the iPad. The iPad only applies the users expression on the first level. Level 2 - 5 are reached by buttons which do not translate the user's expression.
- Direct multi-finger gestures are recognised by the standard gesture recognisers in Apple iOS.

From the analysis it can be concluded that there are no technical or physical limitations that confines improvement regarding interaction with the interface. The next chapter focuses on the how the user interacts and understands the iPad

CHAPTER 3

Analysis of iPad interaction

The previous chapter outlined the iPad platform primarily from the system side. This chapter will focus on the how the user interacts with, and understands, the iPad. The new generation of interface styles that the iPad belongs to, will be outlined in the first section by introducing Reality-Based interaction. Reality-Based interaction unifies the new emerging interactions styles, found in e.g. the iPad, in four different themes: Naïve Physics, Body Awareness & Skills, Environment Awareness & Skills, and Social Awareness & Skills. The themes will outline the topics described in this chapter, i.e. affordances, tangible interaction, direct manipulation and low-level cognition.

3.1 Post-WIMP interfaces

The interface of computers has evolved from batch mode interface with punched-card input and line-printer output (first generation interface), over text based command line interfaces (second generation), to “point-and-click” WIMP GUIs[1] (third generation interface). Post-WIMP can be seen as the fourth generation of distinct interface styles for computers.

One of the first to describe the term Post-WIMP interfaces was van Dam [1997]. The post-WIMP interface is, according to van Dam [1997], an interface “containing at least one interaction technique not dependent on classical 2D widgets such as menus and icons. Ultimately it will involve all senses in parallel, natural language communication and multiple users.” In recent work by Jacob et al. [2008] introduced the term Reality-Based Interaction, for post-WIMP interface. Reality-Based interaction is being used to unify the new generation of emerging interaction styles used in technology such as: virtual, mixed, and augmented reality, tangible interaction, ubiquitous and pervasive computing, handheld/mobile interaction, etc.

In a literature review Jacob et al. [2008] compare what they mean are salient and important commonalities of the new emerging interaction styles. Jacob et al. [2008] conclude that the link between these new interaction styles are, that they draw strength by building on the users’ pre-existing knowledge of the non-digital world to greater extent than before. Jacob et al. [2008] further explain that, by basing the interaction on pre-existing knowledge from the real-world may make it easier for the user to understand the interface.

Jacob et al. [2008] classify four themes from the real world that draw on pre-existing knowledge and introduce them as a framework. The four themes in the frame work are:

[1]Graphical User Interfaces based on windows, icons, menus, and a pointing device

- **Naïve Physics:** Common sense knowledge about the physical world. Humans understand the influence of acceleration, momentum, gravity, friction, velocity, relative scale, and the persistence of objects.
- **Body Awareness & Skills:** Most humans have a fine-tuned awareness and understanding of their own physical body and relative position of their limbs (proprioception). Humans possess skills for controlling and coordinating our bodies develop early in life and are well adapted to navigate the real world.
- **Environment Awareness & Skills:** Humans have skills to process their physical presence relative to other objects in their spatial environment. These skills give clues of ways for negotiating (e.g. finding the fastest routes), manipulating, and navigating within the environment. Objects in the environment can be manipulated by picking up, positioning, altering, and arranging.
- **Social Awareness & Skills:** People are generally aware of the presence of others in their environment and have social skills for interacting with other people, including verbal and non-verbal communication, exchange of objects and collaboration on tasks.

Jacob et al. [2008] write that "while we believe these themes apply to most people and most cultures, they may not be entirely universal". Furthermore, the four themes are build on observations in the literature and are not theoretical founded in their paper. The present study acknowledge the themes as reasonable observations, but if the themes are to be applied, in a more concrete form, in future interfaces, the theoretical aspects must be analysed.

An example of the Social Awareness & Skills on the iPad is the support of social interaction in e.g multi-player games like air hockey games, where the players each have a half of the iPad. The Social Awareness & Skills theme though, is out of the scope of the present study since it implies e.g. communication and sociology, whereas the study will focus on direct perception, low-level cognition and tangibility.

3.2 Applying theory to the Reality-Based themes

On the iPad the user's input is located at the same place as the object being manipulated, but the output is differentiated. When tapping a software button, the feedback on the button is given through a discrete shift between pushed and not pushed. The function of the button, though, e.g. when having pressed an icon on the home screen, makes the selected application appears with slow in/slow out animation which seems to abide the law of acceleration. Whereas e.g. swipe and dragging page content or home screens, and drag and drop of objects seem to abide physical laws of momentum, velocity, acceleration, persistence of objects, and continuous movements. Graphical objects on the screen appear real to the user by giving the object a distinct layout and inertia which is perceived as mass. Scrolling is e.g. made real world like, by applying inertia to the page content. The amount of energy in the gesture, is translated into distance and velocity of the scroll. By utilising the aspects of Naïve Physics the user can express himself in the the interaction. The pre-existing knowledge described in Naïve Physics, is a general human understanding of the effects caused by the Newtonian laws. The effects from the Newtonian laws are seen in the environment, in where humans lives. The environment "refers to the surroundings of those organisms that perceive and behave, that is to say, animals" [Gibson, 1986]. Furthermore, skills from the Environment Awareness & Skills draws on pre-existing knowledge on navigating within the environment. This gives an incentive to explore perception in the environment, which will be investigated in Section 3.3.

Both, the skills described in Body Awareness & Skills, that control and coordinate our bodies, and the skills required to e.g. manipulate objects in the environment, described in Environment Awareness & Skills, are pre-existing knowledge that is used in tangible interaction. The iPad interface contains some of the qualities from tangible interaction and is thus explored in Section 3.4 on page 47.

As seen in Section 3.4.2 on page 49 the iPad interface utilises animated transitions to help the user creating a metaphor of the applications being arranged relatively to each other in a spatial room. The metaphors describe how close the system assembles the real world. Metaphors will be described in Section 3.4.2 on page 49.

When interacting with the iPad, the user can have several intentions that he wishes to be accomplished - e.g. push the back-button. If the intentions are to be fulfiled effortlessly, i.e. when an intentional touch input from the user results in system feedback that the user expected, the way the user thinks the interface, should be consistent with how the interface interprets the users inputs. This issue will be explored in Section 3.5 on page 51.

Naïve Physics is a visual expression in the interface linked to the touch input from the user. Naïve Physics may encourage improvisation and exploration because users do not need to learn new specific skills for navigating the interface [Jacob et al., 2008]. This will also help to reduce the cognitive load which is elaborated in Section 3.6 on page 55.

3.3 Gibson's ecolgical approach to visual perception in the environment

Besides investigating the perception of the environment in where the animal lives, this section will cover how 2D objects could be designed to be more real-world like. "Many designers make these decisions implicitly in their work" [Jacob et al., 2008], but the theory behind is often not documented, why the design is becoming sort of a qualified gut feeling.

Animals, including humans, are active in the perception of the environment. This is a key component of the ecological approach to visual perception. During locomotion in the rigid environment, humans extract invariants and the perspective structure from the stimulus flux, which are arranged in the ambient optic array. The stimulus flux is the light, that is projected to surfaces from a light source and is catched by the eye of the observer. Ambient means the light in a given spatial location, which could be occupied by the observer, and array is the specific arrangement of light beams [Gibson, 1986]. During locomotion the invariants are the specific layout of the rigid environment. E.g. if you pass a rock, the rock still looks the same, but the perspective will differ, which are the perspective structure. An example of this can bee seen in Figure 3.1.

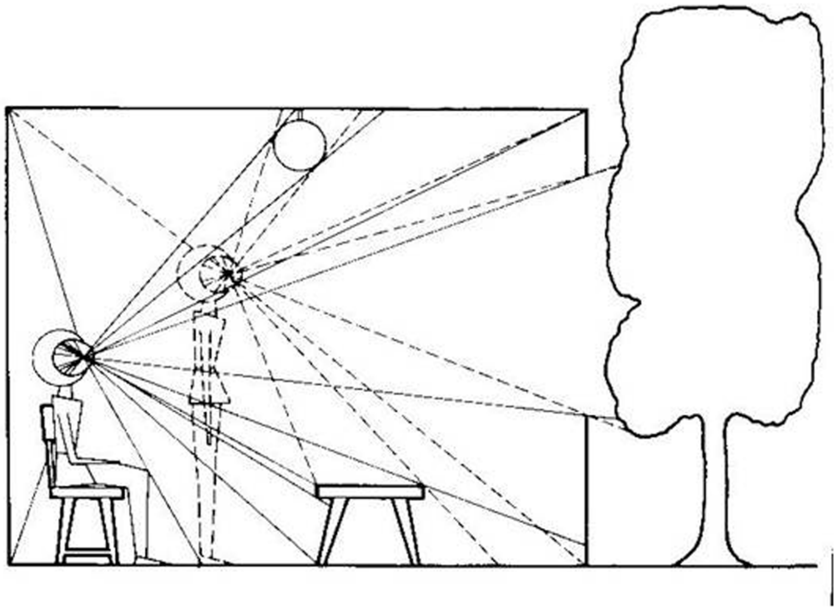

Figure 3.1: Change of perspective seen from the obeserver. The invariants that defines the chair is not changed.

As described in Section 2.13.2 on page 38, the animated transitions use flow in and flow out to create metaphors. Some of the transitions assembles locomotion and is why the user understands the application as coming from the background or flying into the background. Bærentsen [2000] made an experiment, where users navigated in a screen display on a high-end TV to e.g. edit the channel list. Bærentsen [2000] found out that users tend to talk about interactive systems as they are experiencing the real world [Bærentsen, 2000] e.g. "now I'm going out of ...". This shows that pre-existing knowledge stems from the real world, where spatial orientation is dominant in navigation tasks.

To have 2D objects assemble the real world, it is important to define the environment in which the animal lives. Gibson [1986] defines that the physical environment is structured by the medium, substances, and surfaces. Regarding human beings, the primary medium is the air that surrounds us, substances are more or less rigid and less resistant to deformation and impenetrable by solid bodies e.g. a tree. Surfaces are what separates substances from the medium and is where the perception of the object occurs. For instance a piece of sandpaper has a distinct rough surface compared to plain printer paper. The sandpaper cannot be used for printing, even though it is paper, but e.g. to deform the before mentioned tree. The surfaces have a given layout that reflects light. The surfaces are " ... potentially visible ... and could be looked at from some place in the medium where an animal might be" [Gibson, 1986]. Gibson [1986] defines nine ecological laws of surfaces, which in a condensed form outlines that persisting substances have a surface, surfaces are resistance for deformation, depending on the viscosity, surfaces have characteristic textures, have a specific shape, and have characteristic reflectance of light, that provide contrast and colours (defined by wavelengths). The ecological laws of the surfaces have to be obeyed to provide a objects a real-world like feeling. Contrast is especially important since this defines if it is possible to differentiate the object from the background.

Objects on the iPad can be designed in any given form that the developer desires it. If his ability to follow the laws of the surfaces is poor, then the objects in the 2D world that is created on the iPad can be, might not afford the intended usefulness of the object. Affordances is a term coined by Gibson [1986] and is what the environment "... offers the animal, what it provides or furnishes, either for good or ill" [Gibson, 1986].

3.3.1 Affordances

An example of an object that e.g. affords to be *graspable* is a hammer. The features of the hammer is directly perceived. The hammer has distinct surfaces, where the head is one and the handle is another. The form factor, with the long handle, affords grasping. A hammer is as often used to hammer in nails, why the hammer itself affords this type of activity. Gibson [1986] describes two types of activity: the exploratory and the performatory activity. The exploratory activity is the act of scanning the environment for action possibilities. An action possibility could e.g. be eating an apple, but this requires biting, chewing, and swallowing [McGrenere and Ho, 2000]. Biting, chewing, and swallowing would be the performatory activity. An important factor of affordances is that "Although affordances are in a sense constituted by objective physical features of the environment, these objective features only become affordances when some organisms relate to them in their activity" [Bærentsen and Trettvik, 2002]. For instance if a person has never seen a car before, the car may not afford driving, but instead it is a natural affordance of a vantage point for scouting after prey in the Savannah. The canonical affordance of the car is driving, as the manufactor of the car has optimised the car for this type of activity. There is a cultural-historical aspect in canonical affordances, where the canonical affordance can be necessary to learn before a person can relate to it in his activity.

The optimal design of an interface, if everybody was to directly perceive- and understand it, would be to have all graphical elements elicit natural affordances of the intended purpose, since the cultural-historical "layer" of affordance would then be peeled of - but it would be nearly impossible. Objects in the virtual 2D world do not have the exact same feeling as objects from the real world, so a cultural-layer onto the natural affordance cannot be avoided. By applying Naïve Physics to the 2D objects the objects behave more real world like, but the behavior of the object is not a part of the perceived affordance - the behavior would be a part of the performatory activity.

To have the 2D objects appear even more real-world like, they have to occlude each other in specific cases. In the real world environment everything is occluded in some way [Gibson, 1986] - e.g. eclipse of the sun, where the sun has a occluded surface caused by the moon, or the cereal container behind the milk at the breakfast table, where the cereal is occluded by the milk. When using an iPad the user cannot move his head a see the an application from a different view - he has to move it himself. In nature the occluding object often cast a shadow on the occluded object, if the is objects are located near each other. This every-day phenomenon would improve the experience of an object being real world like.

3.4 Tangible interaction

In the real world objects are tangible and when a human is interacting with the real world objects it is done by grasping, moving, applying force and letting go of the object. For instance the task of using a knife for carving meat. This task uses a rich combination of the human senses and motor skills. The classical human computer interaction do not utilise this richness from the real world. The aim for researchers in the area of tangible interaction is to bridge the gap between the computer interface and the physical environment.

Some of the first to define the term tangible interaction were Ishii and Ullmer [1997] in their paper Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms. Their work concerns how to make interactive couplings of physical artifacts with digital information and change how humans interact with digital information. Instead of accessing digital information primarily through mouse and keyboard, Tangible User Interfaces (TUIs) give access to interaction with physical and graspable objects. The approach by Ishii and Ullmer [1997] is a data-centered view that focuses on utilizing physical representation and manipulation of digital data by making interactive couplings between physical artifacts and mediated digital information. In Figure 3.2 on the next page Ullmer and Ishii [2001] presents a model for a traditional GUI and a model for a TUI interface. The illustration (a) shows the model-view-control model this is the traditional model for a computer interface. There is a barrier between the control and the view in the interaction model of the classical GUI. For instance the mouse is disconnected from the cursor on the screen in the physical space. The input device and output device from the system are two separate units in the computer system.

The illustration (b) shows the general principle of a TUI: The model-control-representation (physical and digital) model (MCRpd). The Tangible representations (rep-p), which are physical controls, and tangible representations of information, are interconnected. The intangible representations (rep-d) are digital information mediated through e.g. graphics and sound [Ullmer and Ishii, 2001]. The model is build on an interdependency between the tangible and intangible representations, e.g. intangible representation of information on a display depends on how the user interacts with the physical objects and vice versa.

The same relation can be said to be present in the interface of the iPad when the user use the drag and swipe gestures to navigates page content on level 1, described in Section 2.9 on page 29. The content accommodates the dynamics of the touches on the screen. Information about a button on the interface and the control of the button is in the same unit. The button is made visible "pushable" even if it is missing the tactile quality of a physical button. The iPad is not a true TUI since it is missing the haptic feedback and feedforward from real physical artifacts, but the iPad features lots of the same qualities.

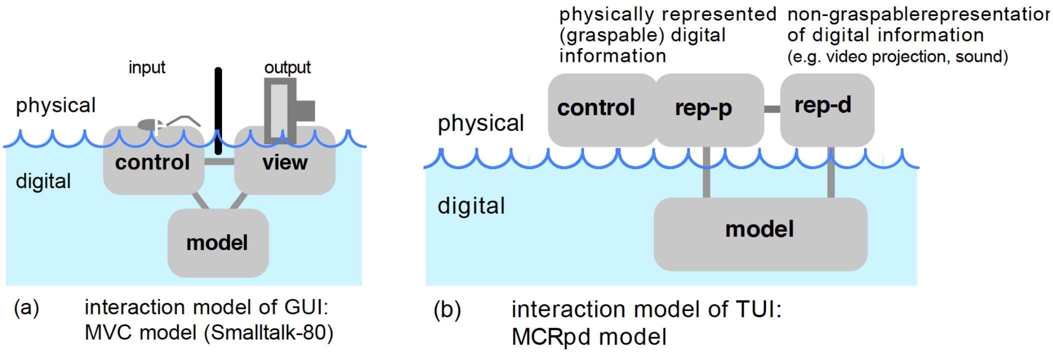

Figure 3.2: Illustration of model-view-controller and model-control-representation (physical and digital) [Ullmer and Ishii, 2001].

To describe the level of tactility in the iPad further, the level of tangibility in different aspects needs to be analysed. Fishkin [2004] describes how the terms embodiment and metaphor can be used to measure the level of tangibility of an interface in two dimensions. Embodiment describes the level of how closely the output is coupled to the user's input and metaphor describes on what level the interface mimic the real world. In the following embodiment and metaphor will be elaborated.

3.4.1 Embodiment

Embodiment, is according to Dourish [2001], central to tangible computing. In general, embodiment means "being grounded in and emerging out of everyday, mundane experience" [Dourish, 2001], furthermore "embodiment is a foundational property out of which meaning, theory, and action arise." [Dourish, 2001]. In this way embodiment is a way of "being" and is not just a physical property. Though, in the context of this study, embodiment in tangible interaction is, purely a physical embedding of action in the world and describes how closely the input and output of the system is connected. With tangible interaction the user's movements in psychical space gives a movement in digital space. The connection between the spatial movement in psychical space and digital space can help the user to establish and understand the structure of the system.

The embodiment is by Fishkin [2004] presented in four levels, see Table 3.1 on the next page.

Embodiment dimension	
Full	*"...the output device is the input device; the state of the device is fully embodied in the device" [Fishkin, 2004, p. 349].* An example of this could be the undo function in iOS where the user can undo a action by shaking the device wile writing text, or the shake to shuffle function in the iPod application.
Nearby	Output takes place close to the input device, typically directly proximate to the object. Fishkin [2004] uses the example of a light pen or some kind of token moving around on a tabletop that modifies the image projected on it.
Environmental	Output is around the user without a psychical object. Ullmer and Ishii [2001] uses the term non-graspable for this kind of output. A typical example of this would be if the system used sound as output.
Distant	Input and output are disconnected and have no spatial connection, e.g. remote control and TV or keyboard and computer monitor [Fishkin, 2004].

Table 3.1: The four different levels of Fishkin [2004]'s embodiment dimension.

Embodiment of the iPad

The interaction with an iPad is nearly fully embodied, for instance when navigating a web page, shifting between home screens, or drag and drop of icons on a home screen, see Section 2.8 on page 22. These functions have a direct connection between the spatial movement of the finger and the output of the screen. In other cases the embodiment is made distant in the interface e.g. when using the virtual keyboard to input text. Here the input and output are disconnected in the same way as a traditional computer monitor and keyboard are. In relation to the navigation of the information structure on the iPad (see Section 2.10.1 on page 32) only level one are implemented with nearly full embodiment, the rest of the navigation in level 2-5 are disconnected with an intermediary between action and function. Even though the iPad offers interaction with graspable 2D objects, some tasks are implemented as a simulation of a normal GUI with point-to-click and keyboard interaction.

3.4.2 Metaphor

Metaphor, in this study, is used to describe how closely the system assembles the real word. When a user makes a input, the level of metaphors in the system determine, how analogue the system reacts compared to the same action applied in the real world. To quantify the amount of metaphor, Fishkin [2004] determines two types of metaphors. Metaphors that relates to the shape of objects are called *nouns* and metaphors that appeal to the motion of an object are called *verbs*. Fishkin [2004] divide metaphors into four levels, see Table 3.2 on the following page.

Metaphor dimension	
None	No metaphors at all in the interface, e.g. a command line interface [Fishkin, 2004].
Noun OR verb	The metaphor can either be considered a noun or a verb - not both. *Nouns* relate to objects and *verbs* relate to actions. In the case of a *noun* metaphor, the physical properties of an object (shape, look, or sound) are similar to the associated information in the system [Fishkin, 2004]. *Verb* metaphor is an action performed on a physical object, causes a similar action to take place in the system [Fishkin, 2004].
Noun AND verb	In this case the metaphor can be considered both a noun and a verb. An example of this is the drag-and-drop metaphor used when a file icon from a computer desktop is dropped on a wastebasket icon and the file is deleted [Fishkin, 2004].
Full	*"...the user need make no analogy at all - to their mind, the virtual system is the physical system: they manipulate an object and the world changes in the desired way..." [Fishkin, 2004, p.351].* As an example Fishkin [2004] mentions an interface in which the user deforms a "landscape". The landscape reacts as if it was made of clay, changing the shape of the clay changes the appearance of its surface directly.

Table 3.2: The four different levels of Fishkin [2004]'s metaphor dimension.

Metaphors are more generally a set of constructs based on universal human experience. This means that metaphors can have various expressions and various levels - e.g. when choosing "cut" in a text editor to cut the word out, the metaphor could be scissors that cut in paper or it could be, in the iPad context, an abstract room, that is produced by animated transitions. Carroll and Mack [1999] states that "metaphors can facilitate active learning", thus metaphors in HCI are often used, with more or less success though. The metaphors draws on pre-existing knowledge from the embodiment of our daily life experiences [Dourish, 2001] - this is a well known fact. Interestingly, this fact is exactly why interface designs are so differently. Interface developers have different experiences with design, see things differently, have different bosses etc.

Metaphor used on an iPad

The interaction metaphor used on an iPad in most cases Noun OR verb. Either can an object be manipulated (e.g. page content on level 1) or it is related to an action (e.g a button). Cases where the metaphor used is nearly Full are when the iPad is used as a drawing pad, the user can make brushstroke with the finger on the screen. Obviously if it was in the real word the user would also need to dip the finger in paint before leaving a mark, but interaction wise there is no analogy needed.

The dynamic output from the iPad described in Section 2.13.2 on page 38, shows a number of Noun metaphors that gives a spatial relation between the applications and home screen on the iPad. The metaphor of the content is moved outside the screen gives a close resembles to the real word where objects continue to exist when we stop using them. The iPad interface try to make a spatial metaphor though it may be a bit abstract and not very consistent in some instances.

3.5 Direct manipulation

The gesture terminology in Section 2.1 on page 4 explained deictic and manipulative gestures, whereas deictic gestures can be similar to direct manipulation e.g. drag and drop. The manipulative gestures involve more complicated interactions, which can be e.g. swipe and pinch. Karam [2006] do not define the manipulative gestures as coming from direct manipulation. In 1982 Shneiderman introduced the direct manipulation paradigm [Shneiderman, 1982]. He described three design qualities of direct manipulation, which was observed across different platforms e.g. spreadsheets, video games, and text editors [Shneiderman, 1983].

(1) Continuous representation of the object of interest.

(2) Physical actions or labelled button presses instead of complex syntax.

(3) Rapid incremental reversible operations whose impact on the object of interest is immediately visible.

When swiping and making pinch gestures on an iPad, the three design principles can be located in both gestures. When changing home screen with a one finger swipe or pinching on a picture - see Section 2.8 on page 22 - a continuous graphical feedback of the movement is seen. Furthermore the gestures are dynamic movements which are interpreted by the the gesture recogniser, which execute code according to the movement. Lastly the two gestures have reversible functions and can be made with a "counter-move" - e.g. pinch close to zoom out. Therefore the manipulative gestures, are by these observations and the design principles above, within the direct manipulation paradigm. It can be concluded that the touch inputs made on the iPad are either of a deictic- or a manipulative nature.

When the graphical interfaces started to emerge in the late 1970's and early 1980's Ben Shneiderman [Shneiderman, 1982; 1983] used the term direct manipulation to describe graphical systems, that allowed the user to "directly" manipulate graphical elements, for instance with a mouse, instead of typing complex computer syntax. Human-computer interaction went from dialogue to manipulation - respectively command line interface (CLI) and graphical user interface (GUI), whereas the GUI has contained directly manipulative graphical elements since the early start. Hutchins et al. [1985] tries to explain why direct manipulation feels so "natural" by assuming that the directness in "direct" manipulation results from the: "commitment of fewer cognitive resources. Or, put the other way around, the need to commit additional cognitive resources in the use of an interface leads to the feeling of indirectness." Hutchins et al. [1985] divides directness into two aspects: engagement and distance.

3.5.1 Engagement in directness

The engagement[2] in directness originates from a term coined by Laurel [1986] that is called first-personness. Laurel [1986] describes personness as the "relation to others and to the world." For instance are movies third-person, as the viewer is outside the action. Second-person experience could be operating a computer with an intermediary interface - e.g. a voice-command based application. First-person experience could be writing a letter or taking a stroll in the forest. A first person interface could be a first-person shooter computer game [Laurel, 1986]. Frohlich [1997] derives from Laurel [1986], that "engagement refers to the perceived locus of control of action within the system". E.g. commanding your dog to go fetch a stick instead of doing it yourself, is an indirect interaction with the stick, which means the engagement is lower, than if you had fetched the stick yourself.

The term engagement is divided into two aspects: a language- and a model-world metaphor. The language metaphor is e.g. a voice-command said to a system, the syntax written in a bash promt (or a command to your dog), where the interface of the system has an implicit role as the intermediary to the system. This will not permit the user to have a direct engagement with the objects of interest in the system [Hutchins et al., 1985]. The model world metaphor presents behaving objects in a world (a GUI), where an object can be manipulated by e.g. pointing at the image presenting it and moving the image to a new location. In this case the expression in the output language is allowed by the input language. When referring to the metaphors described by Fishkin [2004] (see Section 3.4.2 on page 49), the language metaphor here would be NONE metaphor dimension. The model world metaphor would be the Noun AND verb dimension.

3.5.2 Distance in directness

Distance is sub-divided into two aspects by Hutchins et al. [1985]: Semantic- and articulatory distance. These are together called the interface language. In general, the semantic distance reflects the "relationship between the user intentions and the meaning of expressions in the interface languages both for input and output." [Hutchins et al., 1985]. The articulatory distance "reflects the relationship between the physical form of an expression in the interaction language and its meaning, again, both for input and output" [Hutchins et al., 1985]. The overall goal is to reduce both of the distances to minimize cognitive effort. An elaboration of the two different distances is found below. [Hutchins et al., 1985]

3.5.3 Semantic distance

The semantic distance contains two factors: an intention from the user and the expression required to reach the goal of the intention. An intention, from a user, could be to delete a specific txt file in a read/write protected folder on a Linux system. The "easiest" way to express this intention to the system, is if the user type "sudo rm /foldername/specificfile.txt" in a Linux terminal. This is easy for an expert, but if the user is a beginner to the Linux

[2]Hutchins et al. [1985] uses "direct engagement".

environment and the user does not know this type of syntax, then the user must provide enough knowledge himself to complete the task. Here the expression level in the interface language is not matching the level at which the person thinks of the task. If the user instead could type in "delete specificfile.txt" then the description levels would nearly match, and the information-processing structure provided by the user would match the information structure from the system.

3.5.4 Articulatory distance

Articulatory distance is the "relationship between the meanings of expressions and their physical form" [Hutchins et al., 1985]. This relationship could be achieved by e.g. swiping to change between home screens, when the intention is to see, what icons is on another home screen. Or if the intention is to draw a diagram, the interface could accept drawing motions as input [Hutchins et al., 1985].

3.5.5 Gulf of execution and evaluation

Both type of distances (semantic and articulatory) span the gulfs of execution and evaluation. The gulfs can be seen in Figure 3.3, where both the side of the gulfs are connected by bridges with the same names. The span of the gulf is an expression of the mental effort required by the user to bridge this span. The Figure is made by Frohlich [1997]. Frohlich [1997] does not explain directness in details as Hutchins et al. [1985], but the Figure is better than in Hutchins et al. [1985].

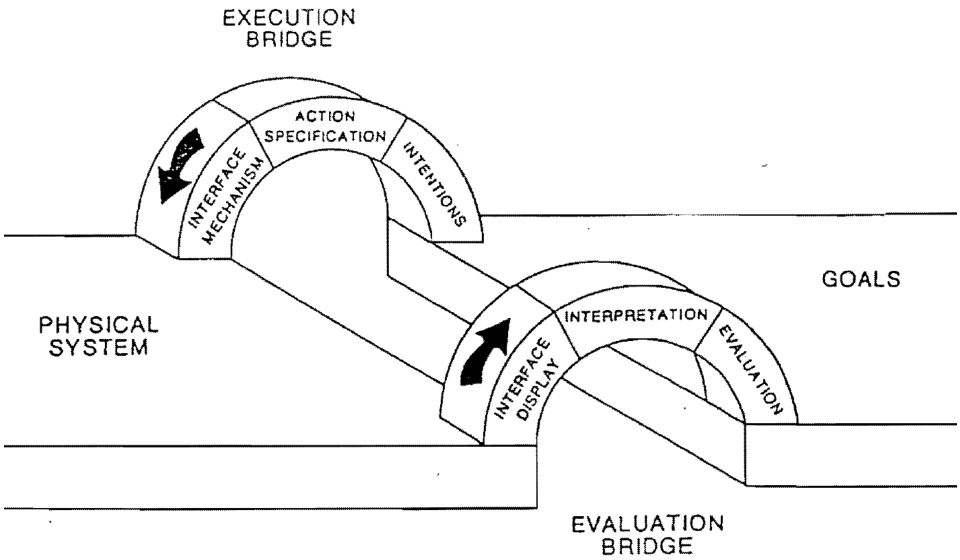

Figure 3.3: The gulf of execution- and evaluation made by [Frohlich, 1997], which illustrates the gulf's better than [Hutchins et al., 1985].

Bridge of execution

The bridge of execution contains three bricks: intention, action specification, and interface mechanism. The first brick Intention is the semantic distance. When the user has a goal, e.g. to tap on a software button on the iPad, the intention is to hit the button with a finger. The intention has to be described by the user himself to start processing the information required to fulfil the task. The user's task description should match the interface language to minimize the "size" of the first brick in the bridge of execution. The next brick, action specification, is where the movement of the body ending in hitting the software button with a finger. This the articulatory distance. Here is the distance the relationship between the intention and the physical form of expression. The last brick, the interface mechanism, is the gesture recogniser on the iPad, which inputs the touch location on the screen to the operating system. To summarise: the execution bridge is build by making commands and mechanisms of the system match thoughts and goals of a user of the system [Hutchins et al., 1985].

Bridge of evaluation

The bridge of evaluation also contains three bricks: interface display, interpretation and, evaluation. The first brick is the interface display. When the operating system has processed the input from the gesture recogniser, the tap on a software button, the GUI changes according to the touch input and provides the user with graphical feedback. The interpretation brick is spanned by the articulatory distance. That is, the meaning of the visual feedback expression in the interface language has to match the form of the output expression. I.e. the software button should seem like it has been tapped. The last brick, the evaluation brick, is the relation between the user's goal and the output expression. This is the amount of processing that is required by the user, to determine if the goal has been achieved. If the output expression is not matching the user's intention, then the user has to translate the output expression to terms he understands. If the amount of information processing is large, the evaluation is bad. To summarise: the evaluation bridge is build by presenting a good conceptual model, on the display, of the system, that is readily interpreted and evaluated [Hutchins et al., 1985].

3.5.6 Examples of engagement and distance on the iPad

Hutchins et al. [1985] define the four interface types seen in Figure 3.4 on the facing page. The Figure shows where direct manipulation is located in relative to the others, with the engagement on the x-axis and distance along the y-axis. It is seen that the distance, in the gulfs of evaluation and execution, are small, whereas the engagement of the interface are model world like. The worst interface style, according to Hutchins et al. [1985], is a low-level language interface, where lengthy or complex syntax must be wrote (into e.g. a bash-promt).

As outlined in Section 3.1 on page 42 the iPad interface is a fourth generation of interface styles, which was defined as "containing at least one interaction technique not dependent on

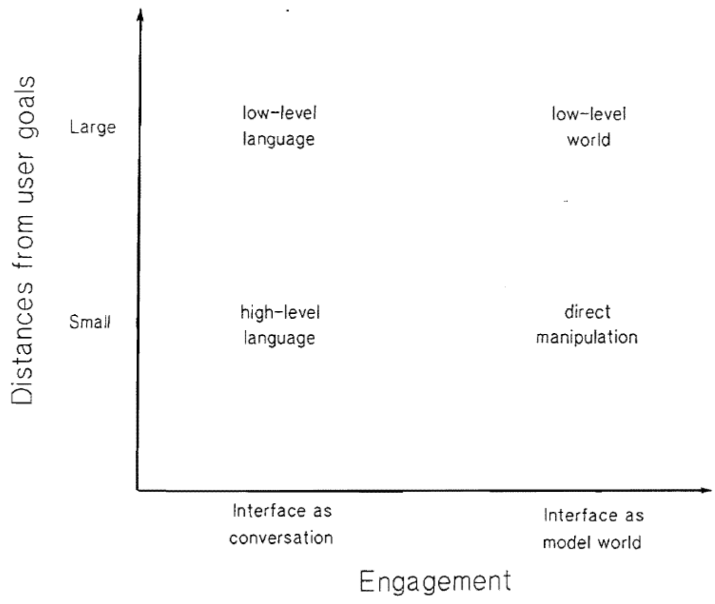

Figure 3.4: The space of interfaces [Hutchins et al., 1985]

classical 2D widgets such as menus and icons" [van Dam, 1997]. That would naturally mean that the types of interaction on the iPad is diverse. An example of this would be how the iPad can be used as a typewriter, where the keyboard is virtual and does not, give tactile feedback. The engagement would be low, since the keyboard is a intermediary between user and system feedback, whereas the distance would be relatively low since, that user can pres on the "a" and have an "a" on e.g. the URL-line in the browser. When the user wishes to change home screen, implying that he knows how, the engagement is high, since you drag the home screen and the distance would be low. If the user did not know how to shift home screens, then distance would be larger, until the evaluation on the bridge of evaluation was good. Herefter the distance would be reduced.

3.6 Low level Cognition

Human cognition is a complex area to describe. Depending on the approach different models for human intelligence can be derived. One of the more interesting models is the hierarchical six-level model proposed by Velichkovsky [1990]. The model by Velichkovsky [1990] is a elaboration on the four level theory of motor control by Bernstein et al. [1996]. The reason for examining this theory is, that it provides a methods for uncovering whether a given mental process belongs to low- or high-level cognition. A description of the six levels can be seen in Figure 3.5 on the following page.

Level A to D are implicated in direct interactions with the environment. Level E and F refer mainly to the formation and modification of the symbolic representation. [Velichkovsky, 1990]. This can be used as guidelines to lower the cognitive level in a interface by reducing the amount of level E and F within the interface.

Code	Level	Basic Function	Examples of phenomena	Form of awareness	Means of formalization
F	metacognitive coordinations	relativization and rearrangement of the conceptual model of the world	propositional attidudes, semantics of mental spaces	reflexion, self-consciousness, productive imagination	metaprocedures (metanetworks)
$E_{1,2}$	conceptual structures	fixation and accretion of the conceptual model of the world	associative effects of proximity and contrast, "survey map"	common consciousness, memory images	declarative-procedural structures
D	actions	regulation of actions with objects	perceptual organization, attention to attributes, "path map"	perceptual image	production systems or neuronal networks
$C_{1,2}$	spatial field	orientation in the near environment	changes in metrics of perceptual "chronotope" and body scheme	spatial sensations	neuronal networks
B	synergies	regulation of organism movements as a whole	motion rhythmic and cyclic patterns	proprio- and tactual-receptor sensations	neuronal networks
A	palaeokinetic regulations	regulation of tonus and basic defensive responses	tonic and palaeovestibular reflexes	protopathic sensitivity	procedures

Figure 3.5: Levels of functional organization of cognitive processes. [Velichkovsky, 1990]

Another approach to the low-level cognition processes core knowledge [Spelke, 2000]. Spelke [2000] describes four core knowledge systems for representing objects, actions, number, and space. The interesting about these systems is that they are universal low-level cognitive processes that can be found in all human infants, children, and adults, and in adult non-human primates [Spelke, 2000]. We can thereby be sure that if the knowledge from these systems are applied to interaction with a system, it is already known by the user and the overall learning curve is reduced. General guidelines for reducing learning can thereby be created, which as a result would facilitate understanding of the system and provide a overall lower cognitive load for the user. The function of the different core systems are according to Spelke [2000]:

- **Objects:**This system gives understanding of object representations and object motion. The key principles are:
  - **Cohesion:** Individual objects moves as one whole and bound thing.
  - **Continuity:** Objects can only move from A to B in a connected and unobstructed path.
  - **Contact:** Objects can only influence each others motion by contact.

  These principles make it possible to recognise different shapes and predict movements of objects. This core knowledge is almost analogue to the Naïve Physics described in Section 3.1 on page 42.

- **Agents:** This core system it used to predict the outcome from a given action conducted by an agent i.e. if a person is about to do some action this can be predicted.

- **Numbers:** This system support us in keeping track of up to four or five, but no more, objects at a time. This system also make us able to distinguish between different amounts of objects within a ratio limit, i.e. it is easy to distinguish between the amount of 3 and 4, 500 and 700 but not as easy between 990 and 1000.

- **Geometry:** This system captures the distances, angles, and relations among surfaces in an environment. A limitation of this system is that it cannot represent colour or odour, or other non-geometric properties of a surface.

This list of function of the core knowledge can be used as guidelines for designing that support low level cognition.

CHAPTER 4

Problem specification

4.1 Problem specification

It was summarised in the findings in Section 2.14 on page 41 that a user of the iPad has to use buttons when engaging the information structure level two to five, where level one is e.g. dragging page content - see Section 2.9 on page 29. When navigating in the iPad interface eleven navigation functions are needed, see Table 2.5 on page 33. Only navigation on level 1 uses a rich interaction form i.e. drag, swipe, pinch. Navigation on level 2 - 5 are accomplished by intermediary interaction with buttons. To enrich the navigation on the iPad, it is therefor needed to find an alternative to the one-finger tap gestures currently used for navigation on the iPad at level 2 - 5. An alternative method can be accomplished by applying multi-finger drag gestures for the nine navigation functions on level 2 - 5.

Using direct gestures, as the drag gesture, it is technical possible to show direct visual feedback on the users input - see Section 2.12 on page 36. If gestures of a symbolic nature were to be applied, it would lead to a delay between user input and visual feedback. Using direct gestures also support the use of Naïve Physics - see Section 3.1 on page 42, by translating the expression of the touch input.

The directness is an important factor for making an enriched interaction since it enables the user to make a more direct coupling between the intention of the action and the evaluation of the function, see Section 3.5 on page 51 and Section 2.7 on page 19. By removing the intermediary between action and function in the navigation it will enhance the engagement in the interaction.

Objects reacting differently to a specific number of touches are a very uncommon occurrence in the real world. The multi-finger drag gestures applied to navigate in the iPad interface, would make the iPad interface seem as such an object. This would lead to an unnatural addition to the interaction with the interface. The user needs to become acquainted with this new type of interaction i.e. the interface does one thing if a drag gesture is conducted in one direction with two fingers, and another thing if the drag gesture is conducted in the same direction with three fingers. The user needs to understand how to make use of these new qualities of the interaction, before an enriched navigation of the iPad interface can be achieved.

To finally answer the initial problem in the motivation (see Section 1.1 on page 1), it is needed to explore what the tradeoff cost is to the user, when introducing a new type object that do not obey the normal rules of interaction with the real world. The authors of this study believe that the benefits of a persistent enrichment in the interaction exceeds the cost of learning to manipulate the new object. For further examination of this claim, a user experiment will be necessary.

The overall experiment hypothesis, which will be elaborated in the next chapter (Chapter 5 on the following page) is as follows:

> *The use of multi-finger gestures in the navigation on the iPad will lead to an improved work flow by enriching the interaction, which is measured in effectiveness, efficiency, easiness, and naturalness compared to one-finger gestures used for the navigation.*

CHAPTER 5

Verifying the test hypothesis

This chapter documents the experiment conducted to verify the hypothesis in Section 4.1 on page 58. The experiment hypothesis requires to put a test subject in a context where it is possible to make measurements and ask questions that will answer whether the experiment hypotheses is true. To answer this question a number of null hypotheses can be made.

5.1 Null Hypotheses

The null hypotheses are based on the overall experiment hypothesis in Section 4.1 on page 58. These predict no differences between the one-finger gesture and multi-finger gestures.

H_0 1 Null hypothesis: The multi-finger interaction method can not improve effectiveness compared to the one-finger interaction method.

H_0 2 Null hypothesis: The multi-finger interaction method can not improve efficiency compared to the one-finger interaction method.

H_0 3 Null hypothesis: The multi-finger interaction method can not improve easiness compared to the one-finger interaction method.

H_0 4 Null hypothesis: The multi-finger interaction method can not improve naturalness compared to the one-finger interaction method.

To confirm or reject the hypotheses in the experiment a context needs to be defined.

5.2 Experiment context

In Section 5.1 the null hypotheses are outlined. These predict no difference between one-finger gesture and multi-finger gestures measured in, effectiveness, efficiency and easiness regarding work flow in navigation. When the difference between two conditions is to be measured, an AB-test is suitable. Condition A in this experiment is the one-finger gesture and condition B is the multi-finger gestures.

To be able to measure on the difference between the two conditions all other variables needs to be constant. It is therefore needed to use a context where a method for navigation can be changed without changing other variables i.e. level of feedback, level of feedforward or the complexity of the task.

Having the test subjects try the gestures in an ecological context, in this case, on an iPad with iOS, would seem logical, since a direct comparison of how the work flow of one-finger gestures and multi-finger gestures could be made. There are several troublesome aspects in this though. The one- and multi-finger interactions methods should have the same level of feedforward in the interface (see affordance in Section 3.3 on page 44). This to avoid the difficulty of conducting the correct gesture becoming a highly influential confounding variable, which would increase the chance of conducting type 1 errors, where the hypothesis is correct, but the test rejects it [Dalgaard, 2008].

In Section 2.6 on page 19, it was seen that the iPad interface gives the opportunity to conduct one- and two-finger gestures (in default iOS 4.3). The functions coupled to one-finger gestures have a somewhat feedforward as they can be activated via visual available buttons, whereas gestures utilising more than one finger has no feedforward. If the multi-finger should be implemented in iOS, and the design theme of iOS is to be retained, the multi-finger gestures would not have any indications of being available. One-finger dragging or swiping on page content, though, has no feedforwad, but most people who have experience with smartphones know they can manipulate page content page in a given direction by using one-finger gestures, why the multi-finger gesture would still be impaired compared to one-finger gestures regarding feedforward. It was therefore decided to make the present experiment without the iOS context, but still with navigational tasks to observe the work flow.

A context that is comparable navigational work flow of the iPad was needed to be designed. A gesture set of at least eleven different gestures is required to fulfill the navigation functions needed to navigate level 1 - 5 on the ipad - see Section 2.10.1 on page 32.

The gesture chosen must support the use of Naïve Physics in the interface. Naïve physics can be accomplished by implementing one of the qualities in direct manipulation - continuous representation of the object of interest - the object should during a move, follow the fingers touching the screen. This would also abide the time, direction, location, dynamics, and expression guidelines described in Section 2.7 on page 19. To satisfy these requirement a multi-finger drag gesture seams best suited.

Multi-finger drag in four directions(left, right, up, down) would add 16 gestures to the current iPad gesture set and still allow for the one-finger drag, swipe, pinch, tap, double tap, touch and hold, Drag and drop, and rotate. It is hard to say if some of the multi-finger drag gestures would be better than others, it is therefore decided to test all of them in multi-finger condition. The context therefore needs to be one where an object with continuous representation, that can dragged in four directions in five different levels. To make an AB test with one-finger the object must support one-finger manipulate on five levels and one-finger drag in four directions.

With these considerations the context chosen for the experiment are:

- Object with continuous representation that can be manipulate in five levels.
- Object that can be dragged in four direction(left, right, up, down).

- Object that feedforward the number of levels it can be manipulate on.
- Object that give continuous feedback on what level it is manipulative.
- Condition A: one-finger level selection and one-finger drag in four. directions(left, right, up, down)
- Condition B: 1-5 finger drag in four directions(left, right, up, down).

5.3 Experimental Design

To have the qualities of one- and multi-finger gestures compared, a directly subjective comparison was needed. Specifically it was desired to have the test subjects explore both of the gesture methods to make a decision on what method is their preferred. To do this, a within-subject experiment design was needed. The main advantage of a within subject design, is that it does not require a large subject pool since the conditions are tested across the subjects. If the conditions were to be tested in two different groups, a between subject design, it would require, as a thumb rule, a twice as large subject pool. In a within-subject design it is possible to reduce the subject pool, due to the reduced individual differences across conditions. Specifically, it is assumed that the within subject variability will not vary across conditions.

Disadvantages of the within-subject design are e.g. the practice effect and the carry-over effect. The practice effect is an experiment effect where subjects improve from the first to next condition. Furthermore, the test subjects could get simply bored of the amount of trials or other long lasting experiment parts. The carry-over effect is an experiment effect, where e.g. a negative first-expression influence the rest of the experiment. Or in the opposite direction - if the first-expression is really good, the test subjects will not rate the second condition as low as they would have, if they had got the second condition first. To reduce these effects in the present experiment, the condition order were counter-balanced. First test subject got the condition A then condition B, the next subject was given condition B then condition A, and so on.

5.4 Task design

To be able to compare performance data from the 20 different combinations of levels and directions the tasks needs have the same work flow.

It was decided to use a task where the subject needs take a part of a figure and drag and drop it to a another part of the screen. To make the task comparable the length of the drag needs to be the same in all tasks. Furthermore it is decided to reduce the need for preciseness in the task by making the object snap to either the figure or a drop zone. It was decided to make the drop zone larger than the object to make the drop easier. A list of the 20 combination of task can be seen in Table 5.1 on the facing page.

A illustration of how a task is completed in condition A is shown in Figure 5.3 on the next page. Figure 5.4 on the following page shows the object manipulated on the wrong level. The same illustrations for condition B is shown in Figure 5.1 and Figure 5.2 on the next page.

To have the possibility of comparing each subject and keeping the experiment settings constant for each test subject, the task order was randomised. This would avoid the task order becoming influential on the data outcome. For instance if the five-finger tasks where found extremely hard to perform by the test subjects, then continuously placing it at the end of the multi-finger session could be a possible carry-over effect. Given that the task order was randomised it was necessary to control, for each task, in which direction, the test subjects had to move the selected levels of the object to the dropzone (grayed area). If the task at hand, was to move four levels from the object to the left, then to accomplish the task, the test subjects would have to select and move a specific number of levels from the object, to the dropzone located on the left side of the object.

Tasks	**Action in iPad context**	**Action with multi-finger**
Level 1		
Move level 1 of figure up	One finger drag up	One finger drag up
Move level 1 of figure down	One finger drag down	One finger drag down
Move level 1 of figure left	One finger drag left	One finger drag left
Move level 1 of figure right	One finger drag up	One finger drag up
Level 2		
Move level 1+2 of figure up	Tap level 2 + drag up	Two finger drag up
Move level 1+2 of figure down	Tap level 2 + One finger drag down	Two finger drag down
Move level 1+2 of figure left	Tap level 2 + One finger drag left	Two finger drag left
Move level 1+2 of figure right	Tap level 2 + One finger drag right	Two finger drag right
Level 3		
Move level 1+2+3 of figure up	Tap level 3 + One finger drag up	Three finger drag up
Move level 1+2+3 of figure down	Tap level 3 + One finger drag down	Three finger drag down
Move level 1+2+3 of figure left	Tap level 3 + One finger drag left	Three finger drag left
Move level 1+2+3 of figure right	Tap level 3 + One finger drag right	Three finger drag right
Level 4		
Move level 1+2+3+4 of figure up	Tap level 4 + One finger drag up	Four finger drag up
Move level 1+2+3+4 of figure down	Tap level 4 + One finger drag down	Four finger drag down
Move level 1+2+3+4 of figure left	Tap level 4 + One finger drag left	Four finger drag left
Move level 1+2+3+4 of figure right	Tap level 4 + One finger drag right	Four finger drag right
Level 5		
Move level 1+2+3+4+5 of figure up	Tap level 5 + One finger drag up	Five finger drag up
Move level 1+2+3+4+5 of figure down	Tap level 5 + One finger drag down	Five finger drag down
Move level 1+2+3+4+5 of figure left	Tap level 5 + One finger drag left	Five finger drag left
Move level 1+2+3+4+5 of figure right	Tap level 5 + One finger drag right	Five finger drag right

Table 5.1: Functions and actions needed for navigating the information structure of the iPad.

5.4.1 Illustration of task in condition A

The subject can solve the tasks with one-finger tap and one-finger drag.

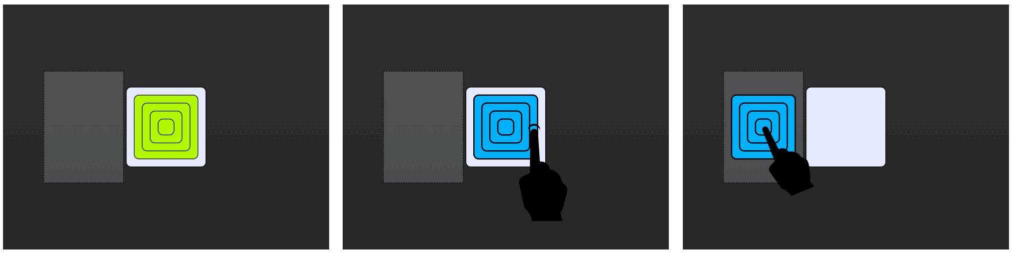

Figure 5.1: Example of task in condition A.

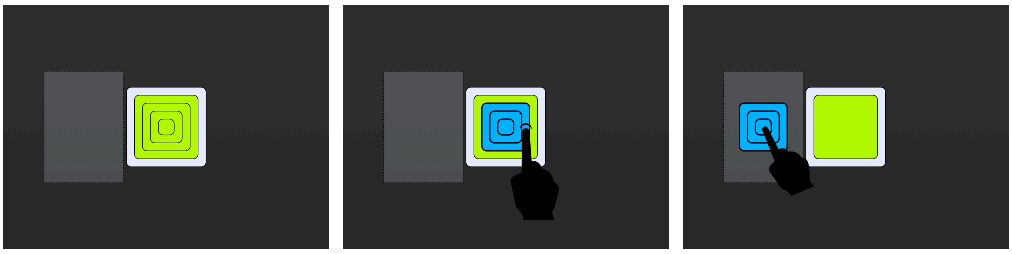

Figure 5.2: Example of task complete wrong in condition A.

5.4.2 Illustration of task in condition B

The subject can solve the tasks with multi-finger drag.

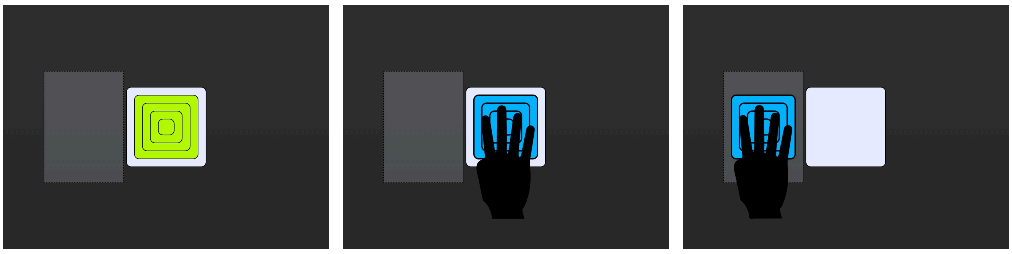

Figure 5.3: Example of task complete right in condition B.

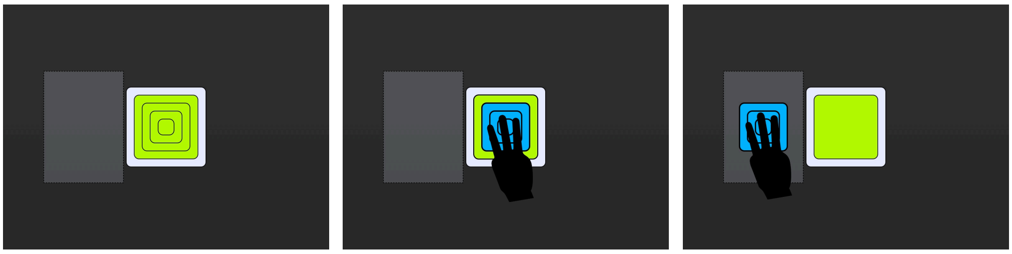

Figure 5.4: Example of task complete wrong in condition B.

5.4.3 Rules of the task

To make the task comprehensible a set of rules must be made on how the object react and how the task is completed.

- The game is first completed when the correct levels of the object is dragged into the dropzone.
- If too few levels are dragged into the dropzone the task is incomplete. The levels have to be moved back to the rest of the object, before the correct levels from the object can be dragged into the dropzone.
- If too many levels are dragged into the dropzone the task is incomplete. The levels have to be moved back to the rest of the object, before the correct levels from the object can dragged into the dropzone.
- If levels are dropped outside the dropzone they will snap back to the start location of the object.
- If levels are dropped inside the dropzone they will snap to the center of the dropzone.
- The object can only be separated in two parts. i.e. it not possible to have level 5+4+1 in the start location and level 3+2 in the dropzone. In this case level 1 would snap back to level 2+3.
- If the wrong number of levels are in the dropzone, the levels outside dropzone are locked. It is only possible to make levels snap back to the start location if all levels in the dropzone are moved together. If too few levels are dropped outside dropzone they will snap back to the center of dropzone.
- Whether the object is dropped in the dropzone is determined of whether the centre point of the object is dropped into the dropzone. I.e. when more than half of the object is dropped in the dropzone it will snap to dropzone.

5.5 Design of test application context

After removing the iOS context, the functions and graphical elements in iOS are not available, why an object with the unnatural nature as described in Section 4.1 on page 58 was found applicable. The object would have to behave differently on a differentiated number of finger touches moved in the same direction. To give the test subjects the appropriate feedforward the object had to be shown at all time. The alternative was to have them drag an invisible object into focus, from outside the edges of the screen, but a predominant disadvantage was coupled to this approach. Besides the missing feedforward (Section 2.7 on page 19), the test subjects would have to link a specific number of touches to a specific task, which would make the experiment more a memory experiment than an experiment concerning the gestures and the understanding of them.

It was desired to have the subjects move the object the same distance in all four directions, why the distance from object center to dropzone would have to be the same in all directions. This way, it would give the directions the same conditions, when interpreting the ergonomic measures from the experiment. This distance constrain yielded, that the width of the iPad screen became the maximum length from the rear edge of the object and dropzone - see Figure 5.5.

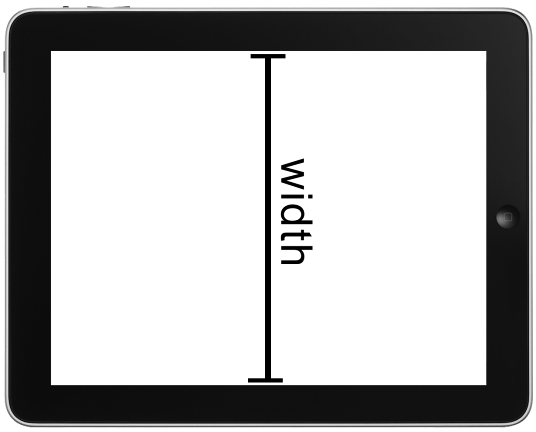

Figure 5.5: Maximum distance that the object and dropzone can occupy.

To avoid visual search as much as possible, it was desired to have the object located in the same point of origin e.g. the center of the screen at all time, and only have the dropzone changing position. This would give the test subjects an opportunity to quickly learn where to focus when a new task appeared. This approach though, was problematic since the object became too small. By using one half of the screen to the object and the other half to the grayed area, real screen estate was optimised - see Figure 5.6. An alternative that was not selected can be seen in Figure 5.7. This way, visual search would still be reduced but not as much, as locating the object in the same point of origin.

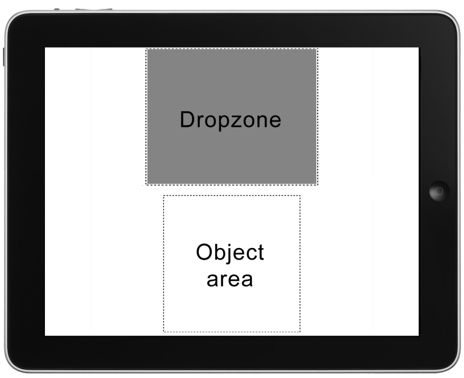

Figure 5.6: The selected object and dropzone poportions.

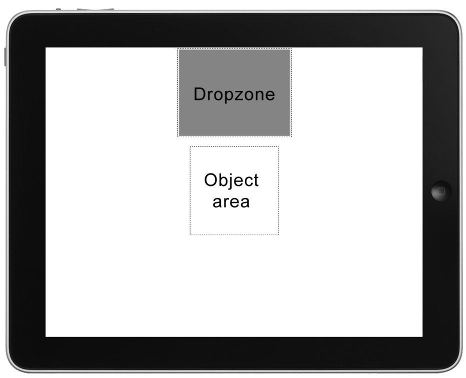

Figure 5.7: The deselected alternative. The object size in this propositions is to small.

5.6 Graphical design

Firstly, the manipulatable object in the experiment application should afford grasping, which will be tested if holds true in the trial round. Secondly, it should be visually divided in five levels, where each level has to be, individually or together with other levels, movable in four directions (left, right, up, down). This will allow for observing if the test subjects understand the unnatural nature of the object, and furthermore if there are directions that are ergonomically more troublesome than others to move specific levels of the object in. When separating the levels it should be easy to see a difference in the visual layout e.g. by using high contrast, colours, occlusion (see Section 3.3 on page 44) or other visual effects. It was considered how to optimise screen real in the experiment. In the application design, this gave the advantage of having the largest possible area compared to e.g. a cylinder form. An object with the mentioned qualities can be seen in Figure 5.8. The Figure shows three stages. a) The levels to be moved are marked. b) The levels are selected. c) The levels are being moved.

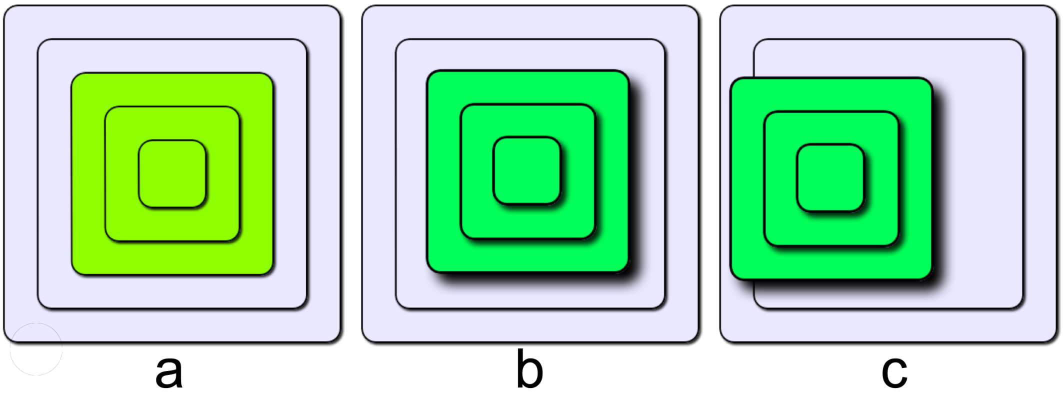

Figure 5.8: An object with the wanted qualities.

5.7 Experiment flow

The experiment was designed to make the test subjects believe that they should test and give feedback on two different forms of interaction methods for a new game. The game context was used to give the test subjects an element of stress and heighten concentration and focus on the task.

The experiment consists of two conditions that need to be tested. Each conditions have three rounds: trial, training, and performance. The manuscript for the experiment can be seen in Appendix B on page 120 and the templet to declaration of consent can be seen in Appendix C on page 122.

5.7.1 The trial round

This implemented to observe the test subjects' immediate understanding of the condition.

The test subject was instructed to move the green part of the pyramid to the dropzone to solve the task. The test subject would not receive any further help on how to do that. By having the test subjects explore the application themselves, it should be possible to evaluate if the condition were designed in a satisfactory way regarding feedforward and feedback, e.g. if the object afforded grasping. This session was restricted to one minute.

After one minute of trial the test subjects were interviewed, before continuing to the training round.

5.7.2 The training round

In this round the test facilitator gave the test subjects detailed instructions on how to use the interaction methods. The training round continued until the facilitator and the test subject agreed that, the test subject had understood the interaction.

5.7.3 The performance round

The test subjects were to complete a task set with 60 tasks as fast as possible. The set consisted of three of each variations of the gesture set. It was decided that all subjects should have the same sequence of tasks to make the data comparable. The task set can be seen in Table 5.2 on page 70.

After the performance round the test subjects were asked to fill out a questionnaire, after which the test subjects were interviewed, before proceeding to next round.

A flow diagram of the experiment flow can be seen in Figure 5.9 on the facing page.

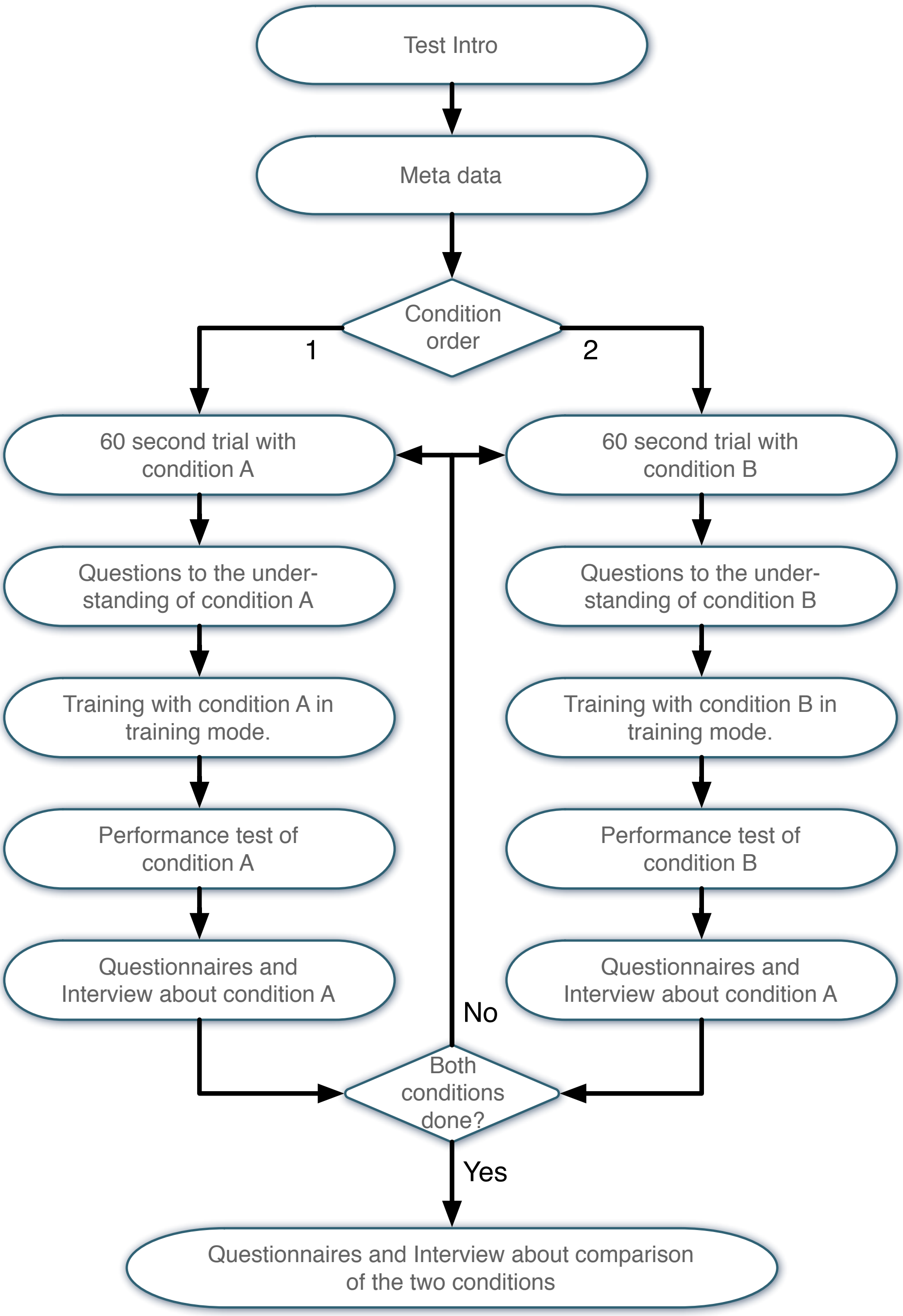

Figure 5.9: Experiment flow.

5.7.4 Task order

The set of tasks are the same for the one-finger and the multi-finger condition. It is thereby possible to compare the completion time and errors in the individual tasks. The task order can be seen in Table 5.2. The trial round and the training round use different tasks sets to prevent the test subjects from learning the task order by too many repetitions.

Task number	Levels	Direction	Task number	Levels	Direction
1	2	Left	31	3	Down
2	5	Left	32	2	Left
3	3	Down	33	4	Right
4	2	Up	34	4	Left
5	1	Right	35	4	Down
6	5	Left	36	2	Down
7	1	Up	37	4	Left
8	5	Up	38	3	Up
9	2	Right	39	3	Right
10	1	Left	40	1	Up
11	4	Up	41	5	Down
12	3	Right	42	4	Down
13	5	Up	43	2	Right
14	2	Down	44	4	Up
15	3	Up	45	5	Right
16	2	Down	46	4	Left
17	3	Down	47	5	Left
18	3	Left	48	5	Down
19	1	Right	49	3	Up
20	2	Right	50	4	Up
21	5	Down	51	1	Right
22	2	Up	52	1	Down
23	2	Left	53	4	Right
24	5	Right	54	1	Left
25	3	Left	55	3	Left
26	2	Up	56	1	Down
27	4	Right	57	5	Right
28	5	Up	58	1	Up
29	1	Down	59	4	Down
30	1	Left	60	3	Right

Table 5.2: Task Order for one-finger and multi-finger condition in taskMode.

5.8 Experiment setup

The experiment was conducted with one experiment facilitator and one experiment assistant. The role of the test facilitator was to guide the test subject through the experiemtn and conduct the interviews. The role of the assistant was to observe and make a note of what the test subject did and said. A list of the equipment used to conduct the experiment can be seen in Table 5.3. A illustration of the setup used can be seen in Figure 5.10 on the next page.

Equipment	Model	Description
iPad	Model: iPad2 16GB wifi	Runing the test application
Dictaphone	iPhone 4 32GB	Used to record the sound under the experiment
Laptop	VisionNotebook running windows 7	Used by the experiment assistant to take notes

Table 5.3: Equipment list

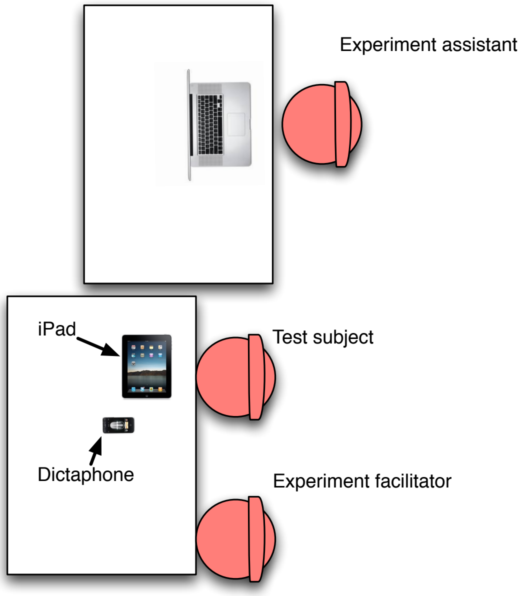

Figure 5.10: Experiment setup seen from above.

5.9 Data collection

To answer the null hypotheses a set of more specific test hypotheses and interview hypotheses was made.

5.9.1 Test hypotheses

H_0 1

1. The amount of different types of errors is not greater in the multi-finger interaction method compared to the one-finger interaction method.
2. One- to five-multifinger gestures have the same effectiveness compared to the one-finger interaction method.
3. The amount of different types of errors perceived by the test subjects is not greater in the multi-finger interaction method compared to the one-finger interaction method
4. The multi-finger interaction method is perceived less difficult of righting errors by the test subjects compared to the one-finger interaction method.
5. Errors in the multi-finger interaction method are perceived less problematic when righting errors by the test subjects compared to the one-finger interaction method.

H_0 2

1. The multi-finger interaction method is more efficient compared to the one- finger interaction method.
2. One- to five-multifinger gestures have the same efficiency compared to the one-finger interaction method.
3. The multi-finger interaction method is perceived more efficient by the test subjects compared to the one-finger interaction method.

H_0 3

1. The multi-finger interaction method is perceived more easy when selecting the correct levels from the pyramid by the test subjects compared to the one-finger interaction method.
2. The multi-finger interaction method is perceived more easy when moving the correct levels from the pyramid by the test subjects compared to the one-finger interaction method.
3. One- to five-multifinger gestures are perceived more easy by the test subjects compared to the one-finger interaction method.
4. The multi-finger interaction method is more easy when compared to the one-finger interaction method.
5. The multi-finger interaction method do not contribute to more cognitive load compared to the one-finger interaction.
6. The easiness of the four drag directions is perceived the same by the test subjects.

H_0 4

1. The multi-finger interaction method is perceived more natural when grasping the correct levels from the pyramid by the test subjects compared to the one-finger interaction method.
2. The multi-finger interaction method is perceived more natural when moving the correct levels from the pyramid by the test subjects compared to the one-finger interaction method.

Trial round

1. The test subjects do comprehend the multi-finger interaction method better than the one-finger interaction method.

Interview

1. The multi-finger interaction method do not contribute to more fatigue compared to the one-finger interaction.
2. The test subjects would prefer the multi-finger interaction method in future play with the game.

5.9.2 Meta data

To be able to categorise potential differences between test subjects the following meta data was gathered:

- subject ID
- Gender
- Age
- Dominant hand
- Experience with media tablets (Five items Likert scale)
- Experience with touch screens (Five items Likert scale)

5.9.3 Quantitative data

To measure effectiveness and efficiency some quantitative data were to be gathered in the experiment. The specific measurements are elaborated upon in Section 5.12 on page 81.

Efficiency data:

Time it takes to complete each of the tasks in performance mode.

Effectiveness data:

The number of errors in each of the tasks in performance mode. To give a detailed account of errors these are categorised into three different events.

Event 1 The subject drags the wrong level into the dropzone.

Event 2 The subject starts and ends a drag without dragging levels out of the start zone.

Event 3 The subject starts and ends a drag without completing the task.

These Events can be seen as errors on different levels. Event 1 can be seen as a more critical error because it needs a reverse action before the task can be completed. This reversible action has to easily accomplished to encompass the qualities from direct manipulation - see Section 3.5 on page 51.

5.9.4 Qualitative data

This section elaborates on the qualitative data gathered during the experiment.

Interview after exploration of both conditions

After introduction of the experiment, the test subjects were supposed to explore the first introduced condition themselves. The trial round, was where the test subjects tried to figure out the interaction method themselves. Afterward they had to explain how they understood the interaction method designed. How well they understood the interaction method will be quantified on the following scale:

- ❑ The subject did not understand the interaction.
- ❑ The subject did understand the interaction partly.
- ❑ The subject did understand the interaction fully.

Instructions after exploration

After the subjects were asked for their understanding of the interaction methods, they were provided with the same instructions by the test facilitator. This to give all test subjects the same chance to understand the given method.

Questionnaire and interview after the performance tests

After each conditions the test subjects answered a questionnaire on the iPad. The questionnaire was answered on a 15 cm long open ended VAS [Seymour et al., 1985] with anchor points 1.5 cm and 13.5 cm from the left edge of VAS. The design of the VAS can be seen in Figure 5.11.

The questions on the VAS scales are formulated on basis of the null- and test hypotheses. The questions answered to in the experiment were formulated in Danish. Below an English translation is seen.

Figure 5.11: Example of VAS design used for experiment

One-finger gesture interaction

1. How was it to select the correct level of the pyramid? Very hard - very easy
2. How was it to move the selected levels?: Very hard - very easy
3. How was it to grasp the pyramid? Very unnatural - very natural
4. How was it to move the pyramid? Very unnatural - very natural
5. I thought the amount of errors I made was: Very low - very high
6. To right my errors was: Very hard - very easy

Multi-finger gesture interaction

1. How was it to move with level 1?: Very hard - very easy
2. How was it to move with level 2?: Very hard - very easy
3. How was it to move with level 3?: Very hard - very easy
4. How was it to move with level 4?: Very hard - very easy
5. How was it to move with level 5?: Very hard - very easy
6. How was it to grasp the pyramid? Very unnatural - very natural

7. How was it to move the pyramid? Very unnatural - very natural

8. I thought the amount of errors I made was: Very low - very high

9. To right my errors was: Very hard - very easy

Interview after the questionnaire

After the questionnaire the test subjects were interviewed to gain a more detailed opinion on the current game interaction method. During the experiment interview questions were asked by the facilitator.

1. Test subjects were asked to elaborate on their choice in the questionnaires.

2. Test subjects were asked if they had to think a lot during task solving, and whether they needed to count the number of levels to figure out the number of fingers they should use the move the correct number of levels.

3. Test subjects were asked it they have noticed a difference in how difficult it was to move the object in different directions.

4. Test subjects were asked it they had noticed fatigue in their hand and arm under during performance task.

5.9.5 Exit interview and questionnaire - after completion of booth conditions

After the last performance tests and interview was conducted. The test subjects were given a questionnaire on the iPad, concerning a comparison of the two conditions on three VAS scales. Here the anchor points where the two conditions and a neutral point was naturally located in the middle of the VAS scales. The English translation of the questions can be seen below.

Comparison of One-finger and Multi-finger gesture interaction

1. In regards to completing the game: The one-finger game was much easier - The multi-finger game was much easier

2. In regards to completing the game: The one-finger game was much faster - The multi-finger game was much faster

3. In regards to completing the game, the errors I experienced were: Much more problematic in the one-finger game - Much more problematic in the multi-finger game

Exit interview

The exit interview consisted of following questions.

1. Test subject was asked to elaborate on there choice in the questionnaire
2. Test subject was asked they should think about hot to complete tasks in one of the conditions compared to the other one.
3. Test subject was asked to choose between what condition they would prefer in a final game. They was asked to elaborate on there thought.
4. Finally the test subjects was asked if the thought multi-finger interaction would be useful to use in other contexts on the ipad.

5.10 Experiment application design

The application for the experiment is made as a native objective-c app for iPad iOS 4.3.3. The app is made with native iOS navigation elements and standard iOS gesturerecognizer.

The iPad screen resolution is 1024x768 px (pixel) in portrait mode. To ensure the length that the subjects need to move the object is identical in all directions a square area of 768x768 px will be used for object area - see the white area on Figure 5.12 and Figure 5.13. It is hard to use the five-finger gesture on a small area, so it was decided to maximise the size of the object. A size of 370x370 px was decided to be the optimal size. This to allow a little space between object and the dropzone area. The task was to move the object from area 1 to 2, from area 2 to 1, from area 3 to 4, or from area 4 to 3 - see Figure 5.12 and Figure 5.13.

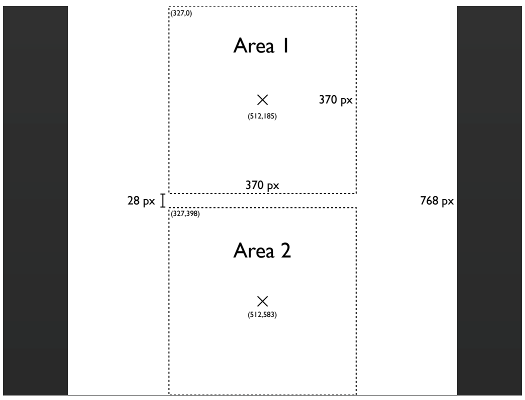

Figure 5.12: Area 1 and 2, placement of pyramid start zone and drop zone in up and down tasks

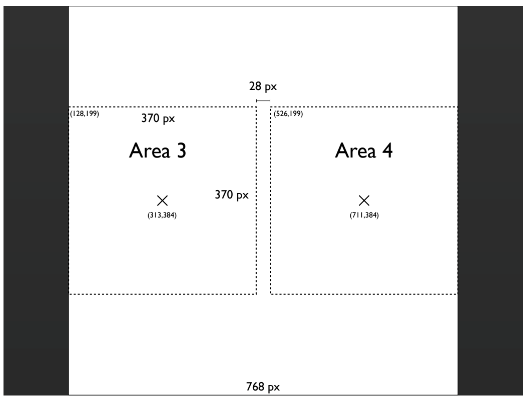

Figure 5.13: Area 3 and 4, placement of pyramid start zone and drop zone in left and right tasks

The object that the test subjects need to move, has to be manipulatable in five levels, and the distance required to move the levels needs to be the same in all five levels. The object has be able to provide feedback on what level the test subjects need to manipulate to solve the task. Furthermore the object needs to give continuous and distinct response on the user's actions. It was decided to use a pyramid-like shape - seen from above. This shape will satisfy all requirements for the object to be manipulate by multi-finger gestures and one-finger gestures. Furthermore it will also provide some functional feedforward (see Section 2.7 on page 19) to how many fingers are needed to manipulate each level. I.e. the larger the figure gets the more fingers are needed to manipulate it. A illustration of this figure can be seen in Figure 5.14. Each level can be seen as a independent button, apple suggest a size of 44x44 px in their human interface guideline [Apple Inc., 2011*c*]. The size of each levels of the pyramid figure are encreased by 74 px, relative to layer above, which gives 37 px of touch area. In comparison the spacing of the iPhone keyboard are 29 px. Therefore, there should be a good chance for the test subjects to hit the intended level of pyramid, even though it is a bit smaller than the optimal size of 44 px.

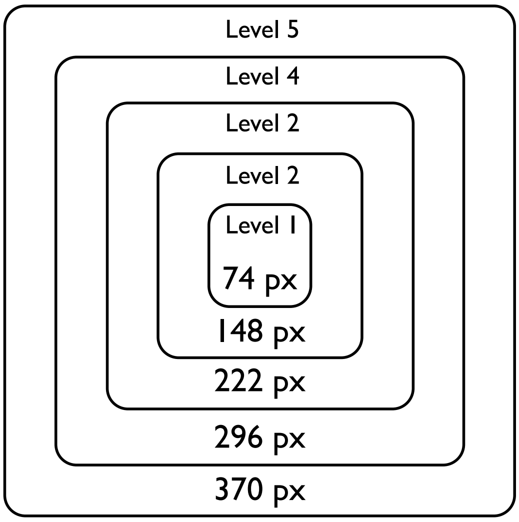

Figure 5.14: Illustration of the 5 levels of the pyramid with pixel values

The object have four stages to give feedback and feedforward: no indications, indication of a what level needs to be manipulated, indication of what level of the figure is selected, and what level of the figure is being moved. These stages are illustrated below.

5.10.1 No indications

All levels are same colour and there are only a small shadow to give the pyramid a feeling of perspective (see Section 3.3.1 on page 46) - see Figure 5.15 on the following page.

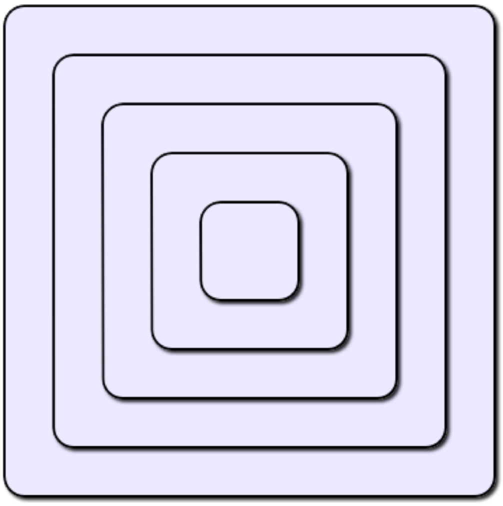

Figure 5.15: Graphics for pyramid with no indications

5.10.2 Indication of a what levels need to be manipulated

What level needs to be moved is indicated by a colour change of the figure, see Figure 5.16.

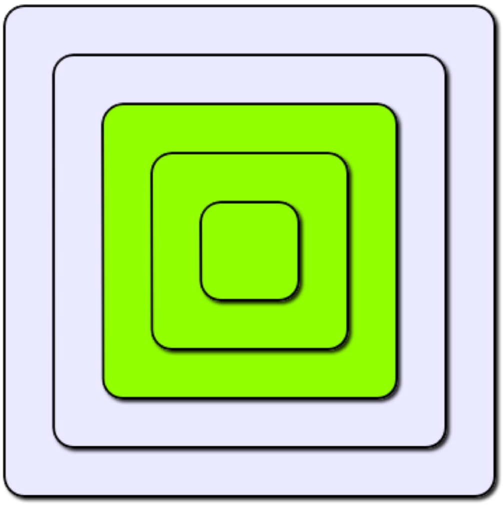

Figure 5.16: Graphics for pyramid with indication of a what level need to be manipulate

5.10.3 Indication of which levels of the figure are selected

When a level is selected, the selected levels move 3 px up and to the left. Then a larger shadow appears beneath the lowest selected level. The stroke is expanded from 2 to 3 px and the colour is tinted. These effects are applied to indicate that the selected levels are lifted from the pyramid, and to make it easy to see what is currently manipulated, see Figure 5.17 on the facing page.

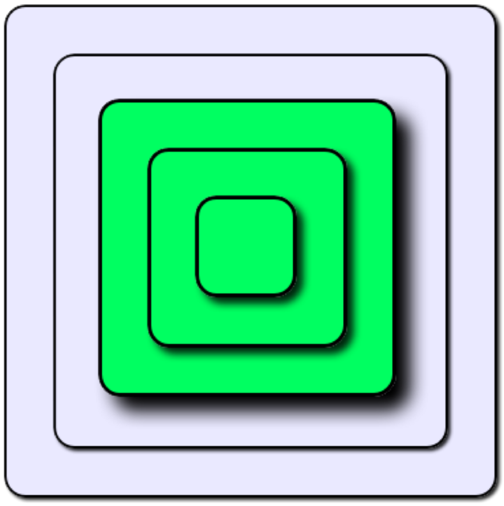

Figure 5.17: Graphics for pyramid with indication of what level of the figure is selected

5.10.4 Levels of the figure are being moved

When a number of levels are selected they are draggable in all directions and follow the dynamics of the drag. A illustration of a drag can be seen in Figure 5.18.

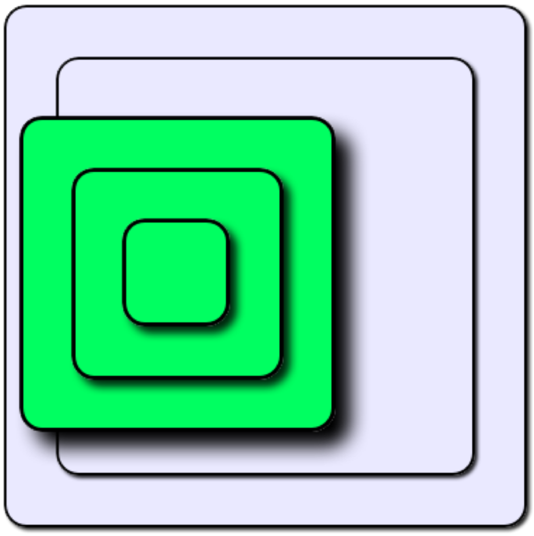

Figure 5.18: Graphics for pyramid when levels of the figure are being moved

5.11 Design of game mechanics

5.11.1 Snap points

When the levels of the pyramid figure is dragged and dropped it will snap to either the centre of pyramid or the centre of drop zone. Depending of task direction these points have different coordinates.

- When task direction = up
  - drop area (512,185) when coordinate of drop is between (277,0) and (747,370)
  - else drop (512,583)
- When task direction = down
  - drop area (512,583) when coordinate of drop is between (277,398) and (747,768)
  - else drop (512,185)
- When task direction = left
  - drop area (313,384) when coordinate of drop is between (128,149) and (498,619)
  - else drop (711,384)
- When task direction = right
  - drop area (711,384) when coordinate of drop is between (526,149) and (896,619)
  - else drop to (313,384)

5.11.2 Task completed

When the game starts the screen is empty and the task is animated in from the left with a 300 ms long slow in- and out transition. The test subjects are not able to move the object before the animation stops. The measurement of task completion time starts when the animation stops and ends when the right number of levels are dropped in the drop zone. The duration of the animation are not include in the task completion time.

When a task is completed it is animated out to the left and a new comes in from the right.

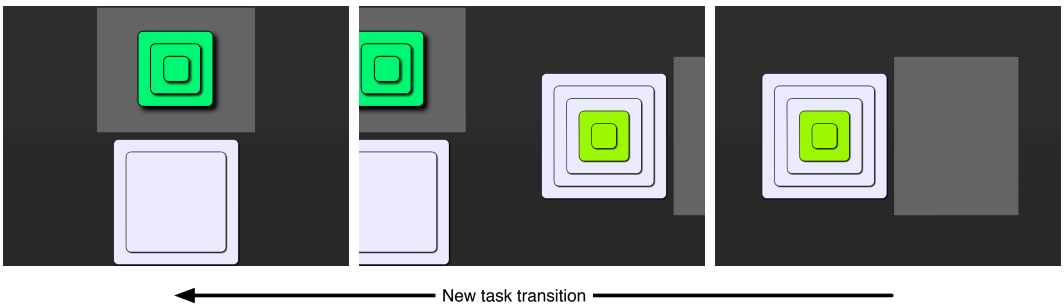

Figure 5.19: Transition between tasks.

5.12 Data structure

5.12.1 Variables

Metadata

Variable name	Description
ID:number	subject identifier
gameOrder:boolean	0 = one-finger game first, 1 = multi-finger game first
gender:boolean	0 = male, 1 = female
age:number	subject age
handOrientation:boolean	0 = left, 1 = right
ipadskill:number	0-4
iphoneskill:number	0-4

Table 5.4: Variable name for metadata

Questionary

Variable name	Description
VAS_A1:number	Number between 0-780 markings at 80 and 700
VAS_A2:number	Number between 0-780 markings at 80 and 700
VAS_A3:number	Number between 0-780 markings at 80 and 700
VAS_A4:number	Number between 0-780 markings at 80 and 700
VAS_A5:number	Number between 0-780 markings at 80 and 700
VAS_A6:number	Number between 0-780 markings at 80 and 700
VAS_B1:number	Number between 0-780 markings at 80 and 700
VAS_B2:number	Number between 0-780 markings at 80 and 700
VAS_B3:number	Number between 0-780 markings at 80 and 700
VAS_B4:number	Number between 0-780 markings at 80 and 700
VAS_B5:number	Number between 0-780 markings at 80 and 700
VAS_B6:number	Number between 0-780 markings at 80 and 700
VAS_B7:number	Number between 0-780 markings at 80 and 700
VAS_B8:number	Number between 0-780 markings at 80 and 700
VAS_B9:number	Number between 0-780 markings at 80 and 700
VAS_C1:number	Number between 0-780 markings at 80 and 700
VAS_C2:number	Number between 0-780 markings at 80 and 700
VAS_C3:number	Number between 0-780 markings at 80 and 700

Table 5.5: Variable name for VAS ratings

Game data

5.12.2 Data files

The data export in to four different csv-files. One file is a complete log-file and the other three file are filtered down datasets to aid data processing.

Variable name	Description
gameCondition:boolean	0 = One-finger mode, 1= multi-finger mode
gameMode:string	learnMode, freeMode, taskMode
numberOfTasksInGame:number	Number of tasks before game mode stops
gameStartTime:time	sets when the first task starts
gameEndTime:time	sets when the last task is completed
gameTotalTime:time	gameEndTime:time - gameStartTime:time
taskShownTime:time	sets when animation stops and task is shown
taskTouchTime:time	sets when the user touches the screen
taskEndDragTime:time	sets when drag ends
taskCompletionTime:time	sets when task is completed
taskCompletionTimeTotal:time	taskCompletionTime:time-taskShownTime:time
numberoflevels:number	1, 2, 3, 4, or 5
direction:string	0(left), 1(right), 2(up), or 3(down)
currentTasknumber:number	0-numberOfTasksInGame
touches:number	number of touches,sets when a level is selected
event:string	TouchStart,TouchTap,TouchEnd
dropPoint:position	Centre position of figure when drag starts
toZone:boolean	StartZone,DropZone,NoZone (The zone the pyramid snaps to when a drag ends)
fromZone:boolean	StartZone,DropZone,NoZone (The zone the pyramid are in when TouchStart or TouchTap occur)
taskNotCompleted:boolean	0 = No, 1= Yes

Table 5.6: Variable name for Game data

High score

Contains time form condition A and condition B for all test subjects

String: ID, gameMode, gameTotalTime

Questionnaires

Contain VAS ratings from all test subjects. All vas ratings are saved when the subjects exits the test.

String: ID, gameOrder, gender, age, handOrientation, ipadskill, iphoneskill, VAS_A1, VAS_A2, VAS_A3, VAS_A4, VAS_A5, VAS_A6, VAS_B1, VAS_B2, VAS_B3, VAS_B4, VAS_B5, VAS_B6, VAS_B7, VAS_B8, VAS_B9, VAS_C1, VAS_C2, VAS_C3

Task Data

Contains data form when a task is complete. Each time a task is completed the data is saved to this file. The file will contain Task Data from all subjects.

String: ID, gameOrder, gender, age, handorientation, ipadskill, iphoneskill, gametype, gameMode, currentTasknumber, taskTotalTime, numberOfLevels, direction,

Logfile

The log file contains all data logged by the software. There is written to the log at following events:

When a touch starts or when a touch ends

String: ID, gameType, GameMode currentTasknumber, numberOfLevels, direction, timestamp, event, touches, startZone, endZone, completed, dropPoint

5.12.3 Application flow

The flow of the application is shown in Figure 5.20 on the following page and Figure 5.21 on page 85 and description of screen shots are in Table 5.7 on page 86.

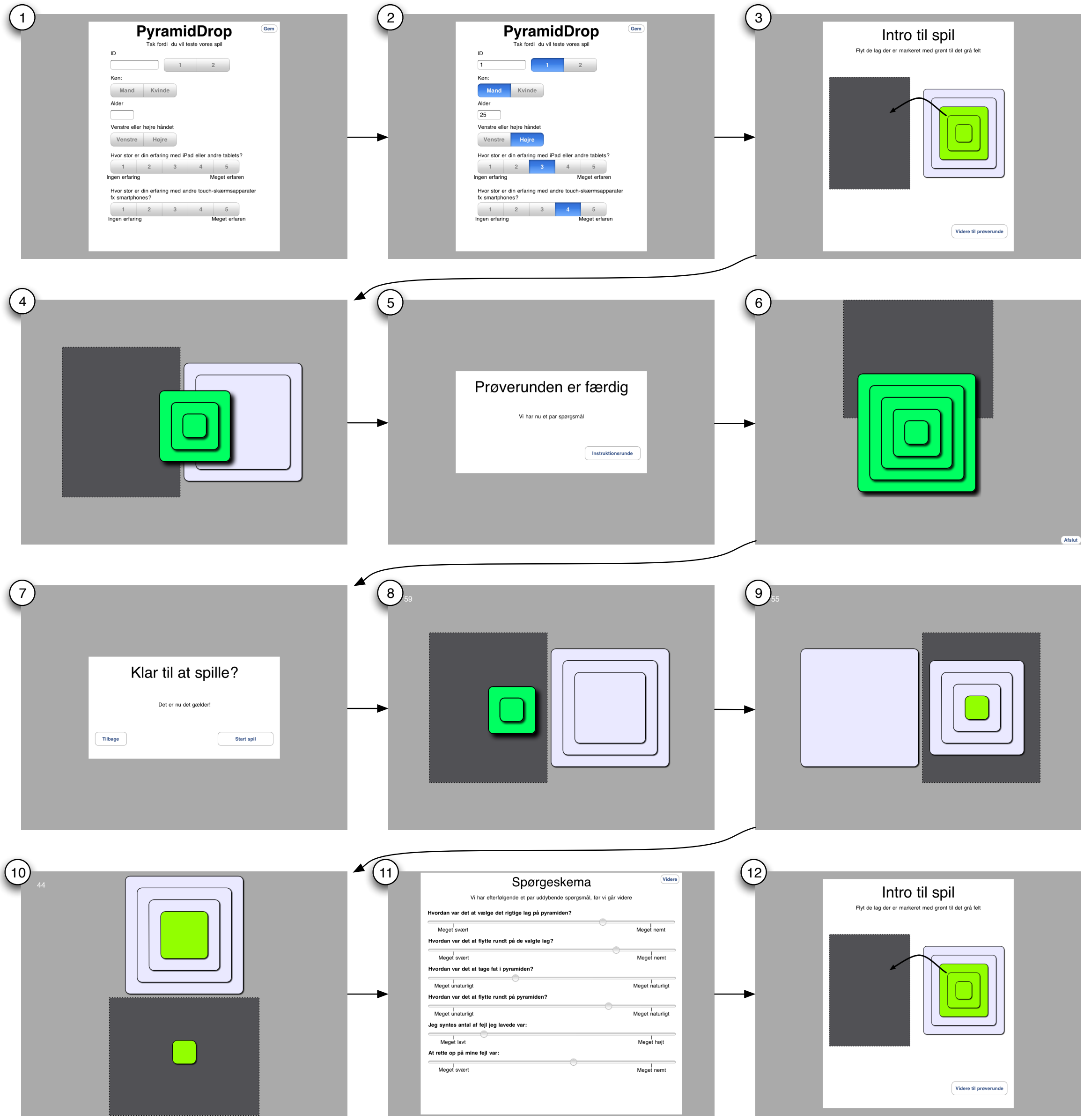

Figure 5.20: Storyboard of application flow is continued in Figure 5.21 on the facing page

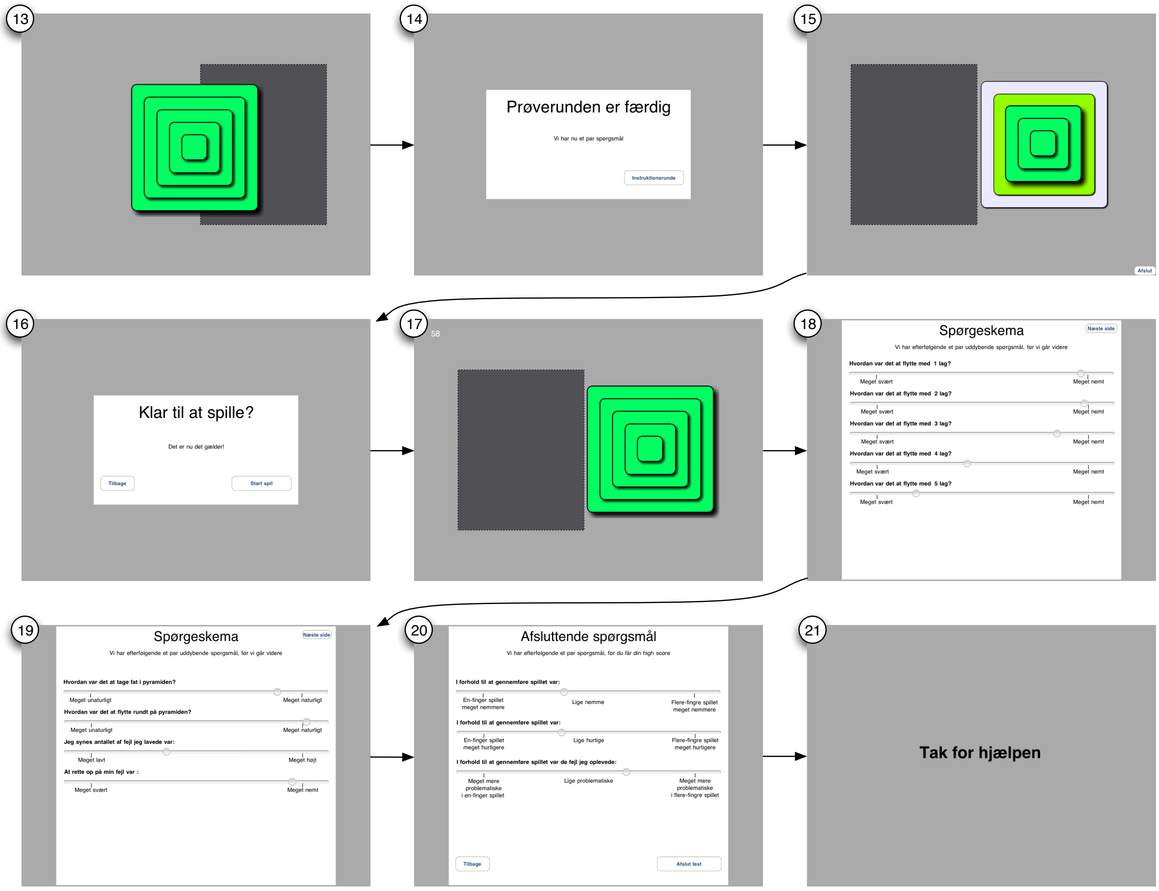

Figure 5.21: Storyboard of application flow continued from Figure 5.20 on the facing page

Number	Description
1, 2	Meta data screen all metadata i registred here by the test subject and the order of condition are selected. If the game order 2 are selected screen 3-11 switch with screen 12 - 19
3, 12	Are used to explain the task in the game
4	60 sek one-finger trail mode
5, 14	When this screen appear the subject are asked to explain how the pyramid is manipulated
6	One-finger learn mode, needs to be manually closed
7, 16	used to explain task mode and make sure the subject understand how the game works
8	One-finger task mode, all 60 tasks needs to be completed before task mode ends
9	Example of to many levels moved to the drop zone, all level needs to be moved back to the pyramid before the task can be completed by the right number of levels
10	Example of to few levels moved to the drop zone, all level needs to be moved back to the pyramid before the task can be completed by the right number of levels
11	Questionnaire with six VAS ratings of the one-finger condition
13	60 seconds multi-finger trial mode
15	Multi-finger training mode, needs to be manually closed
17	Multi-finger task mode, all 60 tasks needs to be completed before task mode ends
18	Questionnaire with first five VAS ratings of the multi-finger condition
19	Questionnaire with last four VAS ratings of the multi-finger condition
20	Questionnaire with three VAS ratings to compare one-finger and multi-finger condition
21	Experiment completed screen.

Table 5.7: Description of iPad application screenshots

5.13 Pilot study of experiment

To evaluate the experiment setup a pilot study with 3 persons was made. Two male and one female, the age subjects was 24, 27, and 29 and they all right handed. There experience with media tablets was 0, 0, and 1 and there experience was 3, 1, and 3 with touch screens. The performance data and interview data gathered form the pilot study was not analysed and were not inculcate in the experiment.

All pilot test subjects was able to complete the experiment satisfactory. Some minor issue ware found in the navigation between the pages within the experiment applications. The test subjects were eager to tap the next buttons before all interview questions ware asked. To prevent this in the experiment, the buttons ware made smaller and placed at the top of the screen, instead of at the bottom of the screen. It was also decided to explicit to tell the test subjects to wait with taping on the next button until they were told to.

No further adjustments was made to the experiment procedure.

CHAPTER 6

Analysis of the experiment data

To verify the null hypotheses in Section 5.1 on page 60, an analysis of the data gathered in the experiment described in Chapter 5 on page 60 will be put forth in this chapter. When testing for significance, the null hypothesis will be rejected at the 0.050 significance level. Notes from the experiment can be found in Appendix D on page 124 and recordings of the sound from the experiment can be found on the appendix CD.

As mentioned in Section 5.9 on page 71 each null hypotheses have test hypotheses. If one or more of the test hypotheses, contained in the null hypotheses, are accepted, then the specific null hypothesis is accepted or partly accepted.

6.1 Meta data

The meta data was collected prior to the the first training round, see Section 5.7 on page 67 and Section 5.9 on page 71.

Ten females and ten males participated in the experiment, ranging from 21 to 33 years ($\bar{x} = 24.55, SD = 2.63$), of which 3 where left handed and 17 where right handed.

Their rating on how much experience they had with respectively media tablets, such as the iPad and other touch screen technologies such as smartphones, was ticked on two five step Likert scales. 1 was no experience - 5 was very experienced. The rating distribution is seen in Table 6.1. It is seen, that the majority of the test subjects (12) have no or little experience in using media tablets. A matched-pairs Wilcoxon test showed a significance difference between the ratings on the experiences scales ($v = 15, p < 0.009497$).

Ratingpoints	1	2	3	4	5
Tablet experience	6	6	5	1	2
Touch-technology experience	1	7	2	4	6

Table 6.1: Experience rating of respectively media tablet- and smartphone use.

6.2 Trial round

6.2.1 Trial round hypothesis: The test subjects do comprehend the multi-finger interaction method better than the one-finger interaction method.

Data gathered form the trial round can be seen in Table 6.2. The Understanding variable was quantified by the authors of this study, based on the notes and audio recordings gathered during the experiment.

It is seen that there is a logic correlation between the amount of number of task completed and the duration of time before the first task was completed. E.g. test subject 4, regarding the one-finger interaction method, completed 20 task in the trial round, with the first task completed after 12.7 seconds. Whereas he did not complete any tasks in the multi-finger interaction method.

Subject	condition	Order	Understanding	Time before first task completed	Number tasks completed
1	one-finger	first	Almost	50.6 sec	1
1	multi-finger	second	Almost	53.9 sec	3
2	one-finger	second	Yes	20.2 sec	10
2	multi-finger	first	No	na	0
3	one-finger	first	Yes	20.5 sec	11
3	multi-finger	second	No	na	0
4	one-finger	second	Yes	12.7 sec	20
4	multi-finger	first	No	na	0
5	one-finger	first	No	na	0
5	multi-finger	second	No	na	0
6	one-finger	second	Yes	13.2 sec	20
6	multi-finger	first	Yes	45.8 sec	4
7	one-finger	first	Yes	15.1 sec	10
7	multi-finger	second	Yes	46.2 sec	4
8	one-finger	second	No	41.8 sec	3
8	multi-finger	first	No	na	0
9	one-finger	first	Yes	50.6 sec	4
9	multi-finger	second	Yes	13.3 sec	16
10	one-finger	second	Yes	7.8 sec	20
10	multi-finger	first	No	na	0
11	one-finger	first	No	na	0
11	multi-finger	second	Yes	12.6	20
12	one-finger	second	Yes	24.0	13
12	multi-finger	first	No	na	0
13	one-finger	first	Yes	24.1 sec	13
13	multi-finger	second	Yes	38.6 sec	5
14	one-finger	second	No	na	0
14	multi-finger	first	No	na	0
15	one-finger	first	No	na	0
15	multi-finger	second	No	na	0
16	one-finger	second	No	na	0
16	multi-finger	first	No	na	0
17	one-finger	first	Yes	56.0 sec	1
17	multi-finger	second	Almost	17.1 sec	9
18	one-finger	second	Yes	8.7 sec	18
18	multi-finger	first	Yes	na	0
19	one-finger	first	Yes	16.3 sec	15
19	multi-finger	second	No	20.5 sec	4
20	one-finger	second	Yes	6.0 sec	20
20	multi-finger	first	No	na	0

Table 6.2: Trial round data

In Table 6.3 a summary of the data in Table 6.2 on the facing page is found.

Condition	**Yes**	**almost**	**no**
One-finger first	6	1	3
One-finger second	7		3
Multi-finger first	2		8
Multi-finger second	4	2	4
Total	19	3	18

Table 6.3: Trail round data summery

The data shows that in 19 of the trial rounds (47.5 %), the interaction method was fully understood within the 60 seconds time limit. With 13 out of 20 Understandings of the one-finger method and only 6 out of 20 Understandings of the multi-finger, the difference between the interaction methods is to large, to accept the hypothesis. No significance test was made, since the Understandings measures are fully subjective and might be biased.

6.3 H_0 1: The multi-finger interaction method can not improve effectiveness compared to the one-finger interaction method.

6.3.1 1: The amount of different types of errors is not greater in the multi-finger interaction method compared to the one-finger interaction method

In Section 5.9.3 on page 73 three types of errors were categorised. The data from these three categories were: number of moves from startzone to dropzone without completion, number of moves with start and end in the startzone, and the total number of touch ends without completion. Touch ends are defined as an action by the user, in where he touches the screen and drags the selected pyramid levels.

The distribution of events for each conditions is seen in Table 6.4. Note that the number of events is a summation over the 2400 tasks completed by the test subjects in total. Individually, all three events are significantly different when comparing one- and multi-finger interaction ($\mathrm{t} < -4.5256, \mathrm{df} = 19, \mathrm{p} < 0.000753$).

	Startzone to dropzone	Startzone to startzone	Number of touch ends
One finger	13	57	77
Multi finger	140	1014	1162

Table 6.4: Event distribution of both the conditions

To provide a more detailed overview of the three events, each of them is analysed in the following.

6.3.2 Event 1: Moves from startzone to dropzone without completion of the task

Event 1 is split in to the four directions - left, right, up, down - and are seen Table 6.5. It is seen that non of the directions are significantly different from the others. Event 1 is also split in the five number of levels and can be seen Table 6.6. This shows that there is a significance influence of number of levels in the multi-finger condition. The majority of event 1s is conducted with the five-finger gesture. Three-finger do contribute to a high number of event 1 errors, though it is significant lower than the five-finger gesture. The number of event 1 errors conducted by each test subject is shown in Figure 6.1.

Direction	Left	Right	Up	Down
Multi-finger	33	41	30	36
One-finger	0	5	6	2
Difference in events	33	36	24	34

Table 6.5: Moves from startzone to dropzone without completion of the task split in directions.

Number of levels	1	2	3	4	5
Multi-finger	1	3	37	13	86
One-finger	0	5	3	5	0
Difference in events	1	-2	34	8	86

Table 6.6: Moves from startzone to dropzone without completion of the task split in number of levels.

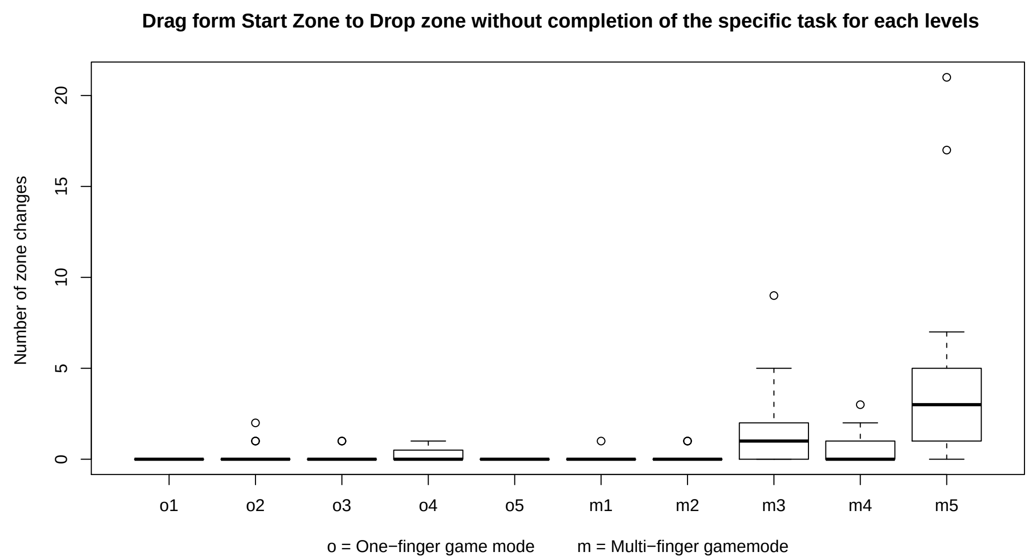

Figure 6.1: Drag form Start Zone to Drop zone without completion of task.

6.3.3 Event 2: Drags from startzone to startzone

Event 2 is also split in to the four directions - left, right, up, down - and are seen Table 6.7. The numbers shows much the same as with the Event 1 errors. The direction of the task have no great significance in the number of tasks, even though there seems to be a tendency towards, more left events than right events. Event 2 is also split into the five number of levels and can be seen in Table 6.11 on page 93. This shows that there is a significance influence of number of levels in the multi-finger condition. Almost all cases of event 2 are conducted with the five-finger gesture. There is almost no difference between level one to two in the one-finger and multi-finger condition. The number of event 2 errors conducted by each test subject is shown in Figure 6.2.

Direction	**Left**	**Right**	**Up**	**Down**
Multi-finger	315	187	246	266
One-finger	5	18	16	18
Difference in events	310	169	230	248

Table 6.7: Moves from startzone to startzone without completion of the task split in directions

Number of levels	**1**	**2**	**3**	**4**	**5**
Multi-finger	4	24	178	162	646
One-finger	6	15	14	13	9
Difference in events	-2	9	3	149	639

Table 6.8: Moves from startzone to startzone without completion of the task, split in number of levels.

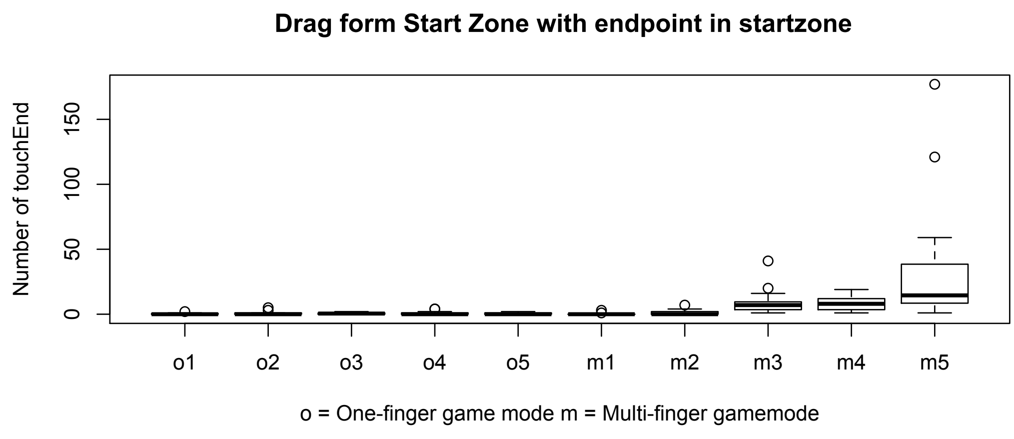

Figure 6.2: Drag form Start Zone with endpoint in startzone.

6.3.4 Event 3: Number of touchEnd without completion of the task

Event 2 is also split in to the four directions - left, right, up, down - and are seen Table 6.9 on the next page. The numbers shows much the same as with the Event 2 errors. The direction of the task have no great significance in the number of tasks, even though there seems to be a tendency towards more left- than right events. The amount of event 3 is split into the five number of levels, and can be seen in Table 6.10. This shows that there is a significant influence of number of levels in the multi-finger condition. Almost all cases of event 3 are conducted with the five-finger gesture. The number of events conducted with three-finger gestures is higher that with event 2. The number of event 3 errors conducted by each test subject is shown in Figure 6.3.

Direction	Left	Right	Up	Down
Multi-finger	351	229	278	304
One-finger	6	26	23	22
Difference in events	345	203	255	282

Table 6.9: Number of touchEnd without completion of the task split in directions

Number of levels	1	2	3	4	5
Multi-finger	6	28	216	176	736
One-finger	6	22	18	19	12
Difference in events	0	6	198	157	724

Table 6.10: Number of touchEnd without completion of the task split in number of levels

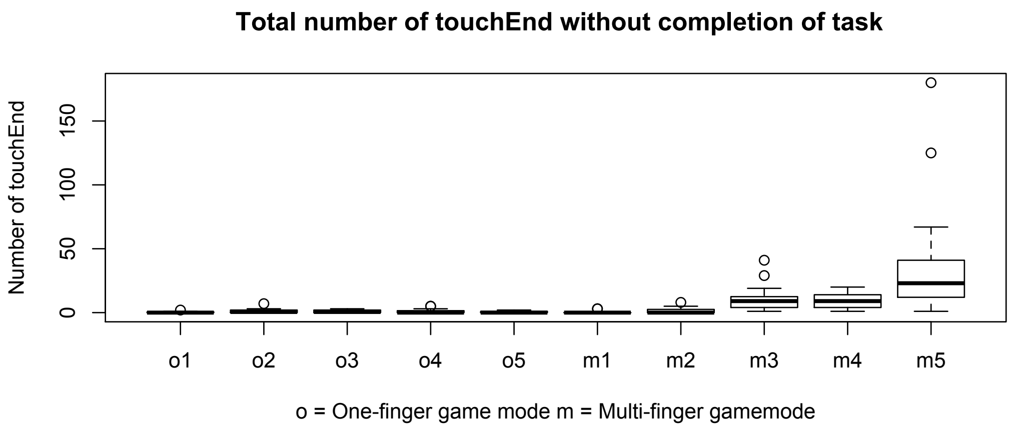

Figure 6.3: Total number of touchEnd without completion of task

The analysis of the three events shows a significant difference in number of error events occurring in the one-finger and multi-finger condition. The hypothesis can thereby be rejected.

6.3.5 2: One- to five-multifinger gestures have the same effectiveness compared to the one-finger interaction method.

To see if there is a difference between one- to five- finger gestures measured in effectiveness the amount of events divided between the multi-finger gestures is shown in Table 6.11 on the facing page.

Number of levels	1	2	3	4	5
Event 1: Startzone to dropzone	1	3	37	13	86
Event 2: Startzone to startzone	4	24	178	162	646
Event 3: Number of touchEnd	6	28	216	176	736

Table 6.11: Number of events in multi-finger task split in number of levels.

From the distribution of the events there is clearly a tendency of lower effectiveness with three-, four, and five-finger-gestures. The hypothesis is thereby rejected.

6.3.6 3: The amount of different types of errors perceived by the test subjects is not greater in the multi-finger interaction method compared to the one-finger interaction method

The Figure 6.4 shows the amount of perceived errors for both the conditions rated on VAS scales. A Shapiro-Wilk normality test showed that the distribution of errors in both conditions are normally distributed ($\mathrm{W} = 0.9293, \mathrm{p} = 0.1496; \mathrm{W} = 0.9279, \mathrm{p} = 0.1409$), why a paired t-test was conducted. This showed a significant difference between the two conditions ($\mathrm{t} = -6.7533, \mathrm{df} = 19, \mathrm{p} = 1.882e - 06$), where the multi-finger condition had the highest rating of perceived errors. The hypothesis can hereby be rejected.

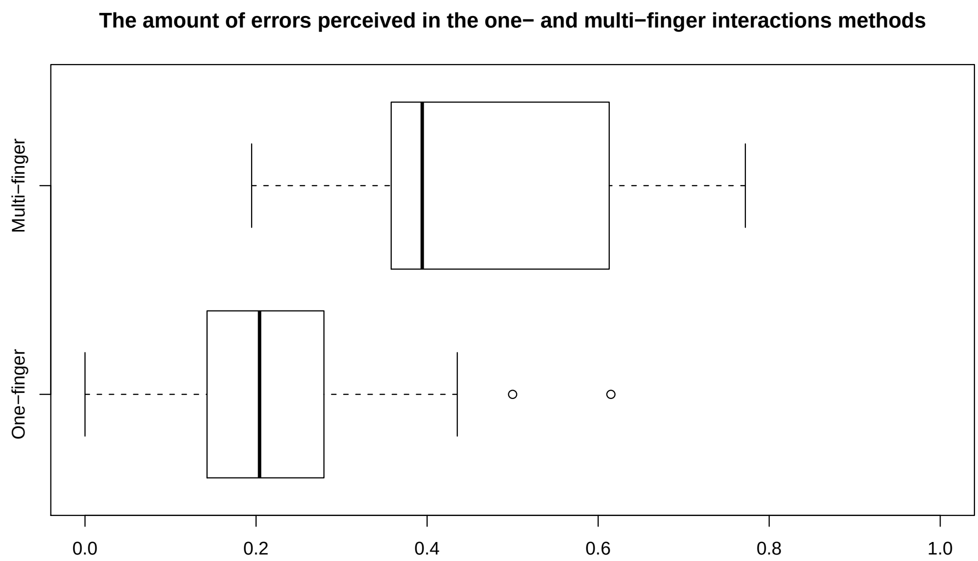

Figure 6.4: Distribution of the VAS ratings regarding the perceived amount of errors. 0 is lower than very low, 1 is more than very high.

6.3.7 4: The multi-finger interaction method is perceived less difficult of righting errors by the test subjects compared to the one-finger interaction method.

Figure 6.5 shows, the rating on the VAS, on how the test subjects perceived the easiness in how it was to right the errors they conducted during the test. The Shapiro-Wilk test showed that both conditions are normally distributed ($\mathrm{W} = 0.9602, \mathrm{p} = 0.5476; \mathrm{W} = 0.9732, \mathrm{p} = 0.821$), why a paired t-test was conducted. This showed a significant difference between the two conditions ($\mathrm{t} = 2.1674, \mathrm{df} = 19, \mathrm{p} = 0.04312$). The hypothesis can be rejected.

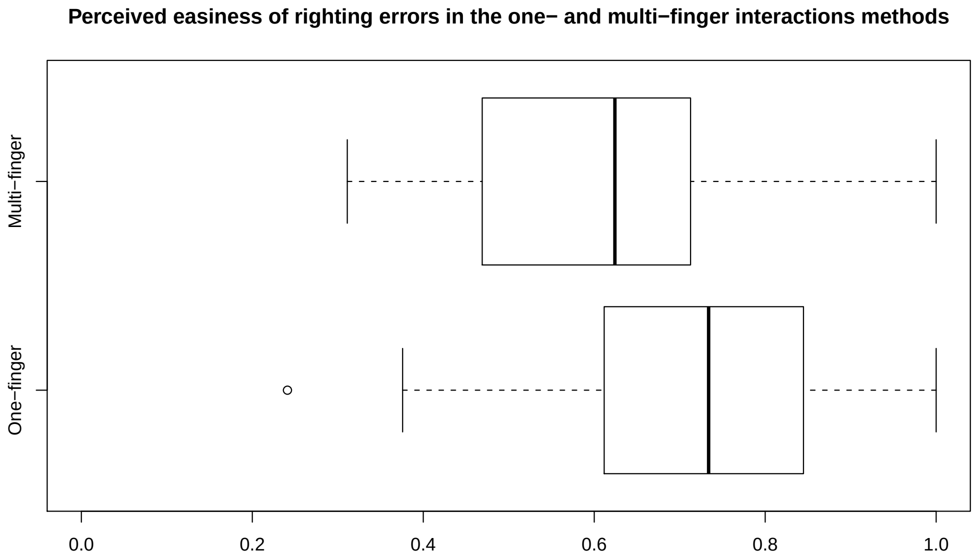

Figure 6.5: The perceived easiness righting errors. 0 is lower than very hard, 1 is more than very easy.

6.3.8 5: Errors in the multi-finger interaction method are perceived less problematic when righting errors by the test subjects compared to the one-finger interaction method.

Figure 6.6 on the next page shows the test subjects' comparison of the one- and multi-finger interaction methods, of how problematic the the thought the error righting was. The Shapiro-Wilk test for normality showed that the distribution of ratings of the VAS scale was coming from a normal distribution ($\mathrm{W} = 0.946, \mathrm{p} = 0.3099$), why a paired t-test was conducted. This shows a significant different from the 0.5, which is the neutral point on the VAS scale ($\mathrm{t} = 4.2701, \mathrm{df} = 19, \mathrm{p} = 0.0004136$). This means that the distribution leans (significantly) towards, that the multi-finger condition is much more problematic to right errors in, than the one-finger condition. The hypothesis in rejected. When the test subjects reported their choice in the questionnaires they stated that it was mostly due to the five-finger gestures, that they rated the multi-finger condition more problematic.

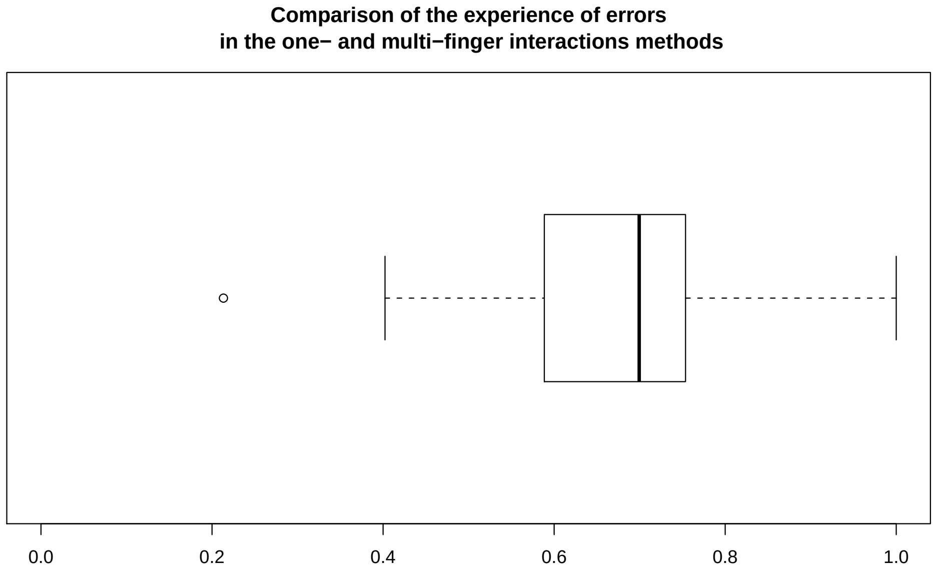

Figure 6.6: The degree of problematic, when comparing the one- and multi-finger interacion methods. 0 is more than much more problematic in the one-finger game and 0 is more than more problematic in the multi-finger game.

6.4 H_0 2: The multi-finger interaction method can not improve efficiency compared to the one-finger interaction method.

6.4.1 Model search

An ANOVA test was conducted to see which factors had an influence on the total time. The output from the test is seen in Table 6.12. Nothing surprising was found. Interestingly, the touch technology experience had no influence on the test subjects' performance. Whereas the their tablet experience had quite and influence.

	Df	Sum Sq	Mean Sq	F value	Pr($> F$)	
Gameorder	1	22741103	22741103	7.1115	0.007712	**
Gender	1	231825	231825	0.0725	0.787761	
Age	1	4031502	4031502	1.2607	0.26163	
Dominant hand	1	4594473	4594473	1.4368	0.230784	
Tablet experience	4	253769867	63442467	19.8396	4.47E-16	***
Touch techonolgy experience	4	12315583	3078896	0.9628	4.27E-01	
Gametype	1	289289736	289289736	90.4661	$< 2.2e-16$	***
Task number	59	868939949	14727796	4.6056	$< 2.2e-16$	***
Residuals		7441212855	3197771			

Table 6.12: Analysis of variance on of the total time of thet task described by meta data

The H_0 2 hypothesis contains three test hypotheses. General difference between one- and multi finger, difference between the 1-5 finger gestures in the multi-finger condition, and a difference in perceived time between the two conditions.

6.4.2 1: The multi-finger interaction method is more efficient compared to the one- finger interaction method.

A specific time for each test subject in both conditions was recorded. This gives a total time for both conditions which is seen in Figure 6.7 and Figure 6.8. Figure 6.7 shows the total time of the game round for each test subject in the one-finger condition, whereas Figure 6.8, shows the time for each test subject in the multi-finger condition. It should be noted that the animation time described in Section 5.11.2 on page 80, are added to each of the tasks, to the total time for each participant.

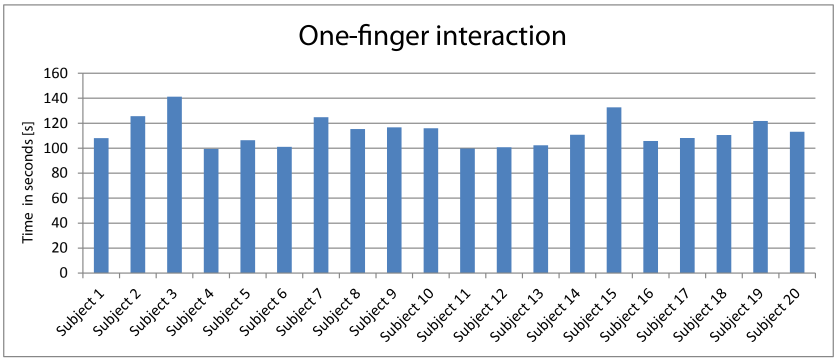

Figure 6.7: Game time [s] for each test subjects for the One-finger interaction

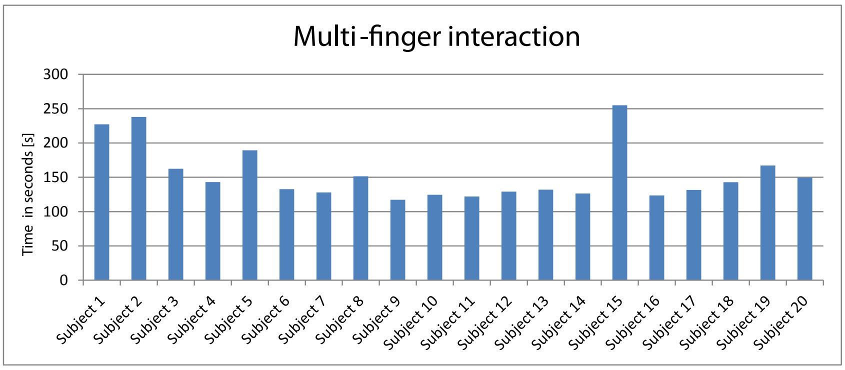

Figure 6.8: Game time [s] for each test subjects for the Multi-finger interaction

Figure 6.9 on the facing page shows the individually difference between the conditions. All differences are positive, which mean the one-finger condition are faster to complete than the multi-finger condition. It is furthermore seen that the majority of the test subjects are under a minute slower to complete the multi-finger condition than the one-finger condition.

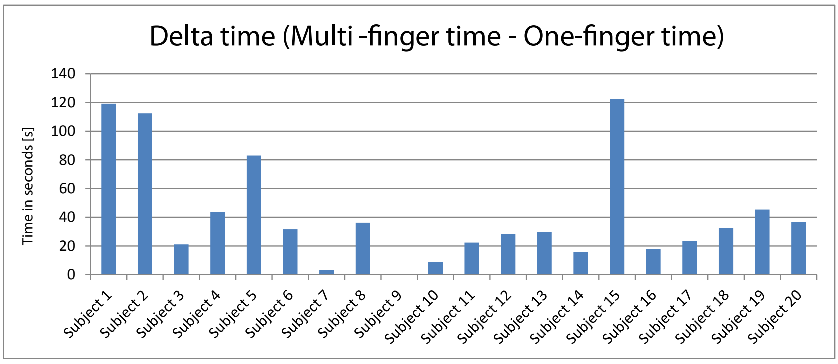

Figure 6.9: Delta game time [s] for each test subjects for the Multi-finger interaction - the One-finger interaction

The time for each task of all test subjects can been in Figure 6.10 on the next page and Figure 6.11 on page 99 - respectively the one-finger and multi-finger condition. It is seen that the time measures for each task of all test subject are highly fluctuating in both conditions. A Shapiro-Wilk normality test shows that the time measures from both conditions are not normally distributed ($\mathrm{W} = 0.6145 \wedge \mathrm{W} = 0.4129, \mathrm{p} < 2.2e - 16$). A matched-pairs Wilcoxon test showed a significant difference between the two conditions comparing total task time for all subjects ($\mathrm{v} = 248402, \mathrm{p} =< 2.2e - 16$), though the one-finger was in favor. The test hypothesis is rejected.

To see if there should be any general development in time used on each tasks for all test subjects strip charts are made. The time for each task of all test subjects can be seen in Figure 6.10 on the next page and Figure 6.11 on page 99 - respectively the one-finger and multi-finger condition. For both Figures it is seen that the time measures for each task of all test subject are highly fluctuating in both conditions, which provides no clear tendency for an development. Due to the randomisation of the tasks, the most difficult tasks would also interfere the tendency. Figure 6.11 on page 99 shows how the task durations are distributed in the multi-finger condition.

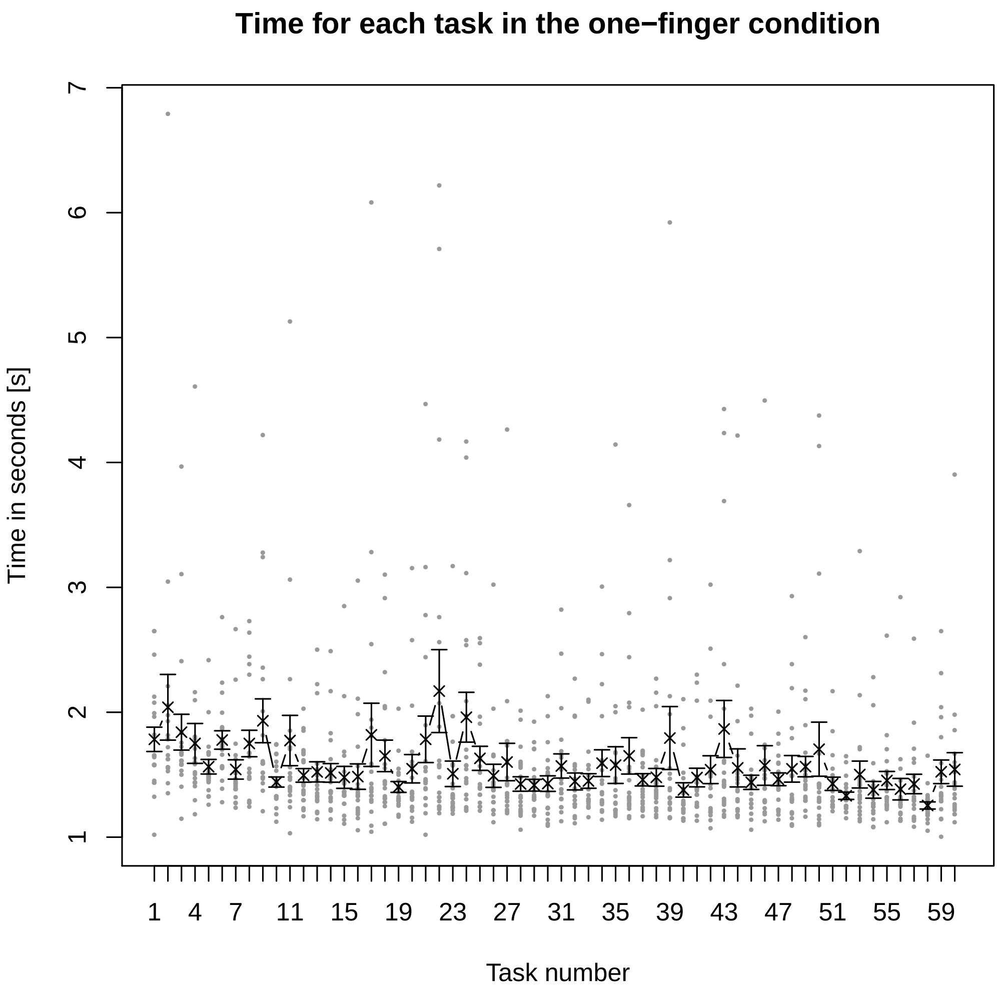

Figure 6.10: A jitter stripchart with the an indication of the mean ($\bar{x}$) $\pm$ 1 SEM of the one-finger interaction.

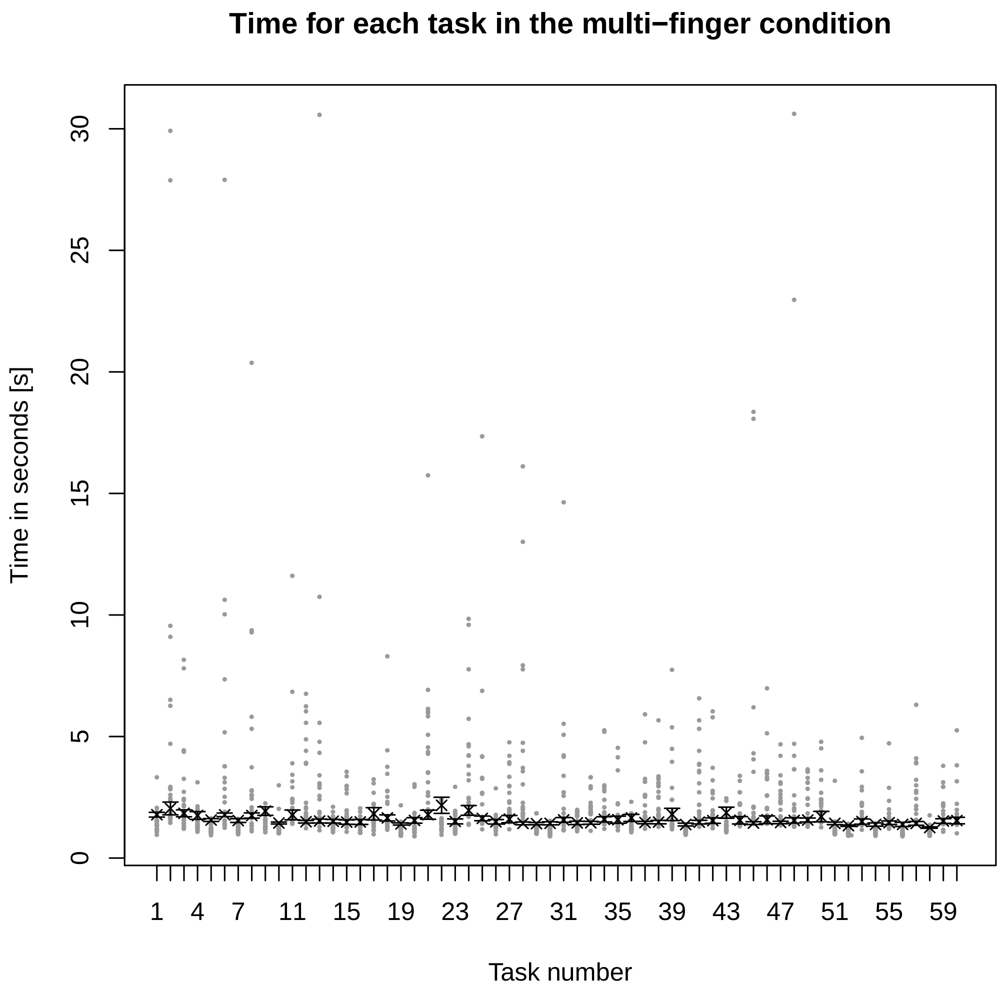

Figure 6.11: A jitter stripchart with the an indication of the mean ($\bar{x}$) $\pm$ 1 SEM of the multi-finger interaction.

6.4.3 2: One- to five-multifinger gestures have the same efficiency compared to the one-finger interaction method.

The plotted differences (delta values) between the one-finger condition and the multi-finger condition regarding the five levels are seen in Figure 6.12. The mean and p-values are seen in Table 6.13.

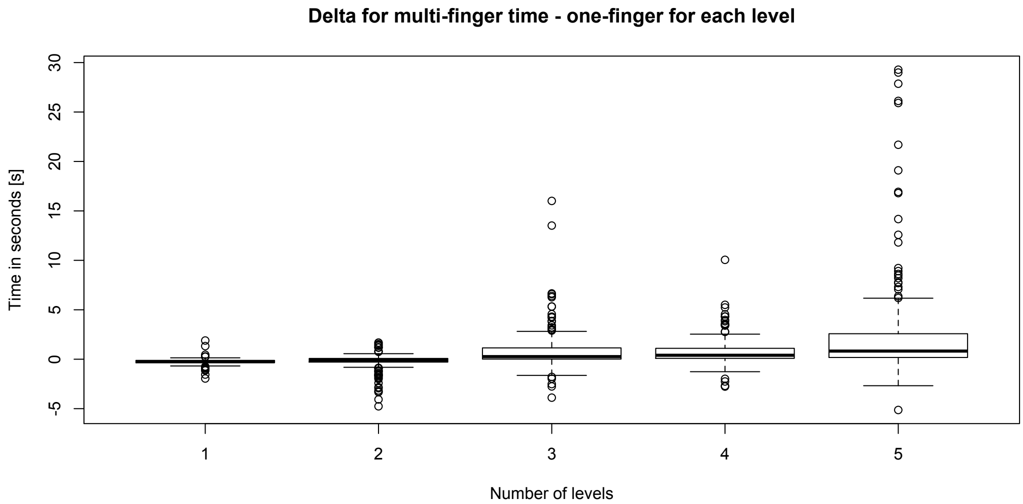

Figure 6.12: Efficiency delta for multi-finger time - one-finger time for number of level 1-5.

	Delta Level One	Delta Level Two	Delta Level Three	Delta Level Four	Delta Level Five
Mean	-0.2545	-0.22064	0.82465	0.71835	2.4040
p-value	2.2e-16	2.788e-05	3.701e-10	6.192e-16	9.617e-13

Table 6.13: Summary of values used in the efficiency delta boxplot. Values are in seconds [s].

It is seen that the delta values are significant and the means are changing according to the number of levels. Furthermore, it is seen that the two means from Delta level one and two are negative. This means that completing tasks with one- and two finger multi gestures - i.e. moving level one and two - are faster than moving level one and two with the one-finger method. Delta Three to Five are postitives, which means that the multi-finger method are slower than the one-finger. Given that not all multi-finger gestures are more efficient than the one-finger interaction, the hypothesis is partly accepted.

A plot of only 1-5 five gestures in the multi-finger interaction are seen in Figure 6.13 on the facing page. There is a clear tendency of the more levels moved, the more time it takes to complete the tasks. The pairwise Bonferroni adjusted t-test seen in Table 6.14 on the next page, shows that there no significant difference between three and four finger gestures. The rest of the comparisons are significant.

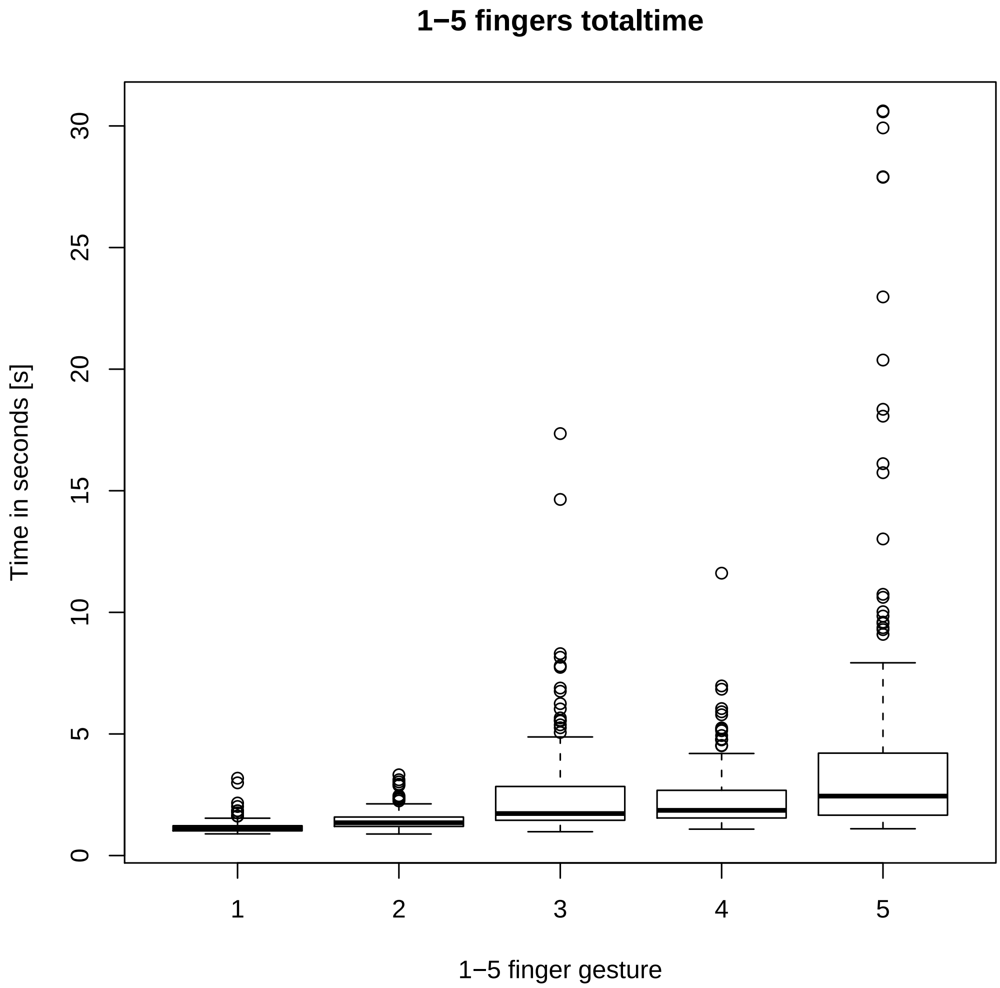

Figure 6.13: The 1-5 finger gestures compared individually

	1	2	3	4
2	2.00e-16			
3	2.00e-16	1.00e-13		
4	2.00e-16	¡ 2e-16	1	
5	3.30e-16	1.40e-13	2.00e-05	1.30e-06

Table 6.14: Bonferroni adjusted pairwise t-test comparing the the multi-finger gestures in efficiency.

6.4.4 3: The multi-finger interaction method is perceived more efficient by the test subjects compared to the one-finger interaction method.

Figure 6.14 shows the distribution in the VAS rating, comparing the time perceived to complete all tasks for each conditions. A Shapiro-Wilk test for normality showed that the VAS ratings were normally distributed ($W = 0.9116, p = 0.06825$), why a t-test was conducted. This showed a significant difference from the neutral zone 0.5 ($t = -7.3401, df = 19, p = 5.874e{-}07$). This shows that the test subjects rated their perceived time to complete all tasks in both conditions to be much faster in the one-finger condition. This rejects the hypothesis.

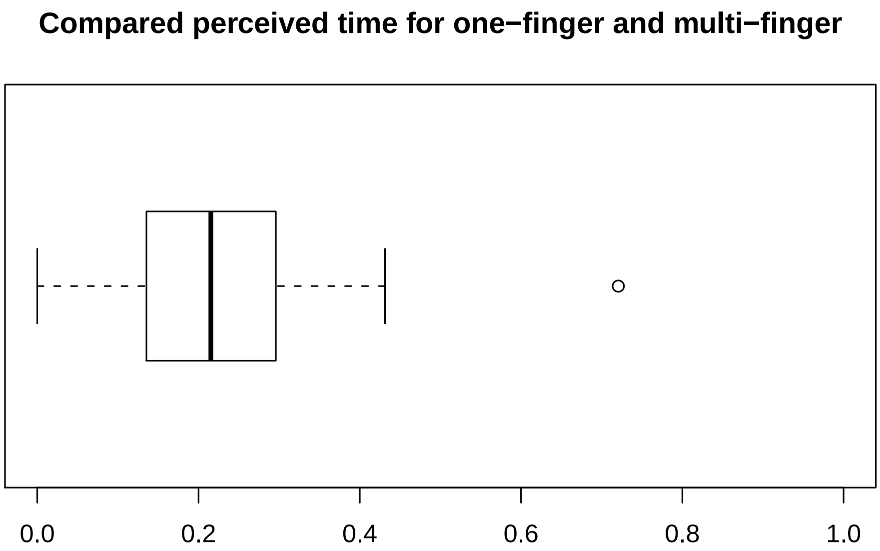

Figure 6.14: VAS rating of how the test subjects perceived the time it took to complete the games in both of the conditions. 0 is that the one-finger condition was more than much faster, 0 is that the multi-finger condition was more than much faster.

6.5 H_0 3: The multi-finger interaction method can not improve easiness compared to the one-finger interaction method.

6.5.1 1: The multi-finger interaction method is perceived more easy when selecting the correct levels from the pyramid by the test subjects compared to the one-finger interaction method.

The one-finger condition VAS ratings, concerning the action of selecting the correct levels and moving them, where split into two questions. This action was only one question in the multi-finger condition. This means that the VAS rating concerning selecting the correct levels, are compared to each of the levels, when moving the levels in the multi-finger condition. The comparisons can be seen in Table 6.15. Since not all of the ratings are normally distributed, when a Wilcoxon test is performed for all comparisons. The comparison between one-finger and level 2 and 3 did not show significant. The hypothesis in then partly accepted. Figure 6.15 on the following page shows a graphical distribution of perceived easiness.

	Wilcoxon	**P-value**
One-finger compared to multi-finger level 1	W = 80	p-value = 0.001151
One-finger compared to multi-finger level 2	W = 163	p-value = 0.3232
One-finger compared to multi-finger level 3	W = 267.5	p-value = 0.0698
One-finger compared to multi-finger level 4	W = 341.5	p-value = 0.0001361
One-finger compared to multi-finger level 5	W = 385	p-value = 5.986e-07

Table 6.15: Wilcoxon rank sum test of VAS rating of one-finger perceived easiness against multi-finger perceived easiness.

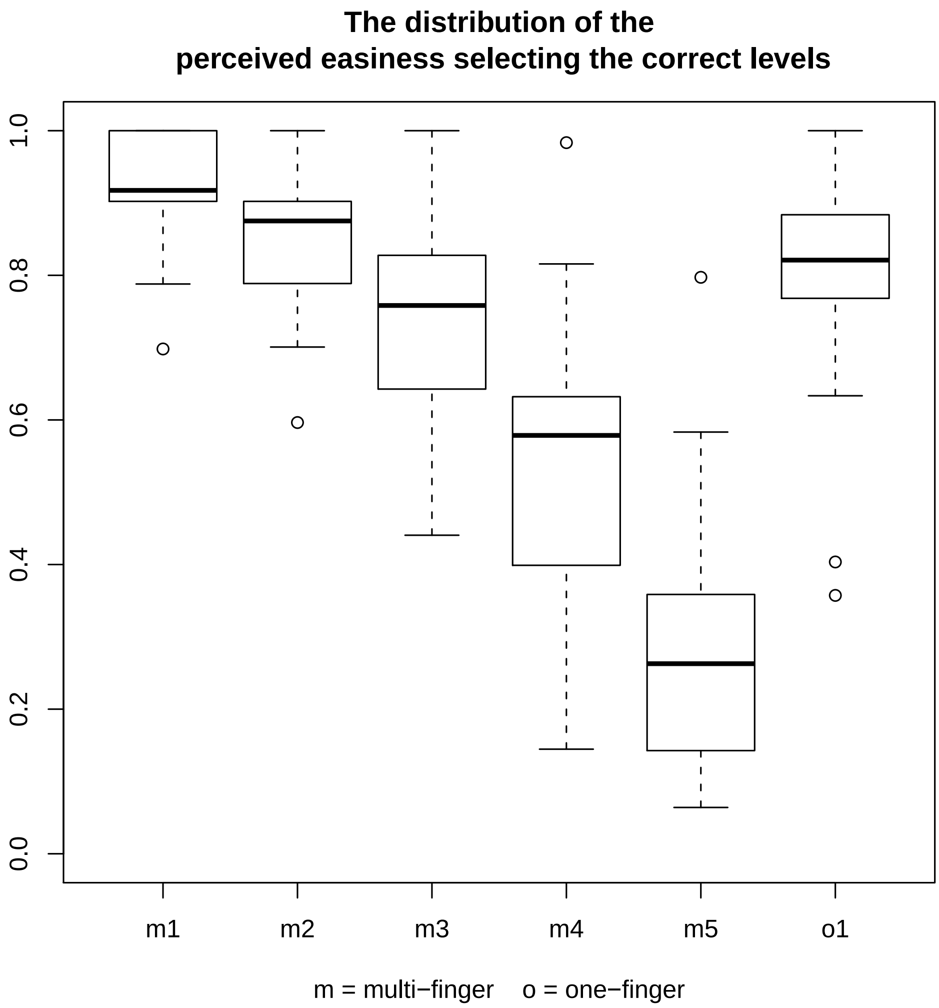

Figure 6.15: 0 is lower than very hard, 1 is more than very easy.

6.5.2 2: The multi-finger interaction method is perceived more easy when moving the correct levels from the pyramid by the test subjects compared to the one-finger interaction method.

The Table 6.16 on the next page shows the comparison of the perceived easiness when moving the levels in the one-finger and multi-finger condition. This comparison is direct, since both of the questions concern moving the levels. It is seen that only the level 2 are not significant from the one-finger. The hypothesis is partly rejected. Figure 6.16 on the facing page shows a graphical representation of the easiness concerning moving the levels in the one- and multi-finger condition.

	Wilcoxon	P-value
One-finger compared to multi-finger level 1	W = 95.5	p = 0.004736
One-finger compared to multi-finger level 2	W = 193.5	p = 0.871
One-finger compared to multi-finger level 3	W = 296	p = 0.009773
One-finger compared to multi-finger level 4	W = 358.5	p = 1.916e-05
One-finger compared to multi-finger level 5	W = 391	p = 2.560e-07

Table 6.16: Wilcoxon rank sum test of VAS rating of one-finger perceived easiness against multi-finger perceived easiness.

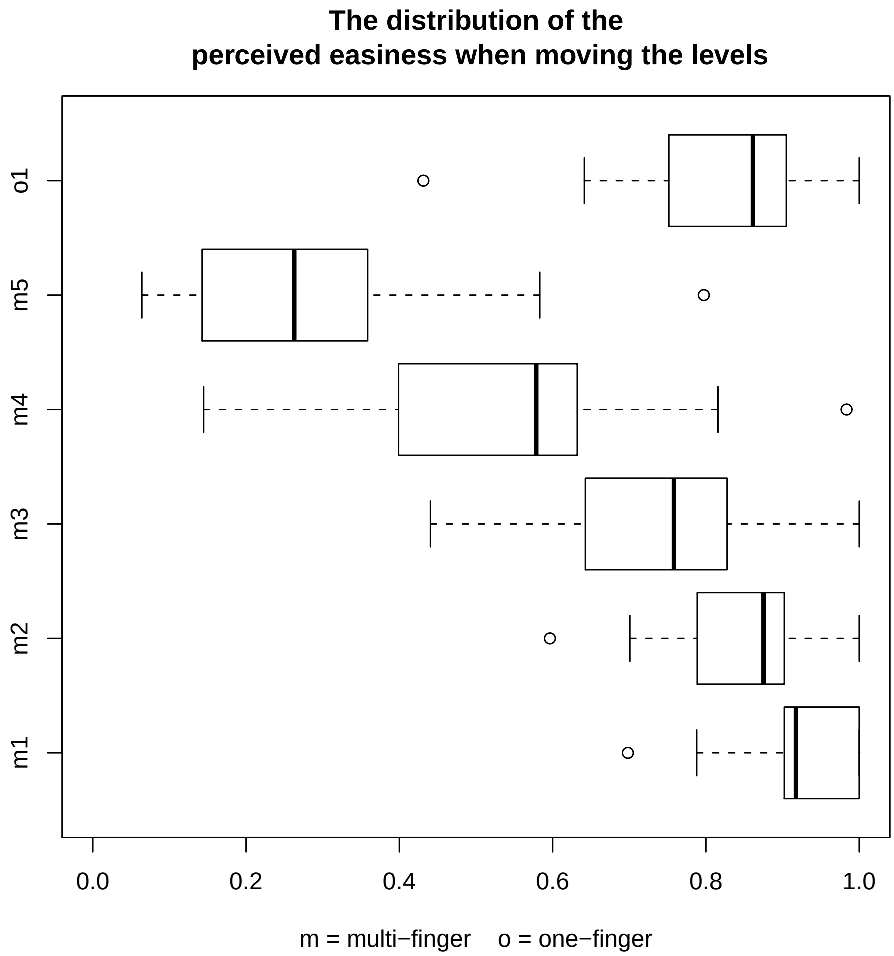

Figure 6.16: 0 is lower than very hard, 1 is more than very easy.

6.5.3 3: One- to five-multifinger gestures are perceived more easy by the test subjects compared to the one-finger interaction method.

Table 6.17 are Wilcoxon tests of the one- and multi-finger conditons comparing the perceived easiness, when moving with level one to five in. They all show a significant difference, in the favour of one-finger. The hypothesis is then rejected. When the test subjects reported their choice in the questionnaires, almost all stated that the steps from three-finger to four-finger was rather larger than the steps between one- two- and three-finger and the step between four- and five-finger was huge. Almost all test subjects stated that five-finger by far was the most difficult of the multi-finger gestures.

	Level 1 (one)	Level 2 (one)	Level 3 (one)	Level 4 (one)
Level 2 (multi)	0.00208			
Level 3 (multi)	8.14E-06	0.002043		
Level 4 (multi)	7.61E-07	7.10E-06	0.000591	
Level 5 (multi)	8.74E-08	4.35E-10	1.33E-08	0.000274

Table 6.17: Easiness VAS ratings of 1-5 finger gestures

6.5.4 4: The multi-finger interaction method is more easy when compared to the one-finger interaction method.

The easiness was compared on a VAS rating going from 0.0(The one-finger game was much easier) to 1.0(The multi- finger game was much easier) with 0.5 as no difference. With a One Sample t-test the mean of the VAS was found to be 0.2219287 ($\mathrm{t} - 9.0199, \mathrm{df} = 19, \mathrm{p}2.699e - 08$). Which means that the one-finger condition was rated significantly easier than multi-finger. The hypothesis is hereby rejected.

6.5.5 5: The multi-finger interaction method do not contribute to more cognitive load compared to the one-finger interaction.

Whether the test subject had high cognitive load during the experiment was difficult to give a exact measured, but on the basis of the interview it estimate that the perceived cognitive load was as following:

- Non of the test subjects indicated that one-finger had higher cognitive load
- Ten of the test subjects indicated that multi-finger had higher cognitive load
- Ten of the test subjects indicated that there was no cognitive load

Ten of the 20 test subjects indicated that they had higher cognitive load during multi-finger condition. The hypothesis is thereby rejected.

6.5.6 6: The easiness of the four drag directions is perceived the same by the test subjects.

Eleven of the subjects mentioned a difference in easiness there statements are listed in the following:

- subject 3 multi-finger from right to left was more difficult
- subject 7 multi-finger from left to right was more difficult
- subject 8 multi-finger from down to up was more difficult
- subject 10 multi-finger from right to left was more difficult
- subject 11 four- and five-finger was more difficult in some directions
- subject 12 one-finger from right to left and left to right was more easy up and down
- subject 13 multi-finger from down to up was more difficult
- subject 15 multi-finger from down to up was more difficult
- subject 17 one-finger from up to down was more difficult
- subject 19 one-finger from right to left was more difficult
- subject 19 one-finger from down to up was more difficult
- subject 19 multi-finger from down to up and up to down was more difficult
- subject 20 one-finger from left to right and right to left was more difficult

There do not seam to be a coincident tendency for what direction is more difficult. Nevertheless eleven out of 20 test subjects perceived a difference and the hypothesis is thereby rejected.

6.6 H_0 4: The multi-finger interaction method can not improve naturalness compared to the one-finger interaction method.

6.6.1 1: The multi-finger interaction method is perceived more natural when grasping the correct levels from the pyramid by the test subjects compared to the one-finger interaction method.

A graphical presentation of the ratings of the naturalness of grasping the levels for both conditions are seen in Figure 6.17 on the following page. A Shapiro-Wilk normality test shows that the distributed of the one-finger vas was not normally distributed ($w = 0.8794, p =$

0.01724). A matched-pairs Wilcoxon test showed a significant difference between the two conditions comparing naturalness of grasping the pyramid ($v = 164, p = 0.02664$). The hypothesis can thereby be rejected.

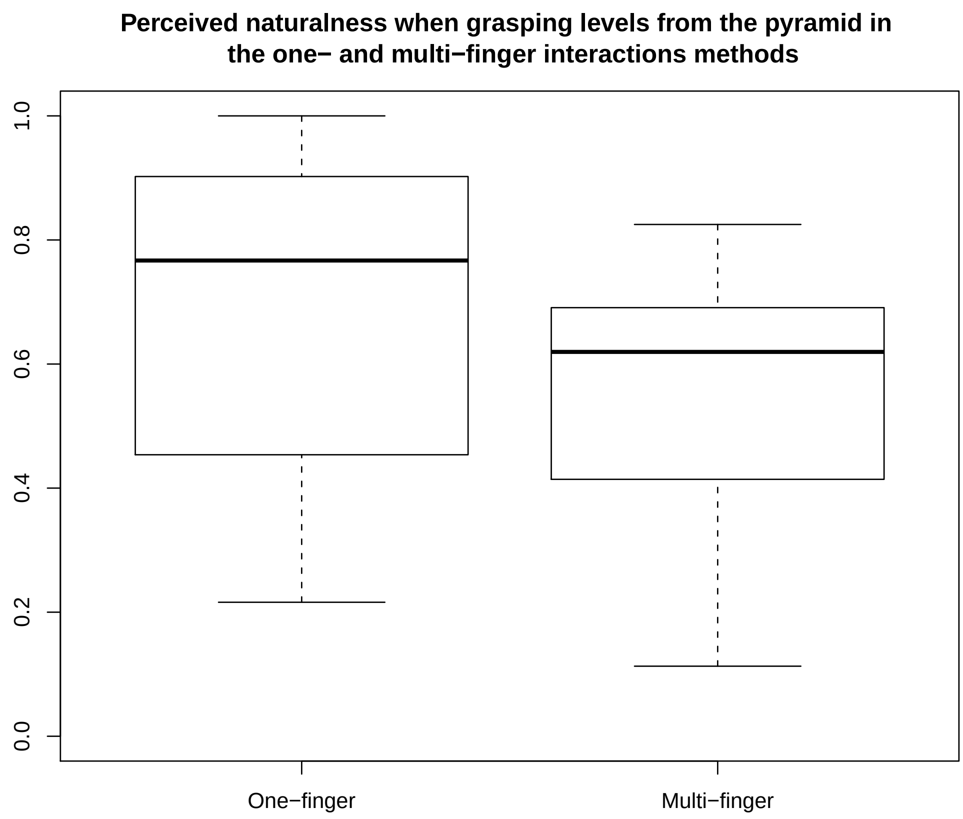

Figure 6.17: One-finger and multi-finger compared regarding naturalness of grasping the pyramid

6.6.2 2: The multi-finger interaction method is perceived more natural when moving the correct levels from the pyramid by the test subjects compared to the one-finger interaction method.

With a One Sample t-test, the mean of the differences was found to be 0.1746037 ($t3.3405, df = 19, p = 0.003437$). The hypothesis can thereby be rejected. The graphical presentation is seen in Figure 6.18 on the next page. When the test subjects reported their choice in the questionnaires, they stated that they did not find any of the interaction methods unnatural. More of the test subjects stated they felt the one-finger being more natural due to their experience with their smartphone/tablet.

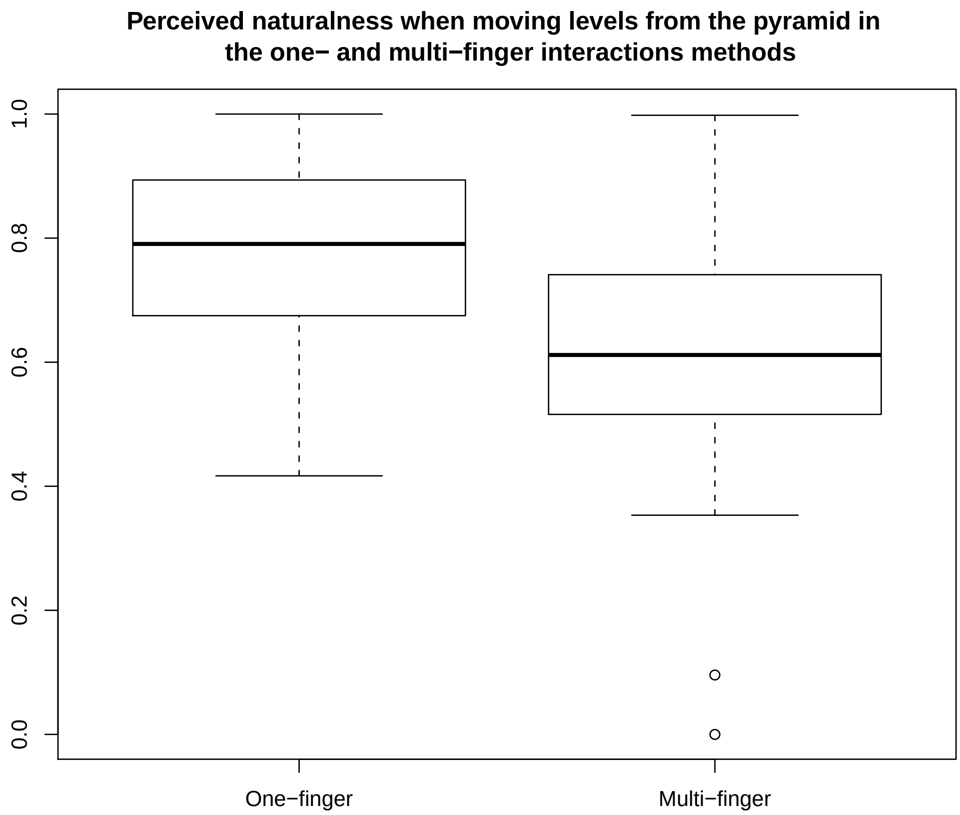

Figure 6.18: One-finger and multi-finger compared regarding naturalness of moving the pyramid

6.7 Interview

6.7.1 1: The multi-finger interaction method do not contribute to more fatigue compared to the one-finger interaction.

When asked only one mentioned minor fatigue with one-finger task and 3 mentioned minor fatigue in multi-finger task. It seams as if there could be more fatigue related to the multi-finger condition when conducting the four- and five-finger tasks. But with only three test subjects out of 20 experience minor fatigue can it not be seen as a critical factor. The difference in fatigue experienced by the test subjects during one-finger and multi-finger gestures are not profound and the hypothesis can thereby be rejected

6.7.2 2: The test subjects would prefer the multi-finger interaction method in future play with the game.

A large proportion of the test subjects state that the problem with using the multi-finger condition was the four- and five-finger gestures. These test subjects state that only would prefer multi-finger over one-finger if four- and five-finger gestures were omit. By making a third condition with one- two- and three-finger gestures the distribution the are as following:

- Six would prefer one-finger
- Five would prefer multi-finger
- Seven would prefer multi-finger without four- and five-finger gestures
- Two had no preference

There seems to be a tendency in favour of a variation of the multi-finger condition but a further investigation of the one- two- and three-finger gestures condition must be conducted before a more decisive answer can be given. The hypothesis can thereby partly rejected.

6.8 Summary of data analysis

Hypothesis	Result
Trial round	
1: The test subjects do comprehend the multi-finger interaction method better than the one-finger interaction method.	Rejected
H_0 1: The multi-finger interaction method can not improve effectiveness compared to the one-finger interaction method.	**Rejected**
1: The amount of different types of errors is not greater in the multi-finger interaction method compared to the one-finger interaction method	Rejected
2: One- to five-multifinger gestures have the same effectiveness compared to the one-finger interaction method.	Rejected
3: The amount of different types of errors perceived by the test subjects is not greater in the multi-finger interaction method compared to the one-finger interaction method	Rejected
4: The multi-finger interaction method is perceived less difficult of righting errors by the test subjects compared to the one-finger interaction method.	Rejected
5: Errors in the multi-finger interaction method are perceived less problematic when righting errors by the test subjects compared to the one-finger interaction method.	Rejected
H_0 2: The multi-finger interaction method can not improve efficiency compared to the one-finger interaction method.	**Partly accepted**
1: The multi-finger interaction method is more efficient compared to the one-finger interaction method.	Rejected
2: One- to five-multifinger gestures have the same efficiency compared to the one-finger interaction method.	Partly accepted
3: The multi-finger interaction method is perceived more efficient by the test subjects compared to the one-finger interaction method.	Rejected
H_0 3: The multi-finger interaction method can not improve easiness compared to the one-finger interaction method.	**Partly accepted**
1: The multi-finger interaction method is perceived more easy when selecting the correct levels from the pyramid by the test subjects compared to the one-finger interaction method.	Partly accepted
2: The multi-finger interaction method is perceived more easy when moving the correct levels from the pyramid by the test subjects compared to the one-finger interaction method.	Partly accepted
3: One- to five-multifinger gestures are perceived more easy by the test subjects compared to the one-finger interaction method.	Rejected
4: The multi-finger interaction method is more easy when compared to the one-finger interaction method.	Rejected
5: The multi-finger interaction method do not contribute to more cognitive load compared to the one-finger interaction.	Rejected
6: The easiness of the four drag directions is perceived the same by the test subjects.	Rejected
H_0 4: The multi-finger interaction method can not improve naturalness compared to the one-finger interaction method.	**Rejected**
1: The multi-finger interaction method is perceived more natural when grasping the correct levels from the pyramid by the test subjects compared to the one-finger interaction method.	Rejected
2: The multi-finger interaction method is perceived more natural when moving the correct levels from the pyramid by the test subjects compared to the one-finger interaction method.	Rejected
Interview	
1: The multi-finger interaction method do not contribute to more fatigue compared to the one-finger interaction.	Accepted
2: The test subjects would prefer the multi-finger interaction method in future play with the game.	Partly accepted

Table 6.18: Summary of test hypothesis

CHAPTER 7

Discussion, conclusion and further work

The initial problem of this project was, if it is possible to enrich interaction on the iPad by adding global area interaction gestures that are not tied to a specific position. It was found that the navigation on the iPad was mostly conducted with intermediary local area interactions i.e. the user pushes a button and the iPad execute the order. Furthermore it was found that there was a possibility to enrich this kind of interaction by adding multi-finger gestures to the navigation and hereby improve work flow. To verify this hypothesis an experiment, where test subjects interacted with both the traditional one-finger interaction method and the multi-finger method, was conducted. The findings of this experiment will be discussed in the following section.

7.1 Discussion

From the results of the experiment it is evident that there is challenge in applying multi-finger gestures to improve the work flow on the iPad. In the following the implications for effectiveness, efficiency, easiness, and naturalness, which defined the enrichment, will be discussed.

7.1.1 Effectiveness of multi-finger gestures

The multi-finger interaction method revealed problems with effectiveness compared to the one-finger interaction method. The large amount of errors in connection with the five-finger gesture has presumably been a significant part in this result. Most of the test subjects mentioned that the five-finger gesture was much more problematic than the other multi-finger gestures. In relation to the four-finger gesture, there were much more divided opinions to whether this gesture was problematic or not. But there seemed to be an agreement about, that the four-finger gesture was less difficult than the five-finger gesture, and more difficult than three-finger gesture. More of test subjects said that the one- two- and three-finger gesture were almost identical in easiness. This is contrary to the number of error events, where the three-finger gesture had a tendency to cause more error events than four-finger gesture - and several more than one- and two-finger gestures.

7.1.2 Efficiency of multi-finger gestures

The experiment showed that the efficiency of the of multi-finger gestures decreases when adding more fingers. One- and two-finger gestures were respectively 0.25 seconds and 0.22 seconds (mean-values) faster than the one-finger interaction mehtod. The Three-finger gesture was 0.82 seconds (mean-value) slower the the one-finger mehtod, the four-finger was 0.71 seconds slower, and the five-finger was 2.4 seconds slower. Compared to the work flow of the one-finger condition in the experiment, only one-finger and two-finger gestures in the multi-finger method would be an improvement in efficiency. The experiment however do not take aspects of finding and pressing the sought button in the interface into account when comparing the two conditions. It is thereby possible that more than one- and two-finger gestures would improve the work flow or at least be comparable in efficiency in a actual media tablet context. It is though doubtful whether applying the five-finger gesture would be advisable in relation to efficiency.

7.1.3 Easiness of multi-finger gestures

The test subjects repported that compared to easiness, the step from three-finger to four-finger is larger than the step between one- two- and three-finger. Furthermore, that the step between four- and five-finger gestures was huge. The five-finger gesture was very difficult to almost every test subject. This properly due to the ergonomically aspects of the gestures. Some of the test subjects said that it was the combination of the thumb and little finger, that made it much more difficult to perform the gestures requiring theses two fingers. Futhermore, it was observed that, some om the objects change gesture-strategy - e.g. shifted from using the thumb when conducting a four-finger gesture to leaving it out.

7.1.4 Naturalness of multi-finger gestures

The ratings of how natural the multi-finger gestures was rated, seemed to suffer form many of the test subjects being accustomed to one-finger navigation on other touchscreen devices. Non of the test subjects expressed the multi-finger gestures as being particular unnatural even though the interaction method was novel to most of the test subjects. This could indicate that the multi-finger interaction method is easy to learn and is quickly adopted by the user.

7.2 Conclusion

It can be concluded that the use of one- two- and three-finger and to some extent four-finger drag would be an interaction method that could be used for navigation on the iPad. It is hard to say if the this interaction method would improve the work flow in a significantly in a actual context, based on the data gather from this study, but the findings indicate that the multi-finger gestures could be used as a additions to the current gesture set and thereby enrich the interaction.

7.3 Further Work

To be able to fully understand how multi-finger gestures used for navigation would impact the work flow on a iPad, further studies are needed. It is clear that there is a potential in improving work flow by providing more global area interaction on the iPad.

Bibliography

Apple Inc. [2010*a*], *Apple Launches iPad - Magical and Revolutionary Device at an Unbelievable Price*, http://www.apple.com/pr/library/2010/01/27ipad.html. .

Apple Inc. [2010*b*], *Event Handling Guide for iOS*, https://developer.apple.com/library/ios/documentation/EventHandling/Conceptual/EventHandlingiPhoneOS/EventHandlingiPhoneOS.pdf. .

Apple Inc. [2011*a*], *Apple Launches iPad 2*, http://www.apple.com/pr/library/2011/03/02ipad.html. .

Apple Inc. [2011*b*], *iOS 4.3 Software Update*, http://www.apple.com/ios/. .

Apple Inc. [2011*c*], *iOS Human Interface Guidelines*, http://developer.apple.com/library/ios/documentation/userexperience/conceptual/mobilehig/MobileHIG.pdf. .

Apple Inc [2011*d*], *UIGestureRecognizer Class Reference*, https://developer.apple.com/library/ios/#documentation/UIKit/Reference/UIGestureRecognizer_Class/Reference/Reference.html. .

Arhus kommune (Aarhus council) [2011], *Vestergaardsskolen indfører iPads i undervisningen (Vestergaard elementary school adopts iPads in class)*, http://www.aarhus.dk/omkommunen/nyheder/2011/1-Kvartal/Vestergaardsskolen-indfoerer-I-Pads-i-undervisningen.aspx. .

Bærentsen, K. [2000], 'Intuitive user interfaces', *Scandinavian Journal of Information Systems* **12**(1), 4.

Bærentsen, K. and Trettvik, J. [2002], An activity theory approach to affordance, *in* 'Proceedings of the second Nordic conference on Human-computer interaction', ACM, pp. 51–60.

Bernstein, N., Latash, M., Turvey, M. and Corporation, E. [1996], *Dexterity and its development*, Taylor & Francis.

Bolt, R. A. [1980], '"Put-that-there": Voice and gesture at the graphics interface', *SIGGRAPH Comput. Graph.* **14**, 262–270.

Bolt, R. A. and Herranz, E. [1992], Two-handed gesture in multi-modal natural dialog, *in* 'Proceedings of the 5th annual ACM symposium on User interface software and technology', UIST '92, ACM, New York, NY, USA, pp. 7–14.

Bragdon, A., Uguray, A., Wigdor, D., Anagnostopoulos, S., Zeleznik, R. and Feman, R. [2010], Gesture play: motivating online gesture learning with fun, positive reinforcement and physical metaphors, *in* 'ACM International Conference on Interactive Tabletops and Surfaces', ACM, pp. 39–48.

Canalys [2011], *Google's Android becomes the world's leading smart phone platform - Canalys reveals smart phone market exceeded 100 million units in Q4 2010*, http://www.canalys.com/pr/2011/r2011013.html. .

Carroll, J. and Mack, R. [1999], 'Metaphor, computing systems, and active learning', *International Journal of Human-Computer Studies* **51**(2), 385–403.

Dalgaard, P. [2008], *Introductory statistics with R*, Springer Verlag.

Dourish, P. [2001], *Where the Action Is: The Foundations of Embodied Interaction*, The MIT Press.

Dourish, P. [2004], *Where the action is: the foundations of embodied interaction*, The MIT Press.

Efron, D. [1941], 'Gesture and environment.'.

Fishkin, K. [2004], 'A taxonomy for and analysis of tangible interfaces', *Personal and Ubiquitous Computing* **8**(5), 347–358.

Frohlich, D. M. [1997], Direct manipulation and other lessons, *in* 'Handbook of human-computer interaction (2nd ed', Elsevier, pp. 463–488.

Gartner [2011], *Gartner Says Worldwide Media Tablet Sales on Pace to Reach 19.5 Million Units in 2010*, http://www.gartner.com/it/page.jsp?id=1452614. .

Gesturecons by Ryan Lee [2011], *Gesturecons*, http://gesturecons.com/. .

Gibson, J. [1986], *The ecological approach to visual perception*, Lawrence Erlbaum.

Hutchins, E., Hollan, J. and Norman, D. [1985], 'Direct manipulation interfaces', *Human–Computer Interaction* **1**(4), 311–338.

Iceland Express [2011], *Does Iceland Express offer any inflight entertainment?*, http://www.icelandexpress.com/flight_info/help_centre/questions_and_answers/?ew_news_onlyarea=&ew_news_onlyposition=992&cat_id=73&ew_992_a_id=152&news_category_id=15. .

IDC [2010], *IDC Forecasts 7.6 Million Media Tablets to be Shipped Worldwide in 2010*, http://www.idc.com/about/viewpressrelease.jsp?containerId=prUS22345010&sectionId=null&elementId=null&pageType=SYNOPSIS. .

IDC [2011], *IDC's Worldwide Quarterly Media Tablet and eReader Tracker Makes Its Debut, Projects Nearly 17 Million Media Tablets Shipped Worldwide in 2010*, http://www.idc.com/about/viewpressrelease.jsp?containerId=prUS22660011&sectionId=null&elementId=null&pageType=SYNOPSIS. .

IMDB - The Internet Movie Database [2002], *Minority Report*, http://www.imdb.com/title/tt0181689/. .

Ishii, H. and Ullmer, B. [1997], Tangible bits: towards seamless interfaces between people, bits and atoms, *in* 'Proceedings of the SIGCHI conference on Human factors in computing systems', ACM, pp. 234–241.

Jacob, R. J., Girouard, A., Hirshfield, L. M., Horn, M. S., Shaer, O., Solovey, E. T. and Zigelbaum, J. [2008], Reality-based interaction: a framework for post-wimp interfaces, *in* 'Proceeding of the twenty-sixth annual SIGCHI conference on Human factors in computing systems', CHI '08, ACM, New York, NY, USA, pp. 201–210.

Karam, M. [2006], A framework for research and design of gesture-based human computer interactions, PhD thesis, UNIVERSITY OF SOUTHAMPTON.

Kendon, A. [1986], 'Current issues in the study of gesture', pp. 23–47.

Kettebekov, S. [2004], Exploiting prosodic structuring of coverbal gesticulation, *in* 'Proceedings of the 6th international conference on Multimodal interfaces', ICMI '04, ACM, New York, NY, USA, pp. 105–112.

Laurel, B. [1986], 'Interface as mimesis', *D. Norman & S. Draper, User Centered System Design. Lawrence Erlbaum, Hillsdale NJ* pp. 67–85.

McGrenere, J. and Ho, W. [2000], Affordances: Clarifying and evolving a concept, *in* 'Graphics Interface', Citeseer, pp. 179–186.

McNeill, D. [1996], *Hand and mind: What gestures reveal about thought*, University of Chicago Press.

McNeill, D. and Levy, E. [1982], 'Conceptual Representations in Language Activity and Gesture.'.

Memory Alpha [2011], *PADD*, http://memory-alpha.org/wiki/PADD. .

Mike Wilson [2011], *Baby Works iPad Perfectly. Amazing Must Watch!*, http://www.youtube.com/watch?v=MGMsT4qNA-c. .

Minsky, M. [1984], 'Manipulating simulated objects with real-world gestures using a force and position sensitive screen', *ACM SIGGRAPH Computer Graphics* **18**(3), 195–203.

Pastel, R. and Skalsky, N. [2004], Demonstrating information in simple gestures, *in* 'Proceedings of the 9th international conference on Intelligent user interfaces', ACM, pp. 360–361.

Pheasant, S. [1996], *Bodyspace : Anthropometry, Ergonomics and the Design of Work*, CRC Press.

Quek, F., McNeill, D., Bryll, R., Duncan, S., Ma, X., Kirbas, C., McCullough, K. and Ansari, R. [2002], 'Multimodal human discourse: gesture and speech', *ACM Transactions on Computer-Human Interaction (TOCHI)* **9**(3), 171–193.

Rekimoto, J. [1997], Pick-and-drop: a direct manipulation technique for multiple computer environments, *in* 'Proceedings of the 10th annual ACM symposium on User interface software and technology', ACM, pp. 31–39.

Rekimoto, J. [2002], SmartSkin: an infrastructure for freehand manipulation on interactive surfaces, *in* 'Proceedings of the SIGCHI conference on Human factors in computing systems: Changing our world, changing ourselves', ACM, pp. 113–120.

Rimé, B. and Schiaratura, L. [1991], 'Gesture and speech.'.

Samsung [2011], *Samsung Infuse 4G Smartphone*, http://www.samsung.com/us/mobile/cell-phones/SGH-I997ZKAATT. .

Scientific American [2009], *Smart Phones: Touch Screens Redefine the Market: Taking apart the Apple iPhone and the BlackBerry Storm*, http://www.scientificamerican.com/slideshow.cfm?id=touch-screens-redefine-the-market&photo_id=DC213CD9-A5B7-8F67-777113C8AC5D167D. .

Seymour, R., Simpson, J., Charlton, J. and Phillips, M. [1985], 'An evaluation of length and end-phrase of visual analogue scales in dental pain', *Pain* **21**(2), 177–185.

Shneiderman, B. [1982], 'The future of interactive systems and the emergence of direct manipulation', *Behaviour & Information Technology* **1**(3), 237–256.

Shneiderman, B. [1983], 'Direct manipulation: A step beyond programming languages', *Computer* **16**(8), 57 –69.

Sony Ericsson [2011], *About the experia^{TM} X10 mini - specifications*, http://www.sonyericsson.com/cws/products/mobilephones/overview/xperiax10mini?cc=gb&lc=en. .

Spelke, E. [2000], 'Core knowledge.', *American Psychologist* **55**(11), 1233.

Ullmer, B. and Ishii, H. [2001], 'Emerging frameworks for tangible user interfaces'.

van Dam, A. [1997], 'Post-wimp user interfaces', *Commun. ACM* **40**, 63–67.

Velichkovsky, B. M. [1990], 'The vertical dimension of mental functioning', *Psychological Research* **52**, 282–289. 10.1007/BF00877536.

Wensveen, S., Djajadiningrat, J. and Overbeeke, C. [2004], Interaction frogger: a design framework to couple action and function through feedback and feedforward, *in* 'Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods, and techniques', ACM, pp. 177–184.

Wexelblat, A. [1994], A feature-based approach to continuous-gesture analysis, PhD thesis, Massachusetts Institute of Technology.

Wexelblat, A. [1998], 'Research challenges in gesture: Open issues and unsolved problems', *Gesture and Sign Language in Human-Computer Interaction* pp. 1–11.

Wu, M. and Balakrishnan, R. [2003], Multi-finger and whole hand gestural interaction techniques for multi-user tabletop displays, *in* 'Proceedings of the 16th annual ACM symposium on User interface software and technology', ACM, pp. 193–202.

Hand measurement in the pre-study

In Figure A.1 a guide for measurement of the hand is seen and in Figure A.2 the values of the different measurements are listed. The guide and table was found in [Pheasant, 1996]. The hand measurements are from British workers, who can be compared to the overall west European male adults. The project member is too a west European male adult. Therefore, it can be stated, if the project member cannot hold and operate the iPad in e.g. one hand, the overall population of male adults in Europe cannot either. Regarding women, the average hand size of females is smaller, why the measurement will not come to focus. Measurements of the authors of this projects hand and the 50th %ile hand of British workers can be seen in Table A.1. Measurements of interest are shown in the black frame. It is seen that the member's hand is not smaller than 5th %ile hand or larger than the 95th %ile hand and falls in 50th %ile category.

Table A.1: Measurement of the right hand of a project member compared to the 50th %ile hand of British workers

Dimensions	Project member	50th %ile hand of British workers
1. Hand length	185 mm	189 mm
2. Palm length	107 mm	107 mm
3. Thumb length	50 mm	51 mm

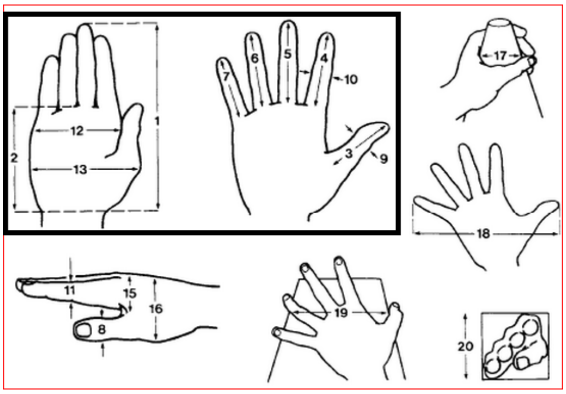

Figure A.1: Hand measurement guidelines

	Men				Women			
Dimension	5th %ile	50th %ile	95th %ile	SD	5th %ile	50th %ile	95th %ile	SD
1. Hand length	173	189	205	10	159	174	189	9
2. Palm length	98	107	116	6	89	97	105	5
3. Thumb length	44	51	58	4	40	47	53	4
4. Index finger length	64	72	79	5	60	67	74	4
5. Middle finger length	76	83	90	5	69	77	84	5
6. Ring finger length	65	72	80	4	59	66	73	4
7. Little finger length	48	55	63	4	43	50	57	4
8. Thumb breadth (IPJ)[a]	20	23	26	2	17	19	21	2
9. Thumb thickness (IPJ)	19	22	24	2	15	18	20	2
10. Index finger breadth (PIPJ)[b]	19	21	23	1	16	18	20	1
11. Index finger thickness (PIPJ)	17	19	21	1	14	16	18	1
12. Hand breadth (metacarpal)	78	87	95	5	69	76	83	4
13. Hand breadth (across thumb)	97	105	114	5	84	92	99	5
14. Hand breadth (minimum)[c]	71	81	91	6	63	71	79	5
15. Hand thickness (metacarpal)	27	33	38	3	24	28	33	3
16. Hand thickness (including thumb)	44	51	58	4	40	45	50	3
17. Maximum grip diameter[d]	45	52	59	4	43	48	53	3
18. Maximum spread	178	206	234	17	165	190	215	15
19. Maximum functional spread[e]	122	142	162	12	109	127	145	11
20. Minimum square access[f]	56	66	76	6	50	58	67	5

Figure A.2: Anthropometric data the hand

Experiment manuscript

Facilitator manuskript

Tak fordi du vil være med i forsøg. I dette forsøg skal du spille to spil på en iPad. Til hvert spil er der en prøverunde og en pointrunde. Der vil være løbende interviews og spørgeskemaer. Du skal forsøge at klare spillerunden så hurtigt du kan. Dine tider vil du få oplyst efter du har spillet begge spil, hvor du kan se dem på en high-score liste.

Først skal vi have dig til at underskrive en samtykkeerklæring, hvor du skriver under på at vi må bruge den data vi opsamler - lyd og tryk på iPad'en – til vores kommende rapport

(Samtykkeerklæring underskrives)

Herefter skal vi have dig til at sætte dig til rette i stolen og derefter placere iPad'en på bordet foran sådan du bedst muligt kan bruge den. Du vil selvfølgelig have mulighed for at justere positionen igen.

Herefter vil vi gerne have dig til at udfylde felterne på skærmen. Når du er færdig trykker på **Videre til forklaring.**

*(metadata-skærm vises. Facilitator vælger enten **1** eller **2** for at vælge spil A eller B. Testperson indtaster data og trykker videre til forklaring..)*

(intro til spil-skærm vises)

Ideen med spillet er, at du skal flytte de markerede grønne lag til det grå felt. Når du har gjort dette, er opgaven løst. Herefter vil der komme en ny opgave; når den er løst, endnu en opgave og så frem deles. Du skal blive ved at løse opgaver indtil du får andet at vide på skærmen. I prøverunden, som er det første du skal igennem, skal du selv finde ud af, hvordan du får flyttet de markerede lag ud på det grå felt – vi kan desværre ikke give dig noget hjælp i prøverunden. Husk at blive ved med at løse opgaver indtil en ny skærm vises. Hvis du er klar så tryk på **Videre til prøverunde**

(prøverunden køres i 1 minut eller indtil de har nået at lave 20 opgaver. Tid/antal opgaver vises ikke)

(Prøverunden er færdig-skærm vises)

Vi vil nu gerne have dig til at forklare, hvordan du løste opgaverne. Hvor mange lag kunne du flytte og hvordan gjorde du? Hvordan flyttede du lagene? Etc.

(checklisten forsøgs udfyldt løbende. Der stilles yderligere spørgsmål indtil de har talt om alle emner på checklisten.)

Vi forklarer dig nu, for en sikkerhedsskyld, hvordan du skal udføre opgaverne. Du skal første trykke på **Instruktionsrunde.**

*(Forklaring af, hvordan de skal lave opgaverne. Der tages udgangspunkt i det de allerede ved. Når facilitator og testperson er enige om at testpersonen har en god forståelse af, hvordan de skal løse opgaverne, skal der trykkes på **Afslut**)*

*(Klar til at spille?-skærm vises. Test personen trykker på **Start spil**, hvor de umiddelbart efter kan gå i gang med spillet. 60 opgaver laves)*

*(Flot – du har gennemført spillet!-skærm vises. Hefter kan testpersonerne trykke på **Videre til spørgeskema**)*

Vi vil nu gerne have dig til at ud fylde et spørgeskema. Du skal læse hele spørgsmålet og flytte slideren med din finger, til den ende du synes passer til spørgsmålet. Herefter har vi et par uddybende spørgsmål.

(Spørg ind til den valgte grad af svært, naturligt og problematisk. Herefter to spørgsmål)

Var der en eller flere retningerne som du synes var specielt svære at flytte lagene i? og hvorfor?
Under testen synes du da, at du fik ondt nogen steder? Fx hånden.

Vi vil nu gå i gang med det andet spil. Dog skal du atter igennem en prøverunde ved at trykke på **Videre til næste spil**. *(Testpersonen trykker på knappen).*

Side **1** af **2**

(Intro til spil-skærm vises)

I dette spil skal du også flytte de grønne markerede lag ud på det grå i felt. Igen vil vi give dig en prøverunde, hvor du heller ikke denne gang vil få hjælp til at finde ud af, hvordan du skal flytte lagene.

Hvis du er klar, så tryk på **Videre til prøverunde**

(prøverunden køres i 1 minut eller indtil de har nået at lave 20 opgaver. Tid/antal opgaver vises ikke)

(Prøverunden er færdig-skærm vises)

Vi vil nu gerne have dig til at forklare, hvordan du løste opgaverne. Hvor mange lag kunne du flytte og hvordan gjorde du? Hvordan flyttede du lagene? Etc.

(checklisten forsøgs udfyldt løbende. Der stilles yderligere spørgsmål indtil de har talt om alle emner på checklisten.)

Vi forklarer dig nu, for en sikkerhedsskyld, hvordan du skal udføre opgaverne. Du skal første trykke på **Instruktionsrunde.**

(Forklaring af, hvordan de skal lave opgaverne. Der tages udgangspunkt i det de allerede ved. Når facilitator og testperson er enige om at testpersonen har en god forståelse af, hvordan de skal løse opgaverne, skal der trykkes på ***Afslut****)*

(Klar til at spille?-skærm vises. Test personen trykker på ***Start spil****, hvor de umiddelbart efter kan gå i gang med spillet. 60 opgaver laves)*

(Flot – du har gennemført spillet!-skærm vises. Hefter kan testpersonerne trykke på ***Videre til spørgeskema****)*

Vi vil nu gerne have dig til at ud fylde et spørgeskema. Du skal læse hele spørgsmålet og flytte slideren med din finger, til den ende du synes passer til spørgsmålet. Herefter har vi et par uddybende spørgsmål. *(Hvis de spiller flere-finger spil, så skal de trykke på* ***Næste side*** *for at komme til side 2 i spørgeskema)*

(Når testpersonerne skal svare på "Hvordan var det at flytte [1-5] lag?", så spørg om de har brug for at prøve at flytte på lagene igen, ved at gå i freemode.)

(Når testpersonerne har udfyldt side 2 af spørgeksema, spørges ind til den valgte grad af svært, naturligt og problematisk. Tilslut to spørgsmål)

Var der en eller flere retningerne som du synes var specielt svære at flytte lagene i? og hvorfor?
Under testen synes du da, at du fik ondt nogen steder? Fx hånden.

(Exit interview)
Herefter har vi nogle lidt mere åbne spørgsmål:

- Hvor meget følte du, at skulle du tænke dig om før du løste de enkelte opgaver i hhv. en-finger og flere-fingre spillet - var det "bare at gribe ud og gøre det" eller oplevede du, at du skulle tænke over dine handlinger inden du gjorde det?
- Hvis du skulle vælge imellem de to måder at styre spillet, hvilken én ville du så vælge, hvis du skulle spille spillet meget?

(Hvis de har erfaring med tablets, stilles nedenstående spørgsmål)

Kunne du forestille dig at bruge denne differentiering mellem antallet af fingre til andre funktioner på tabletten? Eksempler

APPENDICES C

Declaration of consent

Samtykkeerklæring

Produkt- og Designpsykologi Gruppe 1071

Dato: ___/___-2011

Jeg bekræfter hermed som testsperson at:

- Jeg har forstået den givne information og indvilliger i at medvirke i testen.
- Jeg har forstået at jeg kan at forlade testen på hvilket som helst tidspunkt, uden yderligere forklaring.
- En iPad bliver brugt til at observe tryk på skærmen.
- Lyd under testen vil optaget.
- Renskrevne citater og oberservationer fra testen og spørgeskemaer må blive brugt i den efterfølgende rapport.
- Jeg giver tilladelse til at renskrevne citater, observationer og spørgeskemaer må videregives til vejleder og censorer i forbindelse med projekteksamen og anvendes hertil. Ydermere at denne information må videregives til tredjepart efter skriftlig tilladelse fra projektgruppen.

Dit navn vil ikke kunne forbindes til specifikke resultater eller blive videregivet til hverken offentligheden, Aalborg Universitet og eventuel tredjeparts samarbejdspartnere.

Testpersonens navn: ____________________

Underskrift: ______________________________

Testleders navn: ______________________

Underskrift: ______________________________

Tak for din deltagelse!

APPENDICES D

Notes from the experiment

Pilottest 1

En-finger spil:

Prøverunde:

Prøver sig lidt frem med en og fler finger. Finder utrolig hurtigt ud af, hvordan det skal gøres.

Forklarer fint hvordan det virker.

Har en lille smule problemer med at ramme de rigtige lag. Men ellers ser det ikke ud til at være noget problem at løse opgaverne.

Giver udtryk for det er lidt forvirrende, hvornår den snapper.

Spørgsmål:
Svært: Er vant til at bruge smartphone, så det var nemt at flytte. Valget er underligt.
Det virker unaturligt at skulle vælg først og trække bagefter.

Problematisk: Synes ikke han laver særlig mange fejl. Rammer dog forkert engang i mellem.
Han synes det var nemt forståelsemæssigt at ændre på fejl, dog var møgsommeligt.

Multi-finger spil:

Prøverunde:

Vil gerne have fat på ét lag af gangen, selvom det er tre fingre gesture han vil lave.
Tror han skal holde en smule uden for pyramiden for at løse opgaven.

Har svært ved at få fat på fem-fingre. Da der laves mange fejl, føler han ikke der er konsistens mellem, hvordan det virker.

Spillerunde:

Laver nogle "bestemte" bevægelser. Det ser ikke så flydende ud, som med én-finger spillet.

Spørgsmål:
Svært: Har svært ved at lave fire-fem fingre swipe. Siger at hans negle engang imellem kommer i vejen.
Fem fingre swipe er svært at lave.

Naturlighed: Det var nemt at forstå koblingen, det var naturligt at tage fat på lagene. Det virkede mere effektivt.
Ofte mistede man et lag et drag gesturen.
Det var nemt at rette op på fejlen.

Exit:

Det var nemmere at styre lagene med en-finger. Dog var det hurtigere med multi. Han svært at få alle lag med.
Vælger flere-fingre systemet til spil.

Multi kunne fx bruges til acc. I scroll.
Tommelfingeren gør generelt ondt.

Pilottest 2

Multi-finger spil:

Introrunde:

Prøver kun med en-finger til at starte med. Bliver ved med at bruge en-finger. Prøver ikke med multi før forsøgsleder siger til.

Spørgsmål:
Havde problemer med først at få fat i lagene pga. en-finger approach.

Spillerunde:
1-3 fingre ser ud til at køre meget godt. Dog ser det lidt besværet ud med 4-5 fingre.
Har ret godt syr på det hen mod slutningen.

Spørgsmål:
Siger hun har problemer med 4 og 5 fingre. Siger hun ikke rigtig kan få plads til 5 fingre.
Tommelfingren gør det svært. Dvs. 5 er svær. 5 rammes også mere med neglene.
Højre var svære venstre, op var sværere end ned.

En-finger spil:

Introrunde:

Dobbel-tapper på det yderste lag. Men har ellers forstået princippet.

Fortæller at man skal dobbelklikke.

Spillerunde:
Har god styr på kontrollen.
Det virker mere naturligt at tage fat med en-finger da man ikke skal tænke så meget over det. Ift., hvor mange mingre der skal på skærmen.

Spørgsmål:

"Man er vant til det". Ned og venstre er nemmest.

En-finger spillet bliver ratest som det nemmeste. Synes hun skal tænke mere over multi-finger spillet. Det kræver noget tilvænning. Følte hun skulle tænke over koblingen ved multi-finger.

Exit:

Det ville være mere udfordringer i multi-finger. Der er flere muligheder i det, men en-finger ellers.
Med træning vil det være nemmere.

Muligheder:

Fx bladre frem og tilbage i lag.

Pilottest 3

En-finger spil

Introrunde:

Prøver først med flere fingre, herefter med en finger og få det til at lykkes.
Siger man skal dobbeltklikke på det yderste lag.

Spillerunde:

Vil gerne flytte lagene næsten helt ind på det grå område. Har ikke opdaget snap.

Spørgsmål:
Havde lidt problemer med at ramme de rigtige lag.
Synes det virkede logisk.
Lige nemme retninger.
Ikke ondt nogen steder.

Introrunde:

Han prøver at bruge en-finger igen, men finder hurtigt ud af hvordan multi-finger virker.
Ser ud til han har lidt sværtmed 5-finger.

Fortæller korrekt, hvordan det virker.

Spillerunde:

Har utrolig svært ved 5-fingre drag.
Det ser besværet ud og det ser ud som om han lige skal tænke lidt før han sætter et antal finrge på.
4 fingre giver også en del problemer.
Han laver gesturen ved siden af pyramiden. Angiveligvis for at kunne se, hvilke lag han får fat på.

Spørgsmål:

Over 2 fingre giver problemer for ham. Specielt 4 og 5 giver store problemer. 5'eren er den sværeste, men 4-finger giver stadig store problemer.
Højre mod venstre drag er sværest.
At vælge de rigtige lag var sværere end en-finger. 4-5 var utrolig svært.

Exit:
Skulle tænke sig mere om med multi-finger spil.
Vælger en-finger til kontrol, da han ikke skal tænke så meget over det.
Hvis spillet blev mere kompliceret, ville han måske anvende multi-finger.
Det virker ikke virkeligt med flere fingre.

Testperson 1

En-finger spil:

Introrunde:

Prøver sig en del frem, ved først at vælge det øverste lag, derefter det næste.
Han har derfor svært ved at rette op på fejl.
Han finder til sidst ud af hvordan det virker, men er ikke helt sikker på, hvordan det virker.

Spillerunde:

Laver ikke særlig mange fejl. Trykker kun ved siden af, når han laver fejl.

Spørgsmål:

Nemt: Det var passende afstand i mellem lagene, så de var nemme at ramme.
Problematisk: Ingen kritiske fejl. Det var nemt at se, hvilke lag der var markeret. Der kan være lidt tvivl om, hvilken en af farverne som er markerings-farve, når man laver fejl.

Multi-finger:

Introrunde:

Prøver sig frem med en-finger. Det tager lang tid at finde ud af man kan bruge flere fingre.
Vil gerne have en finger på hvert lag for at flytte dem.
Har ikke forstået, hvordan man flytter lagene.

Spillerunde:

Har utrolig svært ved at lave 5-fingre gesture. Prøver med en-finger af gangen i gesturen.
Laver en del fejl ved 3 til 5 fingre. Ved de andre går det fint.
Han har tendens til, når han bruger 5-fingre gesture, at trykke uden for skærmen på iPaden.

Spørgsmål:

1-4 gestures ligger tæt. 5 er langt fra og er meget svær.
En-finger var mest naturligt.
Synes det blev lidt hårdt i hånden.

Exit:

Han tænkte ikke så meget over, hvor mange fingre han skulle bruge. Det var sværere at lave gesture i mult-finger.
5 finger overskygger det hele.

En-finger spillet virker for nemt til at man gider blive ved med at spille spillet.
Dog hvis opgaverne var mere komplicerede ville en-finger være at foretrække.

Dobbelt-klik med to fingre.
Fx kunne det bruges i markeringsøjemed.

Testperson 2

Multi-finger spil:

Introrunde:

Ser ud som om han gerne vil flytte ét lang af gangen med én finger.
Han tager det øverste først og går i stå, fordi han ikke kan flytte de andre bagefter.
Han har ikke forstået, hvordan kontrollen virker.

Spillerunde:

Har problemer med 5-finger gesturen. Resten ser fint ud.

Spørgsmål:

5-finger gesture var svær, da han gerne ville have én finger på hvert lag.
5-finger er svær fordi man ikke kan se så meget på skærmen. Det er svært at flytte tommeltot og lillefinger på en gang.
Naturligheden var okay. Dog er det lidt mærkeligt at man trykker ned og lagene flyver op.

En-finger spil:

Introrunde:

Finder ret hurtigt ud af, hvordan en-finger virker.
Har forstået, hvor kontrollen virker.

Spillerunde:

Har ingen problemer med at klare opgaverne.

Spørgsmål:

Når han kom til at vælge et hvidt lag, ville han afvælge det ved at klikke på det igen.
Retningerne var der ikke noget problem med.
Ingen smerter.

Exit:

Han er ikke vant til multi-finger, da han er vant til at markere ting og derefter manipulere dem.
Skulle tænke mere ved multi-finger.
Han følte ikke god kontrol over fejl-håndtering.

En-finger kontrol til at spille spillet.
Multi-finger ville kunne bruges, hvis det var et mere avanceret spil.

Har ikke rigtig nogen ideer til, hvad det kunne bruges til.

Testperson 3

En-finger

Introrunde:

Dobbel-klikker på den yderste ramme og kan flytte lagene.
Forstår hvordan det virker.

Spillerunde:

Har ingen problemer med at løse opgaverne.

Spørgsmål:

Ingen smerter.
Det var sværeste at hive til venstre.

Multi-finger

Introrunde:

Får en snert af det, men finder ikke ud af hvordan det virker.
Hun gætter på at 1 finger = 1 lag, 2 fingre = 2 lag, men er ikke sikker.

Spillerunde:

Giver udtryk for at 5 finger er akvavet.
1-3 fingre er nemt. 4-5 er svære fordi tommel- og lillefinger er korte.
Hun synes at 4-finger er den sværeste, da man ved 5-finger bare "Kan smide hele hånden på".

Spørgsmål:

Det var ikke så svært at rette op på fejl.
4-finger var den sværeste. 5 er lidt nemmere.
1-3 fingre er nemme. Fra 3 til 4 er der et stort skift.
Hvis man skulle have lange negle, så vil det være utrolig svært at bruge.
Syns det er naturligt at bruge.
Fik lidt mere ondt i hånden.
Retningen til fra højre til venstre var den sværeste.
Koncentrerede sig meget om at tælle fingre og placere fingre.

Exit:

Skulle ikke tælle ved en-finger man bare røre. Derimod ved multi skulle der tænke noget mere.
Skulle overhovedet ikke tænke i en-finger spillet.
Ved multi-finger skulle hun tænke meget mere, da hun både skulle tælle lag og placere hånden.
Ved en-finger tog hun bare det yderste lag og markerede og flyttede.

Ville foretrække en-finger kontrol til spillet.
Hvis spillet var lidt mere avanceret så kunne det måske godt være at multi ville være fint
Hun pointerer flere gange at 1-3 fingre er maks! 4-5 er helt håbløst.

Testperson 4

Multi-finger

Introrunde:

Vil gerne flytte ét lag af gangen med én finger.

Forstår ikke hvordan det virker.

Spillerunde:

Har lidt svært ved at få fat på 4-5 lagene, men det kører rigtig godt og han laver ikke særlig mange fejl.

Spørgsmål:

Synes det var sværest med 5-fingre.
1-3 var nemt og ens. 4-5 fingre var svære.
Ingen smerte.
Igen svære retninger.
Det var ikke indlysende, hvordan det virkede. Det krævede lidt træning.

En-finger

Introrunde:

Forstår ret hurtigt, hvordan det virker.
Og fortæller også på korrektvis, hvordan det virker.

Spillerunde:

Har ingen problemer.

Spørgsmål:

Det virkede ikke helt så naturligt, da man først skal tappe og derefter flytte.
Ingen smerte.
Interaktionen virker meget lig den han bruger på sin smartphone.

Exit:

Synes ikke man skal tænke så meget over interaktionen. Det var nemt at overskue og han skulle ikke tælle.
Problemet var at ramme rigtigt.

I og med der skal være udfordringer i spillet, vil han vælge multi-fingre.
Tror han med træningen vil blive hurtigere.
5 fingre kunne man undlade, da det er svært.
Føler han har 5 fingre på, men synes ikke han tabletten synes det samme.

Han ser bestemt muligheder i at kunne bruge flere fingre.

Testperson 5

En-finger

Introrunde:

Får flyttet det øverste lag, men kan ikke forstå, han ikke kan flytte de andre lag.

Har ikke forstået, hvordan det virker.
Ville gerne flytte det på én gang.

Spillerunde:

Tapper og dragger på nærmest én gang. Det går hurtigt med at få løst opgaverne.

Spørgsmål:

Synes det begyndte at spænde lidt i hånden.
Havde ikke svært ved retninger.
Det var nemt.

Multi-finger

Introrunde:

Prøver at ramme hvert af lagene med en finger. Har svært ved at få det til at lykkes.

Har ikke forstået, hvordan det virker. Dog fanger han at han skal bruge et bestemt antal fingre.

Spillerunde:

Har svært ved at få fat med fem fingre.
Synes det er svært at trække med 4-fingre.
Prøver at undgå at sætte hånden henover pyramiden, for ikke at dække over feedback.

Spørgsmål:

Det var svært at bruge 4-5 fingre.
3 var heller ikke helt nemt, men det var nemmere.
1-3 var meget nemmere end 4-5-

Ville ikke dække over pyramiden for at kunne se feedbacken. Det gav problemer med at få sat fingre rigtigt.
Synes han lavede flere fejl, da det var sværere at få fat på lag.
Fik ikke ondt.
Han svært ved at trække fra venstre til højre, da hånden dækkede for skærmen. Han er højrehåndet.

Exit:

Hvis han kun skulle bruge 3 fingre, ville det været på højre med en-fingre. Med 4-5 fingre var det svært.
Det virkede ikke intuitivt at løse opgaverne.
Synes ikke han skulle tælle, men det var svært at placere det rigtige antal fingre.

Hvis 4-5 fingre blev fjernet ville et kommende spil være sjovt med multi-fingre.

Kan godt se fordele ved at bruge nogle mere avancerede gestures, men kan ikke lige komme med konkrete eksempler.

Testperson 6

Multi-finger

Introrunde:

Bruger lang tid på at flytte level 1 frem og tilbage

Fanger først lige til sidst hvordan multifinger fungere og når at lave 4-5 opgaver hurtigt

Spillerunde:

Klare det uden de store problemer men har lidt svært ved at få fat med fem fingre.

Tager fat i pyramiden med fingerne ikke alt for spredt

Spørgsmål:

Det var svært at bruge 4-5 fingre.

Syntes der var et rimelig jævnt spring mellem hvor svære de blev ekstra for hver finger

Fik ikke ondt. men syntes at opgaven blev noget monotom Syntes ikke at det var nødvendigt at tælle antal finger han skulle bruge men syntes stadig det var kærvene at koncentrere sig om opgaven. Det var mest at få fat på pyramiden rigtigt der var et problem.

En-finger

Introrunde:

Fangede hurtigt opgaven, og det virkede næsten til at han syntes at tiden var for lang.

Spillerunde:

Skiftede mellem dubble tap og enkelt tap. Det går hurtigt med at få løst opgaverne uden problemer.

Spørgsmål:

Det var nemt. og der var ikke nogen problemer i opgaven, ud over den var meget monotom.

Exit:

En finger var meget nemmer og hurtigere end multifinger, det var mest på grund af 5 finger gesturen.

Multifinger var mere anstrangende og der var støre chance for at lave fejl, man skulle tænke mere og være mere præcis.

Hvis man skal bruge multifinger skal man nok udelukke 4 og 5 det er ligesom dem der gør det hele svært.

Testperson 7

En-finger

Introrunde:

Forstår hurtigt hvordan han tager fat på lagene.

Forstår hvordan det virker.

Spillerunde:
Siger der er meget dobbel-klikken.

Spørgsmål:

Synes det er unaturligt, da man ude i naturen ikke skal bruge én finger til at fx at vælge en gren og derefter flytte den. Der var en smule svært med præcisionen. Ingen retninger var sværest. En lille smule spændinger i håndledet.

Multi-finger

Introrunde:

Har svært ved at få sat fingrerne rigtigt på.

Han forstår hvordan det virker.

Spillerunde:

Ved 4-fingre siger han, at han lige skulle tælle.

Spørgsmål:

Siger han skulle tænke over, hvilke lag der var markeret og derefter forme den rigtige gesture.

Havde sværere ved at aflæse 3 og 4 lag og derefter forme den rigtige gesture.
4-5 fingre var svære at få fat på. 1-2 utrolig nemme. 3 er i mellem 4-5. Springet fra 2-3 var mindre ift. 3-4.

Synes det var nemmeste at lave venstre drag.

Begyndte at spænde en smule i håndledet – det blev akavet.

Exit:

Havde en klar fornemmelse af at en-finger var hurtigst. Da man skulle nøjes med at kigge på grøn-hvid kontrasten på lagene.

Synes det var mærkeligt skulle reversere en fejl, ved at skulle lave den gesture man lavede fejl med.

Har ikke en præference for en-finger/multi ved et spil. Det kommer meget an på konteksten.

Tror at man ved multi-finger kan træne det svære væk.

Vil koble antallet af fingre til det at flytte 4 apps med 4 fingre. Det kunne være smart at kunne flytte niveauer i en browser. Forestiller sig at multi-finger kunne bruges til mange forskellige ift. kun at bruge knapper.

Testperson 8

Multi-finger

Introrunde:

Bruger en-finger til at starte med. Flytter det øverste lag og vil gerne flytte resten med.
Prøver ikke med flere fingre. Forstår ikke han ikke kan trykke på andre lag.

Har ikke forstået, hvordan det virker.

I instruktionsrunden har han utrolig svært ved at lave 5-finger gesture.

Spillerunde:

Det ser lidt besværet ud, og det ser ud som om at han tænker en del over, hvor mange fingre han skal sætte på glasset.

Spørgsmål:

Synes at 5-finger var svær at lave. Det var ikke så stor spring fra 3-4 men fra 4-5 var der stort spring.
Synes ikke han tænkte over antallet af lag, han kunne ”genkende” størrelsen på det flytbare i pyramiden.
Nede fra og op drag var sværest.
Spændte kun i hånden ved 5-finger drag.

En-finger

Introrunde:

Sidder fast i at han skal bruge multi-finger.

Han forstår ikke, hvordan han skal gøre.

Spillerunde:

Giver udtryk for at det går godt. Ser også ud som om, at han har styr på det.

Spørgsmål:

Efter forklaring synes han, at han havde nemt ved at løse opgaver.
Ingen retninger var sværest.
Ingen smerte.
Synes han var bedre en med multi.

Exit:

Synes det var svært at sætte alle fingre på glasset. Synes det var sværest med 4 og 5 fingre.
Ville vælge en-finger til at spil, da det var nemmest.

Testperson 9

En-finger

Introrunde:

Prøver at flytte et lag af gangen. Fanger dog hurtigt at han skal ramme det yderste lag først.

Forstår hvordan man bruger det.

Spillerunde:

Har ingen problemer med at løse opgaverne.

Spørgsmål:

Ingen retninger var sværest.
Ingen smerte.
Virkede som han for ventede.

Multi-finger

Introrunde:

Prøver lidt med en-finger et par gange, men fanger hurtigt at han skal bruge flere fingre.

Forstår hvordan det virker.

Spillerunde:

Har godt styr på at sætte fingrene korrekt på glasset.
Det ser desuden ikke ud til at han tænker meget over opgaven.

Spørgsmål:

1-3 fingre er nemt. 4 er lidt sværere. 5 er meget svær.
fra 4-5 er svært. 3-4 lidt mindre.
Skulle tælle en smule for at vælge lag.
Det var lidt svært at få fat med 5.
Ingen retninger var sværest.
Ingen smerte.

Exit:

En-finger var nemmere og hurtigere.
Man skulle tænke mere over sin handling ved multi-finger.
3-4 kan godt være lidt svære at skelne.
Det er nemmest bare at bruge en-finger.

Multi-finger er sjovest. 5-finger ville han undlade.

Mener at multi-finger nemt kunne bruges til at andet. Fx når man browser, men kan ikke komme med konkrete eksempler.

Testperson 10

Multi-finger

Introrunde:

Bruger en-finger til at prøve at vælge. Hun kan dog ikke få det til at lykkes.

Forstår ikke hvordan det virker.

Spillerunde

Har lidt svært ved at få fat på 5-fingre. Ser ikke hun som om hun tæller meget, flowet er godt.

Spørgsmål:

5-finger var svær. 1-2 lige nemme. 3 var lidt sværere. 3-4 ligger meget op af hinanden. 5 ligger meget fra de andre.
Ved 3 og 4 skulle hun lige overveje det lidt ekstra.
Fra højre til venstre fra sværere end de andre.
Ingen smerter.

En-finger

Introrunde:

Trykker på hvert enkelt lag for vælge til at starte med, men finder hurtigt ud af at vælge det yderste lag og flytte lagene.

Forstår delvist, hvordan det fungerer. Hun siger hun kan bruge det på to måder. Vedat vælge det yderste lag, eller vælge alle lag fra midten.

Spillerunde:

Har ingen problemer med at løse opgaverne.

Spørgsmål:

Pyramiden opførte som hun havde regnet med.
Ingen retninger var sværest.
Ingen smerte.
Skulle ikke tænke over opgaverne.

Exit:
Det var hurtigere at kunne nøjes med at bruge en-finger. Det tog længere tid ved at bruge multi-fingre.
Det var sværere at rette op på fejl ved en-finger.

Ville foretrække en-finger til spil. Hvis det kun var 1-3 fingre, ville de være lige gode.

Testperson 11

En-finger

Introrunde:

Vil som det første flytte det øverste lag. Vil flytte det øverste lag med en-finger, det næste med to. Hun bliver ved med at prøve det.

Forstår ikke hvordan det virker.

Spillerunde:

Har nogle få fejl, da hun trykker på forkert lag, men har nemt ved at rette op på hendes fejl.
Ellers ser det ikke ud til at give hende besvær at løse opgaverne.

Spørgsmål:

Pyramiden gjorde som den skulle.
Ingen af retninger var sværest.
Ingen smerte.

Multi-finger

Introrunde:

Fanger ret hurtigt, hvordan det virker. Har lidt problemer med at vælge lag 4-5 .

Forstår hvordan det virker.

Spillerunde:

Er meget god til at forme de forskellige gestures og laver nærmest igen fejl. Dog giver 5-finger en smule problemer.

Spørgsmål:

Det var meget forskel på antallet af fingre. 1-3 fingre var nemme. 4-5 var svære at få ipaden til at reagere.
Tommelfingeren og lillefingeren er svær at få med. 4-5 ligger tæt, hvor der er større forskel fra 3 til 4.
Synes hun skulle tænke mere over opgaverne. Synes det var sjovere dog. Synes ikke hun skulle tælle. Hun kiggede på størrelsen.
Ingen retninger var sværest ved 1-3 fingre. Ved 4-5 var der nogle som var lidt sværere. Dog ikke præciseret.
Igen smerte.

Exit:

En-finger var hurtigst og nemmest. Det var lettere at styre med en-finger, fordi det var svært at få den til at reagere med multi. En-finger versus 1-3-multi var der ingen forskel. Men med 4-5 fingre giver det store problemer.

Multi-finger til spil, fordi det ville være sjovere. ”Det virker mere intuitivt med en-finger.” Det ergonomiske giver problemer. Intuitivt ville der ikke være forskel.

Kan godt se, der ville være fordele ved at bruge multi-finger. Dog vil 5 fingre giver problemer at anvende.

Testperson 12

Multi-finger

Introrunde:

Vil flytte ét lag af gangen med én finger. Bliver ved med kun at bruge én finger. Forstår ikke hvordan det virker.

Spillerunde:

Har lidt problemer med 5 fingre. Det ser ikke ud til at han skal tænke meget over opgavern.

Spørgsmål:

4-5 fingre var sværest. Fra 1-3 og til 4-5 var der et stort spring. Eksponentielt stigende sværhedsgrad.
Størst sværhedsgrad fra 4-5 fem.
Skulle tænke over hvor mange lag han skulle have fat i.
Pyramiden reagerede for det meste som den skulle.
Ingen forskel på retninger.
Ingen smerte.
Det virkede naturligt efter lidt tid.

En-finger

Introrunde:

Forstår hurtigt hvordan han bruger én-finger.

Forstår hvordan det virker.

Spillerunde:

Har nemt ved at løse opgaverne.

Spørgsmål:

Efter at prøve nogle gange fortod han hvordan den virkede. Det er nogle små områder der skal rammes, så det kan godt være lidt svært at få fat på lagene.
Det var nemmest med sidevejsbevægelser.
Ingen smerte.

Exit:

Multi-finger var hurtigere, når man ramte med det rigtige antal fingre.
Ved multi-fingere er det sværere at få fat på lagene. Det virkede mere tydeligt med multi-finger. Dog ikke ved 4-5 fingre. Ved en-finger skulle man være mere opmærksom på feedback.

Ville foretrække multi-finger spil, da der er en naturlig mapping med antallet af fingre og de lag man skal have fat i. Der er dog en større indlæringskurve ved multi.
Det er ikke så vigtigt, hvor man rammer med multi.

Ved 4-5 fingre bliver det problematisk at bruge det i en anden kontekst. Man kunne fx bruge det til at scrolle i information.

Testperson 13

En-finger

Introrunde:

Flytter først det øverstelag og prøver derefter at flytte det næste.
Finder dog ret hurtigt ud af at trykke på det yderste lag.

Forstår hvordan det virker.

Spillerunde:

Det ser ikke ud til at give besvær.

Spørgsmål:

Ville gerne undvære at skulle markere laget først. Ville bare gerne hive det over på det grå område.
Synes ikke der var nogle problemer med at få fat på lagene. Siger han gerne ville tage fat det samme sted på pyramiden hver gang.
Ingen retninger var sværest.
Ingen smerter.

Multi-finger

Introrunde:

Prøver stadig at benytte én finger. Finder dog hurtigt ud af at bruge flere fingre.

Forstår hvordan det virker.

Spillerunde:

Virker som om han lige skal tænke over hvordan han skal sætte fingrene ved mere end to fingre.

Spørgsmål:

Ved 4-5 finger var det svært, da det er svært at flytte rundt med fingre.
1-2 er rigtig nemt. 2 til 3 bliver det lidt sværer. Især giver tommel- og lillefingerproblemer.
Ved 4-finger skiftede han taktik. Skiftede fra lillefinger til at bruge tommelfinger ved 4-finger skift.
Opad drag var sværest.
Ingen smerte.
Nogle gange fik han lidt forkert fat på pyramiden, men ellers synes han den reagerede som den skulle.

Exit:

Koordineringsarbejdet med multi-finger var lidt sværer end en-finger.
Skulle ikke tænke mere over opgaverne ved multi.
4-5 fingre gav en del problemer.
1-3 ligger ikke langt fra hinanden og der er ikke meget forskel til en-finger.
Det ville være hurtigere med multi, da det ikke kræver et ekstra tryk.

I spil ville multi blive valgt, da det ville blive mere udfordrerne og sjovt.

Kunne godt se muligheder i at bruge multi. Kender fra hans Mac at man kan gå frem og tilbage i browseren, det kunne måsk også anvendes på iPaden.

Testperson 14

Multi-finger

Introrunde:

Starter med at prøve at bruge en-finger, men finder ret hurtigt ud af, at bruge multi-finger.

Har ikke forstået opgaven. Tror man skal røre alt det grønne før det kan flyttes.

Spillerunde:

Har svært ved at få fat i 5-finger. Det ser ud som om hun tæller en smule for at beslutte sig for hvilke fingre hun vil bruge til at flytte lagene.

Spørgsmål:

Det er svært at bruge 5-fingre fordi tommelfingeren ikke er på sammen linje som de andre. 4-finger er ikke det store problem. Der er ikke det store spring mellem 1-3. 4-5 er der.
Ingen retninger var sværest.
Ingen smerte.
Det var ikke svært at reversere handlingen.

En-finger

Introrunde:

Prøver med multi-finger til at starte med. Prøver sig lidt frem med en-finger men får kun flyttet det øverste lag og kan ikke flytte resten. Går derfor tilbage til multi.

Forstår ikke hvordan det virker.

Spillerunde:

Vælger på den yderste ring, men flytter fingeren ind til miden for at flytte pyramiden.
Hun løsner dog op for dette og tager fat i ca. samme område som hun har valgt lagene.

Spørgsmål:

Det virkede mere unaturligt at først skulle vælge lag og derefter flytte.
Synes ikke hun skulle tænke så meget over opgaven.
Ingen retninger var svære.
Ingen smerte.
Synes der var færre fejl, da er nemmere at styre med en-finger.

Exit:

Fordi man skal bruge tommelfingeren i multi, gør det at multi bliver sværere.

Det var hurtigere at rette op på fejl ved multi-finger. Da man sparer taps.
man skulle tænke mere ved en-finger for at rette fejl.

Ville foretrække multi, men det ville kræve en del indlæring.

Har ikke nogen ideer til, hvor multi ellers kan bruges.

Testperson 15

En-finger

Introrunde:

Vil gerne dragge med en finger med det samme. Bliver ved med at gøre og prøver ikke at gøre noget andet.

Forstår ikke hvordan det virker.

Spillerunde:

Det ser ud til køre fint for hende. Ser ikke ud som om, at hun er nødt til at tænke synderligt meget over sine handlinger.

Spørgsmål:

Det var ikke svært at få fat på lagene, dog ramte hun ved siden af et par gange.
Det var underligt at man ikke kunne dragge, men skulle vælge et lag først.
Startede med at ville trykke på det nedeste højre hjørne i pyramiden.
Ingen retning.
Ingen smerter.
Ikke problematisk, dog lidt svært at ramme det rigtige sted.

Multi-finger

Introrunde:

Benytter sig kun af en-finger. Hun prøver at flytte det første lag og vil hvert lag bagefter.

Forstår ikke hvordan man gør. Forstår hun kan flytte det øverste lag.

Spillerunde:

Har store problemer med at lave 5-finger. Siger hun ikke kan få tommelfingeren med. Har generelt store problemer med at få sat fingrene ordentligt på glasset, da hun har lange negle. Virker meget irriteret over 5-finger. Laver generelt en del fejl.

Spørgsmål:

1 finger var logisk. To fingre var ikke intuitivt til at starte. Det blev dog nemmere at bruge multi.
5-finger var den sværeste. 4 var lidt mindre svær. 5-finger var svær fordi tommelfingeren skulle med.

Opad var svær, da hun synes neglene gik på.
Ingen smerte.

Over tid, synes hun ikke hun skulle tælle lagene, men det var stadig svært at sætte fingrene korrekt.

Exit:

Det der gjorde multi langsomt, var fem fingre. Hvis det havde været 1-4 fingre så havde de været lige hurtige. Måske at multi havde været hurtigere da man kunne flytte lagene med det samme.

En-finger ville blive valgt til spil. Hvis man havde taget 5-finger ud, havde hun valgt multi.

I kontekst er hun meget konkret på at man skal flytte noget på skærmen. Kan godt se ideen i at adskille funktioner med antallet af fingre.

Testperson 16

Multi-finger

Introrunde:

Prøver kun med en-finger. Prøver sig ikke rigtig frem, sidder og undrer sig over hvorfor det ikke virker.

Forstår ikke hvordan det virker.

Spillerunde:

Er forsigtig når hun tager fat på lagene. Hun ser ud til at koncentrer sig en del om at forme gesturen rigtigt.

Spørgsmål:

Det var svære jo flere fingre man skulle bruge.
Fra 3-4 var der et stort spring. 1-3 var næsten lige nemme. 5 var sværest.
Ingen retninger var sværest.
Ingen smerter.
Skulle tænke lidt over at sætte fingrene, men hun synes ikke det var meget.

En-finger

Introrunde:

Siger hun ikke kan forstå det.

Forstår ikke hvordan det virker.

Spillerunde:

Har ikke de store problemer med at løst opgaven.

Spørgsmål:

Pyramiden virkede som den skulle efter forklaring.
I og med at hun ikke kunne regne det ud, så rater hun den som ikke naturlig.
Synes hun laver mange fejl. Hun ville sætte hastigheden op og lavede derfor flere vejl.
Ingen retning var svær.
Ingen smerter.

Exit:

Det var sværere med multi da hendes negle kom i vejen. Det var mest udpræget ved 4-5 fingre.
Hun skulle være lidt mere opmærksom ved multi for at sætte det rigtig antal fingre.

En-finger til spil da hun ikke skulle tænke så meget over det.

Hvis man fx fjernede 4-5 fingre ville forskellen mindskes.

Hun ville mene de fx skal bruges til fil-organisering.

Testperson 17

En-finger

Introrunde:

Prøver først at flytte toppen af pyramiden, derefter de andre. Lige til sidst forstår hun det.

Forstår hvordan man flytter lagene.

Spillerunde:

Har ingen problemer med at løst opgaverne.

Spørgsmål:

Synes det var irriterende at rette op på fejl, da man skulle vælge den igen.
Oppe fra og ned var sværest.
Ville helst klikke så tæt på det grå felt som muligt, men gjorde ikke altid.
Ingen smerter.

Multi-finger

Introrunde:

Prøver sig først lidt frem med en-finger, men finder hurtigt ud af at bruge flere fingre. Har dog lidt svært ved at få sat fingrene rigtigt på.

Har delvist forstået det. Det er enten at man skal ramme alle lagene på én gang eller bare sætte det korresponderende antal fingre som der er lag.

Spillerunde:

Har svært ved 5-finger. Bruger sin tommelfinger til 2-4 fingre.
Hun har en smule delay på at vælge lag. Det ser ud til at hun skal tænke en smule over sine handlinger.

Spørgsmål:

Skulle til at regne ud, hvor mange fingre hun skulle. "Man skal ikke normalt tænke over, hvor mange fingre man skal bruge til at tage fat". Blev til slut lidt en fornemmelse af hvor mange fingre der skulle bruges. Dog er 5-finger meget svære ift. de andre.
1-3 var nemme ift. 4-5.
Ingen retninger var sværest.
Ingen smerter (dog kun ved 5 fingre)
Det var svært for hende at vide om hun havde ramt forkert. Derfor virkede det unaturligt at tage fat på pyramiden.

Exit:

En-finger var nemmest, da hun havde sikkerhed for at lagene der var valgt fulgte med.
Hvis 4-5 var væk, ville det blive lige nemt. Synes at en-finger var besværligt med dobbel-tap. Med 1-3 finger ville det nok være nemmere end en-finger. Skulle tænke over antallet i multi.

Ville foretrække en-finger spillet. Dog hvis det var op til 3 fingre ville hun vælge multi.

Ville tro det måske kunne bruges til tegneprogrammer, til at vælge tykkelsen af strokes fx

Testperson 18

Multi-finger

Introrunde:

Prøver at flytte toppen til at starte med. Vil herefter gerne flytte resten. Prøver ikke at flytte toppen tilbage.

Hun forstår dog til sidst hvordan det virker.

Spillerunde:

Hun har ret godt styr på, hvordan hun skal løse opgaverne. Det ser ikke ud til at være det store problem for hende.

Spørgsmål:

5 fingre var helt klar det sværeste. Jo flere fingre jo sværere.
mellem 4 og 5 var springet stort.
Havde lidt svært ved at sætte det rigtige antal fingre på.
Da hun er lidt nærsynet, blev hun nødt til lige at kigge en ekstra gang på lagene for at vælge de rigtige.
Ingen svære retninger.
Ingen smerte.

En-finger

Introrunde:

Finger hurtigt ud af at bruge en-finger, dog trykker hun på et lag af gangen, fra midten og ud. Finder til sidste ud af, at hun kan nøjes med det yderste lag.

Forstår hvordan det virker.

Spillerunde:

Har nemt ved at løse opgaver. Laver nogle enkelte fejl.

Spørgsmål:

Der var ikke nogen overraskelser i interaktionen.
Det var nemmere med en-finger. Det virkede mere naturligt.
Ingen svære retninger.
Ingen smerter.
Skulle ikke tænke over opgaveløsning. ”Det var lige til”.

Exit:

En-finger var nemmere, da hun ikke skulle tænke over antallet af fingre.
En-finger var generelt nemmere, selvom man skar ned til 1-3 finger i multi.
Skulle tænke mere over det i multi end med en-finger.

Spil: Kommer an på genren. Men en-finger, hvis det var denne type spil.
Det ville dog give flere muligheder med multi.

I tegneprogrammer kunne man fx bruge multi-finger.

Testperson 19

En-finger

Introrunde:

Vil gerne trykke på hvert enkelt lag for at flytte pyramidedelen.

Forstår hvordan man flytter lagene til sidst.

Spillerunde:

Laver nogle småfejl, men har ellers ingen problemer med at løst opgaverne.

Spørgsmål:

Havde lidt startproblemer, men ellers virkede den som den skulle. Prøvede at dragge den til at starte med.
Synes det var lige for at løst opgaverne.
Venstre mod højre, og oppe fra og ned var nemmest.
Smerter i hånden.

Multi-finger

Introrunde:

Prøver kun med to fingre at tage fat på pyramiden.

Forstår ikke hvordan det virker.

Spillerunde:

Siger at "5-finger er noget lort". Hun siger det op til flere gange.
Ser ud til at tænke meget over at lave de rigtige gestures.
Har stadig meget svært at lave 5-finger.

Spørgeskema:

5-finger er utrolig svært.
1-2 var nemme. 3 var en smule sværere.
4 er svær, dog er 5 værst. Hun vil gerne afgrænse til 4-5.
Det var naturligt at bruge antallet af fingre. Problemet var at tage få fat på de rigtige lag.
4-5 var stadig svært efter forklaring. Heller ikke efter træning vil 4-5 være godt.
Ned og op var sværest.
Der var smerter i håndleddet.

Exit:

Hvis der kun var 1-3 ved multi ville det være lige så nemt som med en-finger.
Det var trælst med 4-5 fingre.
Der var ikke forskel på hvor meget man skulle tænke over opgaverne.

Sidestiller 1-3 fingre med en-finger interaktion.

Testperson 20

Multi-finger

Introrunde:

Prøver først at flytte toppen, derefter resten med en-finger. Prøver med multi-finger.

Forstår ikke hvordan det virker.

Spillerunde:

Har svært ved at tage fat med 5-fingre. Ser ud som om, at hun er nødt til at tænke over hvor mange fingre hun skal bruge for at tage fat på pyramiden.

Spørgsmål:

1-3 var nemme. 4-5 var sværere.
Synes ikke hun skal tænke over opgaverne. Det blev nemmere i løbet af opgaverne.
Ingen retninger var svære.
Ingen smerter.

En-finger

Introrunde:

Bruger med det samme en-finger og forstår lige bagefter, hvordan det virker.
Siger "At det er lidt nemmere end den anden".

Forstår hvordan det virker.

Spillerunde:

Har ingen problemer med at løst opgaverne.

Spørgsmål:

Pyramiden flyttede sig som den skulle.
Ingen smerte.
Det var nemmeste at flytte dem op og ned end fra side til side.
Det er nemt at rette op på fejl.

Exit:

En-finger var nemmeste da det er det hun er vant til fra et tastetur.
Tror at multi-finger dog vil blive nemmere med tiden.

Synes hun skal tænke mere over multi, da men i en-finger ikke skal overskue lagene, men bare se på det ydereste.

Til spil ville hun bruge multi, da det ville være sjovere. "Bliver træt af en-finger".

Hun kan godt se muligheder i multi, men har ikke nogle konkrete eksempler.