Preface

In the beginning of the report I will study children's development and their ability to learn. Here I will research theory of children's cognitive development and learning theory.

The next chapter contains theory about deaf children. Here I will be researching sing language and the use of cochlear implants.

After researching theory on cognitive development, learning and sign language I will study two examples of existing learning tools.

After researching different learning games for deaf children, the final problem formulation will be stated.

The chapter following the problem formulation is the method chapter. Here the methods used to design the product are described as well as design and prototype development.
The different stages of development are organized into four phases, each phase with its own purpose in the development process.

The results of the final test and the discussions are documented, ending in a conclusion.

Acknowledgements

I want to thank Døve skolen på Kastelvej for allowing me to participate and observe during their classes.

Without their participation throughout this semester I would not be able to come up with a product serving the needs of the end – user.

Introduction

According to a statistical research made the year 2007, shows that there is an estimated five thousand children born deaf in Denmark that use Sign Language [Sign Web: Language statistics A, 2009; Web: Sign Language statistics B, 2009]. Of these five thousand people only 10% have deaf parents [Web: Sign Language statistics C, 2009].

The way deaf people experience how they are treated by hearing people are described in the following. Hearing people tend to have some prejudgments about deaf people, Mette Bjørnholt Bertelsen [Web: Sign Language statistics C] experienced that people do not think that deaf people can read or write. She says that of course there are some deaf people that have problems reading and writing, but that does not mean that all deaf people have those problems [Web: Sign Language statistics C, 2009]. *"I have more than once experienced, that people thought I could not take care of myself because I am deaf"* [Web: Sign Language statistics C, 2009 P. (5)]. Mette Bjørnholt Bertelsen tries to explain to people that the only difference between deaf people and hearing people is that they can hear [Web: Sign Language statistics C, 2009].

Being deaf is not a handicap in the deaf peoples own self-apprehension, it is a disadvantage, which they live with. Their mother language, sign language, is their primary mean of communication. A resent technology, Cochlear Implants, which can help children hear and thereby use spoken language. But still there is a need for sign language and extra support when deaf children have to learn to communicate. One interesting problem is how deaf children learn to communicate if they have hearing parents and if their parents do not use sign language very well. This lead to my initiating problem: Is it possible to support the development of communication skills amongst deaf children? And is it possible to create a tool that can help deaf children to learn to read and write, and thereby help deaf children learn to make a connection between a sign and a word?

This problem implicate that I establish a general understanding about how children learn and how this understanding can be transferred into a learning tool for deaf children.

Children's development and their ability to learn

This project is about improving deaf children's learning. To understand the learning process it will be necessary to get some general understanding of children's learning process and their language development. The research will begin with a child's cognitive development and this will lead towards language development and learning theory.

Children's cognitive development

*"During infancy, a baby grows from newborn to toddler, and during childhood from toddler to teenager. We travel this path, developing physically, cognitively, and socially." [*Myers, 2007 *pp. 139]*

Children are born with the basic ability of survival. These abilities are e.g. retrieving an arm or leg when in pain, move our head from side to side when we feel like we are suffocating, etc. As an infant develops consequently so does its ability to perceive. An infant, which is 3 weeks old, starts to recognize its mothers voice and starts sucking more vigorously when hearing her voice. Young infants are clearly using their sensory equipment to learn, even though they only see what they need to see, which is ca. the distance between nursing and the mothers face (20,3 – 30.5 cm). All infants develop more or less similar in a healthy environment. The development pattern may be different for an infant that has suffered any type of abuse [Myers, 2007].

According to Piaget, a child's cognitive development builds up concepts in its brain, these concepts Piaget calls schemas. The schemas are a *"mould in which we pour our experiences".* As we grow up these schemas range from e.g. cat and dog, to our concept of love.
The schemas 'assimilate' as we have new experiences according to our current understanding. In a child's mind every four-legged creature may be a dog. As we get new experiences our schema 'accommodates', so a child soon learns that a

dog schema is too broad and creates a new schema for a cat, recognizing the difference only in the head of the animal [Myers, 2007].

Piaget made approximate stages for children's cognitive development (see Table 1). These are four stages and each stage can be mapped to a certain period of age and they are universal [Myers, 2007]. The first stage is the sensorimotor stage, the second stage preoperational, the third, concrete operational and the fourth, formal operational.

Typical Age Range	Description of Stage	Developmental Phenomena
Birth to nearly 2 years	*Sensory motor* Experiencing the world though senses and actions (looking, touching, mouthing, and grasping)	- Object permanence - Stranger anxiety
2 to about 6 or 7 years	*Preoperational* Representing things with words and images; use intuitive rather than logical reasoning	- Pretend play - Egocentrism - Language Development
About 7 – 11	*Concrete operational* Thinking logically about concrete events; grasping concrete analogies and performing arithmetical operations	- Conservation - Mathematical transformations
About 12 though adulthood	*Formal operational* Abstract reasoning	- Abstract logic - Potential for mature moral reasoning

Table 1 Piaget's table of children's cognitive development stages [Myers, 2007 pp. 143]

Stage 1 – Sensorimotor

As shown in Table 1 this stage is for newborns up to an age of 2 years. It is called sensorimotor because that is how the children at this stage interact with objects around them. In this stage children look, hear, touch, put objects in their mouth and grasp the objects around them. Children at this stage seem to lack 'object performance' [Myers, 2007], this means that the children seem to be lacking the awareness that objects continue to exist when not present. According to Piaget young children are living in the present, in the sense that what is out of sight is also out of mind. Placing a toy in front of a child younger then 6 months old and then taking it away the child will not look for it. At the age of 8 months the child has longer memory and therefore spends some time looking for the toy. Even though Piaget's research shows a good explanation of children's cognitive development, other researchers find that Piaget underestimates the children, e.g. in the sensorimotor stage, researches have found that children as young as 2 months old do try to find an object that has been taken out of view [Myers, 2007].

Stage 2 – Preoperational

The children in this stage are around 2 to about 6 or 7 years old. A characteristic for this stage is a lack of the concept of conservation (the principle that quantity remains the same despite the changes in shape) this makes the children very one-dimensional. They focus on height, e.g. when milk is poured in a high slender glass and the same amount is poured in a wide low glass, a five year old will think that there is more milk in the higher glass.

Children during this stage are also egoistic. Not because they choose to be, but because they do not perceive others point of view. When a two-year-old child is asked to show its mommy a picture it will hold the picture facing its own eyes. The same goes for children that believe that they are invisible because they shield their eyes, if they cannot see you then you cannot see them.

More resent research has shown that children are in fact younger than five years old when they start the 'symbolic thinking'. They are able to recognize e.g. if a teddy bear is hidden behind a sofa, if a 3-year-old child is shown a model of the room which shows the bear behind the sofa the child will go and look for it in

real room. A child half a year younger would not be able to make the connection. This shows that the overlap in / between the stages happens faster and has more flow than Piaget discovered.

In this stage children are developing theory of mind (*"people's ideas about their own and other's mental states – about their feelings, perception, and thoughts and the behaviour these might predict."* [Myers, 2007 pp. 146]) As children develop theory of mind they start understanding that other people have their own feelings. But children with disabilities such as autism or even deaf children with hearing parents, where they have minimal opportunities for communication, have difficulties inferring other's state of mind [Myers, 2007].

Stage 3 – Concrete Operational

Children enter this stage at age six or seven, and it lasts until the age eleven. According to Piaget the change in children's cognitive development during this stage is that the children are more capable of understanding conservation, a change in shape does not have to mean change in quantity. They are also capable of understanding mathematical transformations and conservations. A 6 year old is capable within a few seconds to calculate that 8 + 4 = 12, but takes a bit longer to figure out that 12 – 4 =8, until around eight years old the calculation is instant [Myers, 2007].

Stage 4 – Formal Operational

During this stage children and adolescence are capable of thinking logically about abstract concepts, solving problems reducing consequences, if 'this' happens then 'that' happens as an outcome [Myers, 2007].

Language development

As we read, write, speak or listen we are either comprehending or producing language. Since language is so easily used we tend to overlook the complexity of it [Galotti, 1999]. Language has structure, in spoken language there are three building blocks: phonemes, morpheme and grammar.

A phoneme is the sound of the language, meaning that some words in some languages may sound similar but are written in many different ways. A demonstration by Myers (2007), shows that varying the vowel sound between b and t e.g. bat, creates 12 different meanings: bait, bat, beat/beet, bet, bit, bite, boat, boot, bought, bout, and but.

The phonemes building blocks exist also in sign language where the building block is defined by hand shapes and gestures. When a speaker from one country visits another they no not precisely share hand gestures.

Morpheme is the smallest unit of language. This unit carries meaning. Some morphemes are also phonemes. There are e.g. the pronoun I, and the article a.

Morphemes are in general combinations of two or more phonemes. Some are words in itself, e.g. bat, but others only part of a word. The word Undesirables has four morphemes, un – desir – able- s. Each of the morphemes adds to the total meaning of the word.

The final building block is grammar. Every language has to have a system of rules. These rules allow us to communicate with and understand each other. The systems of rules are called semantics and syntax.

With semantics we obtain meaning from morphemes, words and sentences. A semantic rule is e.g. if a words ends with *–ed*, laughed, it is a past tense.

Syntax is the rules used to order words into a sentence that has a meaning [Galotti, 199; Myers, 2007].

As children start developing language they go through 5 stages of development. These stages have been clarified in Myers (2007).

Month (Approximate)	**Stage**
4	Babbles many speech sounds
10	Babbles resembles household language
12	One-word stage
24	Two-word stage
24+	Language develops rapidly into complete sentences.

Table 2 Table of children's language development [Myers, 2007 pp. 415]

The first stage is at around four months. This stage is called the babbling stage, (see Table 2). In this stage the children make spontaneous sounds such as 'uh-ahh' sounds, these sounds are not imitations of spoken sounds. As these sounds are not based on any specific language a listener would not be able to identify where the child is from. The babbling stage also exists within the deaf community. Deaf children in the babbling stage create hand babbles [Myers, 2007]. Eventually the babbling sounds start to resemble household language, which is the second stage. Children enter this stage at about 10 months of age.

At stage three, one-word stage, the children are around twelve months old. In this stage the children have learned that sounds carry meaning. At this stage children learn by associating words with an object or a picture. As a child grows older its learning ability extends rapidly from one word a week to one word a day.

Children at about twenty-four months enter stage four, the two-word stage. This stage is also called the telegraphic stage, since the sentences children speak are made out of only two words, one noun and one verb, e.g. want juice, big doggy. There is no identified stage between the two-word stage and the last stage, when

the child starts to rapidly develop sentences from two words up to full sentences [Myer, 2007].

Taking this knowledge into consideration it is understandable that it is a difficult task for deaf children to learn the spoken language.

How do we learn - Learning theory

"We associate learning with the deeper processes of influence upon our understanding" – [Ranson et al, 1996 p. 12]

Learning is a process that never ends, as we generate new understandings about our selves and the world, we keep on learning. To define 'learning' we can say that it is a sense of discovery, when we perceive something new it alters and builds on our previous knowledge, we are learning. As we learn we discover the way things work, the 'why', the 'how' and the 'what'. The more we learn the more our understanding of the world grows [Ranson et al, 1996; Web: learning theory, 2009].

Learning methods

There are many theories about learning and there is more than one method of learning. Coffield (2000) distinguishes between formal learning, informal learning, and non-formal learning. But also active learning is important [Mayer 2001].

As the name indicates, formal learning, also called Formalized learning is what we could call the 'typical' way of learning. This type of learning is intentional and has a learning objective typically provided by an educator or in a training institution. In this type of learning people are engaged in the learning process. Here the learning is a task in order to enhance ones knowledge. Formal learning normally ends up with a formal certification [Coffield, 2000; Non-formal learning, 2009; learning theory, 2009].

Informal learning also sometimes called Acquisition learning has to do with our daily lives. Normally activities related to work or family. This type of learning is

seldom structured and does not necessarily have an objective, which is acquired during a specific activity. Informal learning is usually not intentional [Coffield, 2000; web: Non-formal learning, 2009; Web: Informal learning, 2009; Web: learning theory, 2009].

Non-formal learning is in a certain way a mixture of the previous two. It is intentional as formal learning but an educator or a training institution does not provide it. On the other hand, it has a learning objective but does not lead to a certification [Coffield, 2000; Web: Non-formal learning, 2009].

The final method of learning described here is the active learning. There are two types of active learning, behavioral activity and cognitive activity. According to Mayer (2001) behavioral learning is when a student is having hands on experience without being encouraged to make sense out of the material. An example provided by Mayer (2001) is that a student is learning meteorology. He sits in front of a computer and clicks on an interactive tutorial on lightning. On the screen appears the following statement: *Each year approximately ___ Americans are killed by lightning*. He types in his answer. The student is behavioral active since he types the answer on the keyboard.
Being cognitive active on the other hand is about being actively trying to make sense out of the information a student receives. Mayer's (2001) example of cognitive active is: Another student preparing for his meteorology test uses a different tutorial. His tutorial is a short animated explanation about lightning. As the student is watching and listening, he tries to focus on the essential steps in lightning formation and to organize them into a cause-effect chain. Whenever the tutorial is being unclear about why one step leads to another, he uses his prior knowledge to help create an explanation for himself [Mayer, 2001].

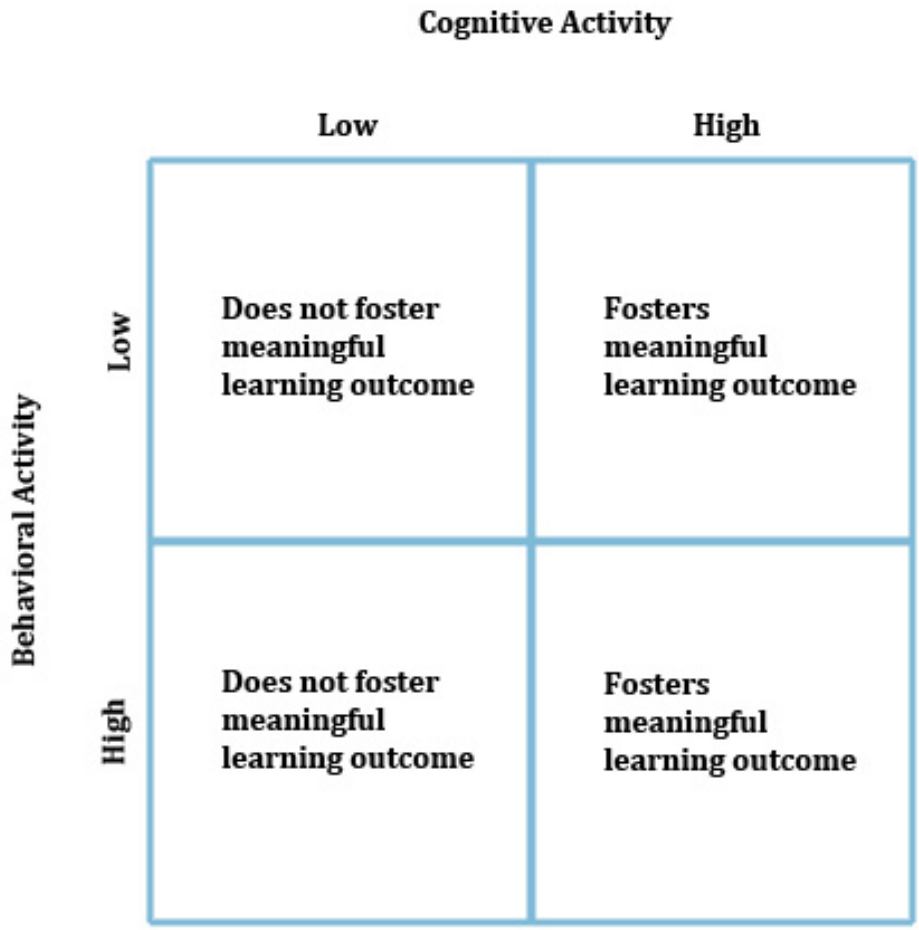


Figure 1 A summarize of two types of active learning. "If meaningful learning depends on active cognitive processing in the learner, then it is important to design learning experiences that prime appropriate cognitive processing" [Mayer, 2001 p. 19]

According to Mayer (2001) research on learning has shown that high cognitive activity and high behavioral activity influences learning outcome (see figure 1). That is the reason Mayers believes that the best way of learning is through a hands-on activity as in a highly interactive program where both behavioral and cognitive activities are imbedded.

As stated in the chapter 'Children's cognitive development' (p. 7) we use our sensory equipment to learn from infancy and beyond. Therefore I am shortly describing learning with the use of senses.

A method called multimedia learning is a method, which focuses on learning with the different senses. Cognitive theory of multimedia learning is learning with 'dual-channel', visual channel and auditory channel. The assumption Mayer

(2001) has made is that human processes separate information from the auditory and visual represented material.

In a cognitive sense, this method is about how people construct knowledge from words and pictures. Multimedia learning is in five steps, (see Figure 2). These five steps are: selecting relevant words from the presented text or narration, selecting relevant images from the presented illustrations, organizing the selected words into a coherent verbal representation, organize images into a coherent visual representation, and integrating the visual and verbal representations and prior knowledge [Mayer, 2001].

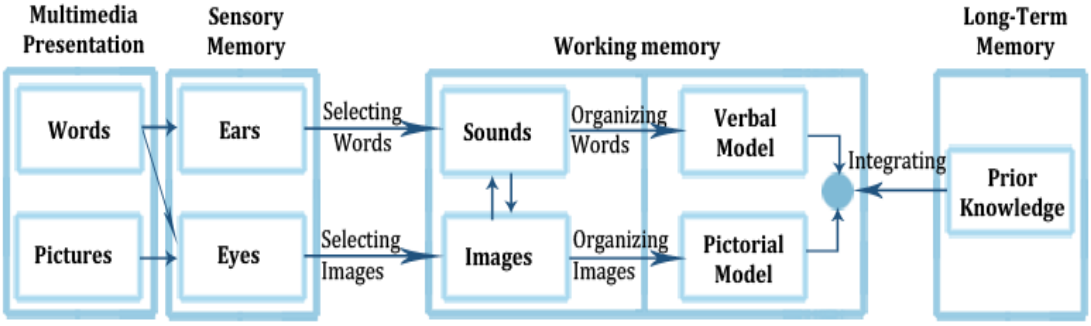


Figure 2 Cognitive theory of multimedia learning – [Mayer, 2001 p. 44]

Each channel processes the input, whether they are visual or auditory. Illustrations are processed in the visual /pictorial channel and spoken words and sounds are processed in the auditory /verbal channel. Processing can occur in both channels, these are e.g. printed words. Their processing begins in the visual / pictorial channel and moves to the auditory / verbal channel.

As Figure 2 illustrates, the cognitive theory of multimedia learning is about the two channels of hearing and seeing. They are divided into Sensory memory, Working Memory and Long-Term memory [Mayer, 2001].

The first memory the stimulation / knowledge enters is the sensory memory. Here the information, whether they are visual or auditory, are held as exact visual / auditory images for a brief period of time.

Word or Pictures are selected from the sensory memory to be processed in the working memory. The sensory modalities in the working memory are visual and

auditory. When the information first enters the working memory it is presented as raw material. Here a material conversion occurs, which means that when you hear the word 'cat' you start visualizing a 'cat', and vise versa. When the information has been selected the material is organized into coherent structures, and moved into the visual and verbal mental models of the working memory where the information / knowledge is constructed.
The long-term memory is the storage for knowledge, it can store large amount of knowledge over long periods of time. In order to use the knowledge in the long-term memory it has to be moved into the working memory.
The arrows that are labeled selecting sound/image, organizing sound/image and integrating are the major cognitive processing for multimedia learning [Mayer, 2001].

Since this project is about deaf children and their learning process I have to eliminate the Ear as a sensory memory and sounds as well as Verbal Model in the Working memory. In this project I am only working with Eyes as a sensory memory, and when working with words and pictures the children will be challenged to combine the input they get via their eyes.
It is important for this project to stimulate the sensory memory they have and thereby help them learn more efficiently.

But there are other learning parameters that are useful to take into consideration when dealing with support for deaf children's learning processes: Play, color and motivation.

Learning through play

When children are playing they combine imagination and intellect. It helps the children to discover things at their own pace and in their own way. When designing a game with a learning outcome it is important to remember not to make it only fun. There has to be a meaningful task. Focusing on a non-formal learning environment you have to remember the elements of play, discovery, and engagement [Roussou, 2004], which are parts of motivation.

Color

Colors are important when it comes to children and especially to deaf children. Therefore there will be a short description of perception of colors and how color can have emotional influence on children.

Colors have a higher purpose than just adding beauty in our lives. They have a great significance in our lives, particularly because some of the colors have been associated with a meaning and can influence people emotionally [Goldstein, 2007; Matlin, 1997].

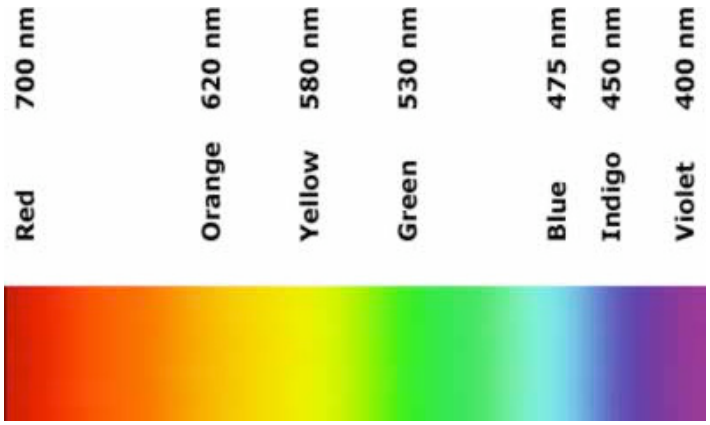


Figure 3 The visible color spectrum going from high frequency colors, red, to low frequency colors, violet [visible light spectrum, 2009]

Colors are perceived when light rays of white light are reflected from an object. This means that when we see a blue ball the long and medium light waves are absorbed into the ball while the short ones are reflected from it [Goldstein, 2007; Matlin, 1997].

Some researchers have tried to connect a meaning to certain colors, even though this can be very subjective since meaning of colors is not always the same. It is based on culture and time in history. On the other hand you can say that the meaning of color is relatively accurate according to psychological research about how colors influence us.

As mentioned, colors can have an emotional influence on people. Colors are also often used to describe emotions e.g. you can be green with envy, blue with sadness and red with anger [Web: The psychology of colors, 2008].
Luescher and Schott (1969) did research on psychological reactions to color. They stated that with galvanic skin response electroencephalograph (EEG) it has been proved that long wavelength colors such as red and yellow are more arousing than the short wavelength colors such as green and blue [Luescher and Schott, 1969]. EEG records the brain activity with use of sensors, which are attached to the head [Web: Epilepsy health center, 2009].
With this in mind, when we walk into a toy store, such as Toys R Us or Fætter BR, there are many strong and bright colors. Especially in the area where there are toys for infants and young toddlers.
Research has shown that the brighter and more saturated colors are, the more pleasure they bring [Guilford and Smith, 1959].

As the deaf children are only using one sensor to learn it is important to stimulate the sensors they use. It can become both motivating and more fun for the child to have the right and stimulating colors.

Motivation

In order to keep our attention to learn we have to be motivated. Motivation comes from being interested in what we learn. When the student is no longer motivated, there is not more learning or only little learning. Lack of interest from students is one of the most difficult problems educators face today. A way to keep students motivated is to give positive feedback every time a student solves a task correctly [Gee, 2003; Educational Motivations, 2009].

When a person has a desire to achieve something they possess a motivation called achievement motivation. Achievement motivation is the ways in which people define and set goals. These goals are presumably goals that relate to their own competences. People that have adopted the achievement motivation are more driven and welcome challenges in order to increase their competence,

understanding, or mastery of something new [Galotti, 1999; Web: Motivation to Learn, 2009; Web: Achievement motivation, 2009; Web: Achievement motivation B, 2005].

Summary

With the focus on deaf children who have only one sensory input, the eyes, the product has to be stimulating and motivating through only this one sensor. Assuming that the children are able to set goals for their learning, and have motivation to achieve this goal, the product has to have an intentional learning goal that can be played without any help from a teacher.
In order to stimulate the children and perhaps motivate the children the colors are important. As research has shown colors can provoke psychological reactions from people. Furthermore it is also important to use the active learning aspects, which use behavioral as well as cognitive activities.

As mentioned deaf children are the focus in this project, therefore the next chapter is about deaf children, in order to understand the situation I am going to be dealing with.

Deaf children

Deaf children develop cognitively as hearing children. An exception being that deaf children with hearing parents tend to lack the communicative skills (see, chapter, 'Children's cognitive development' p. 7). As deaf children have other means of communication this chapter will contain an explanation on sign language and the option parents of deaf children have to day, a Cochlear implant.

Language without sound – Sign Language

Sign Language is the means of communication for deaf people. It is not international standardized as such and has not been developed by one person. It has been developed over time among deaf people and their families, among communities of users [Valli and Lucas, 2000; Web: Tegnsprog 2009].
Language is not based on hearing. Hearing children born with deaf parents learn the language their parents speak, sign language [Gleitman, H, 1999]. When communicating with Sign Language, the users use their hands to send information and their eyes to receive information [Donovan 1998]. Therefore the first rule of signing is to maintain eye contact [Stewart and Little, 2006].

As mentioned, sign language is not international standardized e.g. the sign for 'Student' (see Figure 4), is different in American, Italian and Thai sign language [Valli and Lucas, 2000].

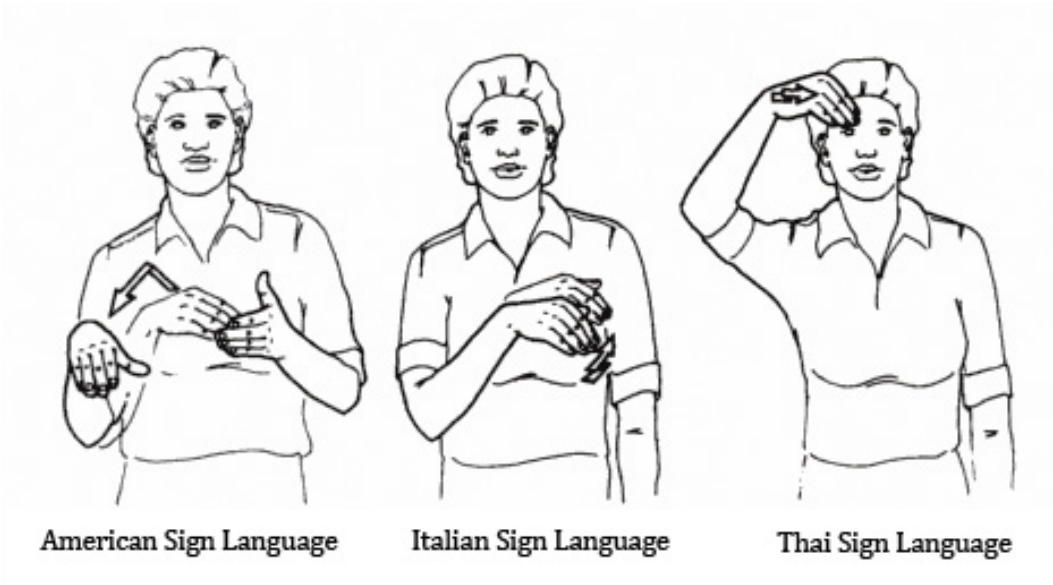


Figure 4 Sign for Student in American, Italian and Thai [Valli and Lucas, 2000 p. 6]

Sign languages are systematic languages with grammatical principles for combining words to sentences, just like the spoken language and written language [Gleitman, H, 1999].
Just as any other language, sign language has a sequence in which it is presented. This means that the segment that make up signs occur in sequence [Valli and Lucas, 2000].

Forming signs are based on two conditions: The Symmetry condition and the Dominance condition. If using both hands to sign and they both have the same hand shape and the same movement it is called Symmetry condition.
When each hand in two handed signing is creating different shapes it is called Dominance condition. In this condition only the active hand can move and the passive hand serves as a base and does not move. Both the right and the left hand can be active, it depends on whether or not the signer is right or left handed [Valli and Lucas, 2000].

Sign language is still a natural language for deaf people, but there has been a change in the deaf community, the change is the Cochlear implants. In the following section there will be a short description of cochlear implants.

Cochlear implants

In order for deaf people and children to gain some hearing they can get cochlear implants (CI). CI is a bionic ear that translates sound into electronic signals. The CI is wired into the cochlear nerves and conveys some information of sound to the brain. If the implant is inserted at young age, children can learn to use oral communication [Myers, 2007].

CI is getting more and more used today. About 90% of deaf children that have hearing parents are using CI. The parents want their children to be able to experience the world with sound. Some groups in the deaf community are on the other hand against CI, unless the individual is born into the hearing world and looses his /hers hearing. One of the reasons for the deaf communities negative response to the CI is that they do not consider themselves as people with disabilities. Deaf people are not linguistically disabled they have their own language, the sign language that has its own grammar, syntax and semantics [Myers, 2007].

Summary

Using sign language for communication, even with CI there still is a need for special efforts and support for deaf children's teaching and learning.

Examples of learning and teaching tools for deaf children

There are several examples on tools, which can support deaf children's learning. This chapter shows examples of what has been done within the digital support for learning and teaching deaf children. There will be a short description of two projects that are related to the field of interest in this report. These projects are various types of learning games/environments for deaf children to support their learning.

A Virtual Learning Environment for Deaf Children: Design and Evaluation

A Virtual Learning Environment (VLE) created by Nicoletta Adamo-Villani. This project is based on deaf children at the age 5-10, where the children interact with fantasy 3D signers and learn American Sign Language (ASL) math terminology and concepts. The town is a cartoon where the focus is on colors and the association between colors and children's emotions. [Adamo-Villani, 2007]

This virtual world includes a series of stores in which the participants perform math activities based on standard elementary school curriculum. The users explore the stores and select and manipulate the objects in the store. The user has to communicate with the virtual storekeeper in ASL. In order to manipulate the objects in the stores the user can either use direct user control or physical control. Using these two techniques requires very little learning and abstractions from the user. Using direct user control involves a Fakespace pinch glove, while the physical control utilizes a six-degree of freedom (dof) wand whose buttons provide the means for interaction with the world. In order to minimize the users memory load the buttons on the wand are kept consistent throughout the experience.

Using the pinch glove allows the user a very natural way of interacting with the interface since the glove mimics the use of a hand. The six-dof wand is perhaps not as intuitive as the glove because it is not as innate to your own movement or

use of hands. But still the wand was found easy to use because it operates as a video game controller. When playing inside the virtual world the users use the most intuitive way to select an object, they reach out and "touch" it [Adamo-Villani, 2007].

The learning experience of the game is that every store is designed for a specific math concept and terminology. E.g. in the bakery (see Figure 5), children learn how to estimate, measure, and sign 'weight', while in the clock store (see Figure 6) they learn how to read and sign 'time'.

Figure 5 The bakery, where the children learn to estimate, measure and sign weight.

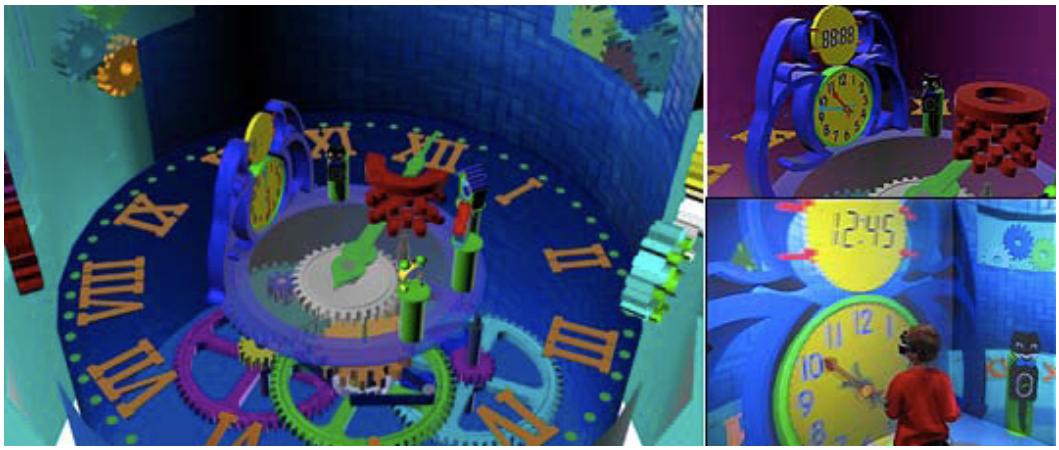


Figure 6 The clock store where the children learn how to read and sign the time.

In every store there is a virtual storekeeper. The storekeeper communicates with the users in sign language, and gives signed feedback upon the completion of certain tasks and/or solutions to math problems. The storekeepers also ask the user questions in sign language, each question requires numbers as answers. The user responds by producing the number sign with the glove or by selecting the

number symbol from a virtual menu that appears in front of the user when activated (pressing a button on the wand) [Adamo-Villani, 2007].

The test subjects were children in the age of five to eleven. Only three of twelve test subjects were deaf children using ASL. The reason for the low number of deaf children was that Nikoletta needed feedback from the subjects, which she was able to get from hearing students, who were able to give their own answers. The results from the testing was that a majority of the children were able to complete the tasks, and in general the children did like the appearance of the virtual world, the colors and the animated objects in the stores fascinated them [Adamo-Villani, 2007].

A gesture-based American Sign Language Game for Deaf children

Students from the College of Computing have developed a computer game to help deaf children learn ASL. Their target group is children in the age of six and eight which are behind their age group in language development. They made a system that consists of three parts: ASL recognition, an interactive game-based interface and an evaluation system.

The motivation for this group to develop this game was that 90% of all deaf children have hearing parents. The goal for this project was to create a tool that teaches and motivates children to create sentences in sign language. This helps them to have clearer communication with other people using sign language and to gain stronger language skills. Deaf children of deaf parents are usually starting to combine signs to communicate at eighteen months, while deaf children of hearing parents develop language skills much slower [Lee, 2005]. For this project they decided to create an ASL game that uses gesture recognition technology. The game is built on three components (see Figure 7). A tutorial video which demonstrates the correct signs, a gesture recognition system, a real life video which provides input for the gesture recognition. A feedback was produced to the child through the interface. Finally, an animated character, Iris the cat, executed the child's instructions.

Figure 7 A screen shot of the interface, A) is the tutor video, B) The real life camera feed C) Attention button, D) The animated environment, E) Action button

Iris is the character that interacts within the environment, she responds to the child's signs. The phrases they use in the game are age appropriate ASL phrases (ages six to eight).

The designers worked with AASD (Atlanta Area School for the deaf), where they did a couple of pilot test on the six to eight year old children.
The first pilot test they did was made while the gesture recognition system was under construction. The goal with the first test was to design a prototype that the children found engaging and interesting enough to practice their signing. In order to be able to get feedback about the interface they tested nine to eleven year old children. The test method they used for this test was the Wizard of Oz (Woz) method, which turned out to be an ideal method to gather data for their gesture recognition system [Lee, 2005].

By doing the first pilot test they were able to find out that using a combination of sensors and gesture recognition would give more accuracy than only with the gesture recognition. Therefore in their second pilot test the children were wearing colored gloves to enhance the computer vision algorithms. Mounted on

the wrists of the gloves were wireless accelerometers. This time the children were more engaged in the game than in the previous test [Lee, 2005].

Final Problem formulation

During this project period I want to study the way deaf children learn, by observing them during selected lessons. This I want to achieve by using elements from ethnographic research, to be able to design an interactive game that helps and motivates deaf children in their learning process.

The idea is to create an interactive application that helps deaf children to develop the skill of associating a sign with a written word. This should be fun for the child to play with and motivating for them to improve their language skill.

Hypothesis and Problem formulation

Based on the knowledge gained in previous chapters, I can come up with the following hypothesis and problem statement.

It is possible to create an entertaining user-friendly interactive application that is educational for deaf children based on iterative design and using ethnographic methods.
This hypothesis has lead to the final problem statement:

To develop an interactive and motivating learning tool for deaf children to support their reading and writing skills in early reading classes.

Method

For this project I have chosen to work with a user-centered approach, which is a method where the user is involved in the design process to a certain extent. The approach I use is called iterative design [Bolvig, 2008]. By involving the user in the design process, the product ensures the designer that the product is designed according to the users needs [Sharp, 2007].

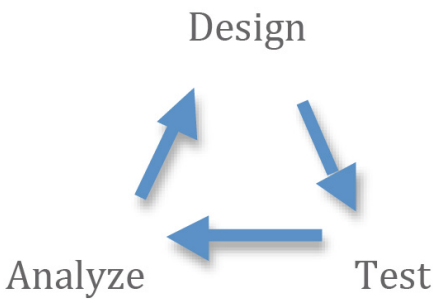


Figure 8 Iteration "test; analyze; refine. And repeat" [Zimmerman, 2003] Test the prototype, modify the product and test again.

Iterative design is a cyclic process (see Figure 8), of prototyping, testing, analyzing and refining work in progress. This process is done as often as necessary [Sharp, 2007; Web: Zimmerman 2003; Web: Iterative design, 2009]. This type of approach to designing a product is also called user-centered innovation [Steinback, 2009].

The method for the design is inspired from ethnographic studies. The group that will be studied is a class of young deaf boys. This study will take place during their lectures where I can learn to understand the way they learn and the way they are taught. Using iterative design together with ethnographic research methods, the design of the product will naturally evolve as I spend time together with the deaf children.

In the following sections I will describe the process of developing a product from the first idea to the pilot product.

The process is divided into four phases. Each phase has its own purpose in the product development. The first phase is the first iteration where the idea development of the product is described. The second and third phases describe the first two prototypes, the development made and the results from testing them. The final phase describes the final testing of the final prototype made during this project.

Phase 1

The first phase is where the study begins with me being at the deaf school. By observing the children and interviewing the teachers, the idea develops. The steps that have been taken in order to develop the idea and the research will be outlined in this chapter.

In the following section I will describe the method used to get to know the end-user.

Ethnographic study

"Ultimately, you want your design team to talk about the things you hear from the users, rather than what team members think the users want" - [Gilmore, 2002 P 30]

In this section the elements of ethnographic studies used in the research period is briefly described. As mentioned this project is about creating a useable product where the needs of the end-user is in focus.

There are both benefits and limitations of conducting an ethnographic research. The benefits are for example that you ought to go in depth in the research. The researchers experience this depth when he / she has to be present with the subject for some period of time. During this time the observer /researcher is able to see what the subjects are doing as opposite to being told by the user. With the in-depth knowledge of his /hers subjects the observer / researcher will get a better understanding of the problem domain. The limitation is very simple time. It can be very time consuming to conduct an ethnographic study, not only the

time of observation but also the time that it can take to analyze the data. Another limitation is that though the research may give an in-depth knowledge of the subjects it does not have much breadth, i.e. the researcher is mainly studying one organization or culture instead of several [Myers, 1999].

Methods within the ethnographic research

There is more than one method when doing ethnographic research. The research method for this project is based on observations and interviews. During class and interviews there are two main methods that will be used while observing the subjects during their classes. The first is the *observer-participant* method where the observer will be "hidden" in the background, giving him/her a wide perspective on the context and the events of the lecture. The downside of this is that the observer will not experience the activities first hand as he/she will not participate directly. The second method that will be used is the *participant-observer* method where the observer will be active and participate during the classes. The downside experienced here is that documenting the events of the lecture proves difficulties. Memory is relied upon heavily in this instance [Blomberg, 2003].

Few rules that are good to follow when conducting an ethnographic research are [Myers, 1999]:

1. Write field notes continuously; observations, impressions, feelings, hunches, and questions that emerge. Memory should never be relied on.
2. Write up an interview as soon as possible. At least write a brief summery the same day.
3. Review and develop ideas regularly.
4. Develop strategy or deal with all the data that needs to be analyzed.

In order to conduct the research for this project I contacted a deaf school in central Copenhagen. This school will be described in the next section.

Døve skolen

The school that has agreed to participate in the ethnographic research is 'Skolen på Kastelvej'. This is a school for children that are either deaf or hard of hearing. This school follows Copenhagen commune's study-plan and is build up as any other primary and lower secondary school for 6-to 16-year-olds. The only difference is that the children are taught two times a week in a class called sign language.
Since the children have different qualifications when entering the school, they get differentiated teaching during class, and thereby all the students are taught according to their needs [Web: Skolen på Kastelvej (2009)].

According to the teachers there are fewer and fewer students attending 'Skolen på Kastelvej'. A few years ago there were around 100 students at different ages attending the school. Since the use of CI there are only about 70 students attending the school today. There are on the other hand many children in the school with CI, the reason they attend this school is that they were to old when they got the implants and therefore they are not able to hear as clear as children getting the implants at birth [Interview 1, Appendix B].

Idea Development

The experience gained during observations and interviews with the staff in 'Skolen på Kastelvej' is elaborated on as well as the idea that has developed from these observations.

Observations

The first phase of the project is about coming up with an idea that can be used in schools today. The first iteration of the project is the two first meetings with the class where I learned about the students in the class, some of their strengths and some of their weaknesses.
In the beginning of the research the appropriate method was the observer-participant method. Here the subjects are participating together as a normal teaching session due to the observers "hidden" presence. As the observer learns more about the children's ways of learning and the students get to know

him/her better, he/she can begin to participate, taking on the participant-observer role. The participant-observer role requires the teaching session to be documented, either by video camera or still camera. These are the necessities in order to gain a valid documentation of the lecture, one that the observer can refer to / analyze at a later time in order to refine the project [Blomberg 2003].

The class consists of four boys, lets call them W, X, Y and Z, these boys have different qualifications. W and X are very bright and do not have much problems with their learning. While Y and Z have difficulties, especially learning how to read and write. Y has a CI and is learning how to read out loud while Z has difficulties learning to articulate the words [Observations, Appendix A].
According to one of the teachers some students have more difficulties than others learning to read and write, not only because they might be dyslexic or have other reading problems, but because their parents are hearing and have difficulties communicating with each other and their child, using sign language while speaking. Therefore the child does not have much input and has problems connecting signs with written words. These children take longer to learn how to read and write [Interview 2, Appendix B].

As the boys all have different qualifications, creating a product that reaches out to all of them would be difficult. Therefore the method that I have chosen to work with is 'going from the specific to the general'.

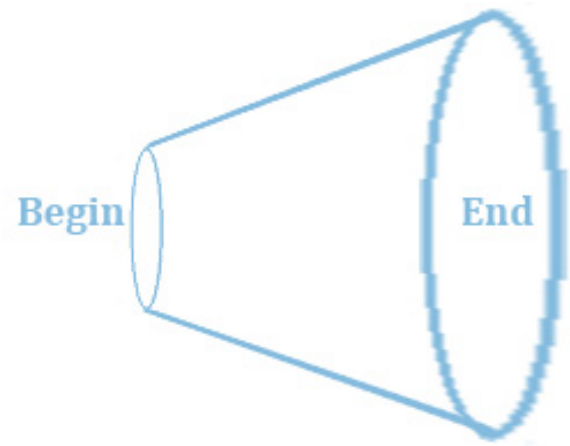


Figure 9 An illustration of 'going from a specific to the general' model. Begin at a narrow end and then expanding the product to reach out to a bigger target.

In order to begin the idea development, child Z was chosen. The reason for this is that this child has a general problem that is not only a problem within the deaf community. The product can be evolved into reaching other children with general reading problems.

After a brainstorming session [Appendix C], after gaining knowledge from the Deaf school, an idea came to life. The idea has to contain three specific elements, play, learn and movement, (see 'active learning' p. 14). I chose these elements assuming it will make the product more entertaining and more motivating for the children.

Idea 1

Learn: The child sees a picture on the screen, after the picture the object in the picture is spelled letter by letter. When the child is ready the word disappears and the child has to spell the word by itself letter by letter.
Play: The letters of the alphabet are on a blanket on the floor. The child has to search for the letter and step on it, the letter they choose will appear on a screen.
Movement: The child has to move around in order to find the correct letter and step on it.

Figure 10 This picture shows how the blanket in idea 1. This could be bit confusing for a child making him/her loose their attention and interest.

Here the child has to look for the letters and jump between them. This can become a little bit confusing for a child learning how to spell. Therefore the idea of the blanket was developed further.

Idea 2

Since the product should not confuse the child and should be easy to play with the idea was developed further.

Learn: The child sees a picture on the screen containing an object, and then the object is spelled letter by letter on the screen. The name of the object disappears from the screen. Afterwards the child has to write the word on its own. When the child has finished a word correctly, stimulation for the child to continue appears.

Play: The letters of the alphabet are on a soft "boxes" on the floor forming a rectangle frame. The child is able to navigate inside and outside the rectangle to find the letter they need in order to write the correct word. Each letter has a set of lights in its "box" which light up when the child has stepped on the correct letter. When the word is finished all the lights turn on in some kind of light show.

Movement: The child is able to walk/run around the rectangle while finding the correct letters.

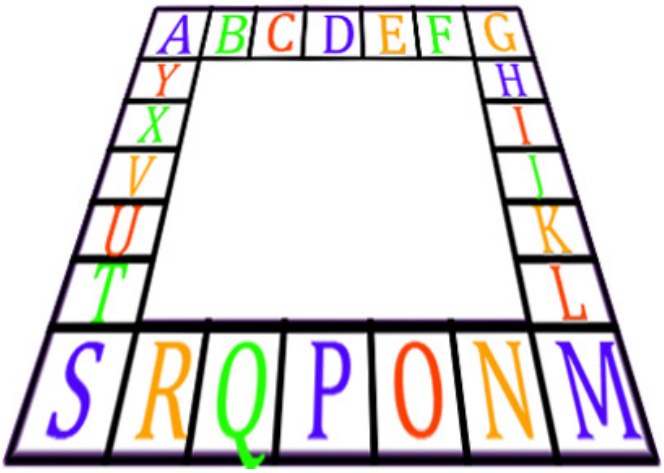


Figure 11 In this idea the letters are organized in alphabetical order, making it less confusing for the child. Also the letters are forming a cube with an empty space in the middle for the child to run around inside while looking for the right letters.

In this design the child does not have to search for each letter since they are presented to him/her in an alphabetical order.

Discussing the idea with the teacher I came to the conclusion that a child needs some type of stimulation. There has to be an element that makes the child want to continue playing the game, and an element that shows the child when he/she is doing a good job. One stimulus for a child is colors. Colors can have everything from soothing and relaxing influence on people to a more stressful and exciting influence. Another stimuli for children can be e.g. light, sound or vibrations. Since this project is aimed for deaf children we can exclude sound.

Phase 2

This phase contains the description of the development of the first prototype. The prototype is tested and the faults of the prototype taken into consideration when moving on to the next phase.

Prototyping

By creating a prototype you are creating a representation of a product developed. Prototyping makes it easier to explore the design options of the

product. Haude (1997) defines a prototype as being a representation of a design idea, regardless of the medium used to create / mediate it.
When working with stakeholders, prototyping can be very useful. A prototype can be used as a communication device amongst team members [Sharp et al, 2007]. A prototype has different meanings within different disciplines of work situations. A model of foam can be a prototype for an industrial designer showing a shape and function of a product. For an interaction designer it could be a simulation on a screen that serves as a prototype, while a programmer calls a test program a prototype [Houde, 1997].

A prototype can be described as a limited representation that allows users to interact with a product and to explore the suitability [Sharp et al, 2007].
How limited can a prototype be? Can a stone brick be a prototype? According to Houde (1997) a stone brick can easily be a representative for a product if it is used for representing the weight and scale of it. According to this a prototype does not have to be self-explanatory, it just has to give an experience and envision of how the product would be like [Sharp et al, 2007; Houde, 1997].
Consequently, a prototype can be everything from a paper-based outline, an electric 'picture', a simulation, a cardboard mockup, storyboard etc. But can also be a complex piece of software [Sharp et al, 2007].

Since there are so many ways of creating a prototype to represent a product it would be useful if, a prototype can be divided into two categories, low-fidelity prototypes and high-fidelity prototypes.
Low-fidelity prototypes are very basic and do not resemble a finished product. They are used because they are simple, cheap and easy to create, and consequently easy to destroy. A positive thing about a low-fidelity prototype is that they are easily modified, this makes it easier to support exploration alternative when presenting an idea / design. A negative thing is the limited detail description of the product [Sharp et al, 2007].
High-fidelity prototypes are more detailed. They use material that resembles more the material used in the final product. In a software prototype, the development is further along and testable. The negative of a software prototype

is that they have more bugs than a finished product and cause more problems during testing [Sharp et al, 2007].

The advantages and disadvantages of either type of prototypes are listed in Table 3, which is taken from Sharp (2007) p. 536

Type	Advantages	Disadvantages
Low- fidelity prototyping	• Lower development cost. • Evaluate multiple design concepts. • Useful communication device. • Address screen layout issues. • Useful for indentifying market requirements. • Proof-of-concept.	• Limited error checking. • Poor detailed specification to code to. • Facilitator-driven. • Limited utility after requirements established. • Limited usefulness for usability test. • Navigational and flow limitations.
High-fidelity prototyping	• Complete functionality. • Fully interactive. • User driven. • Clearly defines navigational scheme. • Use for exploration and test. • Look and feel of final product. • Servers as a living specification. • Marketing and sales tool.	• More expensive to develop. • Time consuming to create. • Inefficient for proof-of-concept design. • Not effective for requirements gathering.

Table 3 Table stating the advantages and disadvantages, [Sharp, 2007 p. 536]

Creating prototypes is important for the design process, since it helps the designers to choose between alternatives. They are also good when testing and evaluating the design [Sharp et al, 2007].

Methods for testing

This phase and the following phases are about creating, modifying and testing prototypes. There are different ways of evaluating the interaction between the tool and the children. Assessing the usability results is not just about evaluating the results, it s about the method used while prototyping that gives you results which can be evaluated upon.

There are six different ways of testing a product on children. There is the 'normal' well-known Usability testing, Peer prototyping, Co-discovery, Think Aloud, Active Intervention and Retrospection methods. Each test method has different characteristics.
Doing usability testing is a good way to evaluate a product on real users, and see if the product meets the needs of the end - users.
In order to get the most positive response out of your final design it is best to start testing early on in the production and test many times. During the process the product is most successful if the testing starts on paper-based stages of prototyping until fully functional products are tested at the last stage. This allows the design and development team to identify problems before they are incorporated in to the final product [Web: Iterative design, 2009].
The earlier in the design process a problem is identified the cheaper it is to fix them. In each testing phase it is important to identify the concerns you have and the goals you want to reach. When these have been identified it is easier to design a test with the right focus [Web: Iterative design, 2009], this is true for all types of testing. A factor that has to be taken in to consideration is that there are different types of people (end - users) with different strengths and weakness. When choosing the test people it is important to have representational groups for each type of users. The different types of users may come across different problems and make different comments upon your project [Donker and Reitsma, 2004].

Two out of these six methods stimulate the child to talk with another child during the sessions. These are called Peer tutoring and co-discovery.

The Peer tutoring method is the only method that has been developed specifically for children. In this type of testing there are at least two children participating at a time. Each child participates in two sessions.

In a child's first session he /she practices the tasks of the test and gets to know the product. When the child has gained experience of the product his /hers next session with the testing is to teach another child how to use the product. The idea with this method of testing is observing the child with the experience, to note down how well he / she is able to explain the task to another child. The better he / she is able to explain the more understanding the child has of the product.

The Co-discovery method involves two children cooperating in order to solve the task of the testing. During this method of testing the children have spontaneous verbalization while consulting with each other. This is a more efficient method than Think Aloud method, which will be described below, since children find it more natural to talk to other children than adults.

The Think Aloud, Active Intervention and Retrospection methods resemble usability testing in a way that there is only one test subject at a session.

During the Think Aloud method the children have to verbalize their thoughts during the session. Using Thinking Aloud the subjects might need some practice for the session to be fruitful. As stated above, the Co-discovery method is more appropriate for children since the child find it more natural to speak with another child than with an adult.

With the Active Intervention method the child is asked questions during the test session. These questions are posed by an evaluator and should be designed in advance.

The Retrospection method is about recording the test session and asking the subject questions while viewing the recordings. It is important to recall what has been done during the session and be patient to watch the session again [Bekke, 2003].

Testing with children

"Children should be considered as individuals with strong opinions, needs, likes and dislikes, and they should be treated as such." [Als et al, 2005, p.9]

Testing a prototype on children gives the designer an insight into the child's perspective and can help with design decisions that have to be made [Howard et al, 2006]. Doing a usability test with children is in many aspects similar to testing with adults. There are though some characteristics that need to be taken with extra consideration [Webcredible, 2006].

Children can be shyer than adults and find new situations, places and people, stressful. Because of this it is very important to remember to find ways in which a child can relax. These can be e.g. to allow the child to get to know you, spend some time with the child. A good conversation-starter with a child is to talk about things such as school, toys, sports, their favorite cartoon or computer games. Another thing that can help ease the child is to tell him / her that you need their opinion on the prototype you are testing [Webcredible, 2006].

Children are in general more used to asking for help than adults. Therefore it is important before starting the test to explain to the child that you want them to try to use the prototype by them selves. The questions the child may ask during the testing have to be redirected as much as possible.
There are some good ways in which deflecting can be done:
You can answer the child's question with another question (what do you think you should do now?) Another way is to re-state that you need them to use the prototype on their own, and finally ask the child to have one last go before moving on [Webcredible, 2006].

Children have less attention span than adults; they get more easily bored, tired or even discouraged. Ways in which to avoid this is to limit the session to one hour or less. It can also be helpful to take short brakes during the session, doing this can avoid the child getting irritated or tired. A way to motivate the child is e.g. asking them to help you, "can you please find out for me how to…?" Pretend

like you are having problems with the prototype. Remember to encourage the child, let him / her know that they are doing a good job and they are being very helpful [Hanna, 1997; Webcredible, 2006].

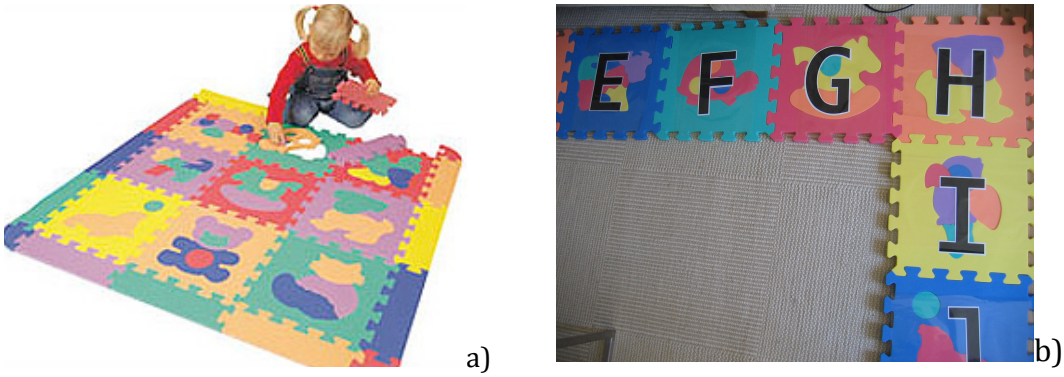
When working with children you cannot always rely on the answers the child may give, it is not because the child is lying to you, but because they may have difficulties articulating exactly what they mean. In some cases they do not want to say the wrong thing and therefore do not say anything at all, and they may even say things that they do not mean just to please the tester.
Because of these facts it is also important to look at a child's expressions and body language (non-verbal cues), these are e.g. sighs, smiles, frowns, making small movements, laughing, swaying, and then body angle and posture [Hanna, 1997; Webcredible, 2006].

As this project is aimed towards deaf children a normal testing session with an interview is not easy to carry out. Therefore an alternative method for assessing the usability testing has been discovered.
Interaction analysis is methods used when investigating interaction human beings have with each other and objects in their surroundings. The activities to be investigated are e.g. talk, nonverbal interaction and use of technology etc. The roots of this method are ethnographic study (particularly observations).
An important element for Interaction analysis is video technology. With video recording it is possible to replay sequences of interaction repeatedly for the evaluation of the results.
Researchers using Interaction Analysis believe that it is the most reliable method for finding the foundation for analytic knowledge of the world.

Prototype 1

Working with the second idea from page 36 the prototype was created. This prototype is in general a low-fidelity prototype, were the child is presented with an image of an object on a screen. The name of the object is spelled one letter at a time and the child has then to write the name of the word by itself.

In order to write the name of the word the alphabet that has been laid on the floor as a mat to write the name of the object.



a) b)

Figure 12 a) play2Learn floor puzzle b) the puzzle is set up as a square with letters printed on them.

The representative for the blanket is the 'play2learn' floor mat, (see Figure 12 a)), which can be purchased in most toy stores around Denmark. The letters of the alphabet is printed on each brick and the map is laid down in a rectangle, (see Figure 12 b)). The "program" runs as power point slides on a computer screen.

Set up

The setup for this prototype is rather simple. The mat is laid on the floor with the alphabet facing the computer presenting the power point (see Figure 13).

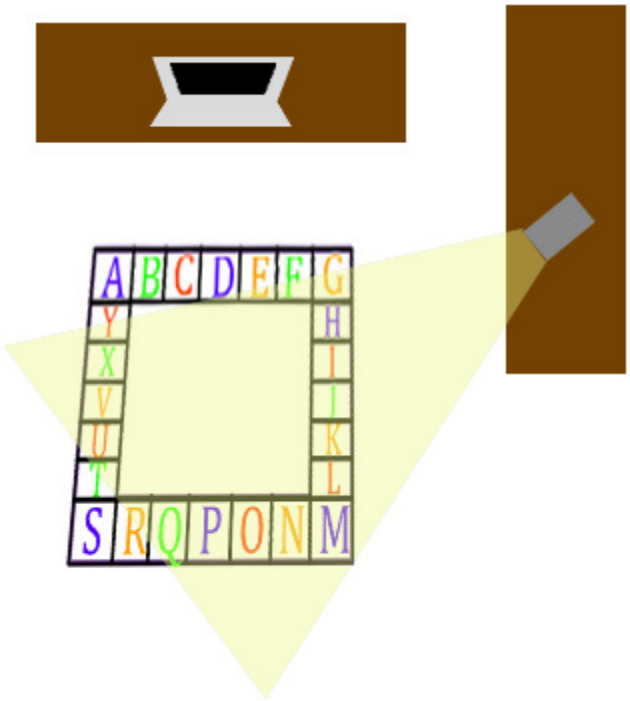


Figure 13 The setup for prototype 1, the yellow shows the camera view

A video camera is facing the floor recording the child's feet, showing the body language of the children and the way they respond to the task.

First testing

The goal for this testing session was to see how the boys responded to the project. During the first testing there were two boys who were tested.

The method used for testing is a low-fidelity prototyping method called the 'wizard of Oz' method. Using this method the user is under the assumption that he / she is in control of what happens on the screen during the session, but it is being control "behind the scene" by me [Sharp et al, 2007].

When the boys spell the word correctly I press a button on the computer revealing the letter they spelled corretly. Consequently, when they spell it wrongly the letter will not "appear" on the screen.

Results

The first one to try the product had some difficulties with it. He started well and did not have any big problems to understanding the task. On the other hand he did have problems when the game became more difficult. When he got unsure of

how to spell a word he would run around the map and stepping on each letter laughing and joking around. He did not have a long attention span for the project when it got harder. He also tended to ask for help from the teacher who was sitting close by during the session.

The second one to test the product was quick to understand the task at hand. He needed minimum help to solve each task, even though it got harder the further along he got. He did not step on the letters but pointed at them, when we asked him afterwards why, he said he was lazy.

Evaluation

From the first testing session it is evident that the children need some support, discussing with the teacher [Interview 2, Appendix B], I came to the conclusion that it would be helpful if the words were presented to the children in sign language before they are presented with the spelling of the word. It would also help if they got to read the rules of the game themselves, the rules that I have set down, instead of the teacher describing the rules to a child at a time, and not giving the exact information I gave to her.

Phase 3

This phase describes the second prototyping session. Here the prototype has not developed much from the previous session. The faults that I found during my first session have been adjusted according to the children's needs.

Prototype 2

This prototype has only a few adjustments from the previous one. The adjustments made for this prototype are e.g. that the child is able to view the sign for the object they are supposed to spell. This allows the child to get a better connection between the object and the sign.

Another adjustment made was colors in the background. I chose blue colors with a yellow as a contrast to the blue. The reason I chose these colors is because blue has a soothing effect on people [Web: The psychology of colors, 2008]. Having a soothing rather than energetic color as the main color is used in order to prevent

the children getting too excited. They should take their time finishing the task and not feel stressed or pressured to finish it in a hurry.

The yellow contrast was chosen because it demands attention. Yellow can have an optimistic effect on people and can also be inspiring [Web: The psychology of colors, 2008].

During the first prototype testing session the child was explained the rules by a teacher. If each child do not perceive exactly the same instructions they might behave differently during the testing session, and interact with the product in different ways. In the beginning of this test session the rules of the game is stated which the child can read before starting the session.

Setup

The setup is nearly the same as in the previous testing, adding a camera from the front view. This camera allows me to see the child's reaction to the game.

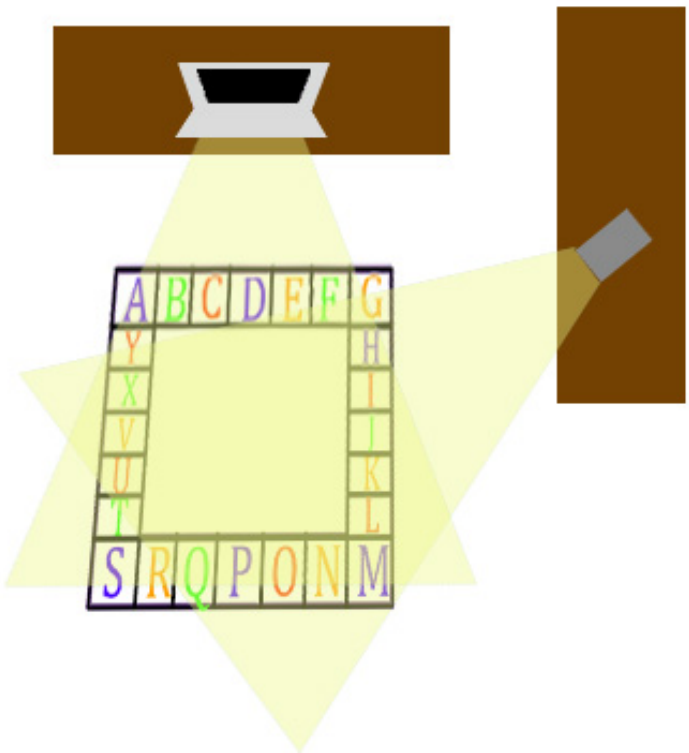


Figure 14 The setup for the testing of prototype two. It is the same as the first testing, adding a video from front to look at the children's facial expressions.

Second testing

The goal for this testing session was to find out if the adjustment made from the first prototype gave better results. To see if the boys found it easier to spell the words where they are able to relate the word to a sign.

During this test session I tested one of the boys from the previous test and the boy for whom this project is designed.

Results

The boy who had tried it before thought it was fun but he did not think it was very challenging. He liked the changes with the sign language being shown first.

The other boy showed more interest. In his everyday teaching he struggles being able to spell words. When he is writing a small essay the teacher says he is only able to spell two letters at a time, if spelling more he gets confused and is not able to remember the first letter spelled to him. During this session the shortest words are three letters. He had no problems spelling the three letter words. Coming to the four letter words he had some mishaps, but seeing a word like 'kanin' (bunny) he had no problems because he knew the image and sign beforehand.

When he was asked about the product afterwards, he was not sure if he felt that it was boring or hard. He wanted to lean against the hard part. He did get through most part of the testing but in the five letter words and up he had problems and needed to see the spelling again and have extra help from the teacher.

Evaluation

Setting up the rules in the beginning of the session gave the boys a better idea of what to do, and they had the same perception of it. The one that had not tried it before needed on the other hand to have the teacher to support his reading with sign language. In the next pilot I will have the rules explained with sign language as well as written. Then the children can read it, and have the support of the sign. It could also help having more short words, which the children find it easier to spell, and encouraging them to continue with the harder words, and hopefully motivate them further.

Phase 4

In this phase I will describe the setup for the final pilot testing. The final prototype is described shortly with the evolvement made from the previous prototype.

Prototype 3

In the previous prototype I added the sign of the object to the game. In this prototype I added the rules of the game in sign language. Doing this helps the younger students and makes them more confident in understanding the game.

This prototype has also been improved with small light diodes, LED lights [Appendix E]. These lights are put in random order into each brick and turns on when a child steps on the right brick while spelling a word. The light is turned on until the child has finished spelling the word correctly. This eliminates confusion as the child gets towards longer words. It also encourages the child to continue spelling the word.
The lights in the brick will only light up when the child steps on a correct brick according to the word he / she is trying to spell.

Setup

During this testing the game is projected on a big screen. The camera is in front facing the child's face to see how the child reacts to the game, while I sit in the back observing their capabilities with the spelling.

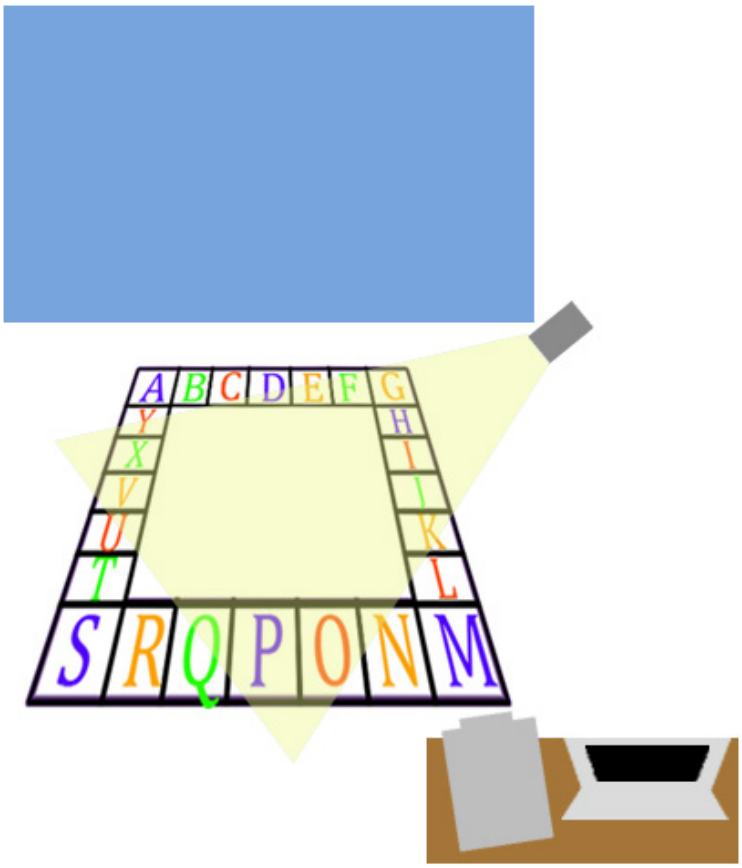


Figure 15 The setup for the final testing. The projector projects the game on a screen, which the children look at while playing the game. The camera angle captures the children playing. The projector and the Computer are placed in the back of the room.

The testing is again done with the Wizard of Oz method where I stand in the background controlling the spelling on the screen as the child step on the correct letter.

Final testing

The goal of the final test session is to see whether the products evolvement of the product has been positive regarding learning. I want to find out if the game has the possibility to be a learning tool.

This prototype was tested with three children from second class and two of the boys from the fourth class, which I have been observing. These two boys have tested different testing session each, one tried the first prototype the other the second.

Evaluation

Using the wizard of oz method the children are not truly aware of the lack of technology in the prototype. Even though there are still some improvements to be done for this product it is evident that it is both fun and educational for the children.

Results

This is a game for deaf children, and I chose to work with them to make sure the product would fit their needs. I could not make an interview with the children but had to trust my observations of the testing and the interviews with the teachers.

The first session was done with the children from second grade. In the beginning they were a bit shy and therefore a bit un-concentrated, and looked for too much support from their teacher.
Observing the children and looking at the video it is obvious that they are just beginning to learn how to read [Appendix F]. They took some time searching for the letters, even though they were presented in alphabetical order.
The boys got more secure and started doing the task on their own, still with the problem of finding the right letters.
The girl on the other hand never got over the shyness and continued looking for support from the teacher, even though the teacher repeatedly asked the girl to try on her own. But observing her it was interesting to see that see had no problems spelling the word to her self first using sign language.
The youngest boy did not have many problems spelling, and he did not search for as much assistance from the teacher as the other children. According to their teacher this boy can not sit still in class, he tends to loose interests and needs to move around a lot [Appendix F]. This is not unusual for young children. The teacher commented that this type of learning tool would be very good and helpful, especially for the boy mentioned above, where he is allowed to move around.

The second session, I tested on the two boys from fourth grade. As mentioned these two boys have already tested once before. The one who tested the first prototype was bit distracted, but he was able to finish the task without a problem.
The second boy, the one the product was designed for, has also shown improvements. He seemed more confident, even though the game was still a bit

hard for him, but with the signing explanations he had no problems understanding the product.

Testing the lights in the mats gave an interesting result. The boy was asked to spell 'Abe' (monkey), after spelling the 'A' and 'B' he pressed a wrong brick 'D' in stead of 'E', during which he got irritated that the light did not turn on. When he paused for few seconds to look at what he had spelled he pressed the right brick.

Discussion

Testing a product on so few subjects does not give reliable scientific results. But it does show that it is a positive experience for the children.
Using the lights in the bricks gives the child an overview over which letters he / she have spelled and which to continue with. It also showed that he felt rewarded when he finally pressed the right brick.

By observing the children it was evident that some of them had fun with it, even though they were a bit shy. This is evident by looking at the active young boy. The way he moves around while spelling and the way he obviously enjoyed the game, asking to play more after the session was over.
As explained in Appendix F. [Dunn and Dunn Model] people use different styles and methods to learn. This product is therefore useful for children who learn best with use of pictures and being able to move around.

Another improvement made is by the boy who this product was made for. He was less confused because of the improved explanation of the game in the beginning and according to his teacher he is able to spell longer words in this environment than he can in a normal classroom.

Conclusion

Conducting my study in the manner that I have chosen has given me a positive result. This method has allowed me to get to know the target group in order to find out what they may need. By using iterative design method, where I have tested different stages of the prototype, I have learned what is missing and what needs to be improved for the future phases of a prototype.

Due to lack of time I was not able to finish putting the lights into the mat and test it properly. But I was able to test a demo of it, which gave a positive result regarding their use.

This product gives children the possibility to engage in learning experience to read and write, without having to sit still and look at a blackboard. This is a non-formal learning through a play tool. It is intentional and has a purpose but it does not have to be provided by a training institution. The product is both active learning as well as cognitive learning, the child has to press the letter in order for something to happen and he / she have to remember how to spell the word.
Another important factor is that it covers more than one element from Dunn and Dunn's learning model, which allows children to be active while learning, use pictures and is motivating.

With the technology and toys / tools that already exists, this learning tool could be in stores already today.

Future perspective

This product has many possibilities for modifications and improvements. These can e.g. be that when the teacher brings up new words in class he / she is able to upload the words to the game for the children to practice on. When the children get more advanced in spelling they may not want to start at the beginning each time they play. A possibility could be that the children are able to chose which

level they begin at. This would be more motivating for the child to see his / hers improvements, rather than have to start over every time.
A beginner level for children learning the alphabet could also be a part of the game. This could consist of a small narrative where the children e.g. have to solve tasks where they will have to find one letter at a time – or it could be developed to support math teaching.

When thinking about already existing technology lets consider the Wii console. They have already made a pressure sensitive board, the fitness board, with few modifications to the fitness board and a spelling mat could be created. It would also be easy to upload new words into the game using SD memory cards, which can be used with the Wii already.

This game does not have to be restricted to deaf people. Changing the sign language into spoken language would also make it a helpful tool for hearing children that have problems reading, e.g. dyslexia.

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Appendix

A. Observations

Observation 1

Four young boys attend the class that I am working with. This is fourth grade where the boys are the age of 9 – 11. The boys are: Mads, Markus, Mathias and Ronas. The boys differ in skills and effort, which are linked. The boys that have better skills in certain areas show more effort than the ones that do not have as good skills.
During both observations they had Danish and sign language class. In the Danish course they were split up for the day. Ronas and Mads, the ones having problems reading were together with one teacher while Mathias and Markus were together with their TA (teacher assistant). Splitting them up gives the teacher more time with each student and they have the right support for their skills. Ronas has got a CI and is learning how to read out loud, while Mads is having problems learning how to read. His reading problem seem to result in him not begin able to concentrate in class and not paying much attention.

During their sign language course they sat together and the teacher told them a story with new words. They were then asked if they understood the words, and if they could explain them to each other and the teacher. During this class Markus was very annoying making weird noises, which bothered the teacher and Ronas, and disturbing the class in general.

Observation 2

As expected, after reading the guide to usability testing with children (see Testing with children, p. 41), the boys were less restless during the meeting. Probably because they recognized me. This time they were working together

discussing what they had seen the week before at a visit to a police station. After viewing pictures taken from the trip they were asked to write a few sentences relating to a picture of their choice. As expected from last meeting Markus and Mathias were quick to get started and seemed to enjoy the exercise. Afterwards they asked permission to write it on a computer and add pictures to the text.

Mads and Ronas needed more support. Especially because Ronas lost focus on his own work when the other two boys started writing their paper on the computer. Mads needed more support than the others. He knew what he wanted to write but the letters had to be fed to him two letters at a time[1]. Showing him more than two letter will make him forget the first one.

[1] The letters are signed to him and he then writes the written letter down.

B. Interviews

Interview 1

During my first meeting with the class I was able to sit down with a few of the teachers and ask them questions about the school and its students.

Q: How many students are attending the school?
A: Now there are only around 70 students, but a few years ago there were over 100 students in the school. This has changed because of the Cochlear Implants (CI). The younger the children are when they get the implants the more usable they are for them.
Q: There are many children in this school with CI. Were they too old then when they got their implants?
A: Yes, these children will not be able to adjust to the implants as the children that get them shortly after birth. There are many students here that are not completely deaf but hard of hearing.

Interview 2

During the second meeting with the class I discussed deaf children's reading problems with a teacher at the school. Deaf children are just as big of a target for dyslexia as hearing children.

Q: Why do you think some deaf children have more problems learning to read than hearing children?
A: Most deaf children have hearing parents. If the parents are insecure or not used to using sign language at home, the child might not get as much input as deaf children with deaf parents. Some children come to the school without having any ways of communicating. The parents have to use sign language at home, while speaking to each other, otherwise the child does not get enough input for them to learn to sign.
I sometimes compare the confusion that occurs in people's lives when having deaf child, when expecting a hearing one, to when people have decided to go on a

vacation. They decide to go to Spain. Preparing for the trip they buy the appropriate clothes for warm weather and buy a handbook about the city they are going to, even learning some Spanish phrases. When the airplane that is supposed to take them to Spain has taken off the captain says that the plane is going to Russia. They are not prepared to go to Russia, they do not have warm clothes, and they know nothing about the city they will be going to or the language they speak.

Q: Any additional comments?

A: I think since you are building this for deaf children that it would be a good idea for the child to see the sign of a word before beginning to spell. It gives a better connection for the child between the sign and the written word.

C. Brain Storming

When beginning the design process I made a brainstorm in order to work out the ideas.

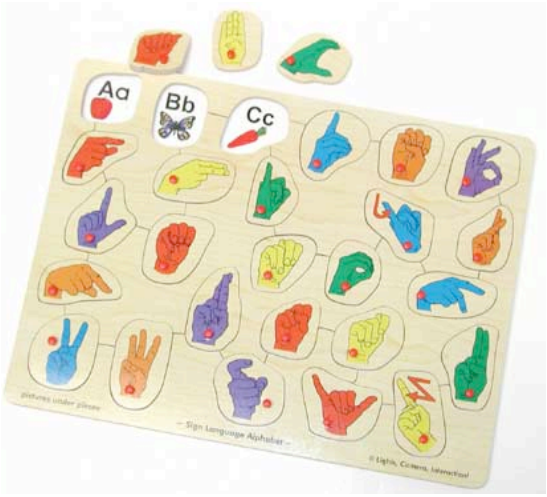
Figure 16 The brainstorming, color coordinated to be able to distinguish the different elements that belong together.

Brainstorming alone might be a bit limited. Working in a group might give more results. From this brainstorm I was able to work out the idea of an interactive learning game, teaching deaf children how to read and write.

D. Toys for deaf children

There have been developed some toys targeted for deaf children created in order to help them to learn sign language. These are e.g.

Alphabetic Sign Language Peg Puzzle. The wooden puzzle features signs that represent the letters of the alphabet. After the peg piece has been removed it reveals the letter the hand shape represents, and an image of an item that the first letter begins with.



A bingo game called ASLingo game. This game is played like any other bingo game, but instead of using numbers it uses hand shapes.

The ASL Elephant Numbers Wooden Puzzle is a game that helps the children to learn how to count in signs. On one side of the puzzle is a sign representing a number, on the other side is the numeral number.

The Sign Language Playing Cards. These have limitless possibilities for improving signing skill. The game comes with teacher's notes, which includes introduction to sign language and instructions to many different games.[2]

[2] These and many more can be viewed at
http://www.harriscomm.com/catalog/default.php?cPath=37_188

E. LED lights

In order to have light turn on when stepping on the right brick, when spelling a word, I use Light Emitting Diodes (LEDs). LEDs need an electrical current in order to turn on. This current runs from a power source through the LED to ground.

It is very important to remember to use resistors, too much current, e.g. when connecting the light directly to a power supply, can destroy the LED by burning it out.

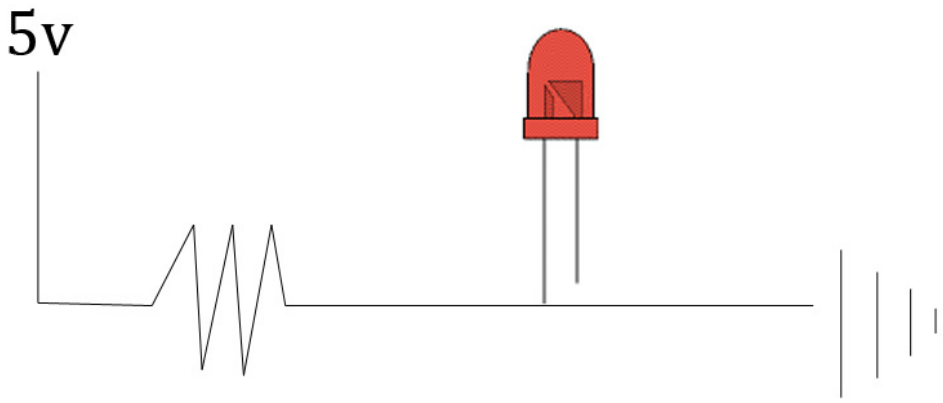


Figure 17 5v current run through a resistor, then through the LED towards ground.

In order to tell the LED when to turn on I used the Arduino platform. This platform is in open-source platform. The coding is relevantly easy to code and upload to the board.

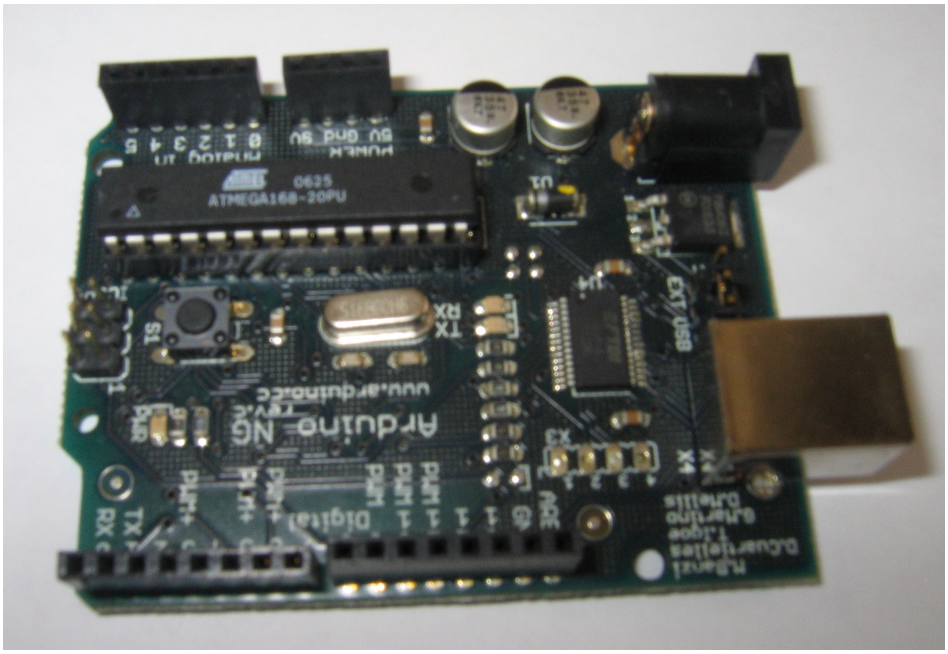
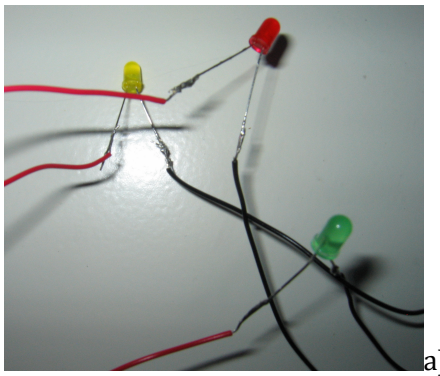


Figure 18 The Arduiono NG board

The board is easy to use and the software is free. Arduino can both work alone, since the program is uploaded to the board, but it can also communicate with software on a computer (e.g. flash or MaxMSP).


a)

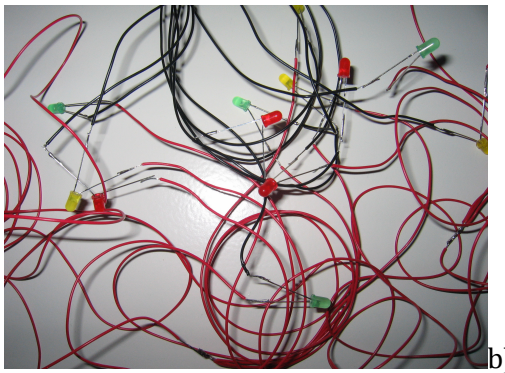

b)

Figure 19 a) the three colors of lights used, b) the LED lights for each brick are soldered together

F. Final Testing interviews

After observing and videotaping the children, I asked the teachers some questions to hear their opinions on the game. Especially in relation to the learning part in the game.

Final testing evaluation interview A 2. Class

This is the first time that I have met this class. I chose this class because they are starting to learn how to read.

How old are the children in this class?

-Age in this school is rather irrelevant. The children are put into classes depending on their skills. These children are between 8 and 10 years old.

What do you think about the game as a learning tool?

-This is a good idea because the children are moving around, it is also bit challenging, especially for the children that are very active and have difficulties sitting still and concentrating. E.g. Adam has to be nearly constantly moving, it can be a bit difficult to make him pay attention, and this would be a perfect tool for him.

Any comments on how this could be improved, either for the children's learning or for you as a teacher.

-The letters are all facing the same direction, which can be a bit difficult for the children when they are standing in the middle of the square. Some of the letters are upside down. It would be better if the letters all faced inwards towards the child.

Children find it easier to recognize words with small letters, which is how they are used to learn. They do on the other hand sometimes mix together p, q and g. Spelling the words in small letters instead of capital letters could help the children, especially at this age.

Another thing that could be interesting is if the teacher could update the game by putting in new words for the children. Then the game could keep up with the children as their vocabulary evolve.

Final testing evaluation interview B - 4. Class

This class it the one that I have observed during the design process. The two boys that tested the final product had both tested the product before, though under different stages in the process.

What do you think about the game now?

-It is interesting to see that Mads is able to spell longer words with this environment than he is able to when he is writing sentences in classes. It may be because he tries harder. Ronas on the hand was a bit more difficult. He was not focused.

Talking about Mads, what do you think about the level of difficulty?

-Well on an everyday basis he is only able to spell two letters at a time. If I sign three letters for him he is not able to remember the first one, sometimes the first two. During the testing he was able to start with three-letter word without difficulties. Though I can see that he gets a little bit insecure and unfocused when it comes to 4 and 5 letter words.

What can be done to help him overstep boundaries of difficulties in the game?

-By having more short words to encourage him. This will keep him and children like him more motivated to continue because they do not feel like they 'can not', which can be very discouraging.

Any comments on how this tool could be improved, either for the children's learning experience or for you as a teacher.

-I think that this game brings more fun into the teaching.

G. Dunn and Dunn learning model

Dunn and Dunn have made a learning styles model. This model has been created because every individual is different and have different strengths and weaknesses when learning. The preferences people may have in order to study are put into a model, which consists of the following preferences.

In the Dunn and Dun's learning style there are five preferences, these are:

- Environmental Stimuli Preferences
- Emotional Stimuli Preferences
- Sociological Stimuli Preferences
- Physiological Stimuli Preferences
- Psychological Stimuli Preferences

Figure 20 This is an illustration of Dunn and Dunn's learning model

[3]

These preferences have elements that characterize them. (see Figure 20), the preferences under environmental stimuli are

Sound element, some people prefer to have background music when learning, while other prefer silence.

Light element, students do not always prefer the same type of lighting when studying, some prefer soft light, while other prefer it to be bright, etc. Temperature element, the temperature in the room is also an element important for each student.

[3] This picture is from http://www.laeringsstil.dk/grafik/dunndunn.gif

Finally, the design element, people have different preferences when it comes to the study environment, some people prefer the standard use of desk and chair while other may prefer to sit in a couch.

There are as mentioned also emotional stimuli preferences that vary between people, the emotional stimuli preferences has the following elements:
People need different types and levels of motivation in order to study, some people are self-motivated, some are motivated through interest, while other are motivated by positive feedback from adults.
The persistence element, this element refers to the student's attention span. This also applies to how people study, some prefer to finish one task at a time while others are working on more than one tasks at a time.
The responsibility elements refer to how much responsibility a student wants to take for their own learning. Do you prefer to work alone, or do you need supervision or an adult to tell you how to proceed.
The final element within the emotional stimuli is the structural element. This element focuses on the student's preferences to structuring their activities or tasks. Some prefer very structured other prefer little structure. This elements also applies to whether or not the students want to be guided through a product or if he / she prefers to get an objective and then proceed alone to reach the goal of the objective.

The third type of preferences is the sociological stimuli preferences. These are:
The self-element, which is when a student prefers to work alone.
The pair element is when students prefer to work together in pairs rather than working alone or in a group.
The peer and team element is where students prefer to work together in a small group.
The adult elements refer to those who prefer to work with an authority figure.
Finally, the varied element, this element refers to whether or not a student prefers be involved with variety of tasks while learning.

The second last stimuli preference is the physiological stimuli.

The perceptual element refers to they way that students learn best. This can be by listening, viewing, or touching.

The Intake element, does the student need to eat or drink or even chew while engaged in learning activities in order to help the student concentrate.

The time element refers to when the student is most focused to be able to learn, some prefer the morning or mid-day, while others work best in the evenings.

The mobility element refers to how much a student needs to move during a task, whether or not the student is able to sit still for a long period of time or if he / she has to move constantly.

The final preference is the psychological preference. Here the elements are:

The global-analytic element, this element refers to whether or not a student need to consider the 'big picture' of a topic or if he / she needs to approach it in sequence. When a student prefers to learn one detail at a time in a meaningful sequence he /she is using the analytic style learning.

The hemispherical element refers to the left and right brain dominance. This elements overlaps with the global-analytical element, because students that are left brain dominance tend to be more analytic or sequence learners while the right brain dominance are more global learners.

Finally, the impulsive-reflective element, does the student prefer to take quick decisions or does he /she prefer to spend time thinking about the solution and alternatives to the solution.