MEDIALOGY 2012

Group C1-20

P2 Assistive technology

Abstract

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Title: Monster Mixer

Theme: Interaction Design - Human Compuer Confluence
Project period: 2. semester 2012

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Abstract:

Monster Mixer is a game developed for the Xbox Kinect camera to help children train phonological awareness with the goal of preventing the impact of dyslexia. The game is about catching and mixing monsters using the body as an input device. Each monster represent a sound in the form of nonsense words. These sounds are used to prevent the children recognizing the words from previous experiences. The purpose of the game is to make the player listen for the monsters and then mix them together to get new monsters. *Monster Mixer* is based on the kinesthetic learning style. The Kinect provides new ways within the field of interactivity and can be used as supplement to the traditional education system. In *Monster Mixer*, the Kinect is used to detect various gestures to catch the monsters. Three prototypes were developed to test the concept: two lo-fi prototypes and one hi-fi prototype. The two latter were tested by children age 6-9. The tests showed positive result, and the children appeared to be engaging. Even though it is not possible to directly say whether the game in the long-term improves phonological awareness, it seems to take a step in the rigtig direction. The children were very positive about the game and some wanted to have it at their homes.

Circulation Numbers: 5
Number of pages: 87
Annex number: 3 (A,B1,B2)
Finished: May 24th 2012

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Introduction

The theme of the project is *Interaction Design - Human Computer Confluence* and the subtheme is *Assistive Technology*.

During one of the group's lectures in Physical Interface Design, lecturer Dan Overholdt described the way a Medialogy student works with technology in his course, using an analogy with Lego bricks. He said that the goal is not to understand every single element in details, but instead to be able to use the knowledge to put pieces together in new and interesting ways, just like Lego bricks. This image inspired our approach to this project. It was chosen to use the Xbox Kinect camera as an input device for a game. The purpose was not to comprehend the Kinect down to the last detail, but rather use it to make an innovative and interesting experience. Instead of focusing on too many technical details, we spent the time making the most entertaining product possible.

Monster Mixer is a game that have been through multiple development iterations. There has been a lot of discussion and long days, especially during the peak hours of the project. Despite this it was all worth it. We ended up developing a hi-fi prototype in Unity, and even though it is not perfect, it turned out pretty well. In all honesty, the game is something we can truly be proud of.

We would like to thank Lene Schmidt for giving feedback regarding our approach to phonological awareness. We would also like to thank Mette Porsborg and the children at Tornhøjskolen for sincerely taking their time to test our prototypes. Lastly, a big thanks goes to Lars Kiesbye Bendixen for lending his voice to the tutor Eigil in the game.

1 Problem analysis

Initial problem

How can we help people with dyslexia by the use of interactive technology?

What is dyslexia?

Unlike a few centuries back when reading was more a luxury than a necessity, we in the 21st century live in an information society where the skill of reading is crucial. Regardless of one's occupation and education it is strictly required being able to read when one is living in a western country like Denmark.

Dyslexia is a broad term used for describing people with reading and learning disabilities.

Dyslexia has been around for many years, but the understanding and definition of it has changed dramatically in the last century. In 1968 the World Federation of Neurologists defined dyslexia as "*a disorder in children who, despite conventional classroom experience, fail to attain the language skills of reading, writing, and spelling commensurate with their intellectual abilities*"[1]. Previously, it was thought not as a disability, but more as a general lack of intelligence.

It is a language-based disorder that is caused by varying degrees of faulty wiring in the brain. Instead of realizing that a word consists of different units, such as the word *kat* (English: cat) as the phonemes *c* + *aaa* + *t*, dyslectics hear it as just one sound[2]. Figure 1.1 demonstrates this concept.

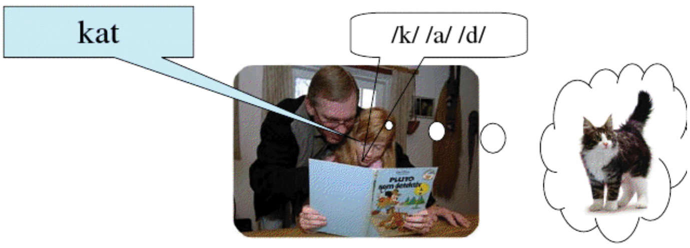


Figure 1.1 - The girl has problems with translating the graphemes k + a + t to the phonemes /k/ / a/ /d/. Dyslectics' problem is to identify and make use of phonemes, both in spoken and written language[3].

In 2003, Lyon published the following international definition of dyslexia, which builds on a previous definition from 1994: "*Dyslexia is a specific learning disability that is neurobiologicaI in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge*"[4].

Dyslectics have a hard time reading and writing, because they have difficulties with making a link between the sounds (phonemes) and letters (graphemes). This makes it hard to decode written text[5]. Dyslexia is caused by an impairment in the brain's ability to translate the images that it receives from the eyes or ears into real language. However, different opinions about dyslexia exist. According to MedicineNet.com, dyslexia has nothing to do with poor vision or hearing problems, nor is it due to brain damage, lack of intelligence or mental retardation[6]. Other studies, e.g. *the auditory theory* and *visual theory*[7], emphasize the biological dysfunctions. They don't exclude phonological deficits, but focus mostly on auditory and visual causes such as poor development of the eye and the processes involved in transporting information to the brain.

Dyslexia is distinct from other reading difficulties that are caused by non-neurological deficiency, such as insufficient teaching in how to read and write[8].

Thorsen states that dyslectics have a poor representation of words in their mental word library. Sounds and words are not clear in neither short-term nor long-term memory. This results in slow construction of words, weak working memory and attention span, as well as poor phonological awareness[9].

People, especially children, with dyslexia often have a hard time learning to read using traditional school instruction. Dyslexia can prevent a person from reading, writing and spelling properly - and in some rare cases even speaking. Reading disabilities affect at least 80 percent of the learning disability population and is thus the most prevalent type, especially in regards to children[10]. Dyslexia has hereditary predisposition, meaning that if the parents are dyslectics, chances are that the child will also have dyslexia, and it will persist throughout a person's whole life[11]. However, with proper and systematic training, the damage can be minimized, and the dyslectic can learn to read relatively fluently. Therefore it is important that dyslexia is treated as early as possible[12].

Stanovich describes a phenomena called the *Matthew effect*. It states that early success in acquiring reading skills will lead to later success and a positive attitude towards reading in general[13]. It is especially important to motivate children early to read; if not, the child will experience problems which can lead to low self-esteem and frustration. However, if the child fails to learn how to read before the third grade in school, he may fall behind and suffer from lifelong problems with reading. In other words: early success makes breeding ground for more success.

Process of reading

Reading is a complex action consisting of various cognitive processes. It requires two main abilities: decoding and comprehension.

To be able to read and comprehend a text, the reader first needs to decode the words. This is possible using decoding skills. Then in order to make sense of given words, i.e. understand them, the reader uses his language comprehension ability. These two processes are separated and equally important. If a person can't decode words on a page, he will never be able to comprehend it no matter how much oral language he can understand. On the other hand, just the fact that he can decode the words is in and of itself no guarantee of reading comprehension. If the sentences that the person is attempting to read are something he wouldn't be able to understand, even if they were read aloud to him, then the chances of him being able to understand the sentences in individual reading are small[14].

Gough and Tunmer describe reading with the so-called *simple view of reading*: reading (R) = decoding (D) x language comprehension (C)[15]. Each of the skills are measured as a numerical value between 0 and 1, where zero stands for no ability and 1 is perfect abilities. Since **R = D x C**, if either D or C is zero, the total reading comprehension will also be zero. This means that even though a person has good decoding skills (e.g. D = 0.8), if his language skills are zero (C = 0), his total reading comprehension will also be zero (0.8 x 0 = 0). An example of this could be that a person has learned some words in a foreign language and is able to sound them out, even though he does not know what they actually mean. He would be able to turn symbols (letters) into sounds, but having no idea what the sounds mean. It could also go the other way around: a person being able to read suddenly becomes blind. His decoding abilities are non- existing in regards to common visual languages (not counting Braille), but his language skills are still intact.

There are different ways of decoding:

- Symbolic decoding
- Logographic decoding
- Alphabetic decoding
- Orthographic decoding

The two first types of decoding relies mostly on shapes and forms, whereas the last two require phonological awareness and knowledge about letters and how a string of letters can form words[16]. When reading, words are split up into smaller parts, phonemes, which is a difficult process for people with dyslexia.

When text has been decoded, it also needs to be comprehended using complex cognitive processes. A reader's understanding of a text is shaped by prior knowledge and experience, as well as culture and language. It is the first part, decoding, that dyslectics have a hard time with. Figure 1.2 is a simplified illustration of the reading process.

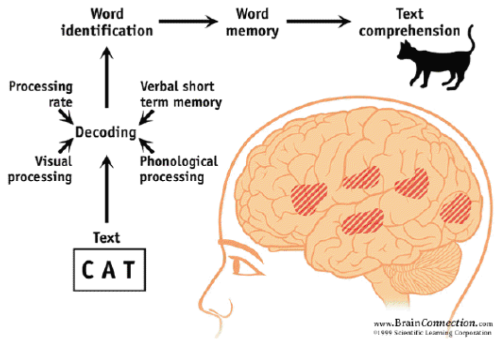


Figure 1.2 - Reading consists of two major concepts: decoding and comprehension. Dyslectics have difficulties in the first part[17]*.*

It is important to stress the differences between a poor reader and a dyslectic. A few studies have been conducted to test and compare the differences between the two, but no general conclusions have been made so far. Some studies find differences between the two kinds of poor readers in reading sub-skills, while others find none[18].

However, according to a 1988 model by Stanovich called the *phonological-core variable- difference*, dyslectics have a deficit only in the phonological core, while general poor readers usually have a variety of cognitive deficits, but their phonological problems may be less severe than those of dyslectics[19].

A poor reader might have problems in decoding, but his main problem is mostly related to comprehending the text. Dyslectics, however, have a hard time decoding written text; their problem lies not in understanding, but in decoding. Compared to a poor reader that, with focused training, can learn to read rather well, it is much harder for a person with dyslexia to learn how to decode text. However, it is still hard to make a clear distinction between the two. Figure 1.3 shows a generalising view of poor readers versus dyslectics.

	Good decoding	**Poor decoding**
Good comprehension	Good reader	Dyslectics
Poor comprehension	Poor reader	Reading retard

Figure 1.3 - A table showing the balance between decoding and comprehending. People with dyslexia are poor at decoding. Table inspired by Marianne Aaen Thorsen.

Importance of preventing dyslexia

According to a 1991 study by Carsten Elbro[20] about 7 percent of Danish adults see themselves as dyslectics. Similar studies in other countries assess about 2-5 percent of the population are dyslectics[21]. This, however, depends on the definition of dyslexia and who makes the judgement: people themselves or specialized doctors. Numbers today are believed to be higher - it is estimated that up to one million of the Danish population have insufficient reading skills[22].

It is believed that early and intense phonological awareness training can help preventing or minimizing the effect of dyslexia. Working with words, rhymes, syllables and phonemes half an hour a day can minimize the chances of developing reading problems in second school grade from 40% to 17%[23].

Recent studies funded by the National Institute of Child Health and Human Development shows that early intervention can alter pathways in the brain. Sally Shaywitz[24] who co-led the study states, "*With proper teaching and stimulation, dyslexia may be correctable*"[25]. Similar conclusions are found by Dr. Joseph Torgesen[26] who reports that "*effective early interventions have the capability of reducing the expected incidence of reading failure from 18 percent of the school age population to 1.4 to 5.4 percent*"[27].

It is believed that helping workers with dyslexia in the Danish society can save the state 1,8 billion DKK[28].

Signs of dyslexia

Dyslexia can go undetected in a child's early school years. If a child has problems in reading, he will become frustrated which can cause other problems such as depression and low self-esteem. The child also appears unmotivated and lacks an interest in school[29]. Dyslexia will often manifest itself in difficulties with the spoken language, delayed development of speech and problems with pronouncing words that have multiple consonants (e.g. "længst", "strømpe", "springe"). A child with dyslexia also has no interest in letters, such as those in the child's own name, and doesn't want to read books at all[30].

Later on in the child's school life, numerous characteristics can hint about if the child has dyslexia. Some of those are[31]:

- Difficulties with rhyming
- Difficulties in remembering words, letters and numbers
- Difficulties with rhymes makes it hard for a child to understand that two words can be in the same sound family, even though they don't look like each other (e.g. "mand/spand", "hus/mus", "potte/måtte")
- Difficulties with quickly recognizing words when reading
- Difficulties with spelling
- Difficulties with learning tables/charts and solving math problems
- Reads very slowly and imprecise in all subjects with texts
- Can have problems with summarizing texts
- Can have problems with answering open-ended questions to texts
- Might have bad short-term memory
- Has poor attention span and working memory

Classroom teachers are not always able to determine dyslexia, but they may detect early signs that can suggest further assessment by a psychologist or other professionals that can diagnose the disorder[32].

It is common for children up to the age of 8 to reverse letters and numbers. However, if this doesn't diminish, it can be a warning sign for dyslexia. The same goes for a general disorganization of written work, as well as the child not being able to remember content from videos or storybooks, even if it is the child's favorites. Children with dyslexia can also appear uncoordinated, e.g. having problems in sports or games, and tend to have problems with spatial relationships. Dyslectics also have difficulties with distinguishing left and right, and often the dominance for either hand has not yet been established[33].

Dyslectics have auditory problems, e.g. having a hard time remembering and understanding what they hear. This also shows when they have to recall sequences of things which can be difficult for children with dyslexia. Parts of words and whole sentences are sometimes missed, and if two words sound similar, they have a hard time choosing which one to use[34].

Types of dyslexia

Although there are general characteristics for dyslexia, numerous different kinds of dyslexia also exist, depending on the cause and symptoms of the disability.

Primary dyslexia is a dysfunction of the left side of the brain and doesn't change with age[35]. Primary dyslexia is the most common form. Unlike the majority of the world population that processes information primarily with the left brain hemisphere, dyslectics have a more dominant right brain hemisphere, resulting in a broader perception. It's often said that they learn by having an overview - the big picture. In other words, they see "the forest before the trees", and see whole images of words instead of the single components[36].

Secondary developmental dyslexia is caused by hormonal development or malnutrition during early stages of fetal development[37]. This can be a result of poor parenting or abuse during a child's first five years of life. Developmental dyslexia is most common for boys and is believed to diminish as the child becomes older[38].

Similarly, there is **trauma dyslexia** that usually occurs after some heavy injury to the area of the brain that controls reading and writing. This permanent brain injury is rare, since it's a result from severe head injuries[39].

Besides the three main groups of dyslexia described above, there are a range of categorizations based on the impact they have on the dyslectics. Some of these are:

One of the types is **visual dyslexia**. As the name suggest, the problem is rooted in perceiving and processing visual information. It's a result of immature development of the eyes, as well as the whole process that transfers information from the eyes to the brain[40]. People with visual dyslexia have difficulty in reading, because text can appear unfocused and jittering. Because the eyes are not completely developed, they'll send incomplete information to the brain[41]. Some describe it as if the words are behind a waterfall. If a person only has visual dyslexia and no other kinds of dyslexia, simply removing the visual problems will allow normal reading abilities[42].

Dyspraxia refers to the learning disability of sensorimotor integration characterized by an impairment of movement. It's also associated with problems in language, perception and thought. A child with dyspraxia appears clumsy and poorly coordinated[43].

Phonological dyslexia is an auditory learning disability that involves difficulty with letters and sounds. A person with this auditory form of dyslexia will have a hard time listening, because sounds are perceived as jumbled. He'll also have problems in sounding out words, especially those that are new and unfamiliar[44].

Detecting dyslexia

There are various opinions about when it is possible to detect and diagnose dyslexia. Even though there are numerous signs, one can't be sure if it's dyslexia or just reading difficulties in general. That being said, it's important to detect dyslexia as early as possible - preferably before it has developed into a real disability. In Denmark, a common test conducted in the early school years is KTI (Kontrolleret Tegne-Iagttagelse - "Controlled Drawing Observation"). This test is a tool that many schools use to detect and assess the children's basis for general perception and processing of linguistic information. It is viewed as a way to test linguistic understanding without having to analyze the reading or writing abilities of the individual child. Its purpose is to test if the child can take instructions and turn abstract descriptions into drawings on paper[45]. This test alone is not sufficient to detect dyslexia, but it still gives the teacher a general sense of the children's strengths and weaknesses.

There is a general consensus about qualitative descriptions of dyslexia among school teachers. It is difficult to determine how big the reading difficulties have to be to diagnose a child with dyslexia. Teachers may be aware of how their pupils are progressing, but they can't make a fair diagnose about dyslexia themselves[46]. Traditionally, teachers identify reading difficulties when pupil's reading and writing skills don't match the expected school level, i.e. when they are not able to read and understand the school material without assistance. However, the teacher's assessment cannot stand alone.

Various screening tests are conducted in Danish schools. Usually these take place in the third grade (age nine) with the use of multiple reading and comprehension tests.

Some common tests are the so-called OS64 and OS120 tests. The purpose of these are to test the children's ability to decode and comprehend words corresponding to their school level[47]. The OS tests solely look at the pupil's skills of reading words, not sentences. Therefore some other tests like Mini SL and SL are used to get a more holistic understanding, because they also test the writing capabilities in general. SL 60, for example, is used in the third grade to determine pupil's reading speeds, as well as their comfort in reading sentences. This reading test is a booklet with 60 tasks consisting of five pictures and one sentence. The goal is to find the picture that corresponds to the sentence[48].

Another Danish test is Phonological Subtraction with the goal of testing the children's phonological awareness. This works by asking pupils to take away a part of a word, either in the beginning ("forlyd"), middle ("indlyd") or end ("udlyd")[49].

Here are some examples:

- What happens if I take away "tand" in "tandbørste"? The answer is "børste".
- What happens if I say "kost" without "k"? The answer is "ost".
- What happens if I say "sand" without "s"? The answer is "and".
- What happens if I say "slut" without "l"? The answer is "sut".
- What happens if I say "skib" without "b"? The answer is "ski".

Nonsense words

A similar approach are tests that don't use real words, but instead rely on nonsense words (Danish: "vrøvleord"). These monosyllable words are made by changing one or more letters in real words and are not intended to make any sense. Using nonsense words makes it possible to observe children's phonological awareness, since they cannot recognize the words from previous readings or use strategies such as guessing. The following is a short list of nonsense words used by the Danish Dyslexia Society (Dansk Videnscenter for Ordblindhed)[50]:

- Køf
- Dån
- Bel
- Yls
- Unst
- Flunt
- Glask
- Fånsk

It is crucial for the children to have mastered a basic set of language skills by the end of third grade, since the following grades will rise to higher abstraction levels and reading of more and more difficult texts. It is expected that pupils can work independently with texts and large amount of information[51]. Therefore it is essential for the children being able to read and write sufficiently by the end of the third grade. If not, extensive training should be conducted so the child doesn't fall behind.

Existing tools and method used for teaching dyslectics

T here are two main types of tools: first, there are tools meant for training and learning purposes. Their goals are teaching the person how to read and write, making him independent from external tools and instead being able to tackle the problems on his own.

Then there are assistive tools that help the dyslectic in his everyday life by assisting in areas that are difficult, i.e. reading and writing. This can for instance be a tool that reads up text for the user. The dyslectic is somewhat dependent on this tool.

Existing learning tools

A tactile approach

There are a lot of different methods and tools used for teaching dyslectic to read and write. One method is made by Ronald Davis, dyslectic and author of the book *The Gift of Dyslexia* has founded the Davis Dyslexia Association International with the goal of helping people overcoming problems with reading, writing and attention focus. The Davis Method is formed by the theory "*that dyslexic individuals are picture thinkers who experience perceptual disorientation in the senses of time, vision, hearing, and/or balance and coordination*"[52]. The main components are orientation counseling and symbol mastery. The orientation counseling will help controlling the mental state of mind that leads to distorted and confusing perception of letters, numbers, etc. The student will learn how to turn off the thought processes that can cause these misperceptions, and by that return their minds to a relaxed and more focused state which is better for reading[53].

Symbol mastery helps by giving the dyslectics the ability to think with symbols and words through the use of clay. The dyslectic forms the alphabet, symbols such as punctuation marks, and numbers in order to learn the accurate perception and understanding of these. Later on, when these are mastered, 3D clay models are made of short abstract words like *and*, *the*, *to* and *it*, that are frequently seen while reading. These words are difficult for a dyslectic, because it is hard to form a mental picture that goes along with them. There are more than 200 words like these in the American language and they happen to comprise about 80% of the words usually seen in print[54]. The meanings of the words are also formed in clay, and by this approach the learning should be permanent[55].

Another tactile approach is the use of object boxes. In this approach there are two basic categories of boxes which each contain a task to be solved. First category contains printed sets of words for example cut out from food- and product wrappings glued on colored cardboard. The other category of boxes contain words and objects such as toys, miniatures and other small everyday items. It is believed that connections to real-world products makes the activity more meaningful. Some of the tasks to be solved for the first category could be to sort words with the same vowel sound into groups (see figure 1.4). For this task the words used are some that are taken from everyday life.

A task in the other category could be to place the correct vowels in a word where only the consonants are given by placing a piece of cardboard on top of another piece of cardboard and then afterwards place the object that corresponds to the word next to it (see figure 1.5). This activity is for the user to experience how the vowel sounds can differ depending on the words in which they are used[56]. Another activity from the latter category can increase awareness of how a vowel in a word changes the sound if the word ends on a silent *e*. For example, how the sound of the *i* in the word *rid* changes when the word *ride* is formed.

Figure 1.4 - Sorting words by vowel sounds[57].

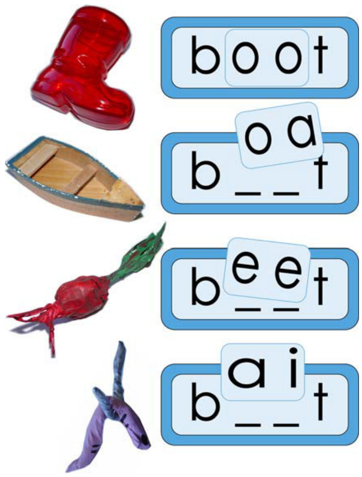


Figure 1.5 - Vowel-change word family[58].

A kinesthetic approach

A kinesthetic approach for alternative teaching of dyslectics is the stepping stone game[59] wherein the user has to recognize a certain type of word by its spoken sound, and then step on the stone whereon the word is printed. In an example given in the article *Hands-on and Kinesthetic Activities for Teaching Phonological Awareness*, a child was to identify *r*-controlled sounds in words. For example the *ar* sound in *car*, *jar* and *market*. This should make future decoding and spelling of the words easier for the dyslectics. Also there is pantomiming and miming of words where the child acts out a little play to emphasize the meaning a word. This could for instance be pantomiming the word *painter* as one who paints.

An experiment testing phonological awareness was conducted at an elementary school in Idaho where the verbal, kinesthetic and tactile approaches were tested[60]. Results were compared to a local traditional program for children with reading and writing difficulties, in which the approach were reading from a basal text and written activities on a worksheet.

Each of the pupils in the experiment took a pretest before their eight week intervention and a posttest after. The results clearly showed that the kinesthetic oriented group and the tactile oriented group gained the most by the end of the intervention. From this it can be concluded that having a tactile or kinesthetic approach on teaching to some degree produces more positive results than traditional ways of teaching. However, it has to be mentioned that only 34 pupils were tested in a single school, which renders the experiment less valid when it comes to making generalizations on the matter.

	Symbol Mastery - 3D caly models	Object boxes	Alphabet carpet	Pantomiming	Letter cards
Appearance	 61	 62	 63	 64	 65
Task	Work with alphabet symbols and short abstract words such as "and"	Sort words with the same sounds	Spell with letters by stepping on them (similar to stepping stone)	Create visual and kinesthetic connections to words	Teach the alphabet
Execution	Creating 3D clay models	Boxes containing different word games, connection to real world objects	Alphabet carpet	Pantomiming words such as "butterfly"	Pictures shaped like letters
Approach	Tactile	Tactile	Kinesthetic	Kinesthetic	Visual

Looking at the table it can be seen that there are a lot of different approaches and learning tools available for dyslectics. Visual approaches like the *Letter cards* have been used regularly for teaching kids letters. Approaches like *Symbol Mastery* and *Object boxes* have gradually started to be accepted learning methods in the educational teaching system, since tactile and kinesthetic learning has shown to be effective when working with kids and dyslexia[66].

Assistive tools

Speech synthesizer

Adgang For Alle is a free speech synthesizer tool for computers, provided by the Danish It- og Telestyrelsen - now Digitaliseringsstyrelsen[67]. By selecting any text, be it on websites, word processors, mails, PDFs, etc., the program sends the data to a server and then starts reading up the text with a synthetic voice. The tool acts like a virtual remote, sitting on the user's screen (see figure 1.6), and is aimed for people with reading difficulties. The pitch and speed of the voice can be adjusted. The voice is somewhat robotic, but understandable, and is at the moment Danish-only. One drawback is that the tool requires an Internet connecting to work, since data is transferred to a remote server before the voice data is sent back. A similar tool is Ordbanken that combines the synthetic voice as well as an intelligent spell checker aimed for school children[68].

Figure 1.6 - Picture of the Adgang For Alle tool used to read-out-loud a website.

Speech-to-text tools

Dictus is a Danish-developed speech-to-text tool that lets the user record words or sentences which are then translated into text on the computer or mobile phone[69]. Instead of manually having to type text, i.e. for a SMS or a word processor, the user dictates and the system will automatically write the appropriate text (see figure 1.7).

Figure 1.7 - The Dictus application is a speech-to-text tool that lets the user record words or sentences which are translated into text[70].

Reading pens

Numerous digital reading pens are available, using text-to-speech technology. Figure 1.8 shows an example of a reading pen. The concept is that the user scans text in a book using a digital pen. The pen will then read out the word, as well as explaining its meaning on the display. Most pens have an internal dictionary, while others require that the user connects it to a computer. Some pens can also translate into different languages.

Figure 1.8 - The ReadingPen is used to scan text and convert it to speech[71].

Audio books

Audio books are recorded books that the user can listen to instead of reading. An audio book can be useful both for people having problems with reading, but also for others who wants to listen to a book on the go e.g. on a train or when walking. Audio books can be bought on numerous online stores such as iTunes[72] and AudioBooks.org[73]. Some Danish libraries also provide audio books such as NetLydBog.dk[74]. There is also The National Library for People with Reading Difficulties (Nota) that provides over 20,000 audio books and digital books for people with documented visual or reading disabilities[75]. According to a study conducted by Nota and Epinion among 497 members of Nota in the age group 12-16, one third of the children listen to audio books daily or weekly[76].

Dyslexie font

Another problem for people with reading difficulties are the letters themselves. Some letters appear very similar - for instance *u* and *n* are the same, just turned around - and this makes it hard for dyslectics to read. A Dutch graphic studio[77] has developed a special font called Dyslexie where each letter has undergone small changes to make the differences between each character bigger and easier for the reader to recognize (see figure 1.9). Doing this prevents dyslectics mixing letters that are otherwise very similar in form and shape.

An independent research undertaken by the University of Twente proved that using the Dyslexie typeface helped people with dyslexia making fewer reading errors compared to using other fonts. However, the reading speed for those who were tested didn't change[78].

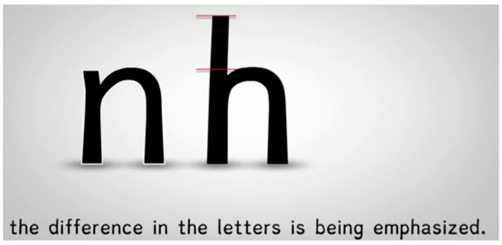


Figure 1.9 - The Dyslexie font makes differences between each letter more clear by using gravity, lengthening the ascender or descender and tipping some of the lines[79].

The conclusion of existing learning tools and the assistive tools

Assistive tools are primarily for specific situations where the dyslectic need help.

One could raise the questions: how does the reading pen help the dyslectic when he is confronted with text and has left his reading pen at home? Similarly, what does the dyslectic do when he wants to read a book that isn't recorded as an audio book? The point is that they are dependent on the tools. And if these tools are not available or don't work, then the dyslectic is left in the dark.

Then there are learning tools: these are used to train the dyslectic to manage oneself in all everyday scenarios.

Learning tools appear to be a more favorable choice when working with dyslexia. They teach the dyslectic to read in alternative ways, so they can read and write in every situation. They don't become dependent on a tool, but instead learn a set of principles that they can use on their own. This makes a functional learning tool a better solution than an assistive tool that only can be used in some situations.

Phonological awareness

Phonological awareness is a rather big subject with a lot of different categories and sub- categories. Concepts such as *phonological*, *phonetics* and *phonemics* are closely related and are often used for describing similar aspects regarding sounds. The following section is a brief exposition of the subject.

It is important to state that there is still uncertainty about the causality regarding phonological awareness. It is uncertain whether some level of phonological awareness is a necessary prerequisite for reading acquisition, or if it develops as a result of reading experience[80].

There are three fundamental ways to decode words[81]:

1. With the phonological principle
2. With the morphematical principle
3. With recognition of word pictures

1. *The phonological principle* is based on phonological and phonemic awareness. *Phonological awareness* relates only to speech sounds and it is therefore not required having alphabetic knowledge to be able to develop phonological awareness. *Phonemic awareness* is a subset of phonological awareness that focuses specifically on the ability to recognize and separate sounds and phonemes in a word. The *phonemes* are the different kinds of sounds used to form words and are used in every language. In 1886 a group of language teachers from France and Britain developed an universal alphabet called the International Phonetic Alphabet (IPA) (see figue 1.10). This alphabet contains every phoneme contained in every language and, when done and read correctly, makes a person able to perfectly read out loud words he has never encountered before. Phonemes indicates the pronunciation of the sounds in a word and it focuses on the physical properties of speech such as pitch and where to put pressure[82].

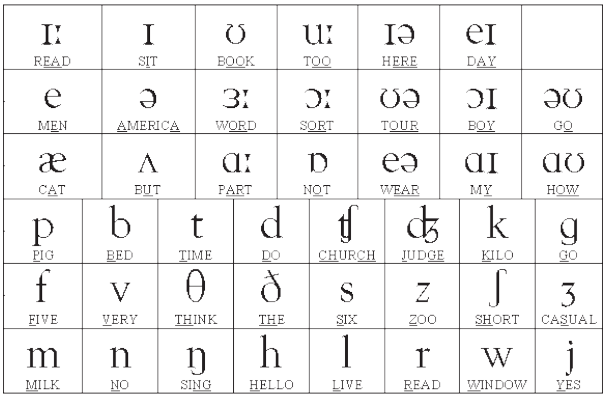


Figure 1.10 - A small segment of the International Phonetic Alphabet used to properly pronounce words[83].

In Danish it can be very hard to distinguish between the different phonemes, since there are many words that sound the same while spelled differently. For example the Danish words "vejr" ("weather"), "hver" ("each"), "vær" ("be") and "værd" ("worth") are all pronounced [vɛʌ̯ʔ] even though the spelling of them are very different. One would have to hear the word in a context to be able to determine how to spell it.

There also exist words in Danish which are spelled the same way, but have different meaning. For example the Danish word "lyst" has three different meanings - "bright", "light" and "desire" but they are all pronounced differently depending on the meaning[84].

A child with good phonological awareness will recognize that the Danish words "seng" ("bed") and "sommerfugl" ("butterfly") are phonologically alike since they both start with the same sound, even though they aren't related in meaning[85].

2. *The morphematical principle* is based on *morphological awareness*. Morphological awareness is the ability to recognize that there are certain words/suffixes/prefixes in each word that determine the meaning of the word. These are called *morphemes* and are the smallest semantically meaningful unit in a language. Of these, there are two types:

- The *free morpheme* is the root of the word and can make sense if stood alone.
- The *bound morpheme* is always seen in conjunction with a free morpheme as either prefix (before the root) or suffix (after the root) and is used to alter/determine the meaning of the root.

As an example, the word "unbreakable" broken down into its morphemes:

	Un-	**-break-**	**-able**
Morpheme	Prefix bound morpheme	Free morpheme	Suffix bound morpheme
Meaning	Signifying "*not*"	*break* (the root)	Signifying "*can be done*"

This can also be transferred to the Danish language with the word "uvenlig":

	U-	**-ven-**	**-lig**
Morphemes	Prefix bound morpheme	Free morpheme (root)	Suffix bound morpheme
Meaning	Signifying "*not*"	*ven* (the root)	Signifying "*like*"

A dyslectic won't be able to separate a word into the different morphemes and therefore won't be able to decode it and because of this, does not comprehend it.

Graphemes, *diagraphs* and *trigraphs* are the smallest semantically distinguishing units in a written language and do, contrary to morhpemes, not carry any meaning by itself. The grapheme consists of one character, the diagraph consists of two characters and finally the trigraph consists of three characters. While the phoneme indicates sounds, the grapheme, diagraph and trigraph indicate how the sound is spelled. For example, in English the phoneme */f/* can both be represented as the grapheme <*f*> and the diagraph <*ph*>.

Phoneme	Grapheme	Diagraph	Trigraph
/v/	<v> (e.g. "Vand")	<hv> (e. g. "Hvad")	-
-	-	-	<ous> (e.g "Contigous")
/f/	<f> (e.g. "Fun")	<phl> (e.g "Phantom")	-
	-	<ch> (e.g "Channel")	<tch> (e.g "Watch")
/ŋ/	-	<ng> (e.g "Sing")	-

An example of some of the few English trigraphs are the suffix *<ous>* used in words like "*contigous*" and *<tch>* in the word "*watch*". In Danish the phoneme */v/* can be represented as the graphem *<v>* in the word "*vand*" and the diagraph *<hv>* in the word "*hvad*".

3. *The recognition of word pictures* is the ability to recognize already-known words and reading them without decoding their meaning using any of the phonological and morphematical principles. This is an important tool to increase reading speed, but is not an usable method of learning since it only can be used on already-known words, making it impossible to learn new words using this principle.

Word spelling and pronunciation ("lydrette ord")

It has been discovered that the Danish language is spoken 40% faster than Swedish[86]. Both Swedish and Norwegian have kept the pronunciation of *p*, *t*, and *k* in a lot of words, contrary to Danish. For example in Danish, the word "*slik*" is pronounced with a soft *k*, making it sound like a *g* instead, while the exhausting *i* gets replaced by *e*. When talking about the letter i being exhausting, it is meant that it is literally more exhausting to pronounce than e, since it causes more tensions in the muscles of the tongue and cheeks to pronounce[87]. The same goes to *k* since this is an "explosion sound" while *g* is more relaxing.

Hansen explains this by saying that the Danes might have gotten lazy and prefer to spend their energy on other things than talking. This is probably why the removal of endings have become common in the spoken Danish language, such as *ikke ~ ik'* or *hvad ~ hva'*[88]. All this makes it difficult to learn and understand the Danish language. The problem is that the spoken language is moving away from the written language. The written language is pretty much consistent, while the spoken language keeps changing[89]. As a consequence of this there are now 3000 words in the Danish language that are spelled as they are pronounced and from those only 500 are child- friendly, meaning that they could be used in children books or in education[90]. This leaves us with a language where 96-97% of the words are spelled differently than they are pronounced[91].

Even though there are few of these words, also known in Danish as "lydrette ord", they are extremely important. Many children get frustrated early on when they find out that most of the times there isn't any logical link between how the words are spelled and how they are pronounced. This can, because of the aforementioned *Matthew Effect* (see page 10), end up placing them in a spiral of negative experiences concerning reading and eventually leave them with no desire to learn to read. Because of this the words are crucial in early learning since they build a logical bridge between spelling and pronunciation[92].

Some languages have a close relationship between letters and sounds, such as Spanish or Finnish, while others, such as Danish and English are not as consistent. These inconsistencies make it difficult to learn the languages, because it requires practical experience[93].

Learning

It is necessary to look into how humans attain new knowledge, to make it easier for children to learn how to read and write. An important aspect of this is learning styles and how individuals differ in learning.

A term often used when it comes to differentiating learners is learning styles - a theory described by several studies. However, opinion on the subject vary from study to study.

Howard Gardner's multiple intelligences (MI) and his learning styles

The theory about multiple intelligences comes from Howard Gardner. He described them the first time in 1983 in his book *Frames of mind: The theory of multiple intelligences*. His theory was that humans don't just stand out in one intelligence but rather in seven different kinds of intelligences[94]:

The seven intelligences are:

1. Linguistic intelligence - the ability to work with language, both spoken and written.
2. Spatial intelligence - means to have a good spatial awareness.
3. Logical-mathematical intelligence - is the ability to work logical, scientific and see mathematical patterns.
4. Musical intelligence - is the intelligence that is responsible for recognizing pitches and rhythms in for example music.
5. Bodily kinesthetic intelligence - means that one has a good body control. This could be someone who draws, dances or does something else, that involves one's body.
6. Intrapersonal intelligence - is the ability to reflect over ones owns thoughts and feelings.
7. Interpersonal intelligence - is the ability to understand others and their intentions and motivations.

In 1999 Howard Gardner revised his theory to eight intelligences. He put the last two of his seven intelligences together to one called Personal intelligence and declared two new intelligences. One is the Naturalistic intelligence which is the ability to recognize if something is man-made or naturalistic. The other is the Existential intelligence which is the ability to see the deeper meaning of one's existence.

In 2004, Howard Gardner defined his MI theory further in relation to how the intelligences interact. There are two possibilities: one is, that there are two intelligences that are stronger than the others and overshadow them; the other is that there are more intelligences of similar strength.

Howard doesn't just measure intelligence in one standard test like how one would measure IQ. Instead, he sees intelligence as something consisting of multiple parts. If someone isn't good at learning how to read and write in school, it doesn't mean that he is less intelligent.

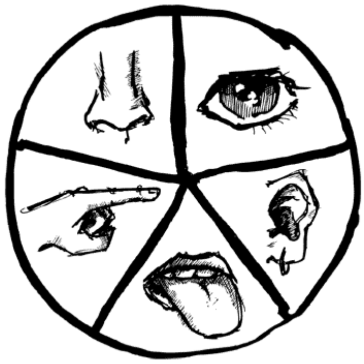


Figure 1.11 - An illustration of the five senses: sight, hearing, taste, touch and smell[95].

Humans have five senses used to perceive the world: sight, hearing, taste, touch and smell (see figure 1.11). Babies learn about the world by putting things in their mouth and by combining different learning stimuli. When they come to school, primarily two of their senses are stimulated for the purpose of learning - hearing and seeing[96].

One of the most popular theories about learning styles is called VAK (Visual, Auditory and Kinesthetic)[97]. It states that when we have to learn something, we have a preferred way of how we would like to receive new knowledge. It divides the learners into three types:

- Visual learners prefer to see the information that needs to be processed
- Auditory learners prefer to hear what the need to learn
- Kinesthetic learners either have to feel or perform what has to be perceived

It's important to keep in mind that the VAK learning styles are not meant to pigeonhole humans into three categories. It is possible that people prefer a combination of more than one of the learning styles. It also differs from task to task what kind of learner the person is. That is why good educational material always has to appeal to all three senses to let the student choose the preferred learning style.

The proof for the VAK-theory

Mahdjoubi and Akplotsyi explore a similar topic in their study *The impact of sensory learning modalities on children's sensitivity to sensory cues in the perception of their school environment*. Using a questionnaire combined with three tests, it seeks out to investigate whether children act after the characteristics of their determined learning styles. The questionnaire was filled out by observations from the teacher of the class. In the study 151 pupils, consisting of 81 boys and 70 girls age 6-11, were observed over four weeks to determine their individual learning style. After four weeks they received three tasks representing to one of three modalities: visual, auditory or kinesthetic stimuli[98].

The visual test

They called the task that should appeal to the visual stimuli *photo-safari*. The test participants were given a camera and the task to take pictures in the school area. They were to place the pictures they took on a map with a corresponding color-coded dot, and they were encouraged to make a note to each picture that justified why they took the picture (see figure 1.12). The possibilities when choosing the color of the dot where green represented a place they liked, yellow for a place they didn't like and red for a dangerous place[99].

Figure 1.12 - This shows the map where the children had to place their pictures together with a color-coded dot, telling whether they liked or didn't like the place or if it was dangerous[100].

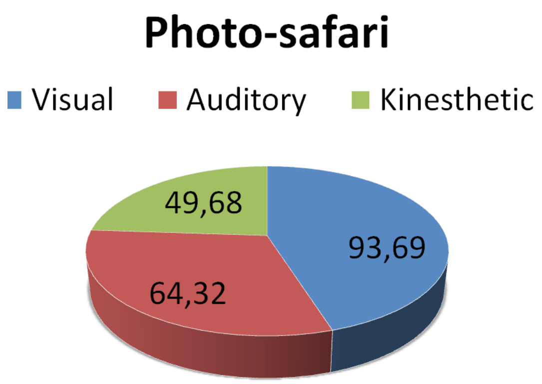


Figure 1.13 - To compare the participant's level of activity, the amount of pictures taken were compared. (self-made chart)

The test compares all the children's level of activity by the amount of photos they took. Then the mean of the amount of the pictures of the three modalities - visual, auditory and kinesthetic - were compared. The data is shown as percentages in figure 1.13 above. It gives a good overview over how many pictures the visual group took compared to the other groups.

The result shows that the children with the visual modality were more active in this task, so this confirms that children with a visual modality also have a bigger interest in solving a visual task.

The auditory test

A dialogue task was usen to display how much the children correspond to the auditory stimuli. In this task the pupils were divided into small groups of ten to fifteen persons, to discuss the school's outdoor environment (see figure 1.14). While they discussed, their speech frequency, the speech duration and number of interactions were recorded and the content of their comments were analyzed afterwards[101].

Figure 1.14 – Small groups of ten to fifteen pupils discuss the school's outdoor environment while their speech frequency, speech duration and number of interactions were recorded[102].

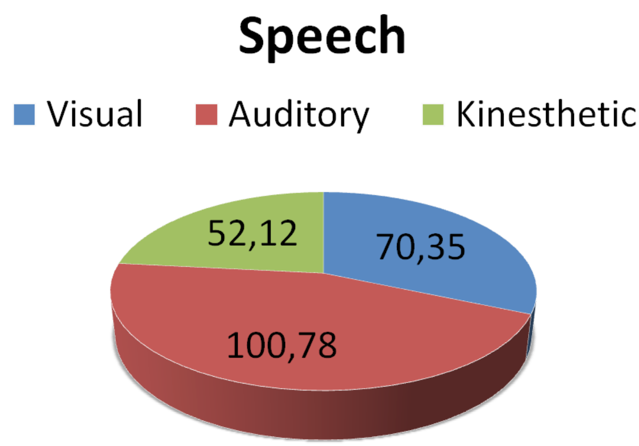


Figure 1.15 – The auditory learners had the highest speech frequency where again the kinesthetic learners were those who were the least active. (self-made chart)

Like in the visual test, the mean of the activeness in this task was calculated for the three modality groups and is expressed in figure 1.15 in a pie chart. The speech frequencies were measured to compare the groups.

Here it is again apparent that the children with the auditory modality are being more active in their task compared to the other children.

The kinesthetic test

To determine how good the test group responded to their kinesthetic stimulus, the participants wore a GPS emitter for two days, so their movement on the school environment could be measured (see figure 1.16). Furthermore, their interaction with the outdoor features were measured.

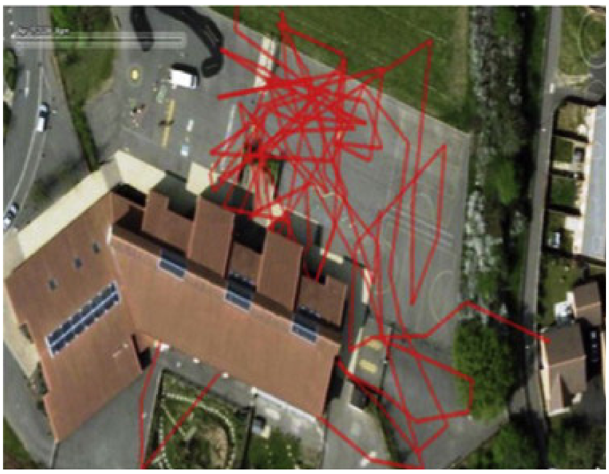


Figure 1.16 – The children each wore a GPS for two days to record their movement around the school area and measure their interactions with the playground[103].

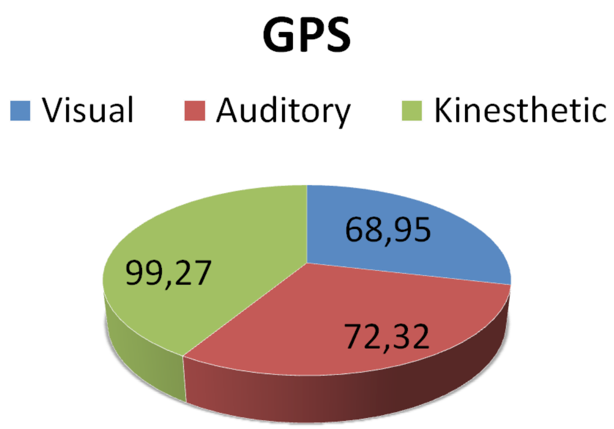


Figure 1.17 – This chart shows how much the different modality groups appealed to the task that should be most attractive for the kids with the kinesthetic modality (self-made chart).

In this third test, the compared quantity was the covered distance in combination with their interactions with the outdoor features of the school.

The results of the third test (see figure 1.17) also confirmed that the children with the kinesthetic modality moved around more in the environment and interacted more with the school's outdoor features such as swings and seesaws than the other children.

The test results

Not all the data that was collected in the study is represented here. It was chosen only to focus on on the quantitative and comparable data, but this already shows the relationship between the modality that can be measured by questionnaire and the way one acts when presented to a task that requires one modality. Even if one is forced to do a task that is not one's preferred learning style, one is still able to perform the task. In average, having a task that corresponds to one's learning style gives a better result.

David Kolb's learning styles model and experiential learning theory (ELT)

Unlike VAK, David Kolb's learning styles describe learning like a process one has to go through to learn new material[104]. He says that every learner chooses his own learning style by deciding two things: Does he want to *watch* or *do* something and does he want to *feel* or *think*. The two decisions can then be plotted into a two-dimensional coordinate system, where the four quarters of the system represent one learning style each.

According to Kolb's theory about learning styles, a person doesn't just use one specific learning style but moves circularly through the system (see figure 1.18). The learner can move from having an experience, to reviewing the experience, to concluding on the experience, to planning the next step and then start from the first step again. The learner can jump into the learning circle at any stage. Kolb states that it's important to go through the whole circle at least one time to get an applicable knowledge on a subject and by that an optimal learning process. This ensures all angles of approaches are met.

The four phases *Accommodating*, *Diverging*, *Assimilating* and *Converging* represent each a part of one's process of learning.

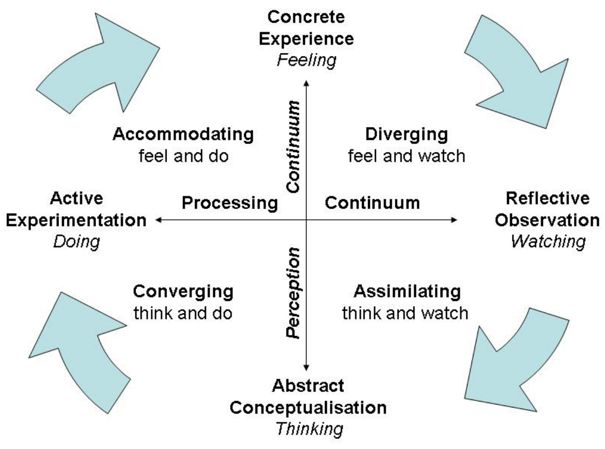


Figure 1.18 - David Kolb's experiential learning theory concentrates on processing new information by feeling, watching, thinking and doing[105].

The senses a person uses are dependent on where he is in the learning cycle. For instance, if the person starts in the *Accommodating* quarter of the model, he feels and does something. This could e.g. be that a child makes an experiment in the school. Then the child goes into the *Diverging* quarter of the model where the experiment is observed. Afterwards the child moves on to the *Assimilating* quarter where he thinks about the experiment. Lastly, he moves to the *Converging Stage* where he reflects his thoughts and compares them to already-existing theories. He could then go on in the circle to the next experimenting round.

Current Information Technology facilitates in Danish schools

Computers are gaining ground in primary and lower secondary schools in Denmark. Students need a digital education alongside the traditional education and must obtain the skills that make them capable of using the modern media and technology[106]. A study from UNI•C Statistik & Analyse shows that in 2006 every primary and lower secondary school had 46% more computers at their disposal than in 2002[107]. That means that there has been an increased use of computers in the Danish school system. The total amount of computers per school increased while the amount of pupils per PC decreased. This direction benefits the individual student.

Computers in municipal primary and lower secondary school 1/1 2006 and 1/7 2002[108]:

	1/1 2006	1/7 2002
Total amount of computers per school*	70	48
Total amount of pupils per computer	5,0	7,2

*Computers provided by school

The primary and lower secondary schools in Denmark are trying to keep up to date with the technology and media world and several schools have invested in iPads[109] to replace or support the use of books, interactive whiteboards like SMART boards[110] or Nintendo Wii for use in e.g. sports[111].

A study on IT in schools from Danmarks Evalueringsinstitut shows that both students and teachers benefit from using Information Technology in education[112]. Teachers are focusing on the motivational factor IT adds, but the study points out that focus should also be on integrating IT towards more specific courses and by that make IT more application-oriented and take starting point in more concrete requirements.

Only few teachers use IT to support subject specific learning goals. Education should be concentrated on and designed for the individual students[113], and IT promotes students to work on their own educational level[114]. The profit of using technology is closely related to the quality of design compared to the fulfillment of the education goals. That means that learning material should be specific designed for the different courses and learning goals.

The study states that today IT is not integrated in education good enough, but is only used as a supplement to the traditional teaching. Good use of IT in schools can enhance student's oral and writing level, and teachers state that their courses are developing according to the use of IT[115]. Information Technology supports interaction which encourage the students to take active part by themselves or in small groups. The teachers find that IT gives the students several approaches on education and accommodate the individual student more.

Motivation and learning

Motivation influences the quality of learning. The more motivated the student is, the higher the potential of achieving academic success is. One question comes to mind: what are the sources of motivation? A Chinese proverb says:

> "*Tell me and I'll forget; show me and I may remember; involve me and I'll understand.*"

It can be assumed that for one to be interested in something there has to be a certain degree of involvement. The need for involvement is especially important when it comes to kinesthetic learners, since they are learning by doing. Students' motivation and desire to participate in a learning environment are closely linked together. However, it also concerns reasons or goals that underlie involvement in and outside education activities[116].

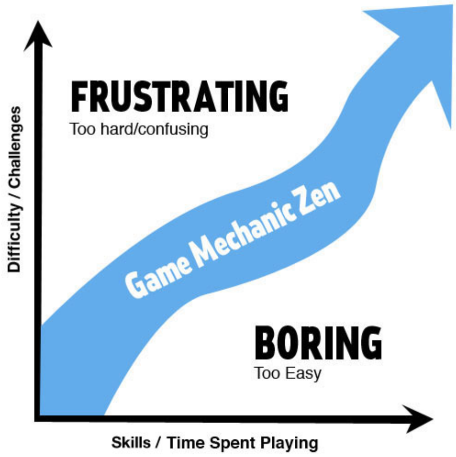
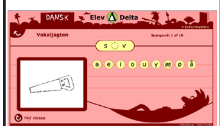
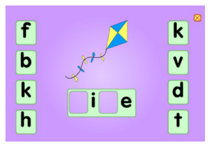


Figure 1.19[117] – Flow state in a game context; if a task is either too difficult or too challenging the process becomes frustrating, since the task is either too hard or too confusing. If the player is too experienced or skilled for a task, the task becomes too easy and by that boring.

Csikszentmihalyi's[118] flow theory states that there must be a balance between challenges and skills to obtain flow state. Flow state (see figure 1.19) is when the learner moves towards total immersion. One focuses so intensely on a task that sense of time and space is lost[119]. When the learner is in an ordered state of consciousness, motivation is at a peak point because of the flow balance.

Current digital learning games

The following learning games can inspire to new learning material where different concepts can be combined in new ways. Examination of current digital learning games gives a view on what have already been done, what have been successfully, and what can be improved to obtain the highest quality of learning. The following table looks at and compares a selection of learning games.

	Pixeline[120,121]	Cookie Monster's Letter of the Day[122]	Spelling Test[123]	Vokaljagten[124]	Starfall[125]
Appearance					
Origin	Danish	American	American	Danish	American
Visual	Yes	Yes	Yes	Yes	Yes
Auditive	Yes	Yes	Yes	No	Yes
Kinesthetic	No	No	Yes	No	No
Interaction	Mouse	Mouse	Gestures	Mouse	Mouse
Platform	Computer	Browser	Computer (Kinect)	Browser	Browser
Target Group	Kindergarten to 3rd grade	Not specified	Not specified	Kindergarten to 3rd grade	Preschool to 2nd grade

Objective	Splitting up words into syllables, learn the alphabet, learning sounds of the letters	Train phonological awareness, find words starting with a specific letter	Spelling	Finding the missing vowel	Train phonological awareness, part of a large collection in categories *ABC*, *Learn to read* and *It's fun to read*

When researching the market for current digital learning games it became apparent that most of the games rely on visual appearances of words and letters together with sounds.

Not many games focuses on kinesthetic learning. The only game that the group found, *Spelling Test*[126], appears to be rather dull, and the kinesthetic aspect of the game was only to let the player move his hand in the air making it work as an extended mouse. None of the games appeal to all three learning styles. Also, there appears to be room for games that focus on kinesthetic and auditory learning.

Definition of a game

There are multiple definitions on what videogames are. Nicolas Esposito[127] defines it with the following words: "*A videogame is a game which we play thanks to an audiovisual apparatus and which can be based on a story*"[128]. Different types of games exist as well. There are games aimed towards certain age groups, games aimed towards people with disabilities, e.g. for vision- impaired people[129], games designed specifically for speakers of certain languages and more.

There are four main elements that are important to consider during the development of a game.

A game has to:

- Have a set of goals
- Have a set of rules
- Be challenging
- Have player-computer interaction

First of all, a game has to have a set of goals. The game has to encourage the player to aim for something, as without a goal there is no point in playing a game.

Having a well-developed rule set in a game is also important. Rules define how everything in a game works: starting with basic functionality such as what should happen in an event of the player pressing a certain button, to advanced and game-specific functions.

In order for a game to be able to keep the attention of its player and make the player want to play the game, it has to offer some sort of challenge.

Lastly, a game needs to involve a certain degree of player-computer interaction. Interaction is an important element in games. It is what defines the medium compared to for example movies or books.

In summary, it can be said that a videogame is an entertaining human-computer interaction tool, which is based on four important aspects - goals, rules, challenge and interaction.

Learning in a game context

Learning through playing should be both fun and educational, and computer games have the potential to provide an alternative to traditional teaching, since they can motivate and engage learners[130]. An educational game is created for educational purposes and is designed to assist its audience in learning while playing. It is important that the game's design is connected closely to the desired learning outcomes. Fongling Fu[131] states that: "*Web-based learning games would appear to have particular appeal to the "net generation" of learners who have grown up playing computer games*"[132].

Danish teacher and speaker Erik V. Hansen has stressed the potential of the interactive medium: "*It could be an interesting challenge to use the full potential of the computer medium when it comes to learning to read - both when it comes to systematics, creativity, joy of gaming and socialization*" [translation our own][133] . He also emphasizes the fact that computer games provide a whole new approach to attention and motivation and that "*even academically weak children can sit for hours deeply concentrated*" [translation our own][134].

Results from a student learning experiment with three electronic learning games and 120 undergraduate students as subjects indicated that challenge and reward encourage the learner's engagement[135]. The student's attitude, motivation and interest will influence the learning performance, as well as the learning environment including freedom, openness and collaboration. The roles between teachers and students have changed with the evolving information and Internet technology. The teacher's role as being the source of knowledge has in a digital learning context been partly replaced by technology. The same applies for game-based learning in an education context. Game-based learning correlates with the interest and habits of the generation who has grown up with computer games. Students depend more on self-learning when playing learning games, and they are in a greater position to control progress, content, and strategy of learning.

Possible platforms

When choosing a platform for a game, the group looked at some of the available possibilities.

A platform worth of consideration is traditional board games. Most board games require no assistance from any external tools or devices, making it a suitable option for those with a limited budget. Certain board games like Twister involve the entire body in the process (see figure 1.20).

Figure 1.20 - Twister is a game of physical skill produced by Hasbro Games[136].

Some drawbacks regarding board games are the fact that they are operated by the players themselves. Compared to a digital game where the computer is responsible for maintaining the system, a non-digital game requires humans to keep the underlying system running. This is especially important to have in mind when it comes to kids, since it will require a great amount of attention span just playing the game. If the child also has to operate the system itself, this might be too much to handle. Children with dyslexia has even worse sense of attention span, which makes board games an unfitting choice. The child would most likely not be able to operate the game without help from somebody else. Board games are usually meant for social experiences. This might prove to be a problem if a dyslectic child would play a game with some non-dyslectic children. The dyslectic child would most likely feel like an outsider and have a bad experience with the game.

Then there are digital games. There have been various attempts with motion controls in games through the medium's lifetime, such as the dance mat from Konami's *Dance Dance Revolution* (see figure 1.21) and Sony's EyeToy camera for the PlayStation 2 (see figure 1.22). These devices were add-ons to already-existing game consoles, making them a secondary interaction method. Traditional controllers were still the most common input methods for digital games.

Figure 1.21 - Dancing game Dance Dance Revolution with its corresponding dancing mat[137].

Figure 1.22 - Sony's EyeToy camera are used for various motion-controlled games[138].

That changed in 2006 when Nintendo launched their Wii game console. Here, the motion controls were not only built-in from start, it was also the core component of the machine and its games.

Using a controller called the Wii Remote (see figure 1.23) that looks like a remote for a television, games are controlled by moving and pointing the remote at the screen. Inside the Wii Remote is an accelerometer that tracks player's movement, as well as an infrared camera that are used for pointing at the screen. The software translates gestures into actions on the screen, e.g. the player swings his arms, and the on-screen character replicates that in a game of baseball (see figure 1.24).

Figure 1.23 - The Wii Remote detects motion using a three-axis accelerometer[139].

Figure 1.24 - Using the Wii Remote as an input-device for controlling a game of baseball in Wii Sports[140].

The Wii became an enormous success and have by this date sold over 95 million units worldwide, which makes it the fifth-best selling game console ever[141].

In 2010, the two other major game console manufacturers, Sony and Microsoft, released their counter-response to the Wii. Sony released the Move controller for the PlayStation 3 (see figure 1.25) which has similar form and functionality to the Wii Remote. The technology in the Move controller is more advanced, since it not only has an accelerometer, but also a gyroscope and magnetometer. The gyroscope and magnetometer allow for more precise data compared to the Wii Remote's limited motion-detecting. However, Nintendo has since then released an expansion device for the Wii Remote called Wii MotionPlus that enhances the technology with a gyroscope that can determine rotational motion similar to the Move[142]. The PlayStation Move controller also uses a PlayStation Eye camera that tracks the Move controller in space using an orb with light-emitting diodes.

Also in 2010, Microsoft released their Kinect camera for Xbox 360 (see figure 1.26). Unlike the Wii Remote and PlayStation Move, Kinect requires no buttons whatsoever. Instead, players use their bodies to control the games through natural user interfaces and spoken commands[143].

Figure 1.25 - The PlayStation Move controller (right) and the Navigation controller. The glowing orb on top of Move is captured by the Eye camera as an active marker to detect its position in space[144].

Figure 1.26 - the Kinect camera released for Xbox 360. It uses depth-sensing to allow for motion-based games[145].

The Kinect device sold a total of 8 million units in its first 60 days of release, making it Guinness World Record's "fastest selling consumer electronics device"[146]. Since then, the Kinect has shipped over 18 million units[147]. Even though the camera was intended for console-use only, hackers and developers all over the world have utilized the device in various other ways. Shortly after its release, hackers had made unofficial drivers that made it possible to work with the Kinect through a computer. This later led to Microsoft releasing an official Software Development Kit (SDK) in June 2011 as a free download[148]. Since the Kinect is relatively cheap compared to similar 3D cameras on the market, such as ASUS Wavi Xtion Pro and PMD [vision] time-of-flight cameras, it has been a popular choice among hobbyists and students making non- commercial software.

	Wii Remote	Move	Kinect
Visual appearence	149 	150 	151 
Technical features **Field of vision** **Sound Output** **Soun Input** **Tracking Tools** **Other**	Three-axis accelerometer Infrared optical sensor to track pointing 8 digital buttons 1 Digital D-pad In-built speaker Can be extended with various add-ons (Nunchuck, MotionPlus and Balannce Board)	Three-axis accelerometer Three-axis angular rate sensor (gyro-scope) Magnetometer Position tracking via Eye Camera 1 analog trigger button 8 digital buttons Can be extended with Navigation controller	Infrared light projector RGB color camera (640x480 px) IR depth-sensing camera (640x480 px) 4 microphones Accelerometer Motor-control (tilting)
Interaction methods	Motion-detection of hands	Motion-detection of hands Spatial detecting	Natural User Interfaces (NUI) Body-tracking movement and spatial detecting Voice control
Manufacturer	Nintendo	Sony	Microsoft
Price *	899 DKK ***	325 DKK	399 DKK **

* All prices are from http://coolshop.dk/ of the day of writing (March 30 2012). It should also be noted that most hardware comes in bundles, e.g. you can buy an Xbox 360 with a Kinect camera. Also, the Wii console is the only machine where you cannot buy the console without getting a Wii Remote.

** This price is for the newer Wii Remote Plus that incorporates the gyroscope MotionPlus add-on. Previously it was possible to buy a standard Wii Remote and the MotionPlus add-on separately, but today Nintendo only sells the Remote with the built-in gyroscope.

*** This price is for a Kinect camera + 3 games: Kinect Adventures, Gunstringer and Fruit Ninja Kinect. The latter two have previously been released on Xbox Live Arcade which is an online download marketplace.

Why focusing on Kinect?

Kinect is designed to give the gaming experience a new dimension in where a physical gaming controller is no longer necessary. This is done by enabling the user to interact with and control the Xbox 360 by making gestures and voice commands.

One of the goals for the Kinect is to broaden the audience for the Xbox 360 gaming console and reach out beyond the modern video game player. The method to do this is by including the entire body of the person while playing, with the use of motion sensors and microphones.

To make this vision a reality the Kinect needed to include three main technologies (see figure 1.27)

- An RGD camera
- 3D depth sensors
- Multi-array microphone

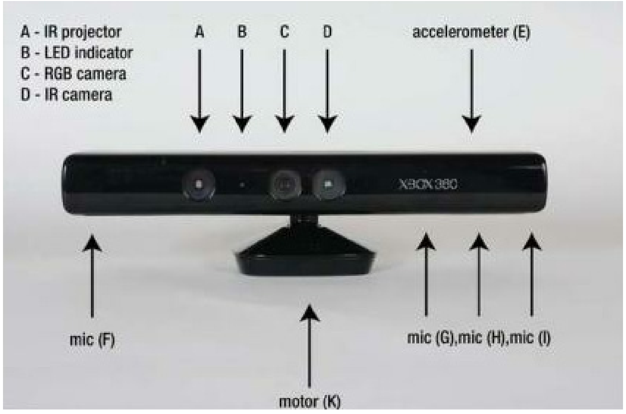


Figure 1.27 - The figure shows the placement of the main technologies[152].

The RGB camera is able to record videos and take screenshots. It can be used for video chatting and taking snapshots of in-game situations. Also, it's used for facial recognition of the user.

The 3D depth sensor consists of an infrared light emitter and a CMOS sensor which are positioned 7.5cm apart from each other. The infrared light emitter sends out an infrared light that floods the play area in where the user is positioned. The CMOS sensor then registers how the light is reflected back at the Kinect and converts this information as a monochrome picture before it passes it to the Xbox. From this monochrome picture the system can determine the depth of the play area, the movements and gestures of the player and his location.

The multi-array microphone consists of four capsule microphones that combined are able to hear and locate where the player is located. The microphones are also able to recognize voices and execute spoken commands with the help of an ambient noise filter that separates the voice of the user from background noise.

All of the abovementioned features are physically gathered inside an horizontal bar which is attached on top of a motorized pivot that has a tilt mechanism that automatically can tilt the Kinect up and down to fit the player within its point of view[153].

Differently from PlayStation Move or Nintendo Wii, Kinect does not rely on an external controller to successfully perform the motion tracking. This makes it possible to involve the entire body of a player in the game, giving significantly more involvement of the player. It also gives the developers creative freedom to use the physical space.

Also, the Kinect fits very well together with the kinesthetic learning style. Controlling a game with the entire body might be a big motivating factor for those who like to engage and be active in the activities they are a part of.

Target group

There are many different types of dyslexia and many different opinions and theories exist about them. Even though there are different characteristics depending on the types of dyslexia, they are all related in some way. One of the types, phonological dyslexia, has a focus on auditory learning disability: problems with letters and sounds. Another is dyspraxia which is problems related to sensor-motor skills. These two dyslexia types appear very relevant to the learning style theory - especially the kinesthetic learning, also described as "learning by doing".

Other characteristics of dyslectics are poor attention span and bad working memory. In kindergarten, focus is on training phonological awareness, morphemes, syntax, vocabulary and general linguistic awareness. Later on, the focus shifts to decoding and comprehension of text[154]. If the children haven't obtained fundamental phonological skills, they'll have a hard time moving forward in the education system, because the phonological understanding is the foundation for learning to read and write. This means that the crucial time for obtaining basic reading skills is somewhere between the kindergarten and first class. As stated previously, if the child haven't mastered the basic skills by the end of third grade, special training is needed.

This leaves the group with a target audience ranging from kindergarten to third grade. Also, it has been chosen to focus on Danish children only. This decision is based on the fact that the native language of most of the group members are Danish. The fact that the majority has grown up with the Danish language gives a better overview and understanding of the difficulties that children experience when learning the language.

Another reason for choosing a Danish target group is that it's easier to access Danish children for prototype testing.

That being said, the target group is Danish children in general and not only those that already have been diagnosed with dyslexia.

Since it is difficult to diagnose dyslexia before the third school grade, it is better to take a preventative approach instead of reactive. The aim is to improve phonological awareness with the hope of helping people who might, in the future, get reading problems or become dyslectic.

Characteristics of the target group:

- Danish children
- Children between the kindergarten and before the 3rd grade (age 6-9)
- Combination of playcentric and kinesthetic learning
- Children who need to enhance their phonological awareness
- All children, not only those with reading problems or dyslexia

Conclusion of the problem analysis

Dyslexia is a disorder that makes it hard to decode written text. It is believed that 80 percent of all people with learning disabilities are dyslectic[155]. Also, about 7 percent of the Danish adults consider themselves as dyslectics[156]. Because of difficulties linking letters and sounds dyslectics have a hard time reading and writing. Even though it is important to detect dyslexia as early as possible, dyslexia can go unnoticed in the early years of school because the teachers can't make a fair diagnose about the disorder. Dyslexia can't be cured, but it can be treated to minimize the difficulties it brings.

Studies have shown that it is possible to reduce the risk of children developing dyslexia through focused and systematic linguistic training[157]. The *Matthew effect* describes an important aspect of learning. It states that early success in acquiring reading skills will lead to later success and a positive attitude towards reading in general. It is therefore important to motivate children as early as possible, giving them the tools and encouragement needed to be able to read and write.

Since dyslexia cannot be cured *per se*, the group has chosen to take a more preventative approach. The group's research has shown that training of phonological awareness can help people with dyslexia later in their lives. Most importantly, the solution should be both engaging and fun. Motivation is also an essential element to be aware of.

Learning styles are an important aspect to have in mind when teaching. It is important to know that each individual has one out of three prefered learning styles where he is most effective in learning: Visual, Auditory or Kinesthetic. Optimal learning requires that teachers reach out to all different learning styles. However, in practice, this is often not the case.

Kolb describes a circular learning model with four different phases: *Accommodating*, *Diverging*, *Assimilating* and *Converging*. A school setting doesn't necessarily give students the option of going through all four phases. If a student falls behind, he might not be able to finish a phase which results in him not going through all phases as the model suggests. Contrary, a game provides the opportunity for the student to train in his own pace. Instead of being stressed, he is able to slowly move through all the phases instead of stopping midway.

Also in the conventional class teaching there is not allocated a lot of time to go through the Active Experimentation and Concrete Experience directions, so the teaching consists for the most part only of listening, watching and thinking. Having a game in the home that would help the student go through Kolb's circle would be a great addition to the student's learning process.

The Xbox 360 Kinect camera facilitates kinesthetic learning using motion-tracking technology. Compared to other game controllers such as Nintendo's Wii Remote and Sony's Move that only allows for tracking of the hands, Kinect provides full-body motion-detection, without requiring any external or physical device. A physical controller might distract from the overall experience, but this is avoided completely with the Kinect.

The Kinect seems a good choice for developing software that focuses on the kinesthetic learning style, as well as training phonological awareness. It can be beneficial when it comes to the chosen target group of young Danish children.

The Kinect appears to be an attractive piece of hardware. Even though it is still relatively new, it is yet to hit a major breakthrough when it comes to learning software in the Danish school system. The theme for this project is *Interaction Design - Human Computer Confluence*. Having the subtheme of the project in mind, *Assistive Technology*, the Kinect provides an interesting opportunity to help people who suffers from reading disabilities.

Problem statement

How can Kinect be used in order to create a game that reduces the impact of dyslexia by training phonological awareness? Is it possible to make a game based on the kinesthetic learning style that is non-intrusive, motivating and fun?

2 Theory and methods

Scaffolding

Scaffolding is an approach that is made to support and secure control of success in learning. This could be a teacher guiding students to do something beyond their independent efforts, or a computer that provides students with web links, online tutorials, or help pages. Chris Quintana et al. express that: "*Scaffolds are software features that support novices in seeing and performing previously unknown and inaccessible tasks*"[158].

Learner-centered design is focusing on the design of software scaffolds to support learners in using software, while addressing the specific needs of learners and support them in understanding new material or work practices. Learner-centered design focuses on tools that advance learning and minimize the gap between the learners and the learning material. It is important that the scaffolding principles keeps a high level learning outcome, and follows the flow theory of Csikszentmihalyi (see page 24). According to Chris Quintana et al. "*if a scaffold makes the work too easy to perform, learners may complete their tasks without the needed reflection, which can be detrimental to learning*"[159].

According to John Dewey[160] there is a great importance in making connections between newly learned material and already obtained experience[161]. Designing learning processes must reflect and support the concept of creating connections. Learner-centered design differs from user-centered design which is centered around the tool usability, ease-of-use and work efficiency. Learner-centered design should involve good usability design, though it alone does not guarantee a good scaffold strategy, since focus should be on the learning material and the interactions that lead to desired learning outcomes.

The waterfall model

In software engineering, one of the first models used widely was the so-called waterfall lifecycle model, which still forms the basis of many software development projects today[162]. As the name suggest, it is a linear model with various steps that need to be completed. As shown in figure 2.1, when a step is completed, you move down to the next. However, it is not possible to go back up and make changes when a step has been completed. The waterfall method usually begins with a set of requirements that need to be met. Then the features are analyzed and designed. After this the actual implementation and coding begins which then goes into testing and verification and, lastly, maintenance. The main problem with this approach is that requirements change over time. Since the waterfall model sets the requirements in stone, thereby freezing it for months or years, there is no possibility to go back and change anything. The concept of iterations is not a part of the philosophy behind the waterfall method, which makes it difficult to change the implementation based on feedback gathered from tests.

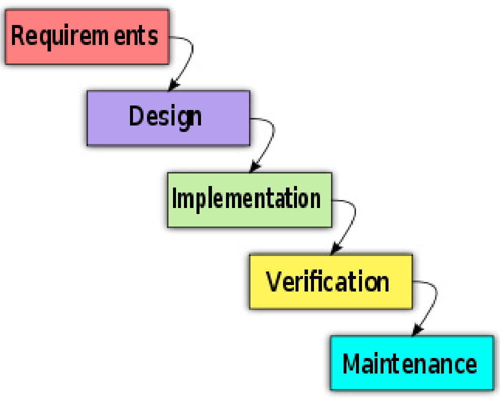


Figure 2.1 – The waterfall model is used in software development. It is divided into multiple phases. A phase can only begin when the previous has ended, and it is not possible to go back[163].

The spiral model

The waterfall model was the de facto way of doing software development until the late 1980's where Barry Boehm came up with a new model: the spiral model[165]. Boehm realized a need for a more iterative approach. Instead of going linearly from start to finish, software should be looked at like a cycle that constantly repeats. The spiral model makes use of an iterative framework that allows ideas and implementation to constantly be checked and evaluated (see fugire 2.2). As it is shown in figure 2.2, the spiral model utilizes a set of phases and lifecycles. There are typically four steps: analysis, design, implementation and testing. The idea behind the spiral model is that the developers start in the analysis phase, researching the problem. Afterwards they design the solution, and then they implement it. After the implementation is done, testing is conducted. The key here is that this is not the finishing line as in the waterfall model; instead, the whole cycle is repeated with all its phases. The spiral model allows for and encourages iterations. It is now possible to make an initiate software product, test it, and then, based on the feedback from the test, change it. Tied together with the idea of prototyping, the spiral model allows for a more dynamic solution that changes over time. The idea is that as long as the developers continue iterating, the product becomes better and better.

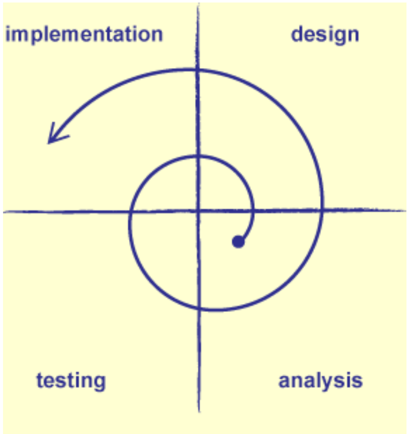


Figure 2.2 - The spiral model introduces the concept of iterations. It uses four phases that are repeated multiple times[164].

Prototyping

Prototypes are used in order to simulate the usage of a product without having the product itself functional and ready for evaluation. The term prototype can refer to almost anything from a simple cardboard box with a few holes cut out to resemble a complex piece of software or an advanced electronic device. Therefore a prototype could be considered a limited imitation of a concept, allowing its users to evaluate the usability, without the need of a finished product[166]. Prototypes are labeled as either *high-fidelity* or *low-fidelity*, often shortened as lo-fi and hi-fi. The main difference between the two is the amount of money and/or time spent during its creation, as well as the actual functionality level of the prototype[167].

A low-fi prototype is a prototype that in most situations does not look like the final, intended product. Neither is it kept as an integral part of it. Lo-fi testing is a relatively cheap way to explore the concept of an idea and get some feedback on it without having to invest time and money into the actual product. Product versions, used for lo-fi testing, tend to be made of materials which are much cheaper and more accessible, for example paper or cardboard instead of metal[168].

An important aspect of lo-fi prototypes is that they are intended to be relatively easy to modify or replace completely. Due to the fact that they are only used for quick evaluation purposes and are not kept as a part of the finished product, the lo-fi prototypes need to be very adjustable to spontaneous concept changes[169].

The downside of lo-fi prototypes is that they are in most cases human-driven and not visually appealing.This makes it hard to hide that it is just a prototype[170].

Hi-fi prototypes, on the other hand, resemble the final product a lot more both in appearance and functionality. They are usually made out of the same materials as the final product, look almost or completely identical, are fully interactive and do not require a human-controller. While significantly more useful than lo-fi prototypes, hi-fi prototypes take much more time and money to develop and therefore are not very efficient when it comes to early product development tasks, such as conceptual testing[171].

Wizard of Oz

Instead of spending a lot of time developing the real system, it is easier and cheaper to use the *Wizard of Oz* prototype method. Here, a human takes the role of the computer. This person is "pulling the strings behind the curtain" and is hidden from the test participant. From the test participant's point of view, the system works as intended, even though it is in fact not finished[172].

Data collection - triangulation of data gathering

Triangulation is a way of confirming knowledge, integrating different perspectives, reducing bias and validating data (see figure 2.3)[173].

Triangulation of sources means cross-checking sources validity and reliability. By having several sources stating the same arguments, the sources will appear more trustworthy.

- *Triangulation of sources* means cross-checking sources validity and reliability. By having several sources stating the same arguments, the sources will appear more trustworthy.
- *Triangulation of theory* is applying several theories to cover different perspectives.
- *Triangulation of data* is collecting data from different places at different times with different people. This could be obtained by giving the same questionnaire to different respondents.
- *Triangulation of methods* is the use of several methods like interviews, questionnaires, prototypes etc[174].

Validity is examining the truth of a conclusion and stating whether a given objective is a valid indicator of the concept that's being investigated[175].

Reliability investigates whether the collected data can be trusted and whether the results are reproducible[176].

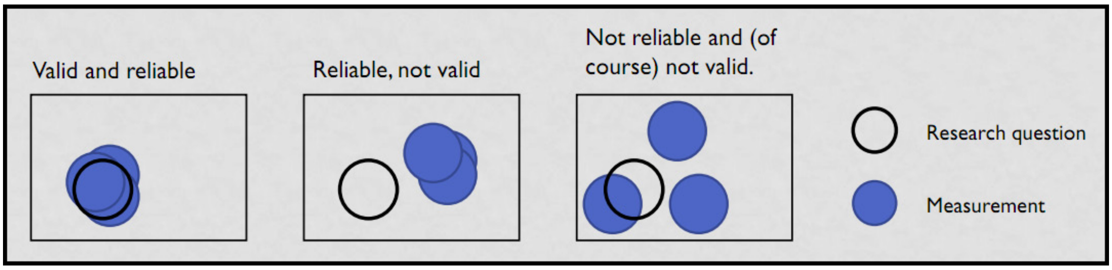


Figure 2.3 - In order for data to be trustworthy and reproducible it should be both reliable and valid[177].

Color theory & composition

Color theory can help designers to create harmonious results. The first color wheel was designed by Sir Isaac Newton in 1666 as a circular color diagram. This color wheel (see figure 2.4) shows from the center the primary and secondary colors, where the secondary colors are created by mixing two of the primary colors. Around them are the 12 colors based on the red- yellow-blue color model (RYB). Color combinations that are considered pleasing are called color harmonies and consist of minimum two colors with fixed relation in the color wheel[178].

Figure 2.4 - The color circle is basic tool for combining colors, and is designed so that any two or more colors picked from the circle will look good together. Inside the color circle are the primary colors and their mixes: the secondary colors[179].

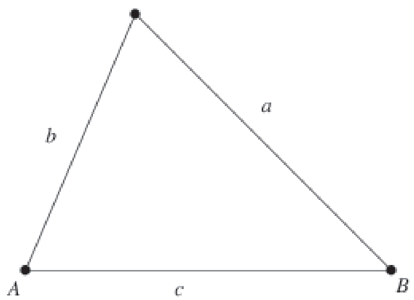
When making a pleasing composition, different methods and rules can help creating the most harmonious outcome. The rule of third is a basic composition rule, where one imagines lines going through the frame horizontally and vertically at 1⁄3 and 2⁄3 (see figure 2.5)[180]. Leading the viewer's eye can be done placing the fields of interest into the one third or two thirds of the frame. Some compositional tools are based on the golden ratio, and one of them is called the golden spiral. The golden ratio based on the Fiboniacci numbers is seen in nature as patterns on snail shells, pineapples and sunflowers (see figure 2.6)[181], and using the golden spiral can help giving the composition a naturally occuring pattern or a line for the eyes to follow comfortably.

Figure 2.5 - Placing the object of focus according to the rule of thirds creates a composition with more tension, energy and interest[183].

Figure 2.6 - This is the Fibonacci spiral, which is an approximation of the golden spiral. It is used to create a pleasing flow for the eye leading into the center, which is the part of focus[182].

Mathematical triangulation and image depth

The concept behind triangulation is that if one has a distance between two point and their angles to another point, that one can calculate the distance from the two points to the third point. It takes advantage of the fact that whenever one has three pieces of information about a triangle, that being the length of a side or an angle, one can calculate every other information. The graphic in figure 2.7 shows a scenario where one has the distance c, the angle A and the angle B. Using these values one is able to calculate the other two lengths of the triangle, a and b. This method was originally used in seafaring for navigation[184].



$$b = c * \frac{sin(B)}{sin(180°-B-A)} \qquad a = c * \frac{sin(A)}{sin(180°-B-A)}$$

Figure 2.7 - This are the formulas used to calculate the length of the sides a and b[185].

3 Design

Starting point

In the beginning of the project, the group had an initial idea about making a Kinect-based body spelling game. Since the subtheme of the project is *Assistive Technology*, the group decided that a major disability in today's society is not being able to read. The logical solution to this was teaching the letters of the alphabet. This lead to an idea about teaching letters using an Xbox Kinect camera in a fun and interesting way: body spelling.

In the game, the player would be told a letter or a word and would then have to spell it with his or her body (see figure 3.1). While the idea seemed great in theory, after careful consideration the group came to a conclusion that this concept would not be successful, primarily due to the fact that those who fall into the designated target group are having a hard time learning to read. Teaching them how separate letters look one by one would not be beneficial in any way.

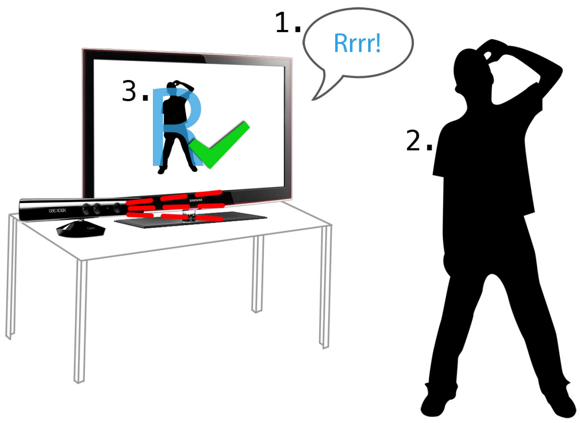


Figure 3.1 - The player hears the sound "Rrrr". He then forms an "R" with his body, the kinect detects it and approves it as being the letter "R".

After researching on the subject of phonological awareness the group chose to focus only on the actual sounds found in the Danish language and not on the visual appearance of letters. This leads the choice of abandoning the body spelling idea in favour of a completely new concept.

Even though the problem and the target group remained the same, a new conceptual idea had to be brought to attention in order to continue progress. That was when the idea for the current concept, *Monster Mixer*, was developed.

The initial concept

Monster Mixer is a possible solution to the problem of being a poor reader and/or dyslectic. The game's purpose is to improve phonological awareness, and it targets Danish children in the early school ages (6-9 years old). It is a game that utilizes a Kinect camera which is a motion- tracking device used for the Xbox 360 game console.

Monster Mixer is a game for one player that has the goal of mixing monsters that each represent sounds. The game uses nonsense words instead of real words. It has been chosen

to use such words primarily because the game requires its player to actually listen and carefully pay attention to what's being said, instead of merely recognizing words he has heard previously. An example of this are the words "mi" and "gos" which are meaningless words with different sounds (phonemes).

The words are linked to a group of monsters. Each monster represents a nonsense word, and the player's goal is to combine them into new monsters. For instance, the game could ask the player to combine two monsters that together make the sound "mi-gos". The two monsters would be mixed together into a new monster with this sound. To catch the monsters, the player performs various movements/gestures with his body. This could for example be a slicing movement with the arm. After two monsters have been caught, they are dragged to a monster mixing machine where the player, using the hands, mixes them together to form the correct sound. This creates a new monster with a new sound.

Finally, after the mixing is done, the newly created monster is transported into, what the group calls, The Word House which acts as a trophy room. Here, the player is given the chance of taking a picture of himself alongside the created monster.

The game has been designed with the kinesthetic learning style in mind. The player should be engaged and physically active during the game, using his entire body to control it. This makes the game both more involving and fun. Figure 3.2 illustrates the game's concept.

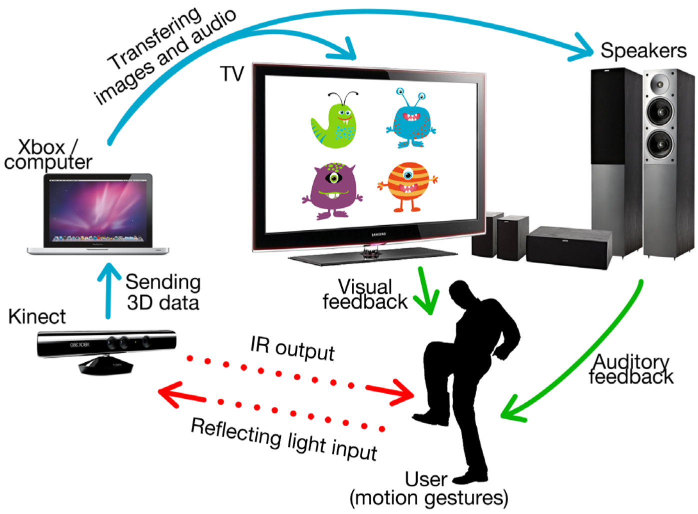


Figure 3.2 - The conceptual model shows that when the user interacts with the Kinect, the camera detects the player's movements and sends information to the computer. Afterwards the player receives two kinds of feedback: visual from the screen and auditory from the speakers.

List of the initial gestures:

- Catch tall monster: Slicing gesture
- Catch flying monster: Jumping and clapping hands in air
- Catch flat monster : Stomping with the feet
- Listen to monsters: Binoculars gesture
- Get hint: Walkie-talkie gesture

The gestures should be connected with the appearances of the monsters. E.g. to catch a flying monster the player has to jump with the hands in the air.

Taking into consideration that the target group is young, it is important for the game to be clear and easily understandable. Audio and graphics are no less important when it comes to making the game interesting enough for the children playing it to continue doing so. Using clear colors to simplify the different shapes and set them in contrast to each other, as well as a small amount of sound cues, the game presents its concept as non-intrusive as possible. This is important to maintain a warm and happy atmosphere well-suited for children.

Lo-fi test 1 - Overhead projector

Test description

The first lo-fi test was conducted early in the project. The concept was not fully established, and running pre-tests internally made the group realize important factors for the gameplay and forced it to get a shared view on many of the previously not-defined details. Having practiced several test runs was the breeding ground for conducting the first lo-fi test. Figure 3.3 shows a woman playing the prototype.

Figure 3.3 – The player is pointing at the screen as at that point there was no other way to determine what monster the players were looking at apart from having them point and say it out loud.

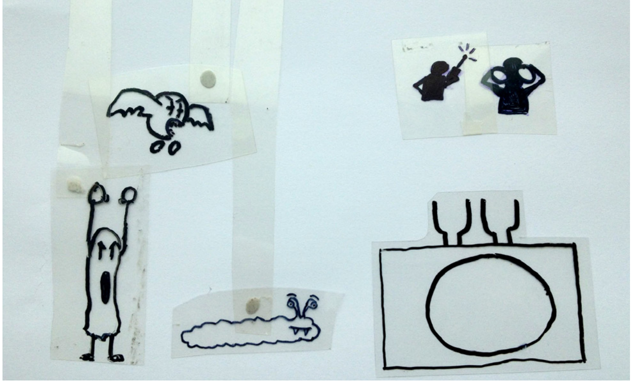


Figure 3.4 – The initial monster catching scene with a small monster mixing machine in the corner.

Goals

The goal of the first prototype was to test whether the test subjects were capable of grasping the general idea behind the game, as well as to get some feedback on the concept. It was conducted as a Wizard of Oz test, having two members of the group simulating the computer. However, it was physically not possible for the two "wizards" to be invisible in this test scenario. Therefore the test participants were told that they should just ignore them altogether.

An important aspect to investigate was whether the movement gestures made sense and were easy to remember.

Variables

There was no software interference in the test. Therefore it was simulated by human operators, and the members of the group had to control everything themselves. This was done by making slides for an overhead projector (see figure 3.4) and changing these whenever the test subject was interacting with the game, creating an illusion of control.

Tasks

The players had to perform several tasks. First, a facilitator gave an in-depth description of how the game works, having the players performing various actions similar to a tutorial section. This was to ensure that test participants knew what to do when the game started.

After the instructions, the game began. The test participant played two sessions: the first was conducted by having the facilitator act as a guide, helping the player. After he/she had successfully created the new word and monster, they played a second game with a new set of monsters. Here, the facilitator didn't help at all, leaving everything up to the test participant.

Setup

The first test was conducted at Aalborg University's auditorium using a pair of overhead projectors to test the concept of the game. It was tested on students from Medialogy and other educations. To receive feedback, it was asked of the test participant to "think aloud". This made it possible to get a closer picture of what the participant was thinking, and why the person acted as he/she did. To make it feel more natural, the participant was asked to read a text aloud before the test began.

Equipment

In the beginning a single projector was used, but after a test run it was decided to use two projectors for quicker and more optimal scene changes. The group used the following equipment for the test:

- Two overhead projectors
- Transparent copies (monsters, settings, props)
- A canvas

The test roles

1. **Facilitator** - the one verbally describing the game to the test participant, explaining the concept and the tasks, as well as providing help throughout the test
2. **"Computers"** - two human operators controlling the process instead of the computer
3. **Event Logger** - the one who logs any important event, such as when the player is stuck and when the game is completed
4. **Note Taker** - the one with a premade questionnaire, answering specific questions such as the gender of the user and the number of attempts taken at something
5. **Test Participant** - the one playing the actual prototype

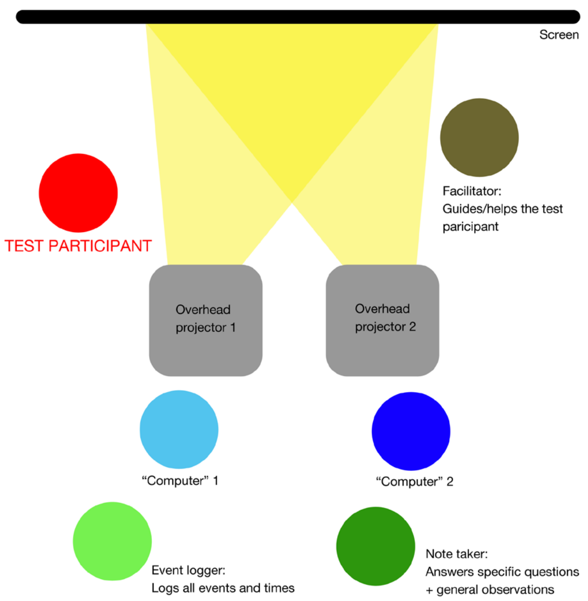


Figure 3.5 – The test scenario involved six persons: two were controlling the actions that would be handled by a computer; the facilitator that spoke and guided the test participant; and two people who were responsible for observing and processing information.

Conclusion

Even though the test participants didn't fit into the target group age-wise, the test gave useful feedback. The concept itself was simple enough to understand after trying for a while, but the amount of information the player had to process before playing was too high.

Since this was a relatively primitive prototype, a lot of the interaction and transitions were slow and imprecise. For instance, it was difficult to change slides quick enough to give a full illusion of the game going from one screen to another. That being said, the important thing was to observe if the test participants could understand the concept of the game. This indeed seemed to be the case. When asked, all participants expressed positive feelings about the game and saw a potential for further development.

Even though the lo-fi test went pretty well, it didn't fully show the concept of the game. Therefore, the group decided to make a second prototype, this time making it digitally. This second lo-fi prototype was developed in a few days using the Game Maker engine.

Game developed for the second prototype

Before the first lo-fi test,some of the details behind the concept were yet to be thought through. It quickly became clear that the group had to specify a lot of the interactions in the game.

Interactions

The actions which the player would be introduced to as soon as the game is started:

- *Clap gesture* - the player jumps with his hands up in the air clapping his hands. Used in order to successfully capture monsters which visually appear as flying.
- *Stomping gesture* - the player stomps the ground with a foot. Used in order to successfully capture monsters which visually appear as flat.
- *Slice gesture* - the player performs a slicing motion with his hand, which would look like a horizontal slice. Used in order to successfully capture monsters which visually appear as tall.
- *Binoculars gesture* - the player positions his hands in front of his eyes so it looks like he is using binoculars. Used in order to zoom in on a monster so the player can hear what sound the certain monsters make.
- *Mixing gesture* - the player shakes his hands to start the mixing machine

The gestures would be designed in a way so that nobody could confuse them with each other. They would be based on different movement directions, i.e. up, down and middle. Furthermore, they would be rather simple and would not require a lot of physical effort. The game encourages the player to "jump high and clap their hands". This approach would ensure that the game was accessible for most people and wouldn't depend on the player's physical proficiency.

The game should consist of three phases: **hunting phase**, **mixing phase** and **Word House phase**. In the hunting phase the player searches for monsters. Here, he would be given an opportunity to hear the word that has to be created to complete the level. There would be a total of three monsters moving around on the screen in a randomised pattern, each with its own designated sound, shape and color. Furthermore, the monsters would be divided into three types - tall, flat and flying - and there would only be one of each on the screen at any given time. Having a noticeable difference in the appearance of monsters would make it less confusing for the player to figure out and memorize which monster is making what sound and how to deal with it.

In order to hear what sounds the monsters are making, the player would need to perform the binocular gesture. It allows for the hearing of a monster's sounds by having them in their field of vision with the binocular active. There will at all times be two monsters with the relevant sounds assigned to them and an additional monster with a sound not related to the actual word that the player is trying to make. After two monsters have been successfully captured, the game transitions to the mixing phase with the monster mixing machine.

The monster mixing machine

Once the user has caught two monsters, the game goes to the mixing machine screen. Here the player is given the opportunity to mix the monsters together into a completely new monster, on condition that the two right monsters were found.

The purpose of the mixing machine is to make the player think about the order the two caught monsters have to have. The machine has two slots, one for each of the monsters, with a light indicator beneath (see figure 3.6). Using his arms, the player can position the monsters in the slots. Depending on their conditions, the indicators will light up in:

Red, if the monster does not belong in any of the slots. It lets the player know that the mixing process can not be initiated and the monster will return back to the hunting screen.

Yellow, if the monster belongs there, but is positioned in a wrong slot. In this particular case, the player can switch the two monsters around. (see figure 3.6)

Green, if the monster is placed in the correct slot of the machine.

The monsters then say their sound in the order from left to right. If both the light indicators are green, the player needs to perform a shaking gesture with the hands. This will combine both of the monsters into an entirely new monster and sound, made by combining the sounds from both of the monsters into one entity.

If one monster is incorrect, the game sends the player back to the hunting phase, so he can find the right monster.

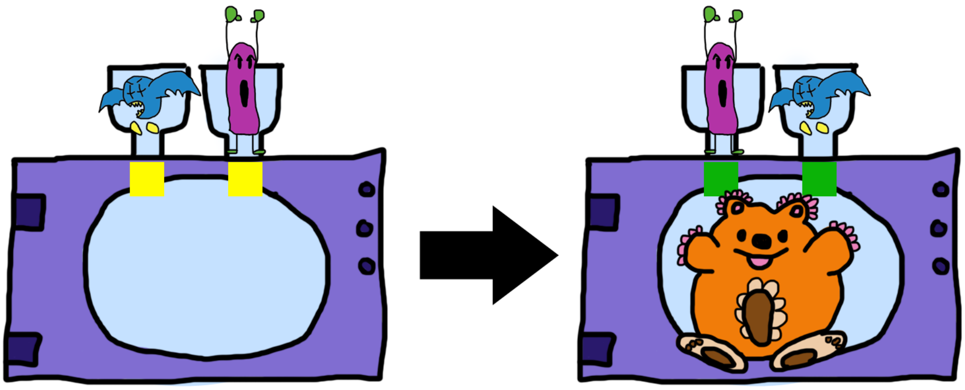


Figure 3.6 - The mixing machine. Here the player has caught the correct monsters, but they are not in the right order, which is shown through the yellow lights. The player needs to swap the monsters and then do the shake gesture to mix them together.

The word house

When the player has mixed the two monsters together and gotten a new monster, he will proceed to the last phase of the game called The Word House. Here, the player is able to take a picture of himself together with the monster. This picture is then stored in a house as a trophy. The player can then later return to the house and see all the monsters he had caught.

Lo-fi test 2 - Game Maker

Test description

Having the first lo-fi prototype in mind, a new prototype was developed in Game Maker. The group wanted to make a slightly more authentic game that could showcase and test the concept. Game Maker was chosen because it allows for quick development of small 2D games. It made it possible to have both the graphics, sound and game logic up running within a few days. It was especially important to have cute graphics and sound that could put the test participant into the right mood.

Also, at this point it was about time to try the concept on the actual target group: Danish kids (see figure 3.7). Even though the previous test gave positive feedback about the interactions, it doesn't necessarily mean that kids will be able to grasp the concept. This lead the group to contact a teacher from Tornhøjskolen where the prototype was tested by several kids in the age group of 6-9.

Figure 3.7 - A girl using the binocular gesture in the second prototype.

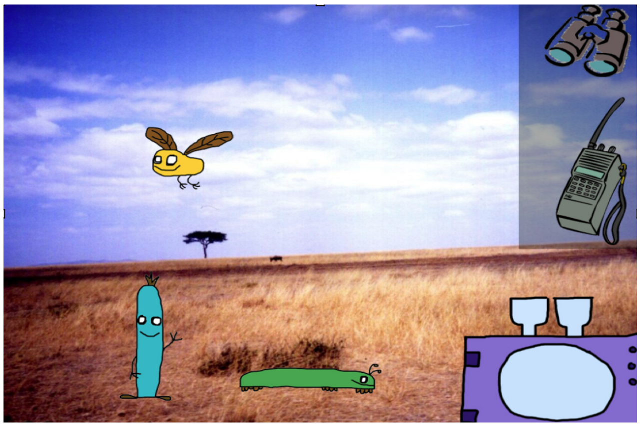


Figure 3.8 - The look of the 2nd lo-fi prototype. It used temporarily graphics and sounds.

The prototype was still operated by the "wizard", but this time around this fact was not known by the test participants. The children believed they played the game by interacting with the Kinect camera.

Goals

The goal of the prototype was to test whether children can understand the concept of the game, as well as to investigate the game's logic in relation to children's understanding. The test was intended to examine the interaction design and whether the gestures are natural in relation to the visual appearances of monsters. Also, it seeks out to provide an insight on the difficulty level of the game and whether the tasks were too easy or too difficult for the test participants to perform.

Variables

There was a large degree of simulation used in the test. All interactions that in the final game are going to be controlled by the Kinect was controlled by the wizard in the prototype. The task variables were few because the test had a narrow range of tasks that could be accomplished. The test participant variables differed since the sounds and pictures in the game could be interpreted differently, and the test subjects might have been able to recognize different sounds or remark different visual aspects. Some of the variables were affected by the wizard's response time and practice in imitating the system. Other variables were defined by the success of communication between the test participant and the facilitator.

Tasks

The test participant's task was to play the game and successfully create two monsters, playing the game twice. The children were helped through the tutorial and first level by the facilitator. They were then explained how to play the game using gestures, as well as how the monster mixing works. In the second test they had to try the same game on their own, but with new sounds. They had to understand what monster they had to create, how to listen and choose the right monsters with the right sounds, and, finally, how to use the monster mixing machine.

List of task during the game:

- Listen to the new word that must be created, and, if wanting to hear it again, use the walkie-talkie
- Zoom and listen to the sounds of monsters by using the radar binoculars
- Choose the right monsters by performing the right moves
- Understand the color coding in the monster mixing machine
- Mix the two monsters into a new monster by shaking

Setup

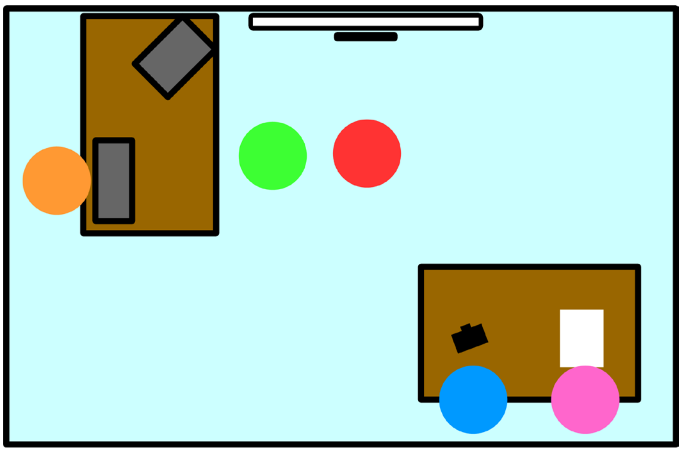
The test was conducted at the school Tornhøjskolen in Aalborg with kids from 0th to 2nd grade. The children that tested the game ranged from 6 to 9 years of age. The children tested the game one by one in a classroom. The test consisted of ten kids: three girls and seven boys. Since the Kinect was still not active at this point, the test participants were told to think aloud. Specially, when it came to the using the binoculars in the game the players had to tell which monster they were looking at. This made it possible for the wizard to switch screens accordingly to their choices.

Equipment

- Kinect camera (not working)
- Projector
- Computer
- Speakers
- Webcam to record the test

The test roles

1. **Facilitator** - communication/going through questionnaire (see appendix A)
2. **Note taker** - observing and taking notes (see appendix B)
3. **Computer operator** - the "wizard" behind the computer
4. **Photographer** - photographing (see appendix C)



Computer operator - Facilitator - Test participant - Photographer - Note taker

Figure 3.9 - The test scenario involved five persons: One was the wizard that controlled the computer, another was the facilitator that spoke and guided the test participant. Lastly, two people were responsible for taking notes on paper and camera.

Test results

Note taking was done using a simple time protocol, which can be seen in appendix A.

Observations made from video and notes:

- Children in 0th grade had a hard time understanding the game and remembering the different moves. Some understood how to listen to the monsters but didn't understand what to do with them.
- Children in 1st grade found the gameplay easier than the children in 0th grade. They were quick to recognize which monsters to use, and mostly remembered the needed attack moves. If they had forgotten an attack move, some could resonate that since the monster is flat, they would need to stomp on it.

- Children in 2nd grade had a better comprehension of how the game worked, could understand the color codes in the monster mixing machine, and overall had more mental resources to spare for enjoying the fun aspects of the game like the quirky sounds, amusing monsters etc.

Differences in the children's phonological awareness were noticed. The higher the grade, the easier it was for the child to complete the tasks. All children were quick to go through the tutorial but without comprehending the purpose of it. This resulted in that they could not remember the gestures. Some had problems understanding the usage of binoculars, but at the time they were being introduced to how they work they seemed to be keen on using them.

The children had different ways of playing the game. Some wanted to listen to all the monsters before making a choice. Others caught the monsters when recognized, while some used the exclusion method. The children also liked making their own variants of the gestures (see figure 3.10).

Figure 3.10 - During the lo-fi test, the children had various ways to perform the gestures. Here, two kids are using the binoculars differently.

Questionnaire

After the test the children were asked to answer a questionnaire with the facilitator (see appendix B). Below, a table shows basic information such as age, gender and class, as well as the most noticeable answers.

Child	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
Class	0.A	1.A	0.A	0.A	1.A	1.A	1.A	2.A	2.B	1.B
Age	6	9	7	6	7	8	7	9	9	9
Gender	Male	Male	Male	Female	Male	Female	Female	Male	Male	Male
Perceived difficulty	Easy	Medium	Easy	Easy	Easy	Medium	Easy	Medium	Medium	Easy

The "Perceived difficulty" question refers to the question whether the game was easy to understand or not. This was done using smilies, as shown in figure 3.11.

Figure 3.11 - Perceived difficulty scale shown using smilies (see also appendix B).

Instead of relying too much on the children's answers to the questionnaire, it is more important to observe and see their reactions while they play the game.

Looking at the table, it would seem that the older children had a harder time playing the game than the younger children, since none of the 6- or 7-year-olds found the game Medium or Hard. This is according to their own statement. However, one should take their answers lightly, since the kids might not be answering completely honestly. Maybe the kids tried to please the facilitator, or they didn't dare telling the truth. It might be hard to express a negative opinion due to the special circumstances of the group observing the children.

All of the kids answered yes when asked if they understood the connection between the monster's appearance, the gesture, and how to catch the monsters. The test also showed progress among the children from 1st playthrough to the 2nd playthrough of the game.

Some kids found the difficulty of the words they had to combine easy while others found it somewhat challenging.

All of the children were eager to tell that they liked the game even without being asked. None of the children were able to point out what they didn't like, but in general they liked performing the gestures. Also some of the kids liked the concept of combining two monsters to create a new monster. Suggestions from the kids included having more different types of monsters and another range of equipment containing a tape recorder to help the player remembering the tasks.

There was no complaints towards the visuals, but during play it was observed that colors, shape and size matter. If for example a game had two green monsters, some kids got confused and suddenly didn't know how to tell the differences in the two green monster's appearances. This was made clear by the fact that the kids had to say out loud what monsters they were looking at.

Conclusion

The game needs a better start tutorial that teaches how to catch monsters, use the binoculars and the function of the walkie-talkie. It should be more interactive and contain better explanations on aspects like how the mixing machine works, explaining what the lights mean, how to swap monsters and how to mix.

The children liked to come up with their own variations of the attack moves, and they like to do the moves more than once. This suggested that the game should be very generous in how it interprets the performance of gestures, i.e. the game should allow for a jump regardless of whether the person is actually jumping, clapping or just standing still while raising arms.

The colors of the monsters are also important, since it helps the children to distinguish and categorize the monsters. Two monsters cannot have the same colors. Shape and size also helps the kids separating the monsters from each other.

The game could make use of scaffolding to explain the interactions gradually. Instead of teaching everything in the beginning, it should teach everything step-by-step. An example of this is the mixing machine: only when it is relevant should the concept of mixing be explained, i.e. when it is required to do the mixing gesture. Likewise, the game could use some kind of mentor or guide person that can call the kids through the walkie-talkie to remind them of the monster they need to catch. Similarly, small pop-up icons could be used to remind what gestures are used to catch the monsters.

The monsters in the mixing machine didn't say their sounds aloud, so the test participants just had to look at the lamps underneath the monsters in the mixing machine, to figure out if the monsters was in the right place. This took away the whole concept of raising the phonological awareness and changed the concept to a trial and error mechanism where the player just guesses until he hit the right combination. Instead of actually listening for the sounds, the player would just look at the colors of the lamps (see figure 3.12).

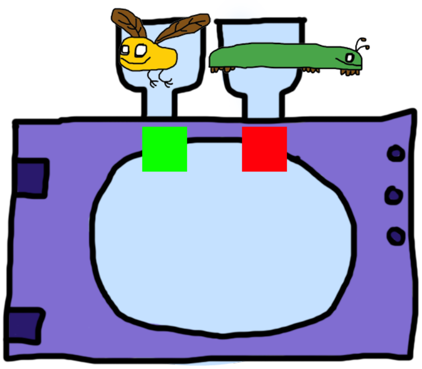


Figure 3.12 - The original mixing machine had a linear left-to-right system where the first sound was to the left and the second sound was to the right.

This led to that the group reconsidering the whole concept of the mixing machine. Even if the sounds of the monsters were implemented, the player doesn't really have to listen to the sound of the monsters but can just try one combination and then the other. This brute force approach doesn't fit with the purpose of the game: to train phonological awareness.

Another thing being considered was the fact that the group had taken it for granted that it would be natural to hear the monster sounds played in reading order from left to right in a linear fashion. Since the target group hasn't learned to read and write, there is no reason to assume that they know about reading order.

The last thing that occured was that the mixing machine is an abstract concept and doesn't have a lot to do with sound. Instead of having a machine that works from left to right, it was chosen that the mixing machine should have a round shape, and that the monsters have to be read circularly instead of linearly. To find a good metaphor for the machine and to come up with a logical explanation for how the machine works, a gramophone music player was chosen (see figure 3.13).

Figure 3.13 - It was chosen to take inspiration from an old gramophone player with a big and clear loudspeaker[186].

The gramophone is an old music device. It is associated with something handcrafted, tactile and of high quality; it is inviting the user to interact with it.

To make the mixing machine more interactive and fun to use, the player would control each monster with his hands. The player would have to stick the monsters onto the gramophone disc. When the monsters reached the reader head, they would say out their sounds. Compared to the previous mixing machine with buttons and lamps, the gramophone player is easier to comprehend and not as abstract.

Making an appealing game for kids

Emphasis on interaction rather than sophisticated graphics has successfully been used in an educational context[187]. This is why this project also focuses on interactions designed especially for the target group. The main focus is the interaction between the children and the game. Therefore it is important that the graphical elements are both appealing and easy to understand, so they don't interfere with how the player interacts with the game.

Research has shown that children get early experienced in using technology because of early exposure to computers, phones and other electronic[188]. When designing computer games for kids, previously known usability guidelines can be used. However, when making a game for the Kinect, not all of these guidelines can be applied, since children might have less experience

in motion-controlled games where the whole body is used to play the game. This provides an interesting challenge of making new and intuitive interactions.

Likewise, research has shown a change in children's willingness to read or go through instructions before starting a game[189]. *Monster Mixer* cannot contain written text due to the target group's inexperience with reading. Instead, the game needs to explain itself using auditory instructions. Having the attention span of kids in mind, the game's explanations are made as short as possible to not make the game boring. Ideally, the game should be as self- explanatory as possible, since children will judge quickly, have limited patience, and leave if the game is not good.

Good games contains many important aspects. According to Krieger they should be fun, engaging, aesthetically pleasing, flexible and easy to learn[190]. *Monster Mixer* is a game that explores these requirements.

Some of the important factors for creating an engaging and immersive gameplay is to design with the target group in mind. This also covers visual design. Kirsh states: "*The visual design of games can influence how usable, playable and acceptable to various audiences they are, and the visual design of learning materials can support or hinder the learning process*"[191]. The visual design of games should therefore support the interests of the target group. In this project this is obtained using colorful graphics and funny sounds. The learning design is highly influenced by the kinesthetic and auditory learning styles. The kinesthetic learning style supports the children's desire to play and by that enhances the enjoyment, while teaching them to listen and enhance their phonological awareness.

Children like animations and sound effects[192] which is why the game has moving characters and gives audio feedback. The animations are simple and consist of few frames due to time schedule of the project.

Use of scaffolding

Instructional Scaffolding[193] is a method often found in computer games[194]. Depending on the amount of different features found in a game, discovering and learning how to use all of them can be challenging and intimidating for the player.

To make it easier for the player to accept and learn incoming information and instructions, the content of games is usually divided into different levels. Games that make use of scaffolding introduce only features when they become relevant and otherwise allow the player to practice skills learned in previous levels of the game. Well-designed progression of levels can attract players to continue playing the game due to the sense of discovery - the player knows he may learn something new in the next level, whether it's a new feature, a piece of the story, or something else. In other words, being taught everything level by level motivates the player to keep playing[195].

Generally in early levels players are only taught the basic skills, such as how to move, interact with objects, etc. Basic skills are usually enough to progress through the first of the levels which allows the player to reinforce his knowledge of the basics. Later, as the amount of completed levels increase and new features are being introduced, the player may have to recall the actions used before in previous levels and use them again along with the newly learned features.

This way of designing progression in the game that slowly teaches the player step by step is known as scaffolding. It limits the tasks to what the player can do initially, with nearly no assistance, and then gradually introduces new game elements[196].

There is a possibility that the amount of information provided in the game may seem overwhelming. The game should gradually explain itself instead of forcing the players to memorize every single element that is introduced in the beginning.

Graphical design

Monster design

Monsters are fictional beings that combine features of the animal and human shape. Often the word refers to something so grotesquely deviating from the normal that it frightens people, but sometimes it only means that it is an unrealistic being.

Since *Monster Mixer* is about combining different monsters into new monsters, it was clear that a lot of monsters needed to be designed and drawn.

It was chosen to aim for a simple and minimalistic monster design. This was done to make them as appealing and comprehensible as possible. Also, the choice was based on the limited amount of time available: the more detailed the monsters are, the more time would be needed to draw them. Therefore the level of detail is rather low compared to other more complex games. However, the coloring and shading of the monsters make them look more detailed.

When coming up with the idea for the graphical design for the game, Nintendo's *Pokémon* series was used as a source of inspiration.

Pokémon, an abbreviation for *Pocket Monsters*, is a game about a young boy that travels around the world to catch monsters. These animal-like creatures are used for battling each other, and the goal of the game is to catch all and become the Pokémon Champion. When the game began in 1996, there were a set of 151 different Pokémon (see figure 3.14). Today, there are a total of 648. Because of this huge number of monsters it is important that all the creatures stand out, so it is possible to differentiate them from each other. Some of the Pokémon also have different states. The game describes these as "evolutions", and a Pokémon can have multiple evolutions.

Figure 3.14 - All the original 151 Pokémon for Game Boy. Each Pokémon is of one or more types, e.g. fire type or grass type[197].

Monster Mixer was designed with this aspect from *Pokémon* in mind. The idea of having a great amount of different monsters for the player to explore, combined with the experience of catching and creating monsters, seems like an appealing concept to kids. The design of the monsters in *Monster Mixer* are among others inspired by the design of *Pokémon*. They are colorful, imaginative but, most importantly, unreal. The group didn't want to have any of the monsters look like real animals, so the player would draw any relation to real world animals.

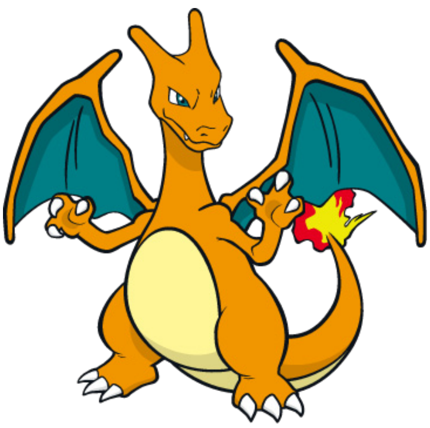


Figure 3.15 - "Charizard" from Pokémon[198]

Figure 3.16 - "NØ" from Monster Mixer.

To get more visual consistency in the game, some guidelines for the shapes of the monsters were created. Each monster would be built using pre-made modules with fixed values. There are three types of monsters in *Monster Mixer*:

- Tall monsters
- Low/flat monsters
- Flying monsters

Each monster type is built out of the same setup of modules (see figure 3.17). All the tall monsters are built out of three modules on top of each other; the low monsters are built from three modules horizontally aligned; and the flying monsters are built out of a single standing module.

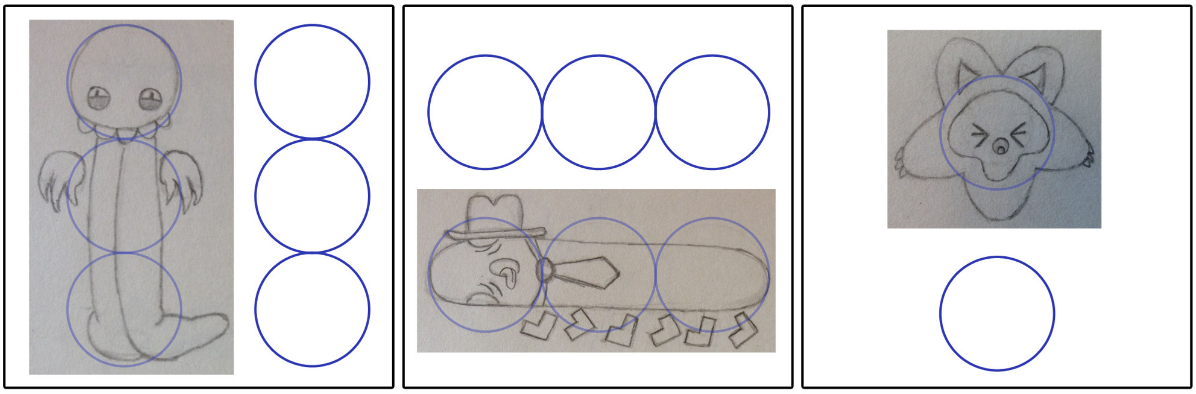


Figure 3.17 - To achieve visual consistency, the monsters are built using circular modules to enhance the monster's organic shapes.

The circular module was chosen mainly because of its flexibility. The possibility to easily create nice rounded shapes simply by letting the outline follow the curves of the modules, had a big influence on the choice. If the modules are square, they might limit the artist's sense of creative freedom, making him draw more strict and edged shapes. On the other hand, curves and circles encourage organic shapes. An organic shape is defined as a combination of edges that are curved or angular[199]. The shape of a monster made from the modules can be decorated in any way as long as it doesn't make any major alteration to the original shape. The reason for decorating is to prevent a situation in where all the monsters would look alike.

When the actual designing of the monsters began, the modules were used in a way so rather than dictating the shape for each monster, they merely acted as guidelines and by that gave way for more creative freedom. E.g. instead of all the flat type of monsters would have the same sausage shape, the modules were used as a frame to show how long the monster should be and what mass it could have. It was more important for the monsters to look apart than having the design of each monster following a strict shape.

Character design

Eigil - a hardened veteran mixer

The game uses a tutor in the form of Eigil. He is a hardened monster hunter and a veteran within the field of monster mixing. He takes the role in *Monster Mixer* of being the character who teaches the player how to play the game.

Eigil acts as the narrator throughout the game and appears during the introduction and the tutorial. Also, when more explanation is needed in the game, he pops up in the lower right corner to help the player. After certain time intervals he appears to give small reminders on the objective and hints on possible actions to do.

When coming up with the idea for Eigil's design, former wildlife expert Steve Irwin was in mind, and his clothes, attitude and charisma were attempted to replicate (see figure 3.18). Eigil is supposed to appear as a tough veteran who has been in the monster mixing business for a long time. Because of this it was important to make him look physically worn out. This was achieved by giving him an eyepatch, a peg leg and a cane. Obviously destroyed by his profession, he shouldn't appear fragile, weak and hopeless, because this could have a discouraging effect on the player. Therefore he was given a self confident grin and a glint in his eye to radiate joy for life and for his profession.

Figure 3.18 - Master Eigil (left) works as a mentor and is inspired by Steve Irwin[200].

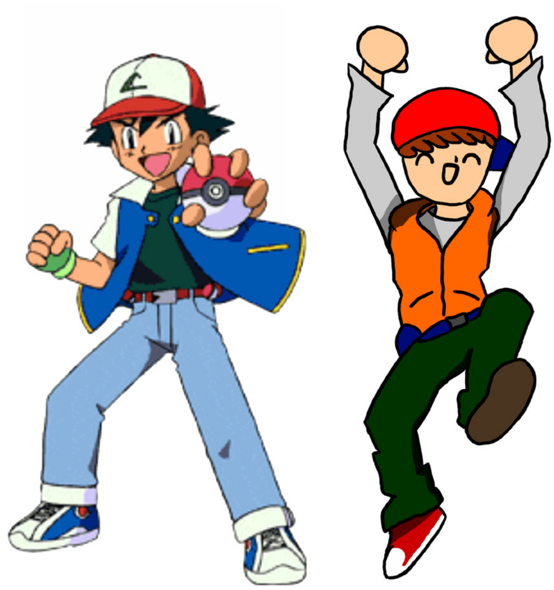


Figure 3.19 - Tom (right) is an adventurous hero inspired by Ash Ketchum from Pokémon[201].

Tom - an adventurous hero

Tom is a young apprentice of Eigil, and is being trained in the art of monster mixing. He is used to teach the player how to perform the gestures in the game.

The design for Tom is inspired by Ash Ketchum, the main character from the Pokémon TV- series (see figure 3.19). When designing Tom, the group has drawn inspiration from Ash's determination, bravery and appearance. Tom's facial expression is also slightly exaggerated and cartoonish.

The idea with the design of Tom is that he should appear as a young and adventurous boy who is ready to travel out in the world and face dangerous monsters. This should be reflected from his clothes and equipment.

Choice of color and composition

The backgrounds in *Monster Mixer* are drawn in pastel colors, which are pale colors with a soft, subdued shade (see figure 3.20). Together with not giving the backgrounds a dominating outline, they are toned down and fulfill their purpose of being in the background. Color gradients, which are smooth color transitions, are instead used to enhance certain differences in the landscapes, as on the sandbars in the desert.

The atmosphere in *Monster Mixer* is meant to be enjoyable and fun, and the color choice should reflect this positive attitude. A blue sky implies a pleasant day, whereas dark clouds would announce rain or storm which often is related to something unpleasant[202].

Yellow relates to sun, orange is tied to energetic and happy times, while green is the color of spring, renewal of life and food for human and animals[203]. Had the settings been black or dark they would imply a depressing or spooky mood.

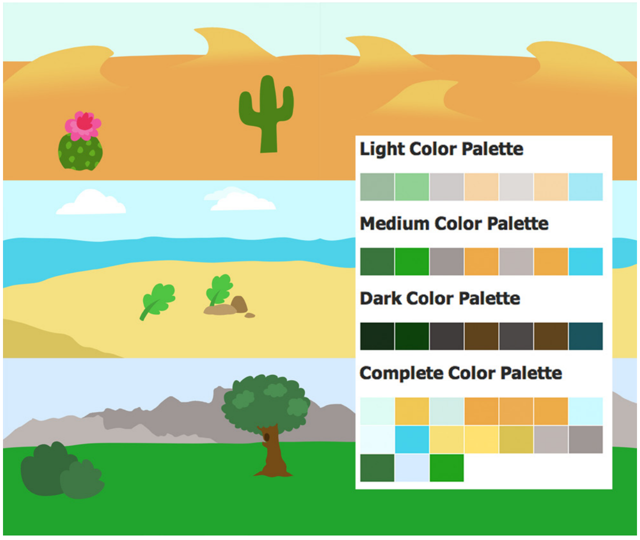


Figure 3.20 - The backgrounds and the monsters are designed with two dissimilar color palettes. The backgrounds are meant to create some pleasing settings.

Figure 3.21 - The monster are colored to stand out and be in focus, and the color palette of the monsters consist of more saturated colors.

The monsters from *Monster Mixer* were designed with a different approach than the backgrounds (see figure 3.20 and 3.21). The monsters were given a contrasted outline and saturated colors to make them stand out from the background and be in focus. The colors chosen was inspired by candy, which calls to mind the pleasant feeling of the taste of flavoured sweets.

Using the whole color wheel the colors were chosen to be complementary and stand in contrast to each other (see figure 3.22). It was important that the monsters were created to be easily differentiated, and choosing different colors or color combinations for each monster was an useful and effective way of keeping them diverse.

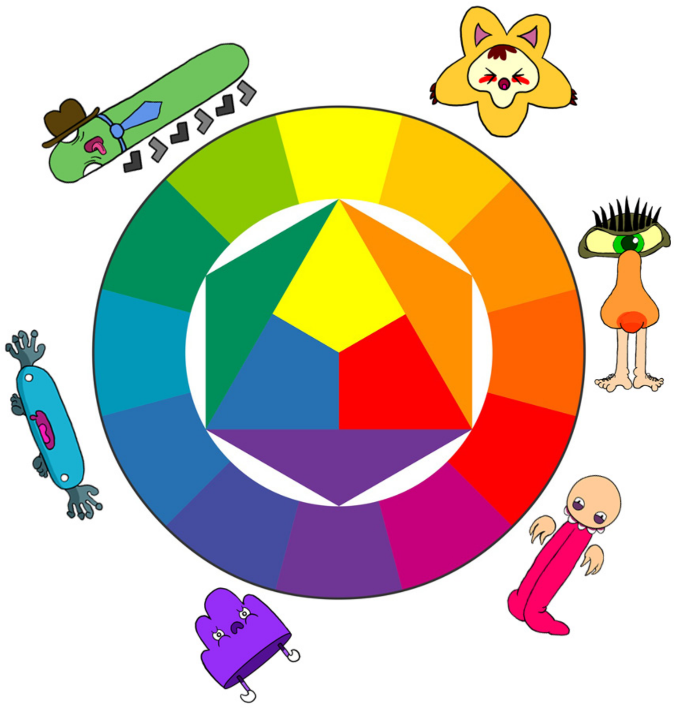


Figure 3.22 - The complete color wheel made inspiration to the colors used for the monsters, unlike the backgrounds which are colored mainly in light blue, green, beige and grey.

The backgrounds were made to be in ratio 16:9 but has double width (see figure 3.23). This is because the scene of catching monsters will take place on the left side of the backgrounds, whereas the mixing scenes will take place on the right side. Instead of changing scene the camera will pan from left to right. The backgrounds are composed with the golden spiral and the rule of thirds in mind when placing decorations like trees, stones and bushes on the left side of the backgrounds[204]. The right sides are created more simple since the monster mixing machine will fill out the space.

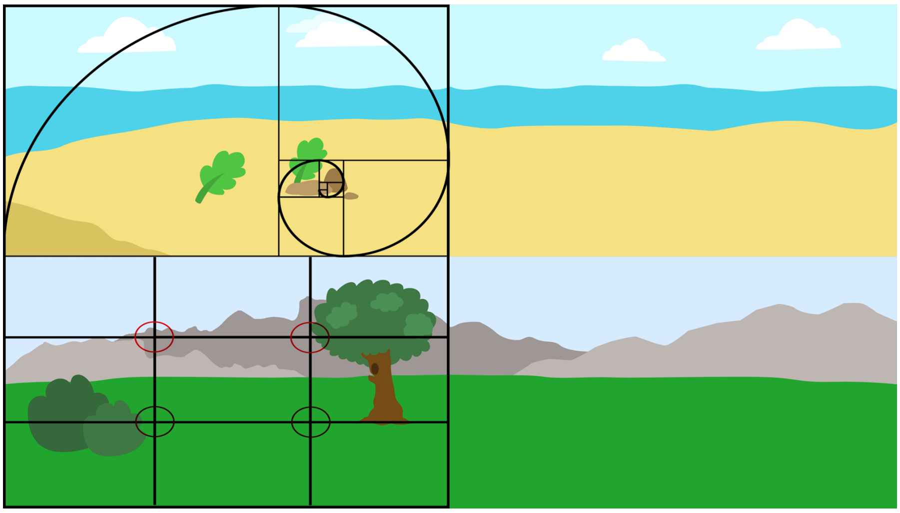


Figure 3.23 - At the beach (upper picture) the leaves and stones are placed in the center of the fibonacci spiral. This is the place on the background that without moving monsters is the most eye-catching. At the mountains (lower picture) the trees and bushes are placed outside of the intersecting lines marked with circles. They take up more space than e.g. the leaves on the beach, and they are placed to make room for the monsters to be in focus.

4 Implementation

Graphic

All graphical elements in *Monster Mixer* started as hand drawn sketches on paper, which then was imported as pictures and traced in Adobe Photoshop. Photoshop works with bitmap graphics, meaning that all images are constructed of pixels and are therefore also resolution dependent[205]. The group chose to work in resolution 1920x1080 px - this is Full HD. This is a good resolution, since it can be used on relatively big screens, and at the same time the images aren't too heavy when implemented in the game engine.

When the monsters were digitized a pen tablet was used to trace the sketches. A pen tablet makes digital drawing feel akin to painting with a real pen or crayons. Photoshop contains many different brushes with different styles and shape dynamics. An example is the use of pressure sensitivity that makes the stroke thinner/thicker or changes the opacity of the line. The pen tool works with paths and bezier curves, and creates vector elements whose curvature, length and thickness are determined by mathematical equations (see figure 4.1)[206]. Paths are good at creating shapes that can be applied with a color. This was chosen to give the illustration a look of being made like paper cut-outs, that can be imagined as cutting layers of colored paper.

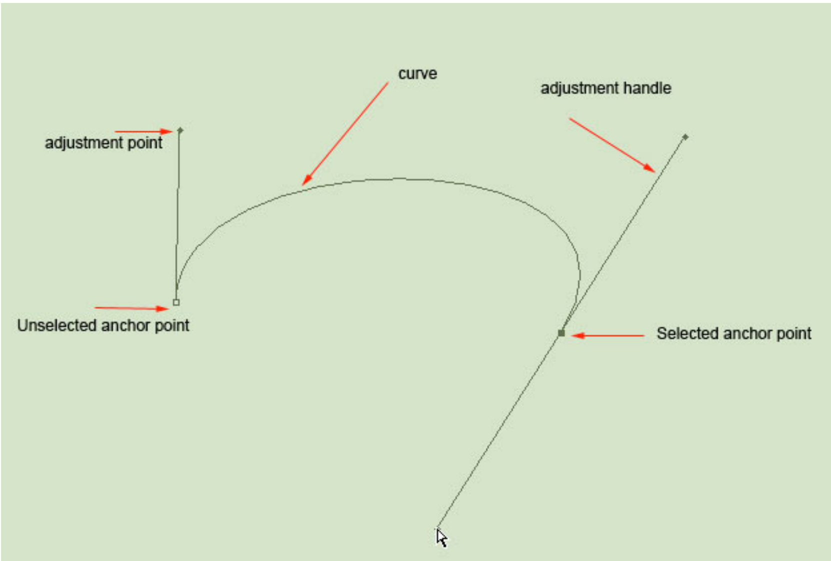


Figure 4.1 - Shapes can be created with bezier curves using the adjustment handles to make soft curves, precise lines and sharp corners. One always draws from one anchor point to another, where the un-selected anchor point is the starting point and the selected anchor point is point in use. The adjustment point are used to shortening, lengthening and changing angles on the adjustment handles[207].

Working with non-destructive edits means not changing the original data[208], or in the case of this project, to preserve as many of the different stages of the work process. Non-destructive editing can in Photoshop be obtained using separate layers for each element where separate changes later on possibly will be made (see figure 4.2). One of the advantages of non-destructive editing is flexibility which could be used to change isolated objects like a specific body part of a monster. If a monster has purple legs, and later on it's decided that they should be green instead, one can easily change the color of the legs by using for example color overlays.

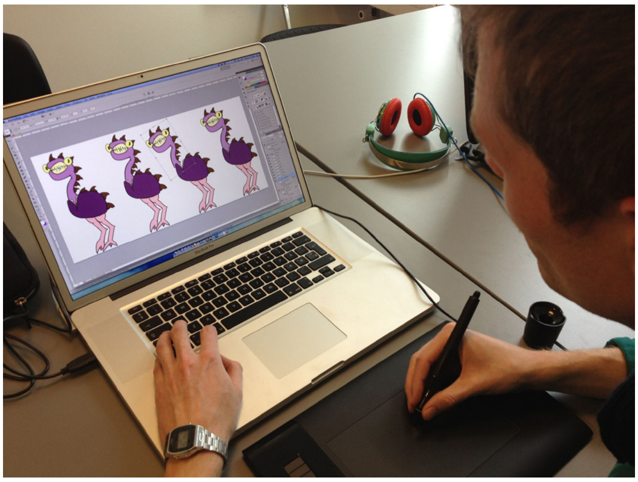


Figure 4.2 - Using Photoshop for sprite sheet animation.

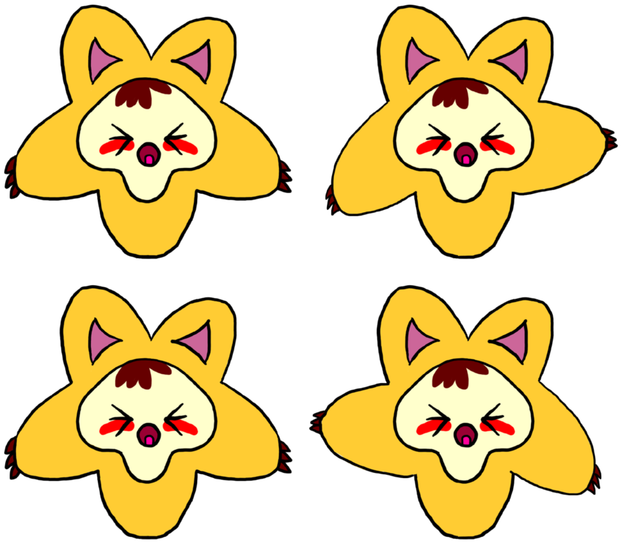


Figure 4.3 - A sprite sheet consisting of four pictures used for animation.

The game uses sprite sheets to animate the monsters. A sprite sheet is a single image containing multiple pictures. By looping over the individual pictures inside the sprite sheet, a sense of motion is achieved (see figure 4.3).

When making the sprite sheets for the animation, having different layers could also benefit the process of alternating the pictures and create the illusion of motion. Making an animation where a monster rotates its head would not require a new head being drawn, but simply rotating the layers in Photoshop could create the wanted effect.

Camera hardware

Standard cameras capture images from the 3D world and store them as image files in a 2D format. The purpose with depth-sensing cameras is to store a 3D image. One kind of a depth- sensing camera is the Kinect. It emits an infrared signal that bounces off objects and is then measured by an infrared sensor in the camera itself. By comparing the emitted signal with the received signal, the camera is able to perceive its environment in three dimensions.

Using an infrared structured light system, the Kinect projects a pattern of shapes on the environment and then observes how this pattern is deformed when it strikes surfaces at various distances[209]. This pattern is not visible to the naked eye, since it is infrared. This also means that the projection will not be affected by normal lights and it enables the Kinect to capture video data in 3D under any ambient light condition[210].

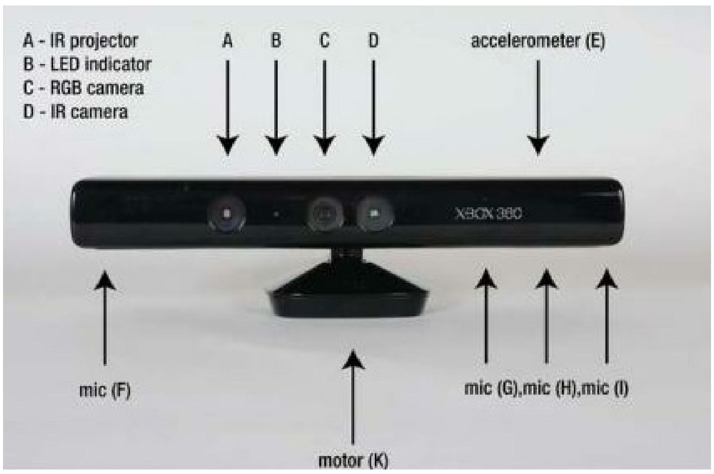


Figure 4.4 - Kinect has a range of input and output components. It uses an IR emitter (A) that shoots light out in the environment and a IR camera (D) to capture the light that bounces off objects. It also has a normal RGB webcam (C) to capture the image like any other camera[211].

Kinect makes use of stereo triangulation to measure depth. However, two measurement points are needed to do the calculation; the Kinect has only a single IR sensor (see figure 4.4). The other measurement point is the IR signal that the Kinect sends out to the environment via the IR emitter. (see figure 4.5) The distance between the IR sensor and the IR emitter amounts around 7.5cm[212].

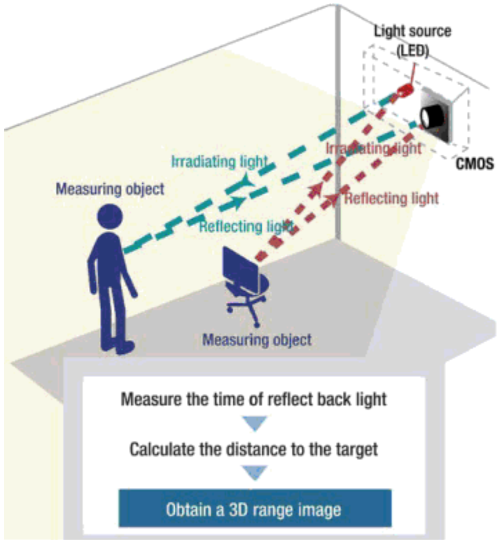


Figure 4.5 – The basic principle of depth-sensing cameras. A light source shoots light out in the environment. The light bounces off objects and is returned back to the camera. Using an image processor (such as CMOS sensor), the distance to the object is calculated[213].

The Kinect uses three pieces of information to measure depth:

- It knows in which angle it has sent out a particular light point.
- It can measure from which angle the light point is coming back.
- It is aware of the distance between the two points.

These three sets of data are used to calculate the distance from the two points to the point it tries to get the depth of. This is done by the use of triangulation.

To do this more precisely and with fewer measuring errors, the Kinect always uses more points and the last measured value. It then compares them to find the new a depth pixel[214].

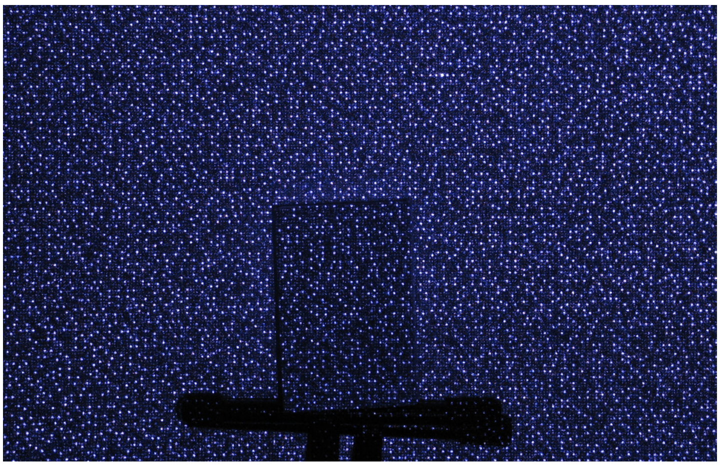


Figure 4.6 – The Kinect's IR projector emits a special dot pattern to compute distance to objects. Here a book is placed in front of the camera, which makes deformation in the pattern. This allows the Kinect to "perceive" the object[218].

Since the Kinect needs not just to find one depth in the picture, it has to send out a lot of light points. The Kinect does that by splitting its laser beam into thousands of individual points of light - it has been estimated to be over 300,000 in total[215]. The dot pattern, which can be seen in figure 4.6, looks like random static, but if observed closely, they are in fact a repeating in a pattern[216]. Because the dots are structured in such a way, the image processor inside Kinect can recognize the dots and make calculations based on their new positions. Out of the measured the points, the Kinect can output a so-called point cloud. A point cloud is a group of points that is often used when talking about three dimensional spaces[217]. It is then possible to compute the information as a depth map image.

Kinect outputs video at a framerate of 30 Hz (30 frames per second), using 8-bit VGA resolution of 640 x 480 px. The 8 bits describe the color range of the color camera.

The monochrome depth-sensing video stream is in 11-bit depth VGA resolution 640 x 480 px and has a practical range limit of 1.2m-3.5 m. The 11 bits describe the ranges of depth the Kinect can sense[219].

Software

Originally, when Microsoft launched the Kinect for Xbox 360, the only way to develop for it was to be an official Xbox developer using the $10,000 for a Xbox Development Kit supplied by Microsoft. This, however, changed shortly after the Kinect launched in November 2010. Hackers around the world managed to interpret the signal from Kinect's USB port. This lead to a wide range of open source drivers, such as OpenKinect, making it possible for hobby programmers to develop for the Kinect camera[220].

When people began making their own unofficial apps, the Israeli company PrimeSense took notice. PrimeSense is the company that developed the technology behind the structured-light depth sensor inside Kinect. They started the OpenNI (Open Natural Interaction) as a non-profit organization. OpenNI provides a framework for developers wanting to make software using depth-sensing devices.

PrimeSense release the OpenNI driver framework that allows interoperability between depth- sensing hardware and software. OpenNI is freely available and open source. Compared to previous unofficial hacks, the OpenNI software provides tools that increase development speed, because it solves many of the problems working with raw sensor data that unofficial drivers had not yet overcome.

Additionally, PrimeSense released a free closed-source skeletal tracking middleware system called NITE that provides full body-tracking and hand-tracking. It interprets raw data and then maps it to coordinates of the body parts. The NITE software is similar to official Xbox Development Kit[221]. OpenNI and NITE are mainly geared toward 3D sensors, but in fact none are specific for Kinect. Instead, OpenNI is simply an interface that allows developers to get depth stream, skeleton data, audio, hand points data and gesture detection from any hardware or middleware device.

After the OpenNI framework became popular among everyday-programmers, Microsoft decided to release an official Software Development Kit for Windows for non-commercial use. The Kinect SDK for Windows 7 was released in June 2011. It enables developers to build Kinect software with either C++, C# or Visual Basic, using the Visual Studio 2012 integrated development environment (IDE). The Kinect SDK provides access to raw sensor streams, as well as skeletal tracking and audio capabilities[222].

Our approach - using Zigfu and Unity

Even though the Kinect was originally made to develop games for the Xbox 360 console, it is now possible to program games for computers as well. Developing for the computer platform makes testing easy and quick. This lead the group to the choice of developing a game for computers instead of for the Xbox itself. At this point in time there is no real benefit of deploying the game on an actual Xbox console, because everything can be done on a standard computer. Also, if one was to develop and release a game for the Xbox 360, it would require a special license from Microsoft to become an official Xbox developer. Microsoft also has the so-called Xbox Live Indie Games channel on the Xbox where hobby programmers can release their games with a low entry-fee[223]. The only requirement is that the games are developed using Microsoft's XNA framework and C#. Unfortunately, Denmark is currently not a part of the Indie Games channel.

Since the focus of the project was more on the interaction than the technical part, it was chosen to use the Unity game engine as the primary tool for developing the application. Instead of using the official Kinect SDK for Windows and developing both the game and the underlying mechanic to use the Kinect, it was chosen to utilize an unofficial C# wrapper called Zigfu. Zigfu is a set of C# scripts that bind with the OpenNI framework and PrimeSense's NITE middleware to Unity224. This provides easy-to-access motion-tracking functionality such as a complete 3D skeleton that takes input from the Kinect, as well as hand-tracking for point navigation. Instead of having to code a skeleton ourselves, we simply just assign 3D models for each body part (see figure 4.7).

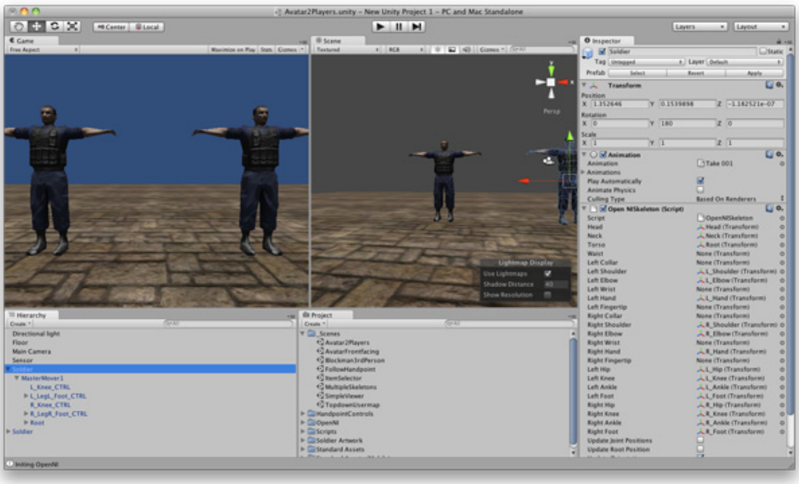


Figure 4.7 – Zigfu comes with a basic 3D model of a soldier. Each body part is tracked by the Kinect and will change the virtual soldier's poses[225].

The Zigfu C# wrapper for Unity requires minimal amount of coding when it comes to using the Kinect as an input device. Compared to programming features from scratch using the official SDK from Microsoft, it was prefered to use Unity and Zigfu, because a lot of basic functionality such as handling of physics, sounds and graphics are already included. This allowed the group to focus more on the interaction and gameplay instead of spending too much time on getting the Kinect camera to work.

The Unity game engine

Unity is a 3D game engine used the development of computer games. Basically, a game engine is similar to an engine for a car: it consists of a lot of nuts and bolts that help driving the car, or, in this case, a game. The game engine handles various things such as physics, rendering, audio, input control and scripting. Unity supports three programming languages: C#, JavaScript and Boo. Using one of more of these languages, one can write scripts that Unity interprets with the help of just-in-time compilation (also known as "JIT"), using the open source C++ library Mono. Unity also takes advantages of the Nvidia PhysX physics engine, OpenGL and DirectX for 3D rendering, as well as OpenAL for audio[226]. This means that one does not have to worry about handling these things, since Unity does it all automatically.

Unity exists in two variants: Unity Free and Unity Pro. The first one is free to download, while Unity Pro costs $1,500 and is more suited for professional developers. The free version of Unity provides plenty of features, but lacks things such as real-time dynamic shadows, version control and post-processing effect such as motion and color correction. Also, if one wants to export a game to the a game console such as the Xbox 360, it is required to have an Unity Pro license, as well as a special Xbox license[227]. Both versions of Unity work on Windows and Mac, and it can export to a wide range of platforms:

- PC/Mac
- Web browsers
- Flash
- Android*
- iOS*
- PlayStation 3*
- Wii*
- Xbox 360*

* Requires a special license besides Unity Pro.

The Unity interface is similar to 3D modelling tools such as 3ds Max or Maya in its structure of navigation and interface (see figure 4.8). Unity uses a modular approach where the developer starts with a simple GameObject. New functionality can then be added in the form of components. Components are the fundamental building blocks of Unity. Components could be rigidbodies and box colliders if one needs to work with physics; it could be a mesh renderer for showing 3D models or textures on the screen; it could be an audio source if the object should emit sound; or it could be a custom-written script to add special functionality. Every object in Unity work in this manner: one can always add more; or if something is unneeded, components can be removed from the GameObject.

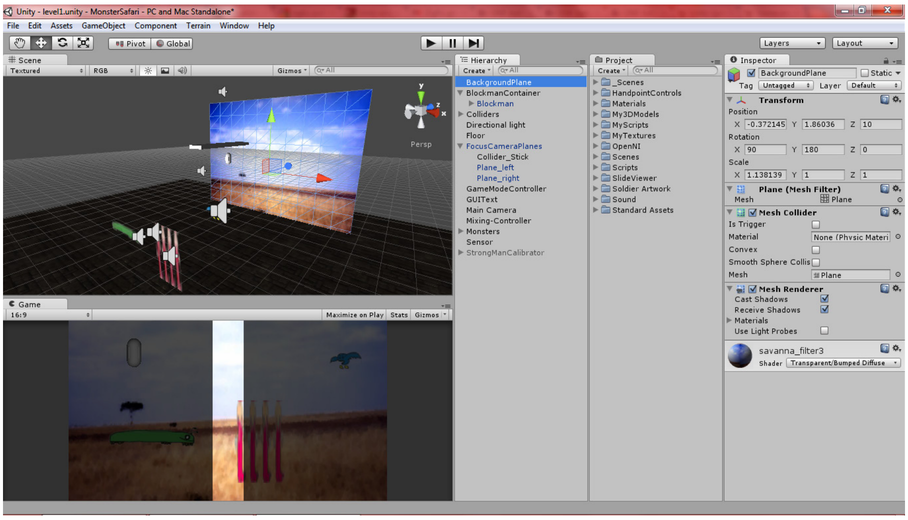


Figure 4.8 – The interface of Unity. The top left shows the Scene view, while the actual Game view is shown below. To the right is the Hierarchy panel that lists all objects in the scene, while the Project panel shows all available assets (3D models, textures, sounds, scripts, etc.). Lastly, there is the Inspector panel that shows properties of the object that is currently selected.

If one wants to write code to add enhanced functionality to a GameObject this is done using scripting. It could be writing a C# script for moving an object when the player presses a button. It could also be scripting an object to emit a certain sound when it hits another object. These scripts are then attached to the object itself, similar to an instance of a class. An example of this can be seen in figure 4.9.

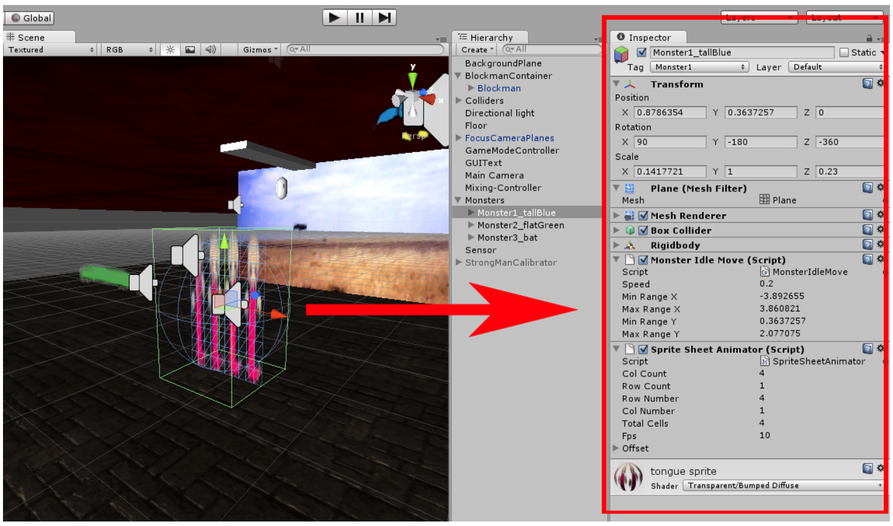


Figure 4.9 – A GameObject is selected, and the Inspector View display its components: Mesh Renderer for displaying the graphic; a Box collider and Rigidbody for collision detection; a C# script that makes the monster move around; and lastly, another script that plays an animation using multiple textures in a sprite sheet.

The implementation of motion detecting

It was chosen to take a relatively simple approach in how the game should perceive and evaluate motion gestures. Instead of having full gesture recognition, the game is based on directional movement. Zigfu already provides a full skeleton that is controlled by the player's movement, so instead of making functionality to detect precise movement, the skeleton's s colliders are used in conjunction with basic collision detection to decide whether or not a certain gesture was performed. However, the actual mesh renderer of the skeleton is turned off, so the player won't see it.

Technically, this approach is easier to implement. The group wanted to have a realistic goal when it came to the implementation in Unity. Doing directional gesture detection also has the added value of making the margin of error bigger for the player. Instead of telling the player that he is doing a gesture in a wrong way, the game allows for a relatively large interpretation of the gesture, e.g. the player doesn't have to jump instead he just has to get his hands above his head to perform the jumping gesture. This also saves development time, since it is much easier to implement a simple collider gesture system rather than full motion-tracking.

The jumping gesture

From the game's point of view it doesn't matter whether a player jumps high up in the air while clapping his hands, or if he just stands still while raising his arms in the air. The only calculation the game does under the hood is to see whether or not the hand objects touch a special roof collider as shown in figure 4.10.

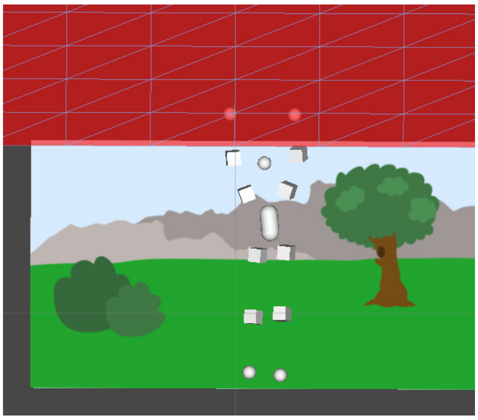


Figure 4.10 – The jumping gesture is based on the position of the hands. The red box collider checks to see if the hands collide with it; if they do, it is interpreted as a jump. The red collider box is parented to the head of the skeleton, so the distance between the skeleton and the box will always be the same, which means that it doesn't matter how tall the playing person is.

The slicing gesture

Similarly, the slicing gesture is based on whether or not an arm is outside of a collider box, as shown in figure 4.11.

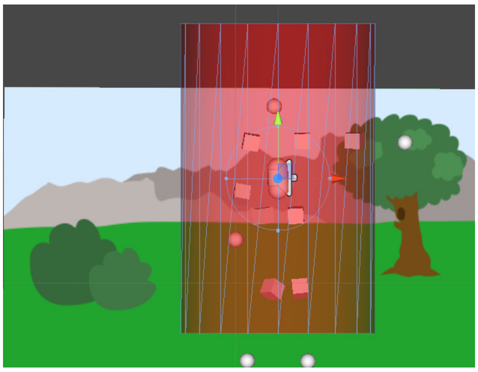


Figure 4.11 – A slicing gesture is performed when one of the player's hands leave the red cylinder collider – and by that are placed in a certain distance to the torso of the skeleton.

The stomping gesture

The last gesture is the stomping gesture. This was originally planned to be some sort of stomp or kick with the feet. Unfortunately the tracking of the player's feet was too weak for it to be a reliable way to track the gesture. If the player's distance to the camera was not perfect, the kicking gesture had a hard time working, because the Kinect couldn't track the feet properly. Instead a stomping motion was implemented so that the player would have to touch the ground with his hands. By telling the player to touch the ground, it forces him to bow down. Instead of tracking the hands for the gesture, the game looks at the position of the head. When the head is below a certain value, the stomping gesture is performed. The downside to this approach is that the player physically has to stand up again, since the system only works when the first time a collider hits. It has to leave again, before it can be activated one more time. Despite this it was better than risking a poor tracking of the feet that would only work some of the time.

The radar zooming gesture

When the player wants to go into zoom mode, he has to set his hands up to his ears.

Previously, the zoom gesture was explained as a set of binoculars. The group tested this gesture with the Kinect but quickly found that it didn't work that as intended. The game would register it as a jump or not register it at all. The Kinect camera has a hard time measuring objects in front of each other, and the binocular motion had the possibility of making the player place his hands in front of or behind the head. This would make the data imprecise, and the hand colliders would jump all over the screen.

This lead to the choice of making it a radar instead where the player has to place his hands near the ears. Figure 4.12 illustrates the differences between the old and new gesture. The radar has two advantages over the binocular motion:

1. It provides more stable data for the Kinect, since it tracks the elbows and doesn't need to measure the hands either in front of or behind the head. This won't interfere with other gestures that use the arms.
2. It has a more logical explanation: the radar simply extends the players ears, whereas before the player would use a binocular to hear sound, which doesn't really make sense.

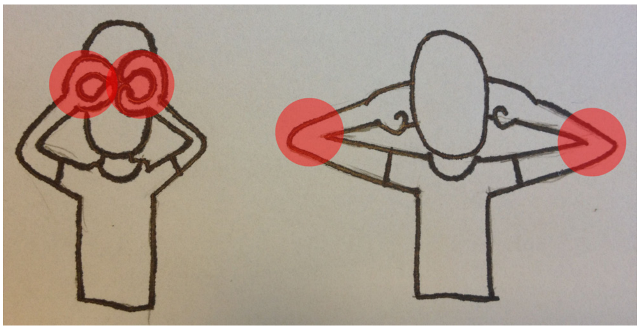


Figure 4.12 - The two different ways of performing the zoom gesture. The first was explained as a set of binoculars; the second as an extension of the ears. The latter provides much more reliable data, since the elbows don't overlap the head.

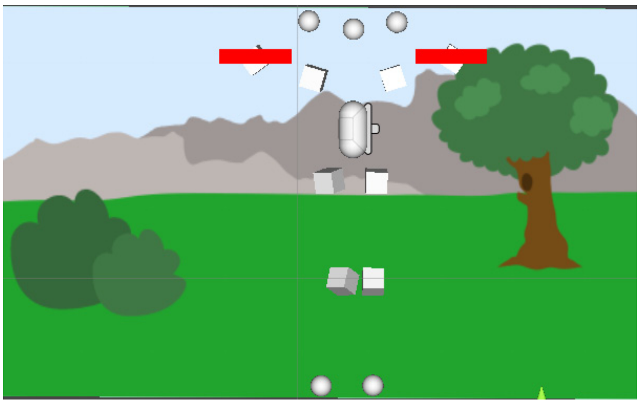


Figure 4.13 - To perform a zoom gesture, the player has to put his hands to his ears. This forces the player to also position his elbows near the red collider boxes. When the elbows touch the boxes, the radar zoom is activated.

Therefore, the game looks at the elbows. This also has the advantage that it is easier to do rotation, i.e. that the player is rotating his upper body to move the zoom radar.

Programming the radar zoom

The radar consists of various C# scripts to make it work. First of all, the two red elbow colliders (figure 4.13) looks for whether they collide with the elbows or not. The following code snippet illustrates this functionality:

```
// This script is put on each elbow collider

// OnTriggerStay is a built-in function
// It is called once per frame for every Collider other that is touching the trigger
void OnTriggerStay(Collider collider)
{
    // Only works if in the right game mode
    if (GameMode.MyGameMode == Mode.Playing || GameMode.MyGameMode == Mode.Zooming)
    {
        // Only triggers if the tag is right
        if (collider.tag == "LeftAlbow")
            elbowTouch = true; // A bool that is used to tell if the elbow is touching or not
    }
}
```

Then, on the actual zoom radar itself, there is a script that among other things constantly checks to see if the two elbows are touching or not. This is done with a simple boolean called “elbowTouch”. Below is a code snippet from the radar that activates when both elbows are colliding:

```
// This script is placed on the radar zoom GameObject

// Update is a built-in function that is called once per frame
void Update()
{
    // Check to see if in the right game mode
    if (GameMode.MyGameMode == Mode.Playing || GameMode.MyGameMode == Mode.Zooming)
    {
        // If both albows touch, start the zoom coroutine
        // Checks the GameObjects "LeftAlbow" and "RightAlbow"
        // Looks for if one or both are touching to collider
        if (LeftAlbow.GetComponent<AlbowCollider>().albowTouch ||
            RightAlbow.GetComponent<AlbowCollider>().albowTouch)
        {
            // If not already zooming, begin a new zoom
            if (!isStartingZoom)
            {
                isStartingZoom = true;
                StartCoroutine("StartZoomCoroutine");
            }
        }
    }
```

All what this code does is looking for whether one or both of the elbows touch the collider. If they do, it will begin a new coroutine. It was chosen that just one elbow has to touch the collider, since there was a small possibility that the Kinect doesn’t register the fact that one of the arms is raised to the head. Therefore it is more safe to accept just a single elbow. From the game’s point of view, this still counts as a zoom gesture.

In Unity, coroutines are special functions that implement the interface “IEnumerator”. Coroutines can suspend execution by yielding for a given amount of time. Using “yield return new WaitForSeconds()”, the game will wait a certain amount of time before proceeding to start the functionality that is placed under it. They allow for multiple functions to be called at the same time. Coroutines are then re-entered at the point where they returned. Also, coroutines can be used in chains to call specific functionality after various time delays.

```
// IEnumerator is a built-in interface that can be used as a coroutine
IEnumerator StartZoomCoroutine()
{
    yield return new WaitForSeconds(2f); // This waits (yields) for 2 seconds before the next part is called
    if (GameMode.MyGameMode == Mode.Playing || GameMode.MyGameMode == Mode.Zooming)
    {
        ActivateZoomFunction();
    }
}

void ActivateZoomFunction()
{
    CamPlanes.SetActiveRecursively(true); // Activates the physical camera planes and all its children
    GameMode.MyGameMode = Mode.Zooming; // Then sets the game mode too zooming
}
```

Make the monsters sound when highlighted with the radar

The monsters only say their sounds when they are within the highlighting part of the radar (see figure 4.14). The way this is implemented is quite simple. What the radar does is that it calculates the distance between itself and each monster. Since the radar consists of two semi-transparent planes, its origin is placed in the space in-between. Visually, this is used to highlight a monster.

As the code snippet below illustrates, the radar adjusts the volume of the monster based on the distance between itself and the monster.

```
// This script is placed on the radar

public GameObject monster1; // This is used to get a link to the actual monster itself
float minVolumeDistance = 0.5f; // Minimum distance

void Update ()
{
    // Check to see if in the right mode
    if (GameMode.MyGameMode == Mode.Zooming)
    {
        // Calculate volume between 0 and 1
        // The float is based on the distance between the monster and the focus radar
        float volumeMonster1 = 1 - (Mathf.Abs(transform.position.x - monster1.transform.position.x

        // Set the monster's via its AudioSource component
        monster1.GetComponent<AudioSource>().volume = volumeMonster1;

        // If the volume is above 0.5, and monster is not already playing --> start playing
        if (volumeMonster1 >= minVolumeDistance && monster1_activate == false)
        {
            monster1.active = true;
            monster1.GetComponent<AudioSource>().Play();
        }
        // Else if the distance is too large --> stop playing
        else if (volumeMonster1 < minVolumeDistance && monster1_activate == true)
        {
            monster1_activate = false;
            monster1.GetComponent<AudioSource>().Stop();
        }
    }
```

If the distance is too large, i.e. the monster is not highlighted, the monster won't play a sound. If the monster is within the highlighting part of the radar, it will start playing its sound. All this

is done by having a link to a public GameObject. This enables the script to talk to the object and its components - in this case, its AudioSource and its properties such as "volume" and the functions "Play()" and "Stop()".

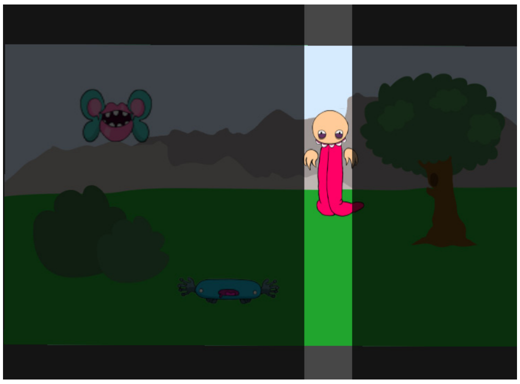


Figure 4.14 - The radar zoom is simply two black planes with semi-transparency. The space between them is called the high-lighting part of the radar. When the player rotates his upper body, the zooming screen moves horizontally. When a monster is in focus, its sound will play.

The use of game modes

The game makes use of various states to decide what functionality should be run. This is done via enumerators, as shown in the code below:

```
public enum Mode
{
    TitleScreen,
    StartMenu,
    Playing,
    Mixing,
    Zooming,
    NoGesture
}

public static class GameMode
{
    // Default game mode
    public static Mode MyGameMode = Mode.TitleScreen;
```

A static variable of the type "Mode" is declared. Since there should only be one Mode variable throughout the game, it is defined as static, so all other object can easily access and change its fields.

Everything in the game works with the "MyGameMode" variable. For instance, when the player is zooming, he shouldn't be able to perform any other gesture. Therefore, the Mode is set

to "Zooming" while he is zooming. Gestures can only be performed when in the "Playing" state, so then the player can't make any gestures until he has stopped zooming. The same holds true for the tutorial and when in the mixing machine.

Removal of the walkie-talkie gesture

In the beginning it was planned to have a walkie-talkie gesture (see figure 4.15) where the player would move his right hand to the ear. Using the walkie-talkie, the player could receive small hints about the monsters he had to catch.

However, this seemed to cause a lot of problems, because the Kinect sometimes wasn't able to track one single hand near the head properly. Also the fact that the walkie-talkie gesture

is similar to the radar gesture makes it hard to distinguish the two gestures from a technically point of view. The data wasn't reliable enough, so this gesture was removed. Also, the earlier prototype tests showed that people rarely used the walkie-talkie at all.

Instead an automatic hint feature was implemented where the guide Eigil would pop up after a certain amount of time and talk to the player (see figure 4.16). This seemed a fair compromise, since the walkie-talkie was only meant as a helping hand for those who got stuck. Now, if the player is stuck, Eigil pops up after about 25 seconds to help the player.

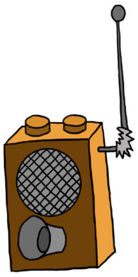


Figure 4.15 - In the beginning it was planned to have a walkie-talkie, where the player would receive hints form Eigil by moving his right hand to his right ear in walkie-talkie position.

Figure 4.16 - In the end, the walkie-talkie gesture was removed in favour of an automatic hint system: after some time Eigil pops up in the lower right corner to tell the player what sounds he should listen for.

Calibrating the camera

For the Kinect camera to work properly, it is important that the player is positioned at the right place and distance. The default gesture in Zigfu to calibrate is either waving with a hand or standing in the so-called "strong man pose". It was chosen to use the latter option. To force the player into this position, a silhouette wooden sign is used, similarly to what kids see in theme parks. Figure 4.17 shows how the strong man sign looks in the game.

Figure 4.17 - Using the strong man wood sign, the player is forced to stand in the right position, so the game can calibrate itself. It is important that the camera can see his whole body, so it can detect when he raises his arms. Depending on how tall the person is, he has to stand either closer or farther away from the Kinect. In this case, 2-3 meters works best. Each time he steps out of the camera's view, the strong man sign appears again.

Interacting with the monster mixing machine

Almost the whole game is controlled by gestures. Only the mixing machine has something that is a little similar to a pointer (see figure 4.18). Here, the monsters are mapped to each of the player's hands, so he can move them around freely on the screen. Though, there is still no real cursor icon like what one would expect from a computer.

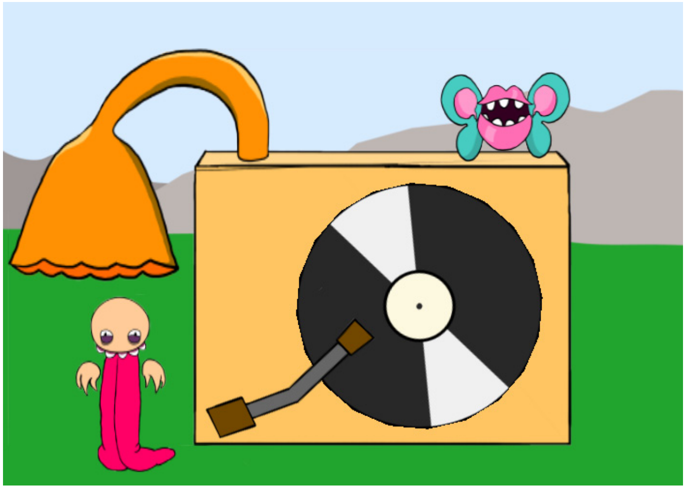


Figure 4.18 - The mixing machine maps the monsters to the player's hands. When he moves his left hand, the monster on the left moves as well, and vice versa for the right hand/monster.

Various approaches were considered for how the mixing machine should work. Also, how the player should interact with the machine was important to discuss. It was considered to use

one hand to move the monsters around, while the other could be used to start the machine by spinning the disc. However, this gave rise to a group of problems. For example, how should the game know when the player wants to pick up or drop a monster? Since there is no "clicking" gesture, it would be difficult for the game to know what to do. Instead of having multiple functions, each monster ended up being mapped to each of the hands. This way was much simpler to grasp and also simpler to implement.

To make the hand control more intuitive, a system was deployed so the player doesn't have to move his hands around in a 1:1 relationship of the screen. This would mean if he wants to point in the lower right corner of the screen, he would have to stretch his arms a lot down to get to the proper position. Therefore, a system was developed that uses offsets, acceleration and speed to make the hand control more fluid and easy to use. Instead of moving his hands around a lot, the player just points in the direction that the monster should move.

The mixing machine constantly spins around. The player interacts with it by placing the monsters on the record. From the beginning the monsters are attached to the hands of the player. When touching the record, the monster attaches itself. This avoid the whole dilemma about whether or not the player wants to drop/release the monster. After a monster has attached to the record disc, it starts spinning around with the monster on it. When the monster hits the reading head, the speaks out its sound and then change color. The color indicates to the player that he quickly has to play the next sound, so they come in a row. An example would be playing the sound "Mi" and then shortly after "Gos". This makes the sound "Mi-Gos", which is the correct sound.

If the player is too slow, or if one of the sounds are incorrect, the monster turns back to its original color and detaches itself from the record. To combine the sounds correctly, the monsters not only have to be placed closely to each other on the record, but in the right order as well. If placed in the wrong order, their sound will play when they pass the reading head, and afterwards they will detach from the record.

In the previous Game Maker prototype a monster could either be correct, incorrect or wrong position. In this prototype a monster can only be correct or incorrect. Based on feedback from tests the group decided there was no advantage having three states, so the "correct, but wrong position" option was cut to make the game more simple to understand.

If both monsters are correct, each monsters plays their sound and then the record player starts spinning around quickly to indicate that the monsters now are getting mixed. Meanwhile, the new monster appears from within the record player's speaker and says its sound.

Screenshot feature

In the design it was planned to have a Word House containing all the monsters caught. It was believed that it would be interesting and useful for the child to get a relationship between himself and the monster and its sound. Due to time constraints the Word House was not implemented, but the screenshot feature itself was.

Figure 4.19 - When the game finishes, the camera takes a picture of the player with the newly created monster. Even though the resolution is 640 × 480 px, it is still nice to have a picture of yourself with the monster.

When the mixing is done and the new monster is formed, the player is able to take a screenshot of himself together with the monster. He has five seconds to position himself, and then the screen flashes and grabs a screenshot. This is done using the Kinect's color camera to project the image onto a plane. Unity has a built-in function called "Application.CaptureScreenshot", and this simply grabs and saves a screenshot of the playing screen. This image is saved on the computer's hard drive (see figure 4.19).

After the screenshot is taken, the screen simply freezes, and the game is finished.

Interactions that were purposely chosen not to implement

Many Kinect games show a graphical representation of the player standing in front of the camera (see figure 4.20). However, the group chose not to show the player on the screen while playing the game. Only when he has mixed two correct monsters will he be able to see himself in the abovementioned screenshot feature.

It was important that the player is focused and has his attention on the monsters. If the player could see himself on the screen during the game, he might be distracted or think that he had to stand in a certain way. Also, since the focus is on the gesture movements, there are no pointer or cursor in the game. This also ties into the game's deselection of using menus. To keep it as simple as possible, there are no menus the player has to navigate through. Instead, the game begins by showing the title screen and shortly after proceeds to the tutorial part. Here, the player is asked to perform all the gestures a certain amount of times before the game proceeds to the hunting phase. This prevents the player from doing something wrong or getting lost in menus.

Figure 4.20 - Dance Central is a popular dancing game developed by Harmonix. Even though the feedback is delivered through the dancing character on the stage, there is also a small yellow window to the right where the player can see himself[28].

Another element the game hasn't implemented is voice recognition. Even though the Kinect supports voice recognition, it was chosen not to use this feature. This was done for several reasons: first of all the built-in voice recognition software only supports spoken English. The game is targeted at Danish kids. Also, these kids are below the age level where they start learning English in school. Therefore, it wouldn't make sense to control the game using English words. Another issue is that the game is about pronunciations of Danish nonsense words.

The group quickly decided it that it would be too difficult trying to make the voice recognition understand Danish pronunciation. In the end, voice control didn't really fit well with the game's concept, and it was decided not to spent time trying to implement it.

5 Hi-fi testing

Hi-fi test - Unity

Test Description

The final test used the Unity prototype. Unlike the previous two tests, this time the game was fully playable and didn't need any Wizard of Oz to control the game. The facilitator was still there to help, but he only offered help when needed.

Figure 5.1 - The hi-fi prototype in action. The boy is playing the tutorial section that teaches each gesture.

Goals

The goal of this final prototype test was to find out whether the game was self-explanatory, meaning that the child would be able to play through the game by himself and understand the concepts on his own without the help of the facilitator.

Variables

There were few task variables. The test participant variables could vary since the auditive guidance, pictures and the tutorial could be interpreted differently depending on the test participant. As opposed to the lo-fi tests there was no wizard variable in this test, since the Wizard of Oz method wasn't used. The facilitator variable depended on the facilitator's ability to communicate and get his help across to the player.

Tasks

The test participant's task was to play through a single game containing the tutorial, the capturing of monsters and the creation of the new word. After finishing the first game, the test participant was given the opportunity to play through a different game with new words and monsters. During the game the facilitator was available for help if needed, but the test participants were encouraged to do as much as possible on their own.

List of tasks during a level:

Tutorial phase

- Practice the "Capture the tall monster" gesture by performing it four times
- Practice the "Capture the flying monster" gesture by performing it four times
- Practice the "Capture the small monster" gesture by performing it four times
- Practice the "Radar" gesture by performing it for a few seconds

Hunting phase

- Use the radar to listen to the words
- Capture the correct monsters by performing the appropriate moves

Mixing phase

- Place the monsters in the right order on the mixing machine

Setup

The test was once again conducted at the school Tornhøjskolen with kids from 0th to 2nd grade. The children that tested the game had ranged from 6 to 8 of years old. There were seven test participants: three girls and four boys. The children tested the game one by one in a classroom.

Equipment

The equipment used was the Kinect camera which this time was plugged in and functioning, compared to the previous two tests where it was just placed as a "dummy" object; a set of speakers; a webcam to record the children during the test; a projector; and a computer running the game.

Test roles

1. **Facilitator** - communicator/going through questionnaire
2. **Note taker** - observing and taking notes
3. **Computer operator** - makes sure to change levels when needed
4. **Photographer** - photographing the session

Test Results

Observation made from video and notes.

The following observations were made watching the videos made of the test participants and from reviewing the note takers notes.

Tutorial

- It is unclear that one has to perform the gestures more than once in the tutorial and therefore more feedback from Eigil would be needed. After the first gesture Eigil should make it clear that the player has to perform it multiple times
- It is impossible to do anything while Eigil is talking, which is tedious when playing through the tutorial multiple times. This also confuses the player since he thinks he's doing the gesture incorrectly because of the absence of feedback.
- A boy thought that he had to time his attack to the animation of Tom. The animation is only meant as a guideline, not something the player has to follow precisely.

- Confusion at the "capture the flying monster" gesture. The animation and sound guide tells the child to jump, but this didn't always work. as intended. The problem occurs if the kid jumps too high in the air, making the Kinect unable to see his hands. The gesture could also be misinterpreted in various ways. Luckily, the game was able to detect most of the jumping gestures:

  - Some were jumping without putting up their hands.

  - Some didn't jump at all.

  - Some kept their hands up and kept clapping to go through the tutorial.

- Feedback is missing at the radar part of the tutorial:

  - The children got confused when only having to use the radar once after using the other gestures 4 times in a row.

  - They also didn't get to try moving the radar across the screen, something they had troubles under standing how to do when entering the hunting level.

  - The positioning of the elbow collider at the radar seemed to be set too high for some of the kids.
  - Feedback for the positioning of the elbows from Eigil such as "Move your elbows up a bit further" would help a lot.

  - Almost all children didn't find the control of the radar intuitive. Instead of rotating their body hori zontally to pan the zoom, they would start moving elbows up and down similar to how they steer with a bike handle.

Hunting phase

- Eigil's guidance when the hunting phase begins is a little too long for some children, especially the younger ones. They lose focus because.
- Eigil shouldn't give hints while the player is using the radar, since this interrupts the listening at the monster sounds.
- Most children weren't certain what to do when the hunting level started. The game should be better to help them in the beginning.
- Some kids seemed to think that the radar was used to capture the monsters.
- Some thought Eigil spoke too fast and too much.
- Most children didn't notice when Eigil mentioned the monster they had to capture. There should be more emphasis on the sound needed to mix. Luckily, he repeats it after a short amount of time.

Mixing phase

- The mixing phase has almost no explanation from Eigil and was not self-explanatory enough.
- It is unclear that the player has one monster in each hand when mixing. To make this more clear an icon resembling a hand could be implemented, a little like a mouse cursor.
- The game could provide more feedback when a monster is being mixed and the is game completed. It could for for example gratulate the player with some kind of fanfare to give positive feedback.
- There is a lack of feedback when an incorrect monster has been chosen. The monster turns red and the player returns to the hunting level, but there seem to be a lack of auditory feedback. However, the game should not give negative feedback that hurt the player's feelings.
- The collider on the mixer needs to be bigger. Some of the monsters are hard to position on the record disc.

General

The girls were generally more shy and insecure when it came to performing the gestures and looked at the facilitator a lot for guidance.

Some of the children seemed intimidated when seeing themselves on the screen for the picture taking. One boy was even afraid of the monster (see figure 5.2). It might have had something to do with the whole test setup and the fact that they were being observed. Nonetheless, it was interesting to see that almost all children didn't like the feature where they could grab a screenshot of themselves with the monster. There was exceptions, however, as seen in figure 5.3. The group thought the picture taking with the monsters would

be something the kids would really appreciate, but it turned out this was not true. It seemed like the children did not like seeing themselves on screen. Also, it could be dependent on the appearances of the monsters.

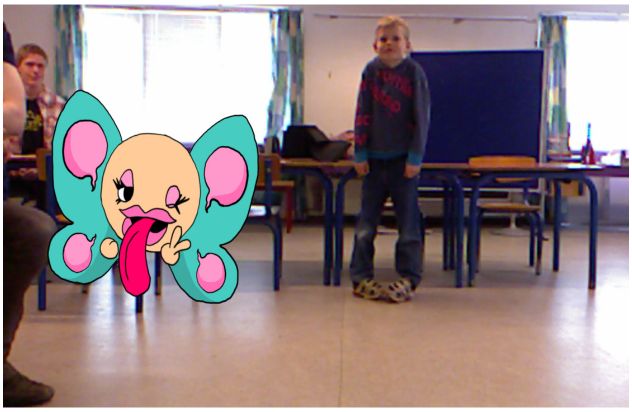


Figure 5.2 - This boy was scared by the monster and didn't want to take a picture with it.

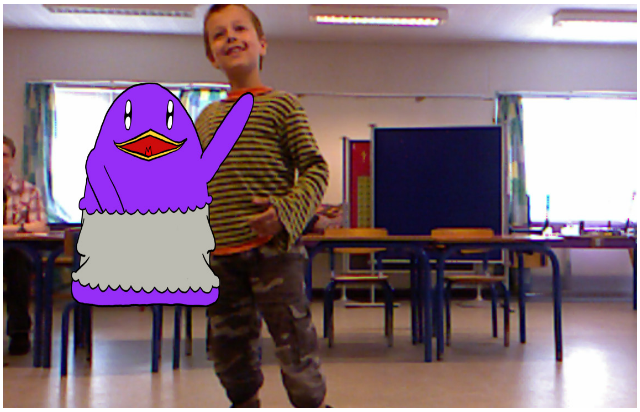


Figure 5.3 - This boy liked the monster and wanted to take a picture with it.

Questionnaire

After trying out the game the children were asked to answer a questionnaire with the facilitator (see appendix B). The answers were very similar and almost only positive. The table below shows data acquired from the questionnaire:

Child#	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**
Class	0.A	0.A	1.A	1.A	1.A	1.A	1.A
Age	6	6	8	8	8	7	7
Gender	Female	Male	Male	Male	Male	Female	Female
Perceived difficulty	Easy	Medium	Easy	Easy	Medium	Hard	Medium
Easy to capture	Medium	Easy	Easy	Easy	Easy	Medium	Easy
Games played	2	2	3	2	2	1	1

Most children when asked didn't have a lot of suggestion of how to improve the game. However, a boy suggested that the game should be like Pokémon where it would be possible to battle with the monsters. Some said that the slicing gesture was really fun, while others liked moving and mixing the monsters in the mixing machine.

Conclusion on the hi-fi

There is still room for improvement of the Unity prototype. For instance, some of the instructions could be a little sharper and more specific. The mixing machine, especially, needs better explanation.

In the beginning of the tests there were some problems with the gesture detection. It seemed like the children had a hard time using the radar zoom. After a few tests the group discovered that this was because the children stood too far away from the camera. This was resolved by asking them to step a little closer.

The kids generally found the game to be fun, but it was clear that some of them didn't understand the concept of mixing monsters and sounds together. This was especially apparent for the younger part of the test participants in 0th grade. The older children in 1st grade clearly had a better understanding of how the game works.

Some of the children didn't realize that the main purpose of the game was to assemble a specific sound.

The group observed two reasons for that:

- The intricacy of the game concept
- The complexity of the kinesthetics given task to solve

On one hand it's bad that the child doesn't focus on the auditory task in the game. But on the other hand, the child don't recognize that he is playing a game with a teaching purpose. Instead, the child focuses on the kinesthetic element which the most children describe as fun.

Feedback was clearly something that could be worked on. It was obvious that those who were able to perform the gesture the first time, e.g. the radar, had a much more enjoyable time than those who had to try multiple times to perform a gesture. Even though the game is built with the idea of allowing a broad interpretation of the performance of a gesture, it wasn't really possible to test it on children before the actual prototype test. Due to a child's smaller body adjustments have to be made to make the gesture recognition better.

Conclusion

It is not possible to say that *Monster Mixer* does indeed prevent dyslexia. The game seeks to improve phonological awareness, but it is meant to have a long-term effect, and therefore it is difficult to conclude whether it fulfils its purpose or not.

Having the constraints of an university project in mind, the group assumes it has done everything possible to develop a game for children to prevent dyslexia.

Even though one cannot directly measure the game's impact, it is still possible to observe how kids react to the game. During the prototype tests they were positive about the game and many wanted to play it at home if possible. *Monster Mixer* is not meant as an replacement for traditional school learning, but more like a supplement.

One can look at the child's enthusiasm for playing the game on his own initiative. An important factor to have in mind is motivation. It doesn't matter if one is dyslectic or not: if a child is not motivated in the work he does, he will have a hard time keeping up with school.

It proved to be a good choice using the Kinect as an input device. It encourages an active kinesthetic approach that appeared to be engaging for the kids. *Monster Mixer*'s finest goal is

to give kids a sense of accomplishment; that they are capable of achieving something on their own. They need to get a positive experience and feel that learning can be fun and exciting. They should discover that being active and taking initiative results in positive feedback.

The children in the prototype tests looked happy and engaged. They had smiles on their faces and many of them were eager to play the game multiple times. This clearly shows an interest in the game. It would require further testing and development to see if the game also works in the long run, but so far it has been a step in a positive direction.

Future perspectives

If more time and money were available, it would be possible to improve the game concept in various ways. The game could scale the difficulty depending on the player's age and skills. One could imagine playing the game in a casual way as a child in 0th or 1st grade. After having mastered the basics of the game, it could progress into a more challenging experience using more than just monosyllables and nonsense words. It might be able to follow the child throughout his whole school life, providing more advanced tasks.

Another aspect that would be interesting to explore further is the player's relationship with

the monsters he catch. When playing the Pokémon games, one slowly grows attached to the creatures. This could be used in *Monster Mixer* where children would not only catch and mix the monsters, but could also use them in other games. One could also imagine taking a cross- platform approach, making the creatures appear in other formats such as apps or games for a smartphone. If the child felt a friendly bond with the monsters, he might be even more eager to want to spend time in their company.

Given enough time and financial support it would be interesting to integrate *Monster Mixer* into the Danish educational system and see the game's impact with a long-term perspective.

Monster Mixer - Medialogy Aalborg University P2 2012 - Kinect Unity game for dyslexia

The AV production can be found on YouTube at:

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Appendix A

Test # ID:
Date:
Start time:
End time:
Total time:

What to log:

- Log transitions between game rooms
- Log participants reaction to sounds and pictures
- Log how many times the participants uses the walkie-talkie
- Log number of times hearing a monster's sound
- Log how many errors the participants do (moves/gestures)
- Log number of tries in monster gathering phase
- Log number of switches in monster-mixing-machine
- Log the time taken to complete a word
- Log how many times is the test participant stuck and has to ask for help?

Time	Log
:	
:	
:	
:	
:	
:	
:	
:	
:	
:	
:	
:	
:	
:	

Appendix B, part 1

Data indsamling - Monster Safari Mi-Fi prototype #3 (målgruppe: Børn)
Test # ID:
Dato and starttid:

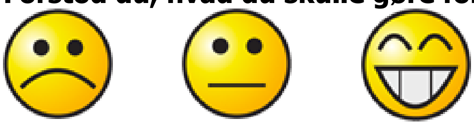
Køn: Dreng Pige
Alder:

Spiller du computerspil - hvis ja, hvilke?

Var det nemt at forstå?

Hvis nej, har du en idé til, hvordan man kan lave spillet nemmere at forstå?

Forstod du, hvad du skulle gøre for at fange monstrene?



Synes du, at spillet har brug for nogle flere forklaringer?

Synes du de ord du skulle danne var for nemme?

Var spillet sjovt?

Hvorfor eller hvorfor ikke?

Appendix B, part 2

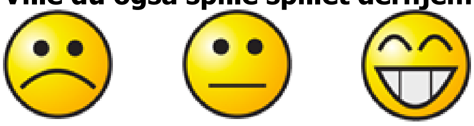
Var der noget du ikke kunne lide?

Var der noget du godt kunne lide?

Har du en ide til, hvordan man kan lave spillet mere sjovt?

Kunne du godt lide hvordan spillet så ud?

Ville du også spille spillet derhjemme i din fritid?



Synes du spillet virker som et læringsspil?

Har du nogle gode ideer, eller andet du gerne vil sige?

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