Eye tracking Deaf People's Metacognitive Comprehension Strategies on the Internet

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ABSTRACT
The neurology in relation to sign language was investigated together with the different memory systems used when using sign language. This led to an investigation of the metacognitive comprehension strategies used by deaf people while reading on the Internet. A test group of deaf test subjects and a control group of hearing test subjects were tested in a between subjects design experiment. Both groups were tested on three fictitious websites with rising reading difficulty. The usage of the metacognitive comprehension strategies of the test subjects were obtained via an eye tracker. The results of the experiment were that both groups used the same number of strategies, but the frequency of their usage was different. The deaf test subjects used the strategy of "search and match" more than the hearing test subjects.

Categories and Subject Descriptors
H1.2: Human Factors

General Terms
Performance, Experimentation & Human Factors.

Keywords
Deaf people, metacognitive comprehension strategy, eye tracking.

1. Introduction

Communication is a basic prerequisite for all social communities. When clarifying the concepts "social community", "social system" or "community" it is clear that one of the defining characteristics is whether the members or participants have developed or have a communicative system available. To determine whether a person is a member of, or participant in a given society, social system or social community, it is crucial, whether he or she has knowledge of the current communication system and can participate in the communication with the other members. [1] The problems deaf people face on the Internet is a subject, which has not received adequate scientific research. Most content on websites is based on text. Deaf people in general have a poor reading level, since text is based on oral language. Oral languages are foreign to deaf people, since their first language is sign language. Sign language is a non-verbal language, which is based on gestures with the body, face and primarily the hands. In a previous project, made by the authors, an eye tracker study was conducted on deaf people. The study revealed that deaf people looked more on text and less on pictures on websites with an equal amount of text and picture. This was compared to hearing people, who looked less on text and more on pictures. Deaf people also used significantly more time on finishing tasks on text heavy website compared to hearing people. Text was identified as the main problem for deaf people on the Internet, which makes sense in the light of that deaf people in general have a poor reading level. Different theories were examined to explain this result, including metacognitive comprehension strategies. A group of deaf people was included in the idea generation to a solution, which could help them overcome text on the Internet. This resulted in a construction of a prototype. The prototype was a simulated sign language dictionary embedded in an Internet browser. The idea was that difficult and important words in a text on a website would be marked and highlighted. The deaf user could then click on the word and receive an instant translation of the word into sign language. Deaf people are in general poor readers and ordinary websites are hard for them to comprehend. The deaf people who had used the prototype found it to be a great asset for them on the Internet. [2] It was unclear as to what exact factors in the prototype made it work well with deaf people and their understanding of text on the Internet. The motivation for this article is to find an empirical and theoretical foundation for the prototype developed in a previous project. The theoretical outset for this article is to investigate metacognitive comprehension strategies in accordance to reading on websites. This lead to the initial problem:

Do deaf people and hearing people use the same metacognitive strategies when reading on the Internet?

2. Neurology

Due to the initial problem it is of interest to examine some aspects of the human brain in order to find, if there is a difference in the deaf and hearing brain when processing and producing language.

According to Dammeyer language has the same neurological basis, whether it is sign language or verbal language. Deaf people are affected by aphasia in the same way as hearing people are. Brain damage in the same language centers of the brain that causes illogical speech in hearing people also causes illogical speech in deaf people communicating in sign language. [3] Neuroimaging have shown that both hearing and deaf people have the same centers of the brain activated when producing words or signs. This indicates that language is located in the same parts of the brains, no matter if a person has verbal or sign language as first language. [4]

Findings indicate that sign language is not a pattern of movement in accordance to motor skills, but a language like any other language in the broader context of the human brain. Deaf people with Parkinson's disease have the same symptom as hearing people do with the same disease: blurred language, just with signs. [5] Studies indicate that sign language is more language based than visuospatial based. [6] Deaf people's ability to produce sign language is not affected by left sided neglect. Because the neglect-affected sign language user can identify signs in the side in which they involuntarily ignore all objects. Similar studies have shown that it is the same with the production of sign language. [6] It is likely that the same cognitive processes are responsible for the production of words in both oral and sign language: studies have shown that deaf people tend to make the same semantic replacement errors in sign language as found in oral language. [7]

There is evidence that the phonological loop found in tests with working memory also is found in sign language users with signs. Studies were conducted where deaf people repeated semantic signs over a time period. The results were similar to tests conducted on hearing people and oral language. The same tests on deaf people showed that they did not use the Visuospatial Sketchpad to recollect the words they were given. This indicates that the phonological loop is not limited to sound but to language in general. From this it can be concluded that the working memory of humans acts in the same way no matter in which modality the word is presented. [8] [9]

Turning to the long-term memory in relation to deaf people, Marschark and Everhart have found that hearing and deaf children use different strategies, while playing a twenty questions game. It was found that deaf children asked specific question e.g. "Is it a cow?" Whereas hearing children asked more constraining questions to eliminate more choices each time and this indicated that the two groups of children used different categorical knowledge organisation and also different strategies of information retrieval from the long-term memory. [10] According to these results and findings it seems that deaf people tend to store the details of concepts more than the relation between them. Banks et al. have observed that deaf people remember isolated fragments of information after reading a text, even though hearing and deaf subjects overall remember the same amount of information. [11]

3. How Deaf People Read and Comprehend Text

According to Perfetti and Sandak reading is not a parallel language system but closely related to the spoken language and its phonology, spoken language is prior to written language – all children learn a native language, but not all learn how to read. Other important factors to reading are: reading experience, the automatic of reading and comprehension strategies. [12]

Since written language is closely related to spoken language and its phonology deaf readers will have natural problems with reading. According Perfetti and Sandak two findings indicate that deaf readers did not make use of phonological cues in spelling as much as hearing readers did. The first finding was that deaf readers did not make phonological spelling errors (skwrl instead of squirrel). [12] The second finding was that the deaf children to a higher degree remembered silent letters when spelling compared to hearing children of the same age. [12] Perfetti and Sandak found three already made laboratory studies, which showed that deaf readers make use of phonology. The first study stated that deaf readers can make use of phonology when they have to judge if a sentence rimes. [13] The second study indicated that deaf readers can make use of phonology when performing a naming task. When the deaf readers in this task had to name pseudo-words they could read these pseudo-words accurately aloud; this is an indication of that the deaf readers assemble phonology from letters. [14] A third study indicated that the memory for visual presented language relies more on its phonology than its visual information and studies indicates that it is the same with deaf readers. [12] The conclusion is that some deaf readers make use of phonology while others do not. It is suggested that if deaf readers do not use phonology, they make use of visual information, contextual information or use sign-based recoding. [12] According to Perfetti and Sandak many deaf readers, like less skilled hearing readers, rely more on orthography and semantic information instead of phonological information. Some deaf readers make use of phonology, but how have they gained that access? According to Perfetti and Sandak there are some possible explanations: lip-reading, different forms of cued speech, where the speaker uses hand signals close to the mouth to distinguish both consonants and vowels. [12] Perfetti and Sandak conclude that many deaf readers are cable of gaining access to phonology and use it when reading. The level of how well deaf readers are to access phonology may elevate their achievements in reading. [12] According to Andrews and Mason there are many possible explanations as to why deaf readers have difficulties in reading; it could be that the deaf reader has poor verbal linguistic skills or because there is a great difference between the structure in verbal language and in sign language. Another reason could be that the deaf reader does not have the same background knowledge about the different topics. [15]

4. Metacognitive Comprehension Strategies

Experienced readers make use of metacognitive comprehension strategies when reading. Andrews and Mason conducted an experiment to identify which strategies both hearing and deaf test subjects used while reading a text. The test subjects received one sentence at the time and had to fill in a blank spot with the correct word. The test subjects had to self-report what they did to identify the correct word to be written.

From this Andrews and Mason identified that both deaf and hearing readers make use of six different strategies:

- Background knowledge
- Rereading
- Looking backward in the text
- Looking ahead in the text
- Identifying contextual cues in the sentence
- Identifying cues from the title [15]

Furthermore Andrews and Mason identified that deaf readers in average used 3.8 different strategies, whereas the hearing readers used 4.7 different strategies. Both groups mostly used background knowledge followed by rereading the sentence and looking back in the text. The hearing readers used identifying (contextual) cues both in sentence and also from the title. *Looking ahead* in the text was rarely used in any of the two groups. An increase in the use of strategies in relation to the reading level was also identified: the better reader, the more strategies were used. [15]

Delgado and González made a series of experiments to investigate deaf people's accessibility to the Internet [9]. Reading comprehension abilities in deaf people in accordance to hearing people were investigated. In one of the experiments both deaf and hearing test subjects were to navigate an online newspaper, which had a hierarchical structure in three levels. In the analyses of the experiment Delgado and González identified that the deaf test subjects to a high degree used one strategy more than the hearing test subjects. Namely:

- *Search and match* [9]

Delgado and González identified that the deaf test subjects more than the hearing test subjects had a behavior in which they scanned for the central and important words or contents of a website.

Furthermore, pictures are an essential and indispensable part of most websites. From the book "Eyetracking Web Usability" written by Nielsen and Pernice, it was derived that:

- *Pictures* are used to gain comprehension

Especially if the pictures have high contrast, colorful and highly related to the content of the website a picture helps comprehension. [16]

Together this makes eight strategies, which deaf and hearing people might use when reading on the Internet.

5. Experiment

To examine if this is indeed the fact for deaf people an experiment was conducted to investigate as to which degree the eight mentioned strategies would be used by deaf people when reading on the Internet. This rationale and the theory led to the hypotheses:

Hypothesis 1:

"There is a difference in the use of metacognitive strategies between deaf people and hearing people when reading web content on the Internet"

This hypothesis was made to estimate whether to there is a difference in strategy usage between hearing and deaf people.

Hypothesis 2:

"Hearing people use more metacognitive strategies than deaf people when reading web content on the Internet"

This hypothesis was made to test whether Andrews and Mason was right when they pointed out that hearing readers in average use one more strategy than deaf readers.

Hypothesis 3:

"Deaf people use the strategy "search and match" more than hearing people when they read web content on the Internet"

This hypothesis was made to test whether Delgado and González was right in their assumption that deaf readers primarily use the strategy of *search and match* when reading on the Internet.

METHOD

5.1 Subjects

Eight deaf male test subjects with a mean age of 36.5 year (std. = 7.69) from Aalborg Center for Døvblindhed og Høretab. All test subjects suffered from pre-lingual deafness and had a hearing loss above 80 dB. All test subjects had sign language as their first language and Danish as second language.

Control group: Eight hearing male test subject with a mean age of 30.9 year (std. = 12.62) participated in the experiment. All test subjects had Danish as their first language and were acquaintances of the authors.

All test subjects were screened via FVU-tests (Forberedende Voksen Undervisning): a Danish test to derive a person's reading level. Six of the eight deaf test subjects had a poor reading level and the two remaining subjects had an insufficient reading level. All the hearing test subjects had a good reading level.

5.2 Materials

In order to test the strategy usage three fictitious websites were constructed in three rising difficulty levels:

- Easy: A public postal information website. The text on the website was taken from exam papers intended for but not yet used for deaf students. The LIX number was 43. See figure 1.

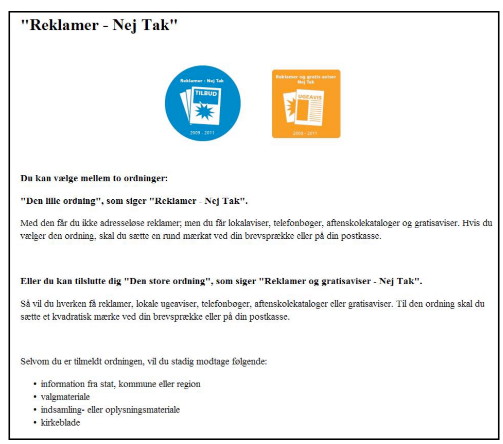

Figure 1: The website with the easy reading level.

- Medium: A news website, with a story about space exploration. The LIX number was 38. See figure 2.

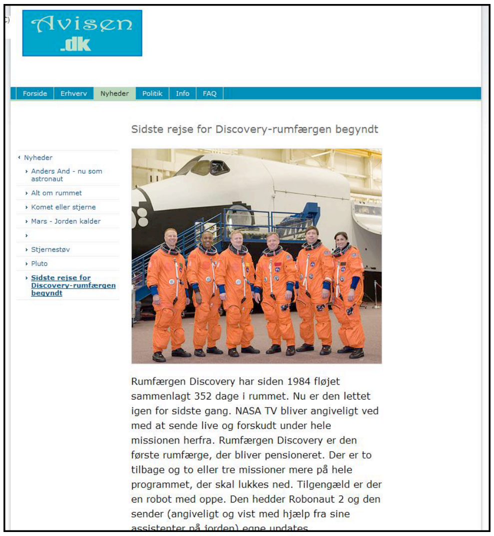

Figure 2: The website with the medium reading level.

- Hard: An official local government website with information about civil marriage. The LIX number was 44. See figure 3.

Figure 3: The website with the hard reading level.

The difficulty levels of each of the three websites were based on subjective estimations on the sophistication and quantity of the content and technical words in the text of the websites. At the bottom of each of the three websites the test subjects were asked one informational question about the content of the website they have just interacted with. This was done to ensure that the test subjects would actually read the text on the website. The websites were constructed to look like and have similar content as found on typical and ordinary websites of the Internet. The rationale being that a realistic setting would ensure a realistic and valid result.

5.3 Design and procedure

The experiment was planned as a between subjects design experiment, in which both the test group and the control group were to interact with the same three websites in the same order: from easy reading difficulty to medium to hard reading difficulty. The data about the usage of strategies was recorded via a Tobii x120 eye tracker.

The test group of deaf test subjects was introduced to the experiment via simple-written text on a piece of paper. The control group of hearing test subjects was introduced to the experiment via an oral presentation of the same information. Both groups were told that they would be tested for reading strategies and that they should interact with the websites as they ordinary would.

The test subjects would finish their task on the website when they had answered the question in the bottom of the page. Before the test subjects would go on to the text website they would be asked whether there were any words in the text which they did not understand and what they did to understand these words. This was done to see whether the strategies of *background knowledge* and *identifying contextual cues in the sentence* had been used by the test subjects. These two strategies were tested in this way because they could not be obtained via the eye tracker. The strategies of *rereading, looking backward in text, looking ahead in the text, identifying cues from the title, search and match* and *pictures* were obtained via the eye tracker.

6. Results

The data from the eye tracker had to be classified before it could be analysed in depth. The results from the experiment were obtained by watching, analysing and counting the data from the Tobii x120 eye tracker. The final data from the experiment was the number of strategies used by both groups of test subjects.

6.1 Classification of the strategies

The reading strategies were classified in accordance to these specifications.

- *Rereading:* The strategy of rereading was counted if the test subject had started reading a sentence and then started to reread the sentence before having finished the sentence.
- *Looking Backward:* The strategy of looking backward was counted if the test subject had read a complete sentence but then jumped back to the start of the sentence.
- *Looking Ahead:* The strategy of looking ahead was counted if the test subject jumped forward in the text to look for certain words. But this strategy would only be counted if the jump forward in the text was within the

vicinity of the sentence they started on and if they jumped back to the vicinity of their starting.

- *Identifying cues in title:* The strategy of identifying cues was counted if the test subject looked at the title on the website.
- *Identifying contextual cues in the sentence:* The test subjects were asked to the usage of this strategy by the experimenter. This strategy would be impossible to test directly with the eye tracker, since it would easily be mixed up with some of the other strategies.
- *Background knowledge:* To identify this strategy the subjects were asked if they know anything about the topic in advance.
- *Search and match:* The strategy of search and match was counted if the test subject looked across the whole or parts of the website in a search for certain words, headlines or pictures. This strategy is also counted if the test subjects look around the whole website not looking for anything particular but to gain an overview.
- *Picture:* The strategy of picture was counted if the test subject looked at the picture(s) on the website. The idea being that the test subject obtained information about the content of the text from the information in and context of the picture.

6.2 Analysis of the data

The strategies used by both groups on each website were counted and analysed. The figures in the following represent the average usage of the strategies in the two groups in accordance to the three websites. None of the test subjects in any of the two groups reported that they had used *background knowledge* or *contextual cues* to understand the meaning of a word in any of the three websites.

6.2.1 Website with easy reading level

As it can be seen in figure 4 the deaf test subjects mainly made use of two strategies: *identifying cues in the title* (38%) followed closely by *search and match* (31%). The hearing test subjects preferred the use of the strategy *looking backward* in text with 36% usage in average of all the used strategies.

Both groups used the same number of strategies, just to a different frequency of usage. Both the hearing and the deaf test subjects in average used 4.9 strategies.

It can be seen that the deaf test subjects used the strategy of *search and match* more than the hearing test subjects. A two sample Wilcoxon test revealed that the difference was not significant (p-value = 0.4586).

All deaf test subjects had the answers wrong in the question in the bottom of the website. One out of eight hearing test subjects had the answer wrong in the question in the bottom of the website.

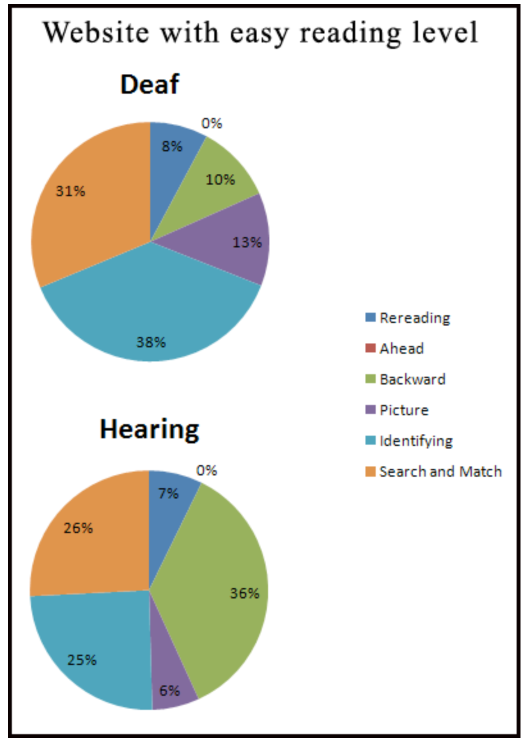

Figure 4: The distribution of the strategy usage of each group on the website with easy reading level.

6.2.1.1 Test of the hypotheses

Hypothesis 1 is **verified,** since there is a clear difference in the usage of the strategies between the two groups.

Hypothesis 2 is **falsified,** since both groups used the same number of strategies.

Hypothesis 3 **cannot be either verified or falsified,** since the difference in usage of *search and match* is not significant.

6.2.2 Website with medium reading level

As it can be seen in figure 5 the deaf test subjects mainly made use of two strategies: *identifying cues in the title* (37%) followed closely by *search and match* (33%). Hearing test subjects preferred the use of the strategy *looking backward in text* (38%).

Both groups used the same number of strategies, just to a different frequency of usage. Both groups in average used 5.1 strategies.

With a two sample Wilcoxon it was calculated that the deaf test subjects used the strategy of *search and match* significantly more than the hearing test subjects (p-value = 0.008168).

Three out of eight deaf test subjects had the answers wrong in the question in the bottom of the website. It was the same result with the hearing test subjects.

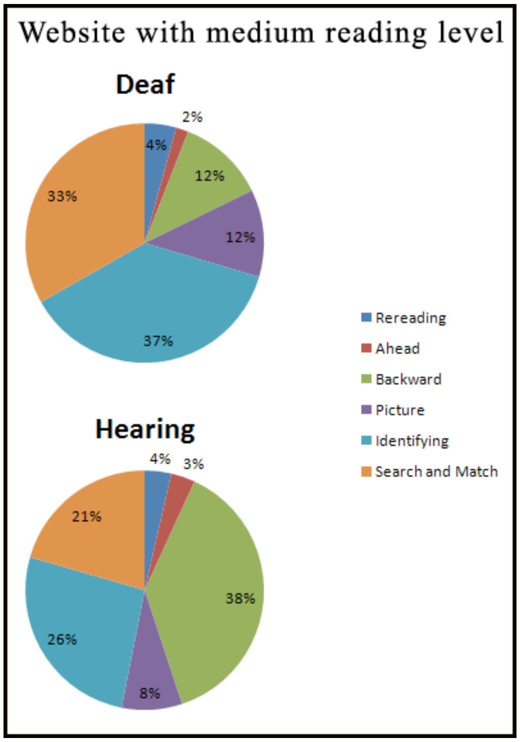

Figure 5: The distribution of the strategy usage of each group on the website with medium reading level.

6.2.2.1 *Test of the hypotheses*

Hypothesis 1 is **verified,** since there is a clear difference in the usage of the strategies between the two groups.

Hypothesis 2 is **falsified,** since both groups used the same number of strategies.

Hypothesis 3 is **verified,** since the deaf test subjects use *search and match* significantly more than the hearing test subjects.

6.2.3 *Website with hard reading level*

As it can be seen in figure 6 the deaf test subjects mainly made use of two strategies: *search and match* (37%) followed closely by *identifying cues in the title* (30%). Hearing test subjects preferred the use of the strategy *looking backward in text*, comprising 50% of all the strategies used.

Both groups used the same number of strategies, just to a different frequency of usage. The hearing test subjects in average used 5.1 strategies while the deaf test subjects in average used 5.3 strategies - the difference between the two was insignificant (p-value = 0.91), which means that there was no difference in the number of strategies used by both groups.

It can be seen that the deaf test subjects used the strategy of *search and match* significantly more than the hearing test subjects (p-value = 0.02697).

Seven out of eight deaf test subjects had the answers wrong in the question in the bottom of the website. One out of eight hearing test subjects had the answer wrong in the question in the bottom of the website.

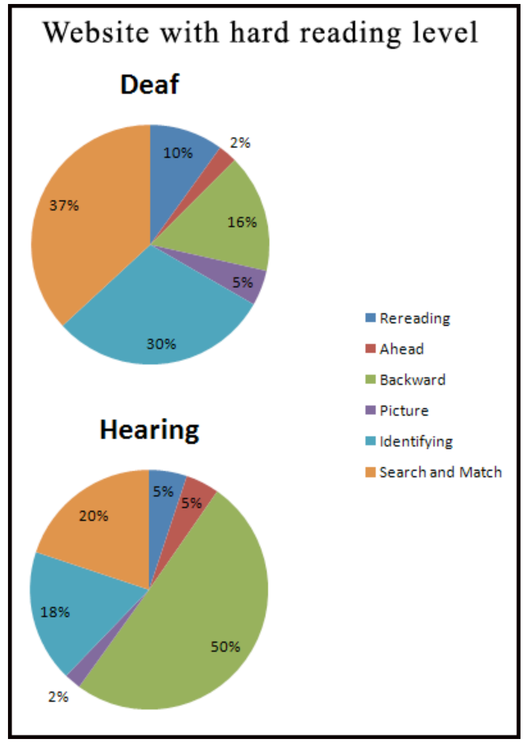

Figure 6: The distribution of the strategy usage of each group on the website with hard reading level.

6.2.3.1 *Test of the hypotheses*

Hypothesis 1 is **verified** since there is a clear difference in the usage of the strategies between the two groups.

Hypothesis 2 is **falsified** since both groups used the same number of strategies.

Hypothesis 3 is **verified** since the deaf test subjects use *search and match* significantly more than the hearing test subjects.

7. Discussion

The results of the experiment revealed that there is a difference in the use of metacognitive comprehension strategies between the group of deaf test subjects and the group of hearing test subjects. Both groups used the same number of strategies, but the frequency of their usage was different. The hearing test subjects preferred the strategy *looking backwards in the text*. The deaf test subjects had two preferred strategies*: Identifying cues in title* and *search and match*. In the websites with the easy and the medium reading level *identifying cues* was preferred slightly over *search and match*. Both strategies being much more preferred than the other strategies. On the website with the hard reading level *search and match* was the most preferred strategy of the deaf test subjects. As the reading level rose in difficulty the more the deaf test subjects used *search and match*.

The goal of this project was to find a theoretical and empirical foundation to why a previously developed prototype worked well with deaf people's comprehension of text on a website. The strategy of *search and match* was frequently used by deaf people, especially compared to hearing people. The prototype had difficult and central words of a difficult text highlighted, which signaled to the deaf person that the word could be translated into sign language. The design of the prototype appeals to the Internet behavior of deaf people and their strategy usage of *search and match*.

The number of test subjects in this experiment was eight in each group. A higher number of test subjects would have assured higher validity to the results. Deaf people are a minority in any society, which means that the number of potential test subjects in a city like Aalborg is limited. This unfortunately sets a natural limit on the number of test subjects who can take part in the experiment which otherwise could have strengthened the validity of the results.

8. General discussion

According to Andrews and Mason deaf readers in average used one less reading strategy than hearing readers. The result of this experiment was that deaf and hearing readers used the same number of strategies, but the frequency of their usage was different. The experiment done by Andrews and Mason is not the same as the experiment described in this article, since two strategies were added and the test setup was different. Furthermore, the test subjects in this experiment reported not to use the strategies of *background knowledge* and *identifying cues from the sentence*. To have counted these two strategies it is estimated that the experiment had to be interrupted and the test subjects had to be asked in the middle of a sentence. It seems that the usage of these two strategies are forgotten, when the test subjects are asked about them. But the missing acknowledgement of the use of these strategies when the test subjects have to report the usage themselves, gives breeding ground to ask questions about the results in the experiment made by Andrews and Mason. The results from Andrews and Mason were obtained by the deaf and hearing test subjects self reporting their reading strategy usage. The results obtained in this experiment were more objective, since the eye tracker logged all eye movements and thereby strategy usage of the test subjects. Since the self reports from the deaf test subjects had to be translated there could have been communication lost in translation, which would have been vital to the classification of a strategy. There is also a possibility that the test subjects in Andrews and Mason's experiment were not aware of all the strategies they were actually using. If the test subjects could not articulate the exact words to the mental activities they did while reading then this would not be linked to a specific reading strategy, which would result in one less strategy being identified and counted. The more artificial approach of Andrews and Mason compared to the ecological approach in this experiment could also explain the difference: Andrews and Mason gave the test subjects one sentence about a subject at a time, with a blank space in between the words of the sentence, which the test subject had to fill in using the reading strategies. In this experiment the test subjects had to read a larger text, which would correspond to typical websites the test subjects interact with on the Internet. A more realistic experiment will give a more realistic result. According to Delgado and González deaf people would have used the strategy of *search and match* more than the hearing people. The result of the experiment supports the theory in this matter. On every website the test subjects had to answer questions in the bottom of the site. This was done in order to make sure the test subjects read the content of the website. The deaf test subjects had fewer correct answers in the easy and hard reading task compared to the hearing test subjects. On the website with the medium reading level both groups of test subjects had three out of eight correct answers. The difference between the easy and hard reading task compared to the medium reading task was, that the answers in easy and hard was a choice between words in the text, while the answers in the medium reading task was a choice between different years. Looking for numbers could have made it easier for the deaf test subjects to make use of the *search and match* strategy, than if they would be looking for words, since deaf people in general are poor readers and have problems with text.
The conclusion is that there is a difference in the usage of metacognitive strategies between hearing and deaf people when reading on the Internet, and that the strategy of *search and match* is used to great extent by the deaf readers.

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SYNOPSIS:

The neurology in relation to sign language was investigated together with the different memory systems used when using sign language. This led to an investigation of the metacognitive comprehension strategies used by deaf people while reading on the Internet. A test group of deaf test subjects and a control group of hearing test subjects were tested in a between subjects design experiment. Both groups were tested on three fictitious websites with rising reading difficulty. The usage of the metacognitive comprehension strategies of the test subjects were obtained via an eye tracker. The results of the experiment were that both groups used the same number of strategies, but the frequency of their usage was different. The deaf test subjects used the strategy of "search and match" more than the hearing test subjects.

Preface

This project is written as a master project at the Department of Electronic Systems at Aalborg University. The group consists of two students at Engineering Psychology. The project was completed in the time period from the 1st of February to the 31st of May 2011.

This project takes its origin in a previous project done by the authors. The topic of the project was deaf people's usage of the Internet. A topic, which is lacking in-depth scientific research.

We would like to thank all of our test persons for participating in our experiments, especially all the deaf test persons from Center for Døvblindhed og Høretab in Aalborg.

All figures in the article and the worksheets are made by the project group, unless noted otherwise.

Aalborg University, 31st of May 2011

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Søren Staal Jensen

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Tina Øvad Pedersen

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DVD:

The HTML test site can be seen at: http://oevad.com/Test_2/Start.html, here the source code can be extracted.

Appendices

Appendix I: Previous Project

Summary of "Deaf People and the Internet – developing a sign language solution for websites"

The present project is a further work in addition to a previous project made by the authors. It is found that the topic from that project was of a character, which was of importance to the involved people. It was therefore decided to proceed with this problem.

The present project is based on a previous project, which was completed from the 1st of September to the 19th of December 2010. In that project it was investigated, whether deaf people used websites differently than hearing people. The topic of deaf people was investigated via different theories, including: sign language, phonology and metacognitive comprehension strategies. These topics were examined and led to the planning of an experiment. On this basis a between subjects design experiment was initiated.

- The first hypothesis stated that deaf people would be focusing more on pictures than on text when reading ordinary websites compared to hearing people.
- The second hypothesis stated that deaf people would be using more time on text heavy websites compared to hearing people.

A test group of deaf test subjects and a control group of hearing test subjects were to accomplish the same tasks on three different websites: one website containing mostly pictures and little text, one website containing an equal amount of both pictures and text and a website, which only contained text. A Tobii x120 eye tracker (see attachment II and III) was used to obtain objective data about which web elements the test subjects focused on. On the website, which mostly contained pictures there was no noticeable difference between the two groups. On the website, which contained an equal amount of pictures and text there was a clear difference between the two groups. Of all the web elements on a website the deaf test subjects focused **56%** on text compared to the hearing test subjects' **47%**. The deaf test subjects focused **19%** on pictures compared to **36%** in hearing test subjects, see figure 1. This led to the rejection of hypothesis one.

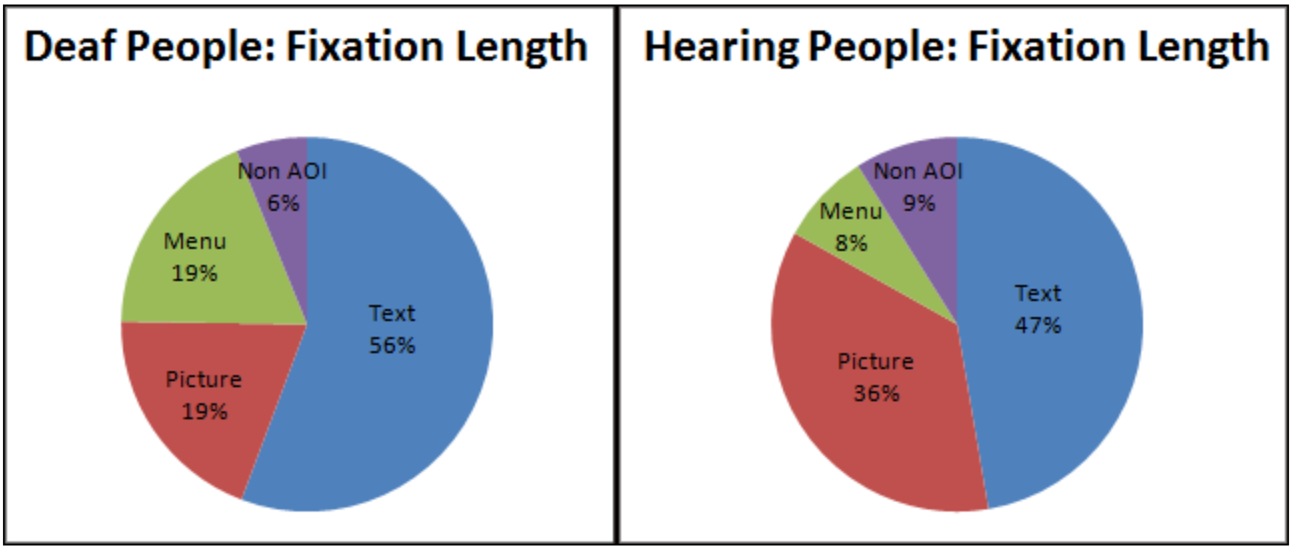

Figure 1: The web elements deaf and hearing people focus on, on the website containing an equal amount of text and pictures

On the website, which only contained text there was a clear difference between the two groups. The deaf test subjects in average used **97.20 seconds** on completing the task compared to the average of **29.09 seconds** in the hearing test subjects, see figure 2. A two sample t.test revealed the time difference to be significant with a **p-value of 0.045**. Hypothesis two was therefore accepted.

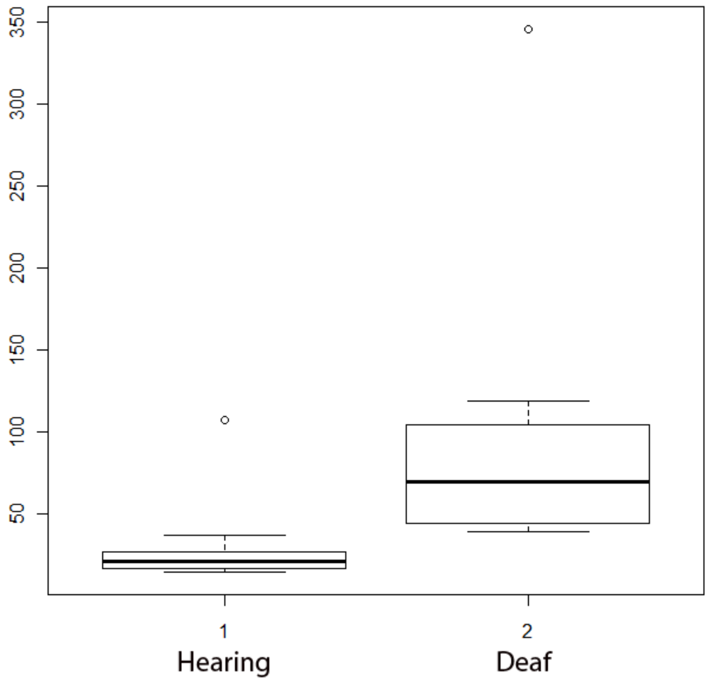

Figure 2: Box plots over the time used on the task, on the website, which only contained text

The results of experiment one lead to that the web element; text, was identified as the main problem for deaf people on the Internet.
A focus group meeting with deaf people was arranged. This was done in order to receive their input to what solutions they could think of, which could help them reading text on the Internet. Of the numerous suggested solutions only one was selected to be made into a prototype and to be tested. In the chosen solution the difficult words in the text of the website would be translated into sign language at the click of a mouse button. The proposed solution was a sign language dictionary embedded into an Internet browser.

A HTML-prototype was constructed to simulate the idea behind the solution, see figure 3. The online version can be seen at: http://www.oevad.com/Test_M/Site_M.html

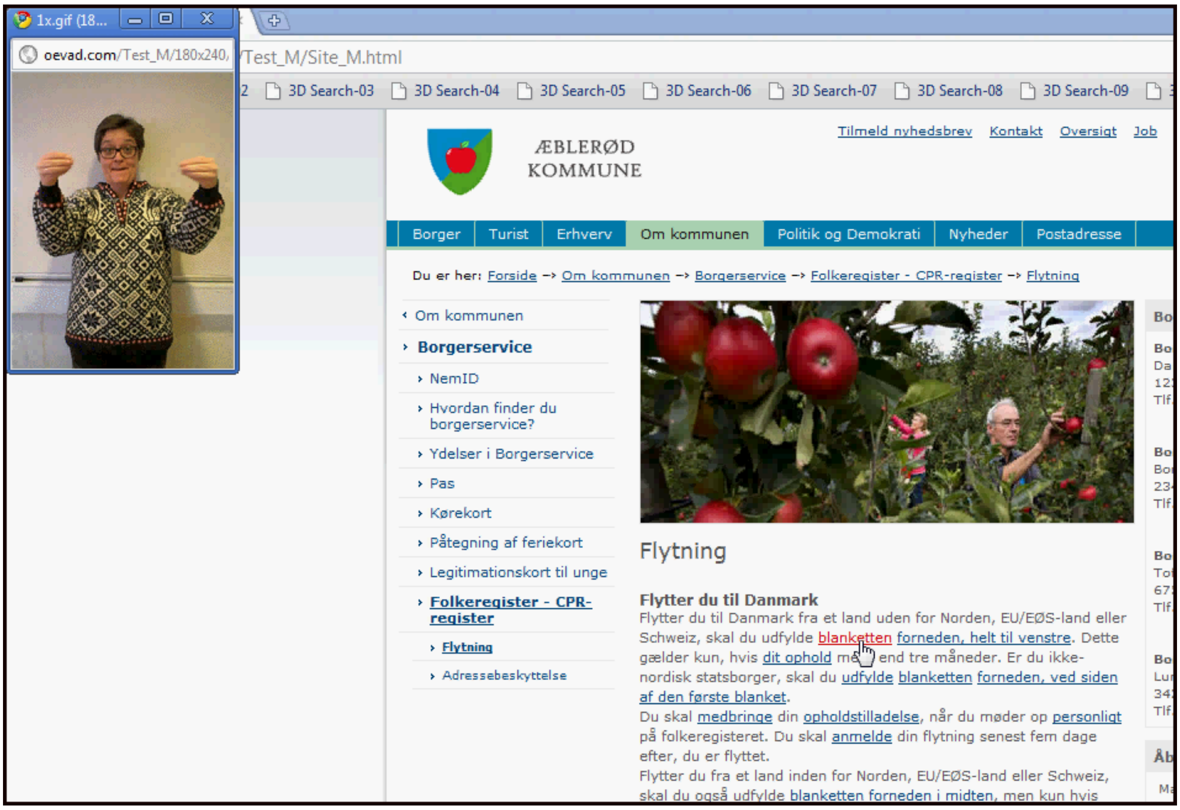

Figure 3: Screenshot of the HTML-prototype

A similar HTML-website without sign language was also constructed in order to have a standard website to test the prototype against.

A between subjects design experiment was initiated. Deaf test subjects were divided into two groups: the first group would use the website with sign language and the second group would use the website without sign language. The test subjects on both websites were to complete the same task, by finding the correct form on a public website of a fictitious local government.

The results of the experiment was that the group of deaf test subjects, who were given the website with sign language completed the given task significantly quicker than the group, which were given the website without sign language. The group who used the website with sign language in average used **92.83 seconds** on completing the task compared to an average of **159.40 seconds** by the group who used the website without sign language. The time difference between the two groups was significant. The p-value was calculated to be **0.002104** by a t.test. The time difference between the two groups is illustrated in the two box plots in figure 4.

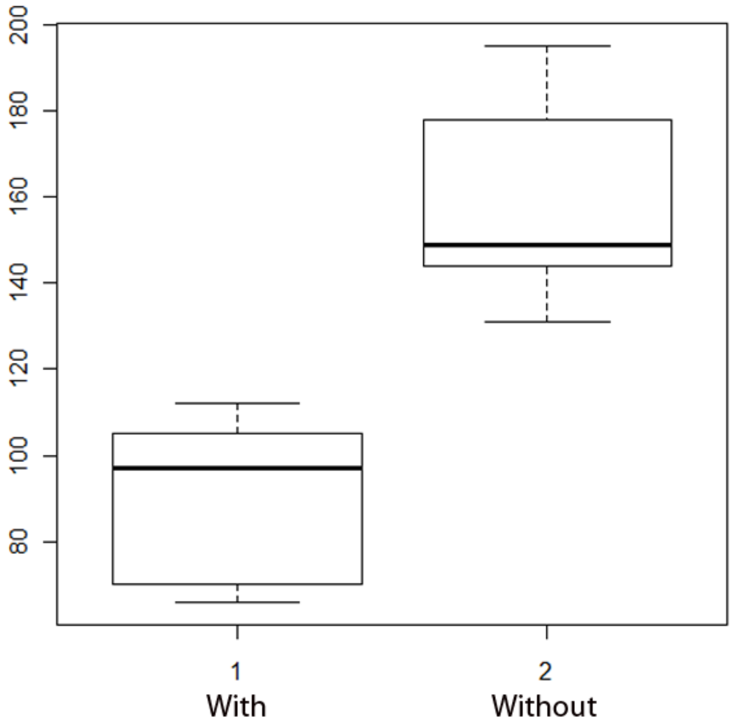

Figure 4: Box plots over the time used with and without the HTML-prototype

A questionnaire was also given to the test subjects. The questionnaire revealed that the test subjects who were given the website with sign language found it easier to find information compared to the test subjects who were given the same website without sign language. It was also revealed that the test subjects who had used the sign language website felt they had a better overview of the website compared to the test subjects who were given the website without sign language.

This project revealed that there is a problem, given that deaf people do not have the same access to information on the Internet compared to hearing people. This is quite a problem, since much information nowadays is given via the Internet. Through the experiment it was found that the HTML-prototype appealed to the deaf persons, since they by means of the prototype felt as a part of the surrounding community and not as a subculture, since they could read the same texts as hearing people and not have it all translated into sign language.
It is therefore of interest to dig a bit deeper in this topic and investigate both what the reason is to why the problem exits and in relation to, how the problem can be solved.

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Appendix II: Initial Problem

Communication is a basic prerequisite for all social communities. No social systems, organisations or communities can be established and maintained - or changed for that matter, without communication. Imagine man without communication skills. It would be an absurd autistic creature without the ability to participate or be a member of any social community or society. [Leksikon, 2011]

When clarifying the concepts “social community”, “social system” or “community”, it is clear that one of the defining characteristics is whether the members or participants have developed or have a communicative system available. To determine whether a person is a member of, or participant in a given society, social system or social community, it is crucial, whether he or she has knowledge of the current communication system and can participate in the communication with the other members. [Leksikon, 2011]

But what happens when members of a society have the current communication system as their second system? What problems do they face? These questions are answered in a previous project made by the authors where the problems of deaf people are being examined. The problems deaf people experience in accordance to the Internet is a topic, which in these authors opinion, has been neglected by the scientific community. It is a topic, which needs more research. The solution found in the previous project worked well, but it lacked a theoretical foundation to explain why and how. The scope and goal of the following project is to gather a theoretical foundation and to produce empirical evidence to explain why the solution from the previous project works so well. The tests of this prototype and the theory investigated led to the question:

Do deaf people and hearing people use the same metacognitive strategies when reading on the Internet?

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Appendix III: Basic Theory

Due to the initial problem it is of interest to examine some aspects of the human brain in order to find, if there is a difference in the deaf and hearing brain when processing and producing language.

III.a: Sign Language

Sign language is a definition of many different independent languages, which have emerged among deaf people. Although most people know about sign language, there are still many myths about it, e.g. that sign language is international or that sign language is Danish spoken with your hands - two very conflicting myths.
However, one can say that the verbal Danish language influences Danish sign language, since the sign language used in Denmark is used in a Danish context.
Many of the sign languages used in the world, have a long history. They have been handed down from generation to generation, but there are still created new sign languages for instance in families with multiple deaf children. Sign language is based initially on gesture and seizes the opportunity to reproduce acts and the contour of things through the hands. Over generations, sign language has developed such that it is not possible to recognise the original gesture. Moreover when sign languages become more established, new characters that are not based on imitation of actions and things are developed. In addition, users of sign language unconscious develop rules for the order of the signs and modifications of the signs - and thereby creating a form of grammar. [Engberg, 1998]
All sign language functions in societies that use one or more vocal languages (Danish, English, etc.). The surrounding language and the attitude towards sign language influence a sign language. To understand how a sign language emerges and develops and how the sign languages look at a given time, it is important to look at the interaction of:

- Originating in the gesture and the fact that sign language is perceived through the eye and not through the ear
- The ability of human language
- Pressure from the surrounding vocal language
- The story each sign of the sign languages has undergone

Bilingualism when dealing with deaf people refers to that the deaf are learned sign language as the first language and then learned e.g. Danish as second language (it has not always been so). [Engberg, 1998]
It is not possible to speak e.g. a vocal language and use ”real” sign language simultaneously because the two languages are completely different, as mentioned in the above. But it is possible to speak e.g. Danish and simultaneous use signs from sign language, and many hearing persons use this form of communication.
There are different terms to the different types of sign languages; the sign language of the deaf, signdanish and Danish with supporting signs, see figure. 5.

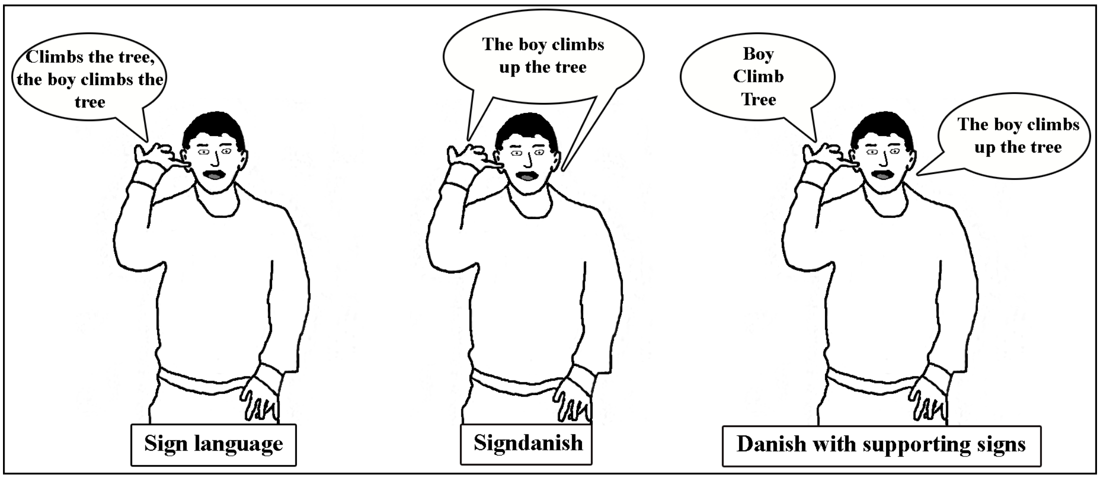

Figure 5: The difference between the three types of sign language

- The sign language of the deaf: the language form used by deaf and hearing people, who have learned sign language at an early age and have a solid connection to the deaf community. This type of sign language has no written tradition.
- Signdanish: a linguistic form, where Danish is spoken together with signs quite similar and with many features from deaf sign language. Signdanish can be heard through the ear and seen through the eye.
- Danish with supporting signs: here Danish is spoken or preformed with mouth movements corresponding to the Danish words, and signs are used for the most important Danish words in the conversation. The signs are used in their basic form. [Engberg, 1998]

Other methods: The hand-mouth system and the hand alphabet

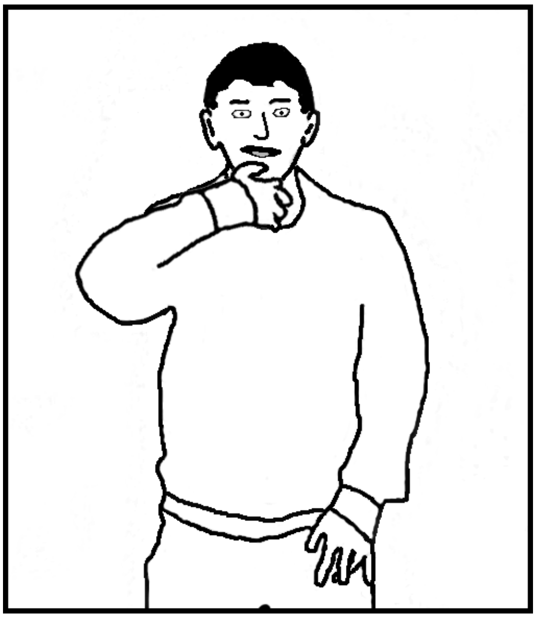

Figure 6: The hand-mouth system

The hand-mouth system: a method for reproducing the Danish speech using the movements of one hand, placed just below the chin. When speaking a vocal language, the speech is accompanied by different hand shapes in different positions, showing the sounds of the consonants. The recipient must read the hand shapes and mouth movements as a single image, see figure. 6.

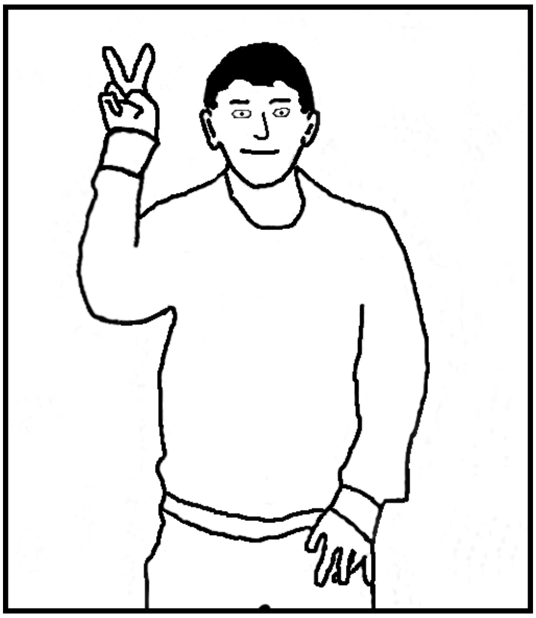

Figure 7: Illustration of the hand alphabet (here the letter V)

The hand alphabet: contains signs for each letter in the alphabet, and by using the hand alphabet it is possible to spell the words instead of using the signs for the words, see figure. 7.

The movements of the head and body, the direction of the gaze and the facial gestures play a major part in communications in the vocal language, but the body, head, face and eyes do not count for vocal language. It is called nonverbal language or nonverbal communication. Sign language is perceived only visually and articulated by the hands and arms, body, head and face, including mouth movements, eye movements and the general facial mimic.
Sign language is performed within what is called sign space or locus. The locus consists of the space around the person speaking sign language, which is the half circle in front of the speaker with a radius of approximately half an arm's length from the body and a height from just below the belt to just above the head. Most of the characters are conducted in the sign space. [Engberg, 1998]
In sign language there is not any grammar there is any way similar to the grammar of verbal language. Since the language is a visual language, the illustrator is to set the scene in the locus at first, followed by the actual story. For instance if the sentence is: *the boy climbs up the tree*, the tree is to be drawn first, followed by the boy and then the action; climbs. One could say that signing sign language is the same as setting up a play, you first have to make the scene, then the actors enters before the story can be told. A very important thing when communicating in sign language is to emphasise the important words, for instance when looking at the sentence with the boy, here you have to see which is the important thing – is it the boy or is it that he climbs the tree? If it is the last-mentioned, in sign language, you first would say climbs the tree the boy climbs the tree. Simply to underline what is important in the sentence. [Schmidt, 2010]
In sign language there is just present tense. To illustrate past and future the illustrator, when setting the scene, points backwards or forwards in relation to what time the sentence is to be told in. For a person, who has sign language as first language, it is very difficult to understand a sentence, where the words of content

are flexed grammatical, e.g. in Danish it can be said: *han tog bussen* (he took the bus). The deaf person will then interpret tog (took) as tog (train). [Schmidt, 2010]
There are some common problems for people having sign language as their first language - they have troubles with: idioms, compound nouns and wider terms. In relation to idioms the deaf people do not read behind the lines but take the message literally. In relation to the compound nouns, the deaf people have a tendency to split the word up in morphemes; an example in Danish could be *hundekoldt*, here they would translate it to, that the dog is freezing not that there is very cold. The wider terms meaning e.g. citizens, it does not make sense to the deaf people, that the word citizens means; I, you, us, them etc. Another problem when handling pronouns is, e.g. if I write a letter and use the pronoun I, the deaf person would read it as themselves. [Schmidt, 2010]
The above-mentioned states that there is a huge difference between sign language and verbal language, and it is not, at all, possible to draw parallels between the two.
Furthermore, there is a huge difference in relation to at what age the deaf person has learned to sign sign language. The younger they are when learning sign language, the better they master it.

Difficulties when deaf people read

As stated there exist some difficulties when a deaf person, who are used to communicate via sign language is to understand written language.
The most important are:

- Reading is an extension of vocal language
- Often the deaf reader do not know the written word, he or she is reading
- If the deaf reader is a poor reader, he does not know the sufficient strategies and the reading cannot be automatic
- The deaf person do not know the written grammar in depth
- The deaf reader has often troubles with:
    - Idioms
    - Compound nouns
    - Pronouns
    - Wider terms

These terms can have an effect, when the deaf reader uses the Internet.

III.b: Neurology

Review of: "Tegnsprog – neurovidenskab og kognition" (Sign language – neuroscience and cognition)

In this paper the author Jesper Dammeyer use many different studies on deaf people to better describe the neurological basis of sign language. [Dammeyer, 2004]
Aphasia is the impairment of the speech ability due to brain damage. Aphasia is widely known in accordance to verbal speech and hearing people. Studies of aphasia have shown that deaf people, whose native language is sign language, can also be affected by aphasia. The same type of aphasia hits both sign language users and verbal language users in the same way. Non-fluent and agrammatical aphasia is caused by damage to the left brain hemisphere both in deaf and hearing people. The aphasia, which causes fluent but illogical speech is caused by damage to the right brain hemisphere, both in deaf and hearing people. Studies using neuroimaging such as PET and fMRI have shown that sign language users have the same activation of centres in the brain as hearing people in the production of language. These findings indicate that language is

located in the same parts of the brain no matter if the person's native language is verbal or sign language. [Hickok & Bellugi, 2001]
Different studies have shown the use of signs is disconnected from the motor functions of the brain. These studies all rely on data, where the parts of the brain, which deal with language is affected, but the motor skills are not. Sign language users with Parkinson's disease have the same symptom as hearing people do with the same disease: blurred language (with signs). Another study revealed that sign language users could use non-sign-language-related gestures and gesticulations even though they suffered from expressive aphasia. These findings indicate that sign language is not a pattern of movement in accordance to motor skills, but a language like any other language in the broader context of the human brain. [Corina et al., 1992]
Evidence point to that sign language is language based and not just visuospatial based. The ability to produce sign language is not affected by left sided neglect; the neglect-affected sign language users can identify signs in the side they involuntarily ignore all objects. Similar studies have shown that it is the same with the production of sign language, which indicates that sign language is more language based than visuospatial based. [Rönnberg et al., 2000]
There is much evidence of plasticity in the brain in accordance to the learning of sign language - especially in the specialisation of the temporal and parietal areas in the right hemisphere. People who learn sign language later in life show more activation in *superior temporal sulcus* in the right brain hemisphere during sign perception compared to people, who have known sign language all their life, see figure 8. [Newman et al.] Another study found more activity in *superior temporal gyrus* in the left hemisphere in deaf people compared to hearing people, both groups mastering sign language, see figure 8. These two studies show plasticity in the language centres of the brain in accordance to perception. There is also evidence of plasticity in accordance to sign production. *Angular gyrus* in the inferior parietal cortex and premotor cortex are more active during sign language production in people with sign language as first language. [Newman et al., 2002]

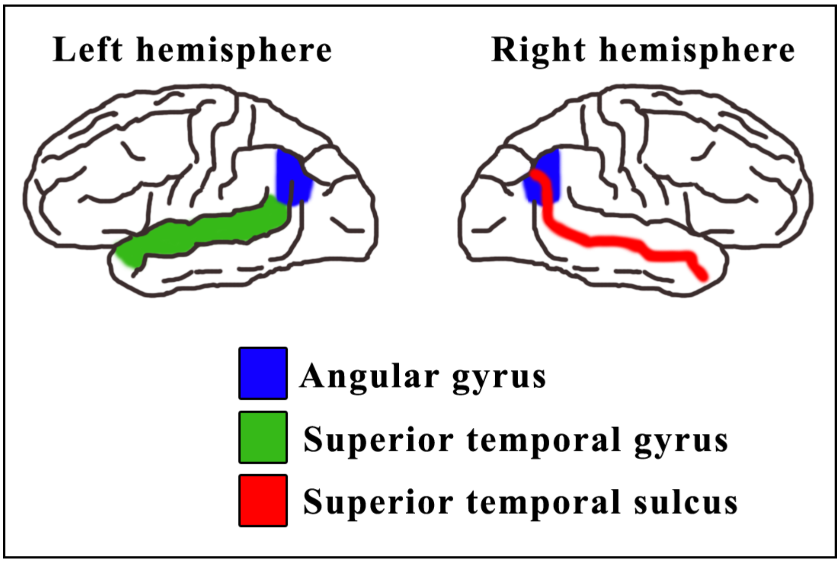

Figure 8: The brain and the affected areas.

The same speaking errors typically found among hearing people in oral language have also been identified among sign language users. Studies have shown that deaf people tend to make the same semantic replacement errors in sign language as found in oral language. These findings go hand in hand with known aphasias in deaf people, which are similar to aphasias in hearing people. It is likely that the same cognitive processes are responsible for the production of words in both oral and sign language. [Corina, 1998]
There is evidence that the Phonological Loop found in tests with working memory also is found in sign language users just with signs. Studies were conducted where deaf people repeated semantic signs over a time period. The results were similar to tests conducted on hearing people and oral language. The same tests

on deaf people showed that they did not use the Visuospatial Sketchpad to recollect the words they were given. This indicates that the Phonological Loop is not limited to sound but to language in general. The working memory of humans acts in the same way no matter in which modality the word is presented. [Wilson & Emmorey, 1997a]
The conclusions of the paper are as following; the human system of language is neutral in accordance to usage of modality, there are no major neural differences between oral and sign language and that the neurological organisation of sign language is plastic/malleable. [Dammeyer, 2004]

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Appendix IV: Applied Theory

From appendix III it was found that there is no difference between the hearing and deaf brain. Therefore, it is of interest to investigate whether there is a difference in the usage of reading strategies between hearing and deaf readers.

IV.a: Review of *"Cognitive Accessibility to Hypertext Systems – The role of verbal and visuospatial abilities of deaf and hearing users in information retrieval"*

In relation to the present project, not all the content from the article is of importance and is therefore not included in this review.
Delgado and González have constructed four experiments in order to overcome the research lack, which exists in understanding the problems deaf people face when accessing the Internet. In this review only the first experiment is described. The goal of Delgado and González is to find solutions to the problems of web accessibility regarding deaf users. All their deaf test subjects suffer from pre-lingual deafness[1]. [Delgado & González, 2005]

Working memory

Memory can be divided into two distinct memory stores: a temporal store (short-term memory also known as working memory) and a more permanent store (long-term memory). Working memory (WM) is of importance when looking at the relation between deafness and memory.
Delgado and González ask the question: "Is there any relationship between deafness and memory?" They answer the question with a "yes", which should be seen in the light of, that structure and functioning of memory depends on the information from the specific information given and since deaf people cannot recieve sufficient information from sounds and oral phonology, the process of their memory could be affected. Baddeley's model of working memory supports the research on memory and deafness. His model regards WM as a temporal storage system, which is used to maintain the information active while it is being used. Three subsystems compose the WM:

1. The Phonological Loop
2. The Visuospatial Sketchpad
3. The Central Executive

The Phonological Loop and The Visuospatial Sketchpad are both slave systems, in which respectively verbal and visual information are stored and manipulated. The Central Executive coordinates the slave subsystems and supervises the storage process. The Phonological Loop consists of two elements:

1. The phonological buffer
2. The articulatory component

The phonological buffer keeps track of acoustic or speech-based material for approximately two seconds. The articulatory component can prolong this time by means of a subvocal rehearsal.

[1] Born deaf or children becoming deaf before mastering oral language

There are some differences between deaf and hearing people regarding the capacity and functioning of their Phonological Loops, since oral language phonology is composed of sound, see appendix IV.b. It is suggested that the WM architecture or some of its components are not fixed and therefore can adapt to the type of information being processed [Wilson & Emmorey, 1997b]. In this way deaf people using sign language also would have a Phonological Loop, involving both components in the processing of sign language. Here the phonological buffer would store signs and the articulatory component would handle the rehearsing of the phonology of linguistic visuo-gestual stimuli, see figure 9.

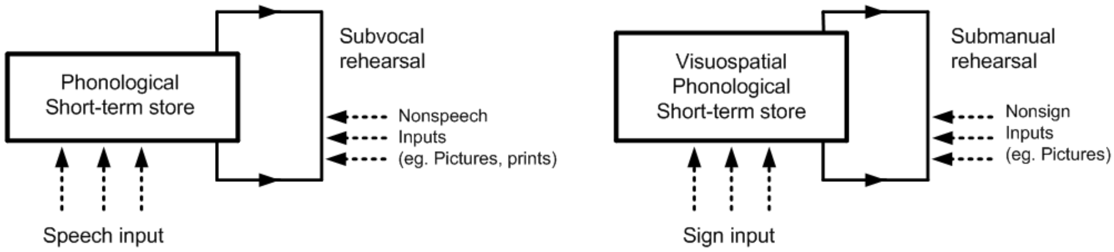

Figure. 9: To the left an oral based phonological loop, with an oral phonological store and a rehearsal process in the Subvocal. To the right a sign based phonological loop, with a visuospatial phonological store and a rehearsal in the Submanual. [Delgado & González, 2005]

There are differences between an articulatory loop based on signs and one based on speech. An example is that the speech loop relies more on temporal coding, whereas the sign loop seems to rely more on spatial coding [Logan et al., 1996][Wilson & Emmorey, 1997b]. It is furthermore observed, that when deaf signers were presented to an immediate recall of a serial of signs, they made use of a strategy where they produced each sign at a separate spatial location, see appendix III.a. In this way the signers codified the information by means of the spatial clues. This is a strategy hearing readers do not make use of [Wilson & Emmorey, 2001]. In relation to this, it has been proven that deaf signers have a larger WM, than hearing (non-signers) have [Wilson & Emmorey, 97b]. Actually deaf people have a tendency to score higher in complex stimuli recognition test, than hearing people do. This could be due to the fact that their visuospatial capacity is higher [Arnold & Murray, 1998].

Long-term memory

The Long Term Memory (LTM) is used as a permanent storage place when information has been stored and processed in the WM and if the information is of a type, which is not to be lost. Findings show that it is possible that hearing and deaf people differ when it comes to the amount and organisation of knowledge in the LTM. One example is found by Marschark and Everhart, in their study they found that hearing and deaf children used different strategies in a 20 questions game (a game where players can ask maximum 20 questions in order to find an objective in a picture set containing 42 pictures). It was found that deaf children asked specific question e.g. "Is it a cow?" Whereas hearing children asked more constraining questions to eliminate more choices each time and this indicated that the two groups of children used different categorical knowledge organisation and also different strategies of information retrieval from LTM. [Marschark & Everhart, 1999] Another example is a study where the aim was to measure the amount and organisation of lexicon (verbal concepts) in deaf people. In the study the subjects had to say the first word coming into their mind after receiving a word (80 words in total). The result revealed a quantitative similarity between deaf and hearing subjects. But the qualitative analysis showed that the answer coherence in with-in groups were higher for hearing subjects than for deaf subjects. Furthermore, a verbal analogy task was used to explore the application of taxonomic knowledge with deaf subjects. In this test the subjects were given a concept and then had to select the right alternative in relation to a specific type of analogy (examples from the article: superordinate, subordinate, coordinate, rhyme, etc.). Difference was found between hearing and deaf subjects in six types of analogies, especially the coordinate analogies; a difficulty in the use of category information in semantic memory tasks. Yet again others have found that deaf people have problems e.g. reading since it is a task involving relational processing of information.

According to these results and findings it seems that deaf people tend to store the details of concepts more than the relation between them. Banks et al. have observed that deaf people remember isolated fragments of information after reading a text, even though hearing and deaf subjects overall remember the same amount of information. [Banks et al. 1990]
The test thesis of Delgado et al. were: "*Which are the cognitive accessibility problems of deaf people to the web*?, *Which cognitive processes are involved in web interaction*? and *Which capabilities or abilities of users could be limiting or, contrarily, favouring web interaction?"*

They take an empirical approach to the questions, not all of the questions are answered in this review. The first experiment tests the reading abilities and their navigation in web structure.
In this experiment Delgado et al. test the effects of both reading comprehension abilities and type of HIR (Hypertext Information Retrieval). The test is also designed to test the effects of the type of users (deaf vs. hearing). To do this, they use a digital newspaper.
The hypothesis: "*Do deaf sign users have difficulties in HIR text-based due to their low reading abilities?"* and "*If it is so, which type of hypertext structure could facilitate their performance?"*
Subjects: Fifty-seven people participated (twenty-seven deaf signers (DS) and thirty hearing non-signers (H)).
Material: Online newspaper made by the experimenters, where the news was in a hierarchical format in three levels, with different amount of nodes on each level.
Task: A search task with twenty-one trials, in each trial the subjects had two minutes to complete it. The subjects had to find an end target in the hierarchical format.
Results: It was found that deaf readers were poorer readers compared to hearing readers. Furthermore the hearing readers had a higher score regarding prior knowledge. It was found that the higher level of reading comprehension, more targets were found and this lead to a more acquired mental model of the web structure. The faster the subjects found the targets, the less they became disorientated. A good prior mental model of a newspaper structure helped the subjects to find the targets, but it did not help the subjects to be faster or less disorientated. But if the reading comprehension ability is introduced as a covariate, the difference between the groups disappears and furthermore, the reading comprehension abilities can predict the performance in HIR tasks for all users – both hearing and deaf.
Therefore it should be taken into consideration that deaf people with oral language as their second language have problems in the comprehension of the text they have read, since they use great amounts of resources in decoding the meaning of the text. Furthermore, they use great amount of time searching and maybe not find or understand the target information of the text. It seems that in absence of reading abilities and the constraint use of literal matching, the deaf subjects made use of a visual *search and match* strategy. This strategy is simply enough to gain information on websites. In this way the subjects are not processing the meaning of the text and structure and therefore do not learn the content structure of the hypertext. [Delgado & González, 2005]

IV.b: Review of *"Reading Optimally Builds on Spoken Language: Implications for Deaf Readers"*

The article written by Perfetti and Sandak states that reading is not a parallel language system but closely related to the spoken language and its phonology. Spoken language is prior to the written language, all children learn a native language, but not all learn to read.
To identify words, phonological decoding strategies are important. When a child learns to read, the child's skills of reading are closely related to the child's phonemic awareness, meaning that they have to have sensitivity to meaningless segments (phonemes), which are abstract building blocks of the phonological system. Other important factors to reading are: reading experience, the automatic of reading and comprehension strategies. These are also very important to the deaf reader, in accordance to sign language.
In relation to the deaf reader, a question emerges: "How does one learn to read in a language one does not know well?" [Perfetti & Sandak, 2000]

It is very difficult if phonology, which is the structure in the spoken language, also is a fundamental structure in reading. In this relation, the authors state two questions:

1. If phonology is important in reading generally, then might it be important in reading by deaf readers?
2. What implications follow the literacy of deaf persons?

[Perfetti & Sandak, 2000]

The article states that two findings support, that deaf readers do not use phonological cues in spelling as much as hearing readers do. The first finding was that deaf readers did not make phonological spelling errors (skwrl instead of squirrel) and the second was that they remembered silent letters when spelling. But this is only an indicator of how the deaf readers read.
A way to have direct evidence on the issue of phonology from both reading and writing is by a reading task concerning a lexical decision. In such a task the subject is presented to a series of letter strings and asked whether or not each string is a word or not. Such a task demands only a small contact with the mental representation of the word to generate a positive decision. The advantage with a lexical decision is that hearing readers make faster decisions when they are exposed to regularly spelled words (e.g. mint) than for irregularly spelled words (e.g. pint). It was different in relation to the deaf readers; here there was no effect between a regularly spelled word and an irregularly spelled word. This led to the interpretation that the deaf readers relied on the whole word (lexical) representations when reading, instead of what the authors call "assembled phonology". But they also state that it is impossible to draw conclusions from the presence or absence of phonology just because no difference is found. They therefore dug a bit deeper and found that several laboratory studies have shown that deaf readers use phonological information when they have to judge if a sentence rhymes. In the test the deaf readers would see two pair of words and then have to decide which pair rhymes. All of the word-pairs were orthographically similar, additionally half of the pairs were also phonologically similar (e.g. save-wave) and half were phonologically dissimilar (have-cave). The hearing readers scored 99.6% right ones and the deaf readers 64.1%, which of course is not as good as the hearing readers but still better than by chance [Hanson & Fowler, 1987]. Another task, which shows that deaf readers use phonology is naming tasks, where the participants should read aloud as fast as possible both words and non-words. When a participant has to name pseudo-words (non-words that are pronounceable) it requires the phonology from letters, since there is not a common way to pronounce them [Leybaert, 1993]. This test found that deaf readers could accurately read pseudo-words aloud, implicating that they can assemble phonology from letters. The authors state that this indicates, "that the deaf participants were capable of mapping orthography onto phonology in ways comparable to those of hearing participants." [Perfetti & Sandak, 2000]. Third evidence, which suggest that deaf readers make use of phonology, comes from tasks where phonology is not required. A result of this could e.g. be a mis-recall of the letter F, which more likely to result in the phonologically similar S than in E, which is more visually similar. This shows that the memory for visual presented language relies more on its phonological information than its visual information and studies indicates that it is the same for deaf readers. Furthermore, it is suggested that deaf readers automatically, when introduced to printed words, activate phonological representations. The authors conclude that some deaf readers make use of the spoken language phonology and some do not. But what do the group of deaf people, which do not use phonology use instead? Alternatives have been suggested, such as: use of visual information, use of information based on context and use of sign-based recoding.

Visual information: As found in the previous some of the deaf readers make visual spelling errors whereas hearing readers make phonological errors. The article states that many errors made by deaf readers have a strong visual basis.

Contextual information: For experienced readers the context helps to verify the identity of a word, to select the right meaning of the word and place the meaning in a mental model. For less experienced readers the context provides an aid to identify the meaning of the word at hand [Perfetti et al., 1979]. It is found that deaf readers rely more on the semantic information from the context when they have to identify words.

Recoding: Recoding refers to hearing readers convert words into phonological forms (print-to-phonology). It was found that some of the deaf readers used a sign-recoding strategy when reading and it is stated that such recoding may help to represent and reinforce semantic information. But it is found that the most skilled deaf readers did not use such a system, they suggest that this group may have an access to other reading support with an implicit phonology. The conclusion is that deaf readers like less skilled readers rely more on orthographic and semantic information than on the phonological information. [Treiman & Hirsh-Pasek, 1983]

Summarised it is concluded that at least some deaf readers use phonology, but how have they gained that access? Here are some explanations:

Lip-reading: It is found that lip-reading can influence the perception of speech, e.g. blind children have more difficulties pronouncing some words, since they cannot see how it is done. It is therefore suggested that deaf persons, who view speech and maybe learn to interpret it, use these visual processes to contribute to the development of a partial representation of phonology.

Cued speech (and related systems): Works with the speaker uses hand signals close to the mouth and distinguish both consonants and vowels. When the speaker makes a cue with his hand, while pronouncing a syllable, he or she gives the viewer unambiguous phonological information. There are other systems like this one.

Perfetti and Sandak state that maybe it is a combination of things that make deaf readers use phonology, if they use it. Examples could be; at what age they are; their education and reading skills and if they are coming from a deaf family etc.
Perfetti and Sandak conclude that reading builds on spoken language, but it is not possible to conclude that reading just is a matter of attaching meaning to print without some sort of reference to the language the written system is based on.
When dealing with knowledge about the spoken language, there are more to it than just the phonological information. Knowledge about morphology, semantics and syntax are also needed. The final conclusion made by Perfetti and Sandak is that many deaf readers are cable of gaining access to phonology and use it when they read, and the level of how good they are to access phonology may elevate their achievements in reading.

IV.c: Review of *"Strategy Usages Among Deaf and Hearing Readers"*

Experienced readers make use of metacognitive strategies when reading, sometimes referred to as comprehension monitoring strategies [Baker & Brown, 1984]. When speaking about metacognitive strategies in relation to reading, it refers to the control and awareness people have over their own reading comprehension. It could e.g. be that trained readers know when they do not understand what they have been reading and then they will often make use of contextual information or reread the passage that they did not understand. It seems that even though deaf readers have difficulties with comprehending the text, deaf readers make use of the same strategies as hearing readers to reconstruct the text by use of their semantic knowledge. [Andrews & Mason, 1991]
Andrews and Mason states that there are different reasons why deaf readers have difficulty in reading.

- One is that the deaf readers do not have the same background knowledge or experience about the different topics.
- Another reason is the deaf reader's poor verbal linguistic skills, their reading vocabularies are smaller, problems with "reading between the lines" etc.

- A third reason is a great difference between the structure in verbal language and in sign language, as a result the deaf readers must convert the printed text into their own language – sometimes using kinesthetic codes e.g. finger spelling, signs etc.

The efficiency of these strategies is not yet known. [Andrews & Mason, 1998]

Andrews and Mason conducted an experiment to examine the strategies used among both hearing and deaf readers. The experiment was conducted so both the hearing and the deaf readers first saw a picture e.g. of a library and were then to fill in a blank word in a sentence related to the picture first shown e.g. "you can find good ____", here they were to say books. The next task would build on the previous sentence and so on. All the subjects were presented with a text below their reading level, one text matching their reading level and one, which was above their reading level. Both groups of test subjects had to self report what strategies they used to the experimenters. The hearing readers were to tell their answers verbally and the deaf readers were to sign their answer in sign language. [Andrews & Mason, 1998]
It was found that both groups of readers used six different strategies:

- Background knowledge
- Rereading
- Looking back in the text
- Looking ahead in the text
- Identifying contextual cues in the sentence
- Identifying cues from the title

It was found that the deaf readers in average used 3.8 different strategies, whereas the hearing readers used 4.7 different strategies. Both groups used *background knowledge*, often followed by rereading the sentence and *looking back in the text*. The hearing readers used *context cues* (surrounding words) both in the sentence but also in the title. *Looking forward* was rarely used in any of the groups. There was also found an increase in the use of strategies in relation to the reading level, the better reader the more strategies used. [Andrews & Mason, 1998]
The deaf readers had trouble while reading words with e.g. two different meanings, and they also had trouble with idioms (word-pictures, figurative speech or/and an expression), such as "dandelions are like little suns". It is concluded that the deaf readers have difficulties with the comparison of homonyms (words that are spelled and pronounced the same but have different meanings). The article states that deaf readers need more experience with reading together with a skilled teacher, who can help them to identify and use the right strategies, so they can be able to understand reading better and in the future be better readers.

Discussion of the articles

Delgado and González state that working memory (WM) is of importance when looking at the relation between deafness and memory. It is suggested that the WM architecture or some of its components are not fixed and therefore can adapt to the type of information being processed. In this way deaf people using sign language also would have a Phonological Loop, involving both components in the processing of sign language. Findings show that it is possible that hearing and deaf people differ when it comes to the amount and organisation of knowledge in the long-term memory (LMT). The study made by Marschark and Everhart indicates that there is a difference between the use of different categorical knowledge organisation and also between the different strategies of information retrieval from LTM. Delgado and González found that it seems that deaf people tend to store the details of concepts more than the relation between them. Banks et al. have observed that deaf people remember isolated fragments of information after reading a text, even though hearing and deaf subjects remember the same amount of information in overall. Perfetti and Mason state that deaf readers are able to access phonology and use it when they read but there are much more to reading than phonology. It seems that there is a connection between the levels of how well the deaf readers are to access phonology and how good they are at reading. Since phonology is the basis for the verbal language and the verbal language is the basis for the written language, it makes sense that deaf people have difficulties in reading, since they do not have this connection. In the article written by Andrews and Mason, it is stated that experienced readers use metacognitive strategies when reading, to be able to comprehend what is being read, this is also the case with deaf readers. In the case with deaf readers the problem is that they do not have the strategies incorporated as a hearing reader has. This is both due to the fact that reading is an extension of the vocal language, as Perfetti and Sandak also state and that the deaf reader does not knows the different strategies and sometimes not even knows the written word. This is in immediate continuation of what Perfetti and Sandak write. They state that strategies are very important to identify words and to make the reading automated. In relation to this, Delgado and González write that they have observed, that the deaf readers, with an absence of reading abilities, in the constraint use of literal matching make use of a visual *search and match* strategy and Delgado and González state that maybe this strategy is enough in order to understand and navigate in a written text.

IV.d: Pictures

When communicating information to users on the Internet, there are basically four forms: text, graphics, moving images and sound. Of these four graphics are probably the most powerful, since there is an instant response to it and it perceived in just a few fixations.
When people scan a website, they make fast decisions of what they are going to look at. People just look at 42% of the pictures presented and in general just look at the pictures for less than two-tenths of a second.
When a person decides if a pictures is worth looking at, there are some general characteristics. The characteristics for a picture worth looking at:
“

- High contrast and high quality (crisp and colourful)
- Cropped, rather than overlay reduced, when necessary to fit small space
- Not excessively detailed: easy to interpret, almost iconic
- Highly related to the content on the page
- Possess magnetic features

“
[Nielsen & Pernice, 2010]

Features, which make a picture magnetic:
“

- Smiling and approachable faces
- People looking at (or at least facing) the camera
- Sexual anatomy (and sexy bodies)
- Appetising food
- Clear instructions or information

“
[Nielsen & Pernice, 2010]

Characteristics for a picture people ignore:
“

- Low contrast and low quality
- To busy for the space
- Look like advertisements
- Not related to content on the page or only slightly related to it
- Boring
- Include people or objects that are generic or obvious stock art
- Cold, fake, or to polished

“
[Nielsen & Pernice, 2010]

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Appendix V: Planning the Experiment

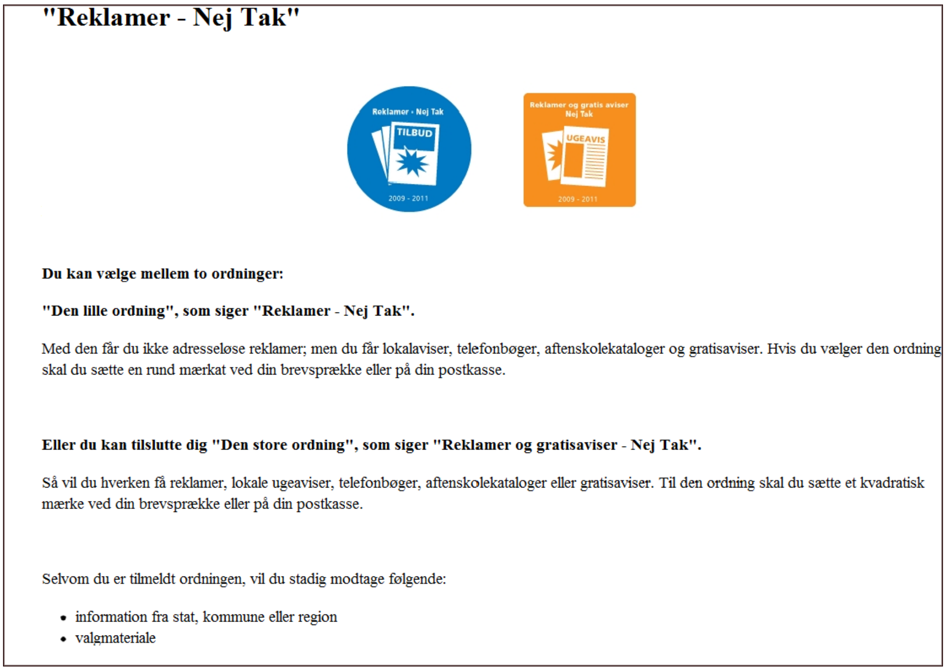
From appendix IV.c it is found that when people read, they make use of six metacognitive comprehending strategies; *background knowledge*, *rereading, looking back in the text*, *looking ahead in the text*, *identifying cues in the sentence* and *identifying contextual cues from the title*. From appendix IV.a, another strategy is introduced. This *search and match*-strategy is not a profound reading strategy, but a strategy used in order to make an overview and detect key elements in the text. Both hearing and deaf readers make use of this strategy, but it was observed by Delgado & González, that deaf readers made heavily use of it when reading on websites. Almost all websites contain pictures. Nielsen and Pernice found through empirical eye tracking studies, that people look at pictures if they are of importance to the context, easy to interpret etc. see appendix IV.d. It is decided to introduce *pictures* as an 8th strategy.

The eight strategies:

- Background knowledge
- Rereading
- Looking back
- Looking ahead
- Identifying cues
- Contextual cues
- Search and match
- Pictures

To test the strategies it was decided to construct three fictitious test websites in order to avoid bias from the test subjects in accordance to potential prior knowledge. If a known website was used some of the test subjects would have prior knowledge of where on the website the essential information would be placed. While test subjects with no prior knowledge would be looking at the website differently than test subjects with prior knowledge. Some test subjects could have prior knowledge with websites of similar design. Making the test websites fictitious would make a comparison of the results more valid by avoiding any severe bias through prior knowledge. Fictitious websites avoids some nuisance variables because the websites are controlled by the experimenter during the experiment.
It was decided to have an increasing level of difficulty of the texts on the websites throughout the test, the order was therefore fixed. This was done in order to make sure that the subject, no matter what reading level they had, would be able to read some of the texts and by doing so make it possible to track the reading strategies, even though the reading level of the subject is poor.
The test websites were made to look realistic, like the types of websites typically found on the Internet. This was done in order to secure that realistic and valid test results would be received.
Three types of websites were chosen in accordance to an estimation of what types of websites were most commonly used and found the Internet. The first website is a postal site, the text on this site is from an exam compendium at FVU level (Forberedende Voksen Undervisning). This site is seen as an introduction site, to make the test subjects calm and to let them know, which type of tasks they are to complete, since the reading level is adjusted to their reading level. The second website is a news website, the topic on this site is chosen, since it was estimated it would be semi-difficult for the readers to comprehend. The third website is a local government with information about marriage. The topic on this site is chosen, since it was estimated it would be difficult for the readers to comprehend.
All the LIX numbers corresponds to the level, which can be found in daily newspapers and magasines. [LIX Calculator, 2011]
The reading level of the three sites is not only based on the LIX numbers, but also on a subjective estimation on, which subjects are difficult to comprehend.

1. Easy: A public postal information website (the text is from a FVU exam)


"Reklamer - Nej Tak"

Reklamer - Nej Tak
TILBUD
2009 - 2011
Reklamer og gratis aviser Nej Tak
UGEAVIS
2009 - 2011

Du kan vælge mellem to ordninger:

"Den lille ordning", som siger "Reklamer - Nej Tak".

Med den får du ikke adresseløse reklamer; men du får lokalaviser, telefonbøger, aftenskolekataloger og gratisaviser. Hvis du vælger den ordning skal du sætte en rund mærkat ved din brevsprække eller på din postkasse.

Eller du kan tilslutte dig "Den store ordning", som siger "Reklamer og gratisaviser - Nej Tak".

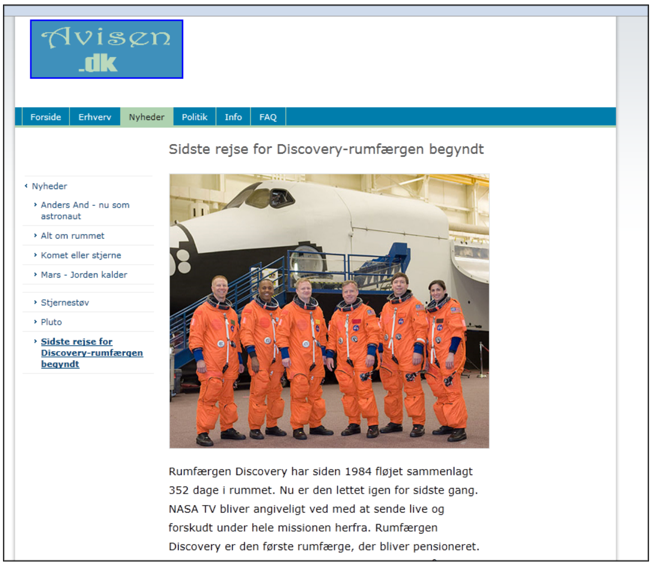
Så vil du hverken få reklamer, lokale ugeaviser, telefonbøger, aftenskolekataloger eller gratisaviser. Til den ordning skal du sætte et kvadratisk mærke ved din brevsprække eller på din postkasse.

Selvom du er tilmeldt ordningen, vil du stadig modtage følgende:

- information fra stat, kommune eller region
- valgmateriale

Figure. 10: This website have a LIX number at 43.
To see the whole website visit: http://oevad.com/Test_2/Post.html

2. Medium: A news website


Avisen .dk

Forside | Erhverv | Nyheder | Politik | Info | FAQ

- Nyheder
  - Anders And - nu som astronaut
  - Alt om rummet
  - Komet eller stjerne
  - Mars - Jorden kalder
  - Stjernestøv
  - Pluto
  - Sidste rejse for Discovery-rumfærgen begyndt

Sidste rejse for Discovery-rumfærgen begyndt

Rumfærgen Discovery har siden 1984 fløjet sammenlagt 352 dage i rummet. Nu er den lettet igen for sidste gang. NASA TV bliver angiveligt ved med at sende live og forskudt under hele missionen herfra. Rumfærgen Discovery er den første rumfærge, der bliver pensioneret.

Figure 11: This website have a LIX number at 38.
To see the whole website visit: http://oevad.com/Test_2/Rummet_Final.html

3. Hard: An official local government website

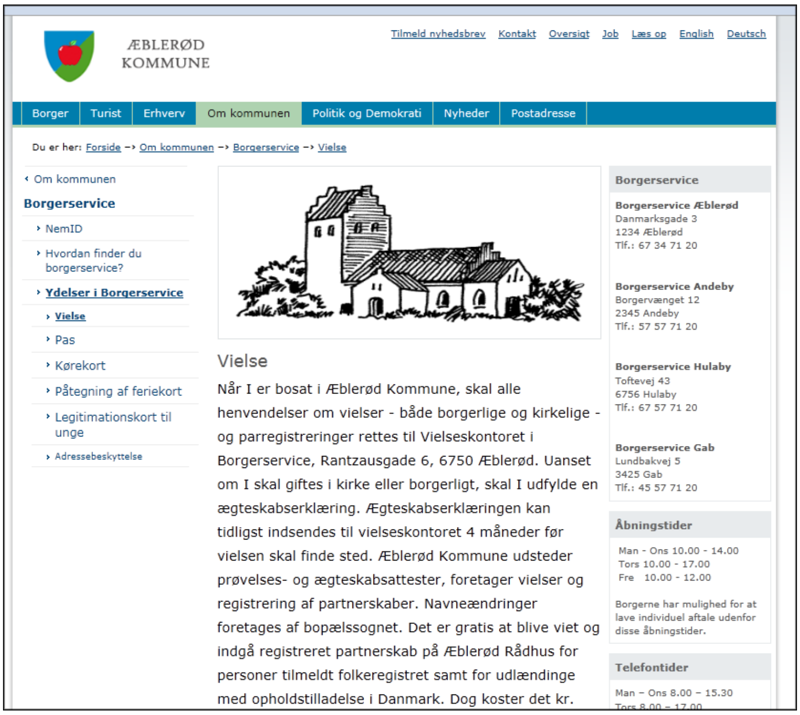


Figure 12: This website has a LIX number at 44.

To see the whole website visit: http://oevad.com/Test_2/Vielse_Final.html

In order to make sure that the subjects would actually read some of the text if not all, they have to answer a question with five fixed answers, which appear at the bottom of the website when they click on a link.
In order to identify the different strategies, they have to be adaptable for the purpose of reading on a website. The criteria for indentifying the different strategies are:

- Rereading: When the subject makes a jump back to the start of the sentence or of the section and reads the text again.
- Looking ahead: When the subject makes a jump forward in the text and then return to the starting point.
- Looking backward: When the subject looks a couple of words back in the sentence and then return to the starting point.
- Identifying cues in title: When the subject looks at the main title, subtitles and at the menus.
- Identifying contextual cues in the sentence: This strategy was impossible to test directly with the eye tracker, since it would easily be mixed up with some of the other strategies. This strategy was therefore tested by asking the test subjects if there were any words they did not understand on the website, and what they did to identify the meaning of the words. The test subjects will have to put words on this strategy themselves. This was done because by telling the test subjects about the strategy would bias them to possibly believe that they had used the strategy when they had not.
- Background knowledge: To identify this strategy the subjects are asked if they knew anything about the topic in advance. If they do, they are asked if they know the answer before seeing the different answers.
- Search and match: If the subjects make an overview of the website. If the test subjects jumps around the website in a searching manner.
- Pictures: If the test subjects focus on the picture, which was placed in the top all websites.

Screening of the test subjects:

In order to identify the reading level of the test subjects, the subjects have been tested with a FVU test. It is a demand from the Ministry of Education, that all students at schools like VUC (Voksen Uddannelses Centre) and adult schools where they teach primary school level in Danish, have to be screened by this test. For the deaf people the test is a problem, since the test is both verbally founded and one of the assignments is totally based on phonology. The test tests the reading level, the subjects understanding of words, their vocabulary and their use of phonology, see attachment II on the DVD to try the test.

In the first assignment the subjects have to choose the correct word out of four in order to make meaning of a sentence. In the second assignment the subjects hear a word and then have to choose the correct picture out of four, which matches the word they have heard. In assignment three, the subjects receive three fake words and one correct word all spelled in a phonologically way. The test subjects then have to choose, which of the words that is a real word, judging it by saying the words aloud.

All the hearing subjects accomplished the test right before the experiment and they did the test as intended. The deaf subjects had been screened by Lene Schmidt (teacher at Center for Døvblindhed og Høretab i Aalborg) before the experiment, since the test is in verbal Danish it was necessary to have the explanations translated in to sign language. In the second test the deaf subjects were given the word, written in Danish on a piece of paper. Furthermore, the deaf subjects had more test to obtain their reading level, see attachment I.

All of the hearing subjects scored an A corresponding to good reading level in the FVU test. The reading level of the deaf subjects was between B and C corresponding to insufficient and poor.

Appendix VI: Experiment

In order to investigate if the eight strategies are used when deaf people read on the Internet, a between subjects experiment is conducted.

Introduction:

This experiment will test whether the metacognitive strategies identified by Andrews and Mason will also apply to websites. Two strategies are added to the six identified strategies: *pictures* and *search and match*. From the theory concerning metacognitive strategies, appendix IV.a and appendix IV.c three hypotheses have been derived.

Hypotheses:

Hypothesis 1:

There is a difference in the use of metacognitive strategies between deaf people and hearing people when reading web content on the Internet

This hypothesis is put forward in order to test, if there is a difference in the use of strategies between deaf and hearing subjects.

Hypothesis 2:

Hearing people use more metacognitive strategies than deaf people when reading web content on the Internet

This hypothesis is put forward in order to test, if Andrews and Mason was right, when they pointed out that hearing readers use in average one strategy more than deaf readers.

Hypothesis 3:

Deaf people use the strategy "search and match" more than hearing people when they read web content on the Internet

This hypothesis is put forward in order to test, if Delgardo and González was right in their assumption, that deaf readers primary use of the strategy *search and match* when reading.

The variables:

Table 1: The variables

Independent variable	The three websites
Dependent variables	The counted strategies
Nuisance variables	Experience with similar websites, usage of glasses or contact lenses, their sight in general, alertness etc.

Subjects:

Eight deaf male test subjects with a mean age of 36.5 year (std. = 7.69) from Aalborg Center for Døvblindhed og Høretab. The reason why only men participated in the experiment was due to the fact that the number of deaf people in Aalborg is small, and the two deaf women present at the time could not be persuaded to participate in the experiment. All test subjects suffered from pre-lingual deafness and had a hearing loss above 80 dB. All test subjects had sign language as their first language and Danish as second language, see attachment I.

Control group:

Eight hearing male test subject with a mean age of 30.9 year (std. = 12.62) participated in the experiment. All test subjects had Danish as their first language and were acquaintances of the authors.

Materials:

Three fictitious test websites in three different reading difficulty levels. A Tobii x120 eye tracker was used to obtain objective data about which metacognitive reading strategies the test subjects used on the test websites. See attachment II and III for an elaboration about the eye tracker.

Design and procedure:

The experiment starts by introducing the test subjects to the experiment. The test subjects are seated in front of a monitor and the eye tracker. The test subjects can interact with the different websites by use of a mouse. The test subjects are being told that the goal of the experiment is to test reading strategies. The eye tracker is calibrated to the individual test subject and the experiment will commence.
The experimenter sits next to the test subjects and guides them through and facilitates the experiment. A minute taker is seated next to the experimenter and observes and takes notes about the test subjects' reactions and interactions with the different websites in the experiment. The test setup is illustrated in figure 13.

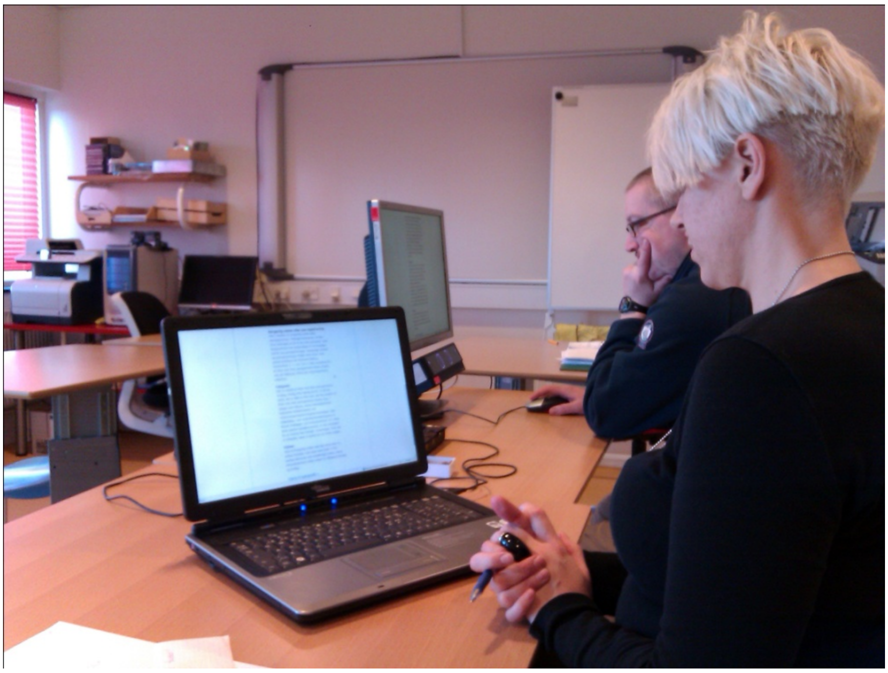


Figure 13: Picture of the test setup

In order to make sure the test subjects read the text on the website, questions about the informational contents of the website, will be asked in the bottom of the website. The test subjects can only pass to the next website by answering the question. The test subjects interact with all three test websites in a fixed order with a rising difficulty. The test subjects are afterwards being asked if there were words, they did not understand and if so what they did to understand the words, to see whether they used *background information* or *contextual cues from the sentence*. The hearing test subjects is asked these questions in verbal while the deaf test subjects are asked the same questions in simple text on a paper, see attachment VI. The metacognitive strategies of *rereading*, *looking back in the text*, *looking ahead in the text*, *identifying cues from the title* and the additional strategies of *picture* and *search and match* are be obtained through the eye tracker.

The test used in this experiment can be found at: http://oevad.com/Test_2/Start.html

Appendix VII: Acquisition of Data and Classification of the Reading Strategies

The results from the experiment were obtained by watching, analysing and counting the data from the Tobii x120 eye tracker via the Tobii software.
The final data from the experiment was the number of strategies used by both groups of test subjects. These reading strategies were classified in accordance to these specifications. The counting of each strategy was based on subjective estimations.

Rereading

The strategy of *rereading* was counted if the test subject had started reading a sentence and then started to reread the sentence before having finished the sentence. This is illustrated in figure 14.

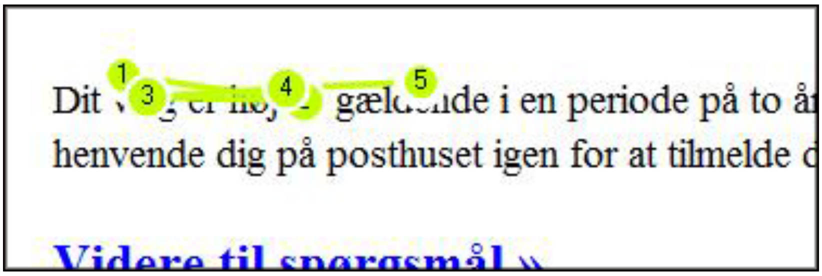


Figure 14a: Rereading

Looking Backward in Text

The strategy of *looking backward in text* was counted when the test subject had read a complete sentence and then jumped back to the start of the sentence. This strategy is illustrated in figure 15.

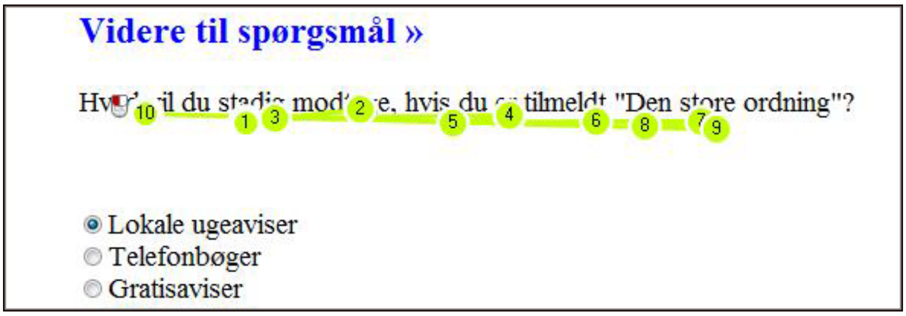


Figure 15: Looking backward in text

Looking ahead

The strategy of *looking ahead* was counted when the test subject jumped forward in the text to look for certain words. But this strategy would only be counted when the jump forward in the text was within the vicinity of the sentence they started on and if they jumped back to the vicinity of their starting point in the sentence. This strategy is illustrated in figure 16.

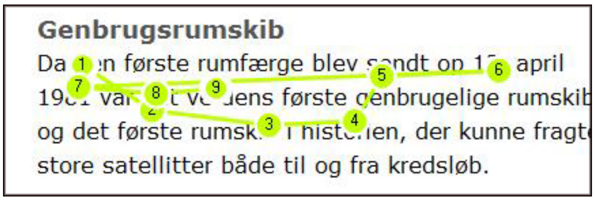


Figure 16: Looking ahead in the text

Picture

The strategy of *picture* was counted when the test subject looked at the picture(s) on the website. The idea being that the test subject obtained information about the content of the text from the information in and the context of the picture. An example of this strategy is illustrated in figure 17.

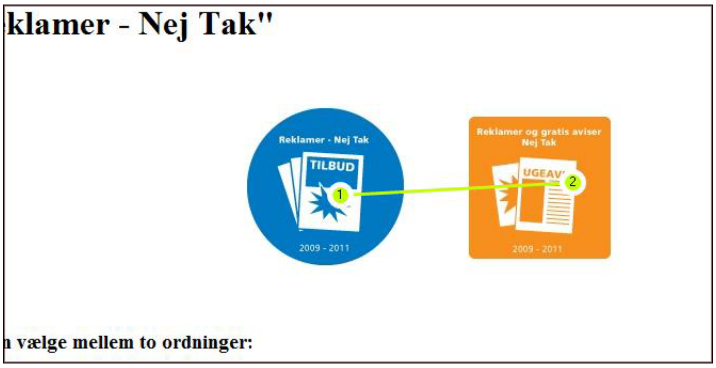


Figure 17: Looking at pictures, here two pictures are counted

Identifying cues from the title

The strategy of *identifying cues from the title* was counted if the test subject looked at the title, subtitles or menus on the website. This strategy is illustrated in figure 18. In this particular screenshot, one *identifying cues from the title* was counted. Furthermore a *rereading* is counted.

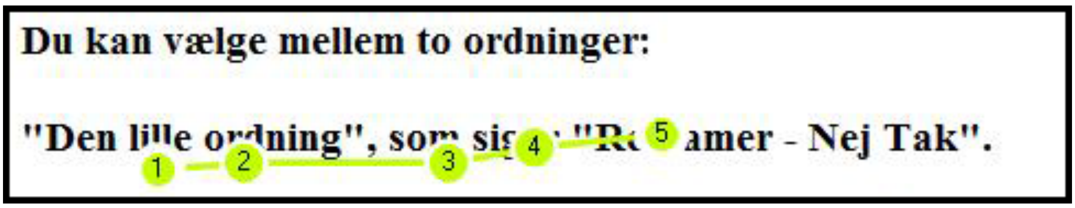


Figure 18: Identifying cues in the title

Search and match

The strategy of *search and match* was counted if the test subject looked across the whole or parts of the website in a search for certain words, headlines or pictures. This strategy was also counted if the test subjects looked around the whole website not looking for anything particular but to gain an overview. An example of this strategy is illustrated in figure 19.

Figure 19: Search and match strategy

A mixture of strategies

Typically the test subjects used more strategies on the same time. An example of this is illustrated in figure 20a and 20b. In the first example the test subject starts by looking at the picture and then switches to a title and another title. The test subject then looked at the picture again and then looked down to obtain an overview over the website. In this example two *picture*, two *identifying cues from the title* and one *search and match* were counted. In the second example the test subject start by looking at the picture and then switches to a title and another title. In this example one *picture* and two *identifying cues from the title* were counted.

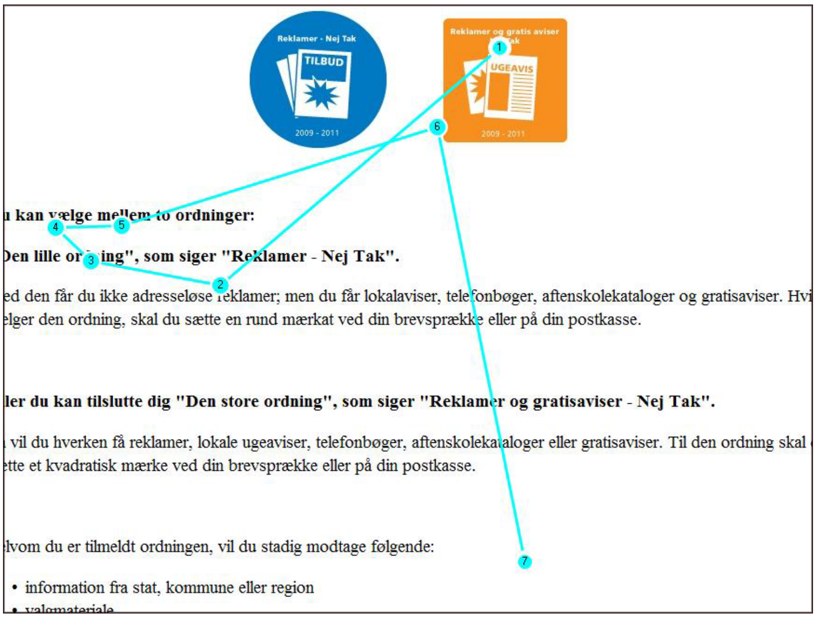


Figure 20a: A mixture of strategies, here five strategies are counted

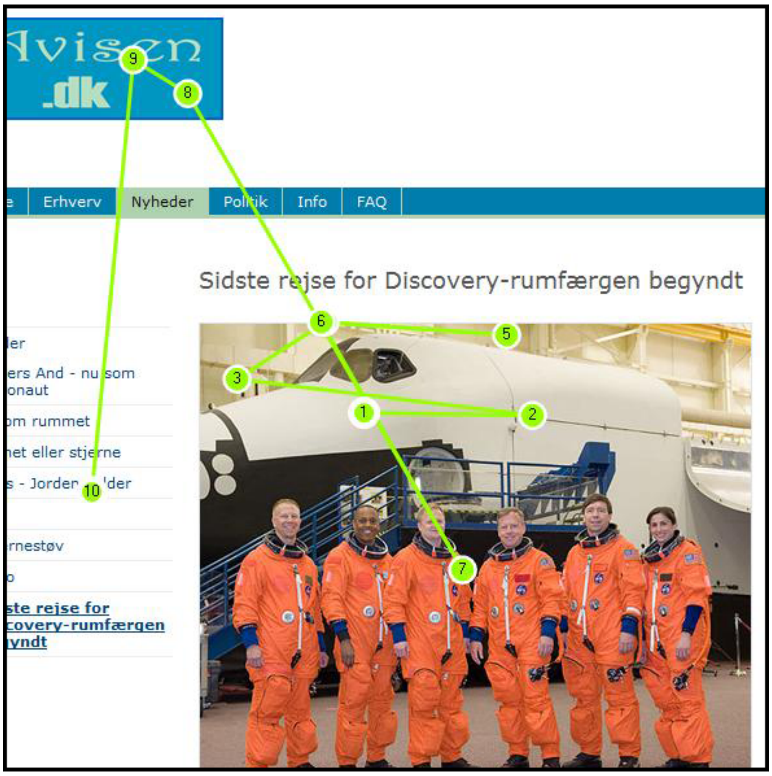


Figure 20b: A mixture of strategies, three strategies are counted

Appendix VIII: Analysis of the Data

VIII.a: Website with easy reading level

The metacognitive reading strategies used by the test subjects were counted and the results are presented in figure 21 and 22. The data used to generate these figures can be seen in attachment IV.

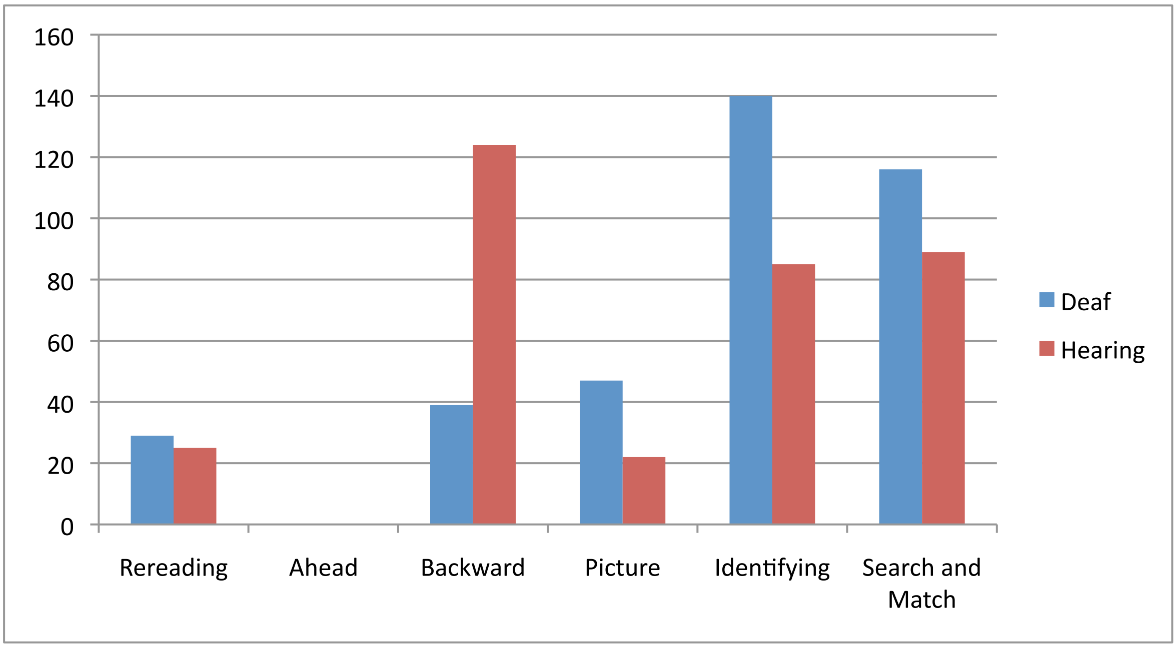


Figure 21: Overview of the strategies used in both groups in the easy task

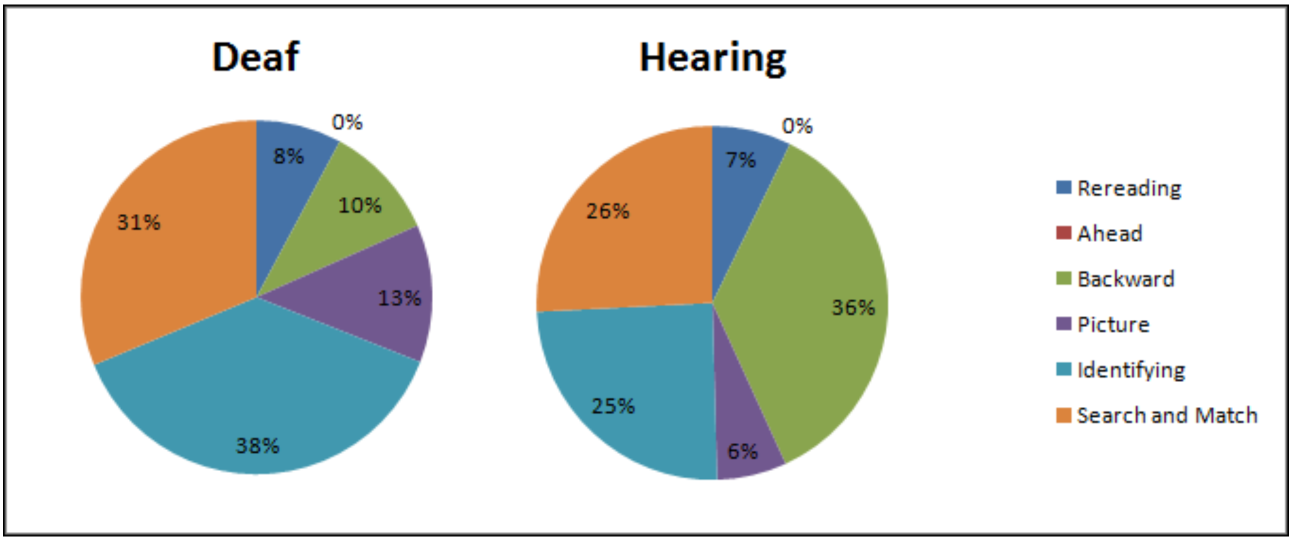


Figure 22: Overview of the distribution of the strategies in both groups in the easy task

No test subjects in any of the two groups reported that they had used *background knowledge* or *contextual cues from the sentence* to understand the meaning of a word. All deaf test subjects had the answers wrong in the question in the bottom of the website. One out of eight hearing test subjects had the answer wrong in the question in the bottom of the website.

Of the six remaining reading strategies both the hearing and the deaf test subjects in average used **4.9 strategies**.
It can be seen in figure 21 and 22 that both groups use the same number of strategies. But there is a difference in the use of the strategies between the two groups, especially in the strategies: *looking backward in text*, *identifying cues from title* and *search and match*.

- In total, of all the strategies, which could have been used, the hearing test subjects in average used *looking backward in text* **36%** compared to the deaf test subject's **10%** usage.
- *Identifying cues from the title* comprised **38%** of the deaf test subjects' average strategy usage. While the hearing test subject's usage of *identifying cues from title* made up **25%** of all the used strategies.
- In regards to the strategy *search and match* it was the preferred strategy of the deaf test subjects comprising **31%** of all the used strategies. The hearing test subjects' usage of *search and match* comprised **26%.**

The difference in the use of these three strategies seems big. Therefore a test for significance was initiated. The non-parametric two sample Wilcoxon test for significance was initiated, since the sample size is small it is not possible to estimate if the data is normally distributed. The hearing subjects use of *looking backward* was significant with a p-value of **0.001103**. The difference in use of the *search and match* strategy was not significant (p-value = **0.4586**) while the difference in use of *identifying cues from the title* was almost significant with a p-value of **0.05685**.

Test of the hypotheses

Hypothesis 1:

"There is a difference in the use of metacognitive strategies between deaf people and hearing people when reading web content on the Internet"

Is **verified** since there is a clear difference in the usage of some strategies between the two groups, since deaf subjects preferred the strategies of *search and match* and *identifying cues from the title*, whereas the hearing subjects preferred the *looking backward* strategy.

Hypothesis 2:

"Hearing people use more metacognitive strategies than deaf people when reading web content on the Internet"

Is **falsified** since both groups in average use 4.9 strategies.

Hypothesis 3:

"Deaf people use the strategy "search and match" more than hearing people when they read web content on the Internet"

Can **neither verified or falsified** since the p-value **0.4586** of the usage of *search and match* among the deaf test subjects is not significant larger than the usage among hearing test subjects.

VIII.b: Website with medium reading level

The strategies used by both groups of test subjects on the website with medium reading level were counted and is presented in figure 23 and 24. The data used to generate these figures can be seen in attachment IV.

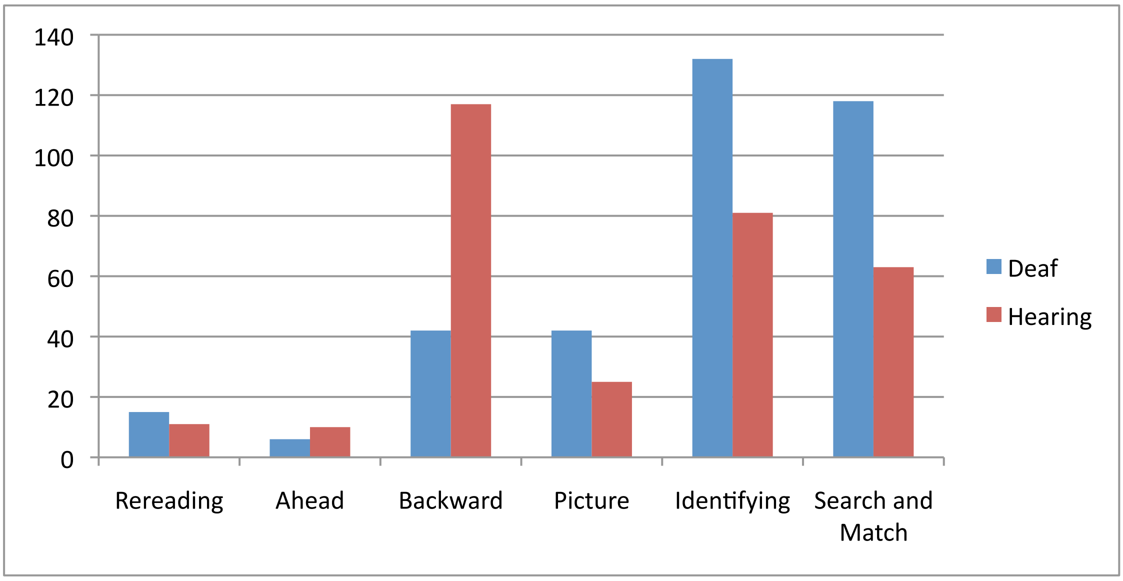


Figure 23: Overview of the strategies used in both groups in the medium task

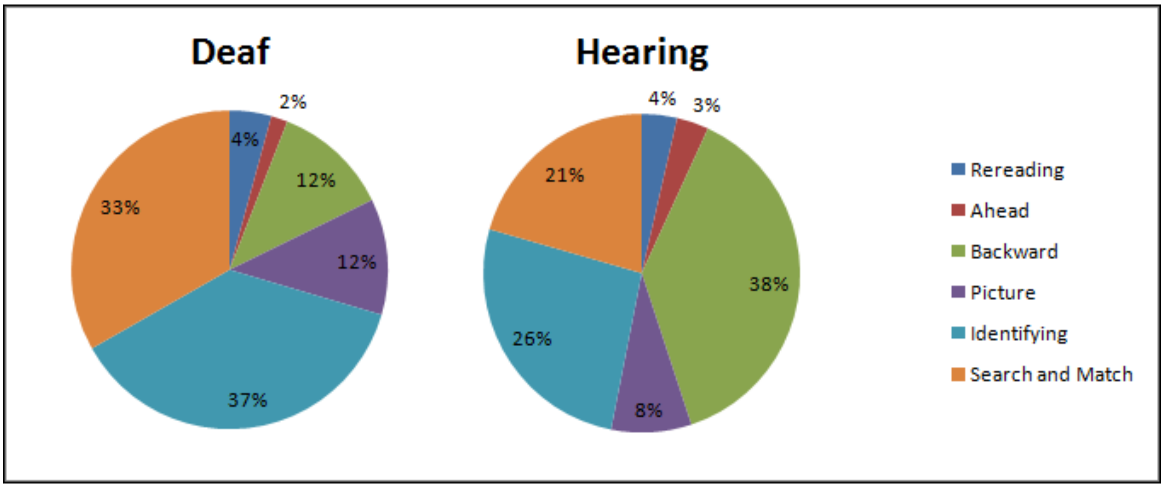


Figure 24: Overview of the distribution of the strategies in both groups in the medium task

Contextual cues from sentence and *background knowledge* were not reported to have been used by any of the test subjects in either of the two groups. Three out of eight deaf test subjects had the answers wrong in the question in the bottom of the website. It was the same result with the hearing test subjects.
Of the six remaining reading strategies both the deaf test subjects and the hearing test subjects in average used **5.1 strategies.**
As it can be seen in figure 23 and 24 there is a difference in the usage of the strategies between the two groups. Especially in *looking backward, identifying cues from the title* and *search and match* here there is a difference between the two groups.

- Of all the strategies the deaf test subjects used *looking backwards* **12%** in total. This is compared to *looking backwards'* **38%** of total usage among the hearing test subjects.

- The deaf test subjects in average used *identifying cues from the title* **37%** of the total strategy usage, while the percentage for the hearing test subjects was **26%.**
- *Search and match* in average made up **33%** of all the strategies, which were used by the deaf test subjects, while the hearing test subjects in average used *search and match* in **21%** of all used strategies.

The differences seem big. To test for significance between the groups in accordance to the use of strategies a two sample Wilcoxon test was initiated. The difference in use of *looking backward* between the two groups was clearly significant with a p-value of **0.008505**. The difference in two groups' usage of *search and match* was also clearly significant with a p-value of **0.008168**. The difference in usage of *identifying cues from title* was significant with a p-value of **0.04488**.

Test of the hypotheses

Hypothesis 1:

"There is a difference in the use of metacognitive strategies between deaf people and hearing people when reading web content on the Internet"

Is **verified** since there is a clear difference in the usage of some strategies between the two groups, since deaf subjects preferred the strategies of *search and match* and *identifying cues from the title*, whereas the hearing subjects preferred the *looking backwards* strategy.

Hypothesis 2:

"Hearing people use more metacognitive strategies than deaf people when reading web content on the Internet"

Is **falsified** since both groups in average use 5.1 strategies

Hypothesis 3:

"Deaf people use the strategy "search and match" more than hearing people when they read web content on the Internet"

Is **verified** since the deaf test subjects use the strategy of *search and match* significantly more (p-value = 0.008168) than hearing test subjects

VIII.c: Website with hard reading level

In figure 25 and 26 the strategies used by both groups of test subjects on the website with hard reading level is presented. The data used to generate these figures can be seen in attachment IV.

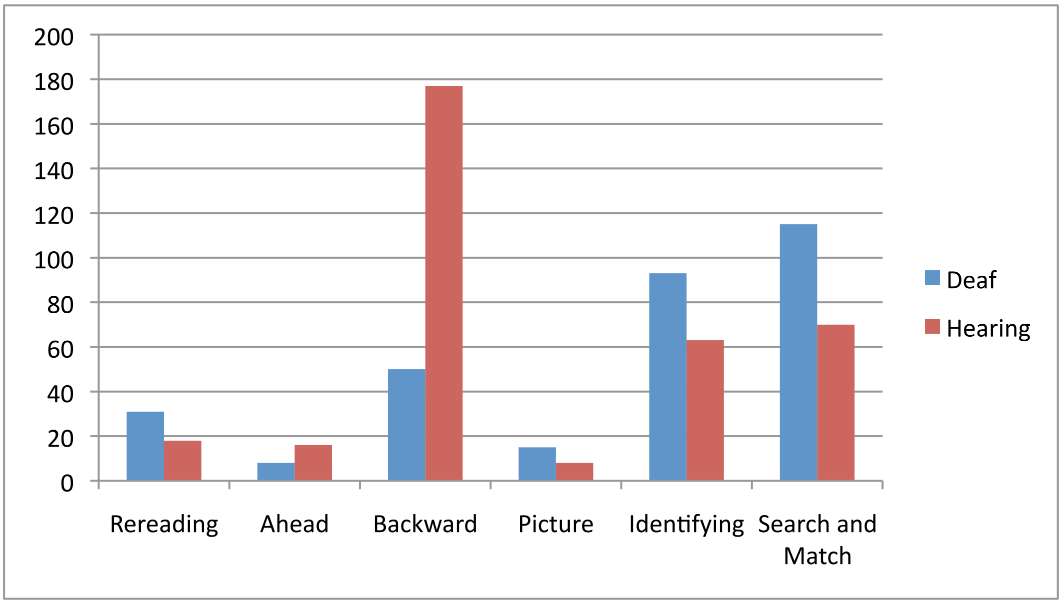


Figure 25: Overview of the strategies used in both groups in the hard task

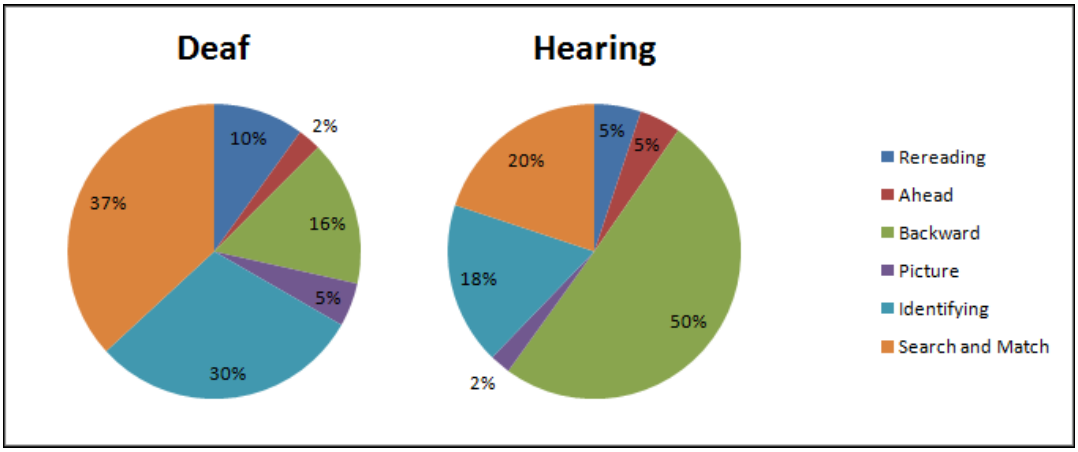


Figure 26: Overview of the distribution of the strategies in both groups in the hard task

Background knowledge and *contextual cues from the sentence* were not reported to have been used by any of the test subjects in any of the groups.
Seven out of eight deaf test subjects had the answers wrong in the question in the bottom of the website. One out of eight hearing test subjects had the answer wrong in the question in the bottom of the website.
Of the six remaining reading strategies the hearing test subjects in average used **5.1** strategies while the deaf test subjects in average used **5.3** strategies. The difference in the average use of strategy between the two groups is insignificant (p-value = **0.91**) because the usage of only one strategy is the cause of the difference.
In figure 25 and 26 it can be seen that the two groups use the strategies differently.

- The strategy of *looking backward* in average comprised up to **50%** of the strategies used by hearing test subjects, compared to **16%** with deaf test subjects.
- *Identifying cues from title* comprised **30%** of the strategies in average used by the deaf test subjects compared to **18%** with hearing test subjects.
- *Search and match* comprised **37%** of all the strategies the deaf test subjects in average used. The hearing test subjects in average used **20%** of all their used strategies on *search and match*.

There seems to be a clear difference between the used strategies in accordance to test group. A test for significance is initiated. A two sample Wilcoxon test revealed a clearly significant difference in use of *looking backward* between the two groups with a p-value of **0.001859**. The difference in use of *identifying cues from the title* was almost significant with a p-value of **0.051**. The difference of the usage of *search and match* between the two groups is clearly significant with a p-value of **0.02697**.

Test of the hypotheses

Hypothesis 1:

"There is a difference in the use of metacognitive strategies between deaf people and hearing people when reading web content on the Internet"

Is **verified** since there is a clear difference in the usage of some strategies between the two groups, since deaf subjects preferred the strategy of *search and match*, whereas the hearing subjects preferred the *looking backward* strategy.

Hypothesis 2:

"Hearing people use more metacognitive strategies than deaf people when reading web content on the Internet"

Is **falsified** since there is no significant difference (p-value = 0.008168) between the two groups in the use of strategies.

Hypothesis 3:

"Deaf people use the strategy "search and match" more than hearing people when they read web content on the Internet"

Is **verified** since the deaf test subjects use the strategy of *search and match* significantly more than hearing test subjects.

VIII.d: Summary and analysis of the results

Table 2: The results

Hypothesis 1	*There is a difference in the use of metacognitive strategies between deaf people and hearing people when reading web content on the Internet*
Hypothesis 2	*Hearing people use more metacognitive strategies than deaf people when reading web content on the Internet*
Hypothesis 3	*Deaf people use the strategy "search and match" more than hearing people when they read web content on the Internet*

Table 3: The website with easy reading difficulty

Hypothesis 1	Verified
Hypothesis 2	Falsified
Hypothesis 3	Cannot be verified or falsified

Table 4: The website with medium reading difficulty

Hypothesis 1	Verified
Hypothesis 2	Falsified
Hypothesis 3	Verified

Table 5: The website with hard reading difficulty

Hypothesis 1	Verified
Hypothesis 2	Falsified
Hypothesis 3	Verified

The results of the experiment revealed that there is a difference in the use of metacognitive comprehension strategies between the group of deaf test subjects and the group of hearing test subjects. Theory predicted that the hearing test subjects would be using more strategies than deaf people. The results showed that they used the same number of strategies, but the frequency of their usage was different. The hearing test subjects preferred the strategy *looking backwards in the text*. The deaf test subjects had two preferred strategies: *identifying cues from title* and *search and match*. In the websites with the easy and the medium reading level *identifying cues from the title* was preferred slightly over *search and match*. Both strategies being much more preferred than the other strategies. On the website with the hard reading level *search and match* was the most preferred strategy of the deaf test subjects. As the reading level rose in difficulty the more the deaf test subjects used *search and match*.

VIII.e: Analysis and Evaluation of the Results of the Experiment

Andrews and Mason found that hearing readers in average used one more reading strategy than what deaf readers did. This experiment gave a different result, namely that deaf and hearing readers used the same number of strategies but that the frequency of their usage was different. The experiment done by Andrews and Mason is not same as the experiment of this project, since two strategies were added and the test setup was different. But only looking at the strategies identified by Andrews and Mason (without the two added strategies) then the two groups still use the same number of strategies. According to theory the hearing test subjects would in average have used more strategies than the deaf test subjects.

The test subjects in this experiment reported not to use the strategies of background knowledge and identifying cues from the sentence. To have counted these two strategies it is estimated that the experiment had to be interrupted and the test subjects had to be asked in the middle of a sentence. It seems that the usage of these two strategies are forgotten, when the test subjects are asked about them.

But the missing acknowledgement of the use of these strategies when the test subjects have to report the usage themselves, gives breeding ground to ask questions about the results in the experiment made by Andrews and Mason. Andrews and Mason obtained their results by the deaf and hearing test subjects self-reporting their reading strategy usage. The results obtained in this project were more objective, since the eye tracker logged all eye movements and thereby strategy usage of the test subjects. Since the self-reports from the deaf test subjects had to be translated there could have been communication lost in translation, which were vital to the classification of a strategy. There is also the possibility that the test subjects in Andrews and Mason's experiment were not aware of all the strategies they were actually using. If the test subjects could not articulate the exact words to the mental activities they did while reading then this would not be linked to a specific reading strategy, which would result in one less strategy being identified and counted. The more artificial approach of Andrews and Mason compared to the ecological approach in this project could also explain the difference: Andrews and Mason gave the test subjects one sentence about a subject at a time, with a blank space in between the words of the sentence, which the test subject had to fill using the reading strategies. In this project the test subjects had to read a larger text, which would correspond to typical websites the test subjects interact with on the Internet. A more realistic experiment will give a more realistic result.

According to Delgardo and González the deaf test subjects would have used the strategy of *search and match* more than the hearing test subjects. The result of the experiment supports the theory in this matter. *Search and match* was indeed one of the preferred strategies of the deaf test subjects on the tested websites.

On every website the test subjects had to answer questions in the bottom of the site. This was done in order to make sure the test subjects read the content of the website. The deaf test subjects had fewer correct answers in the easy and hard reading task compared to the hearing test subjects. On the website with the medium reading level both groups of test subjects had three out of eight correct answers. The difference between the easy and hard reading task compared to the medium reading task was, that the answers in easy and hard was a choice between words in the text, while the answers in the medium reading task was a choice between different years. Looking for numbers could have made it easier for the deaf test subjects to make use of the *search and match* strategy, than if they would be looking for words, since deaf people in general are poor readers and have problems with text.

The number of test subjects in this experiment is eight in each group. A higher number of test subjects would have assured higher validity to the results. But the number of test subjects was limited to the number of people who were available for the project group. Deaf people are a minority in any society, which means that the number of potential test subjects in a city like Aalborg is limited. This unfortunately sets a natural limit on the number of test subjects who can take part in the experiment which otherwise could have strengthened the validity of the results.

The data for this experiment was obtained using an eye tracker. As with any equipment there is a certain inaccuracy in its data acquisition, which needs to be taken into account. The eye tracker used in this experiment has an inaccuracy of 0.5 degrees (see attachment II and III) in the difference between the measured eye gaze direction and the actual eye gaze direction. This gave a certain inaccuracy in the data acquisition, which typically manifested itself in that the measurements from certain test subjects were displaced about one centimetre in a certain direction. This inaccuracy was a nuisance, but it did not skew the data acquisition since the reading strategies could still be identified if this displacement was taken into consideration.

Appendix IX: Evaluation and Conclusion

IX.a: Evaluation of the results in accordance to the solution from the previous project

The goal of this project was to find the theoretical and empirical foundation for why the solution from the previous project works well with deaf people. One of the most important results from the experiment was that one of the most preferred strategies of deaf people was *search and match*. In the mentioned solution it was simulated that difficult and important words on an informal website was highlighted, to signal that they could be translated into sign language. That one of the most preferred strategies were *search and match* gives the mentioned solution an empirical foundation, since their behavior tend to be a search for central and important words in the text of a website. How the solution fits this behavior well is illustrated in figure 27.

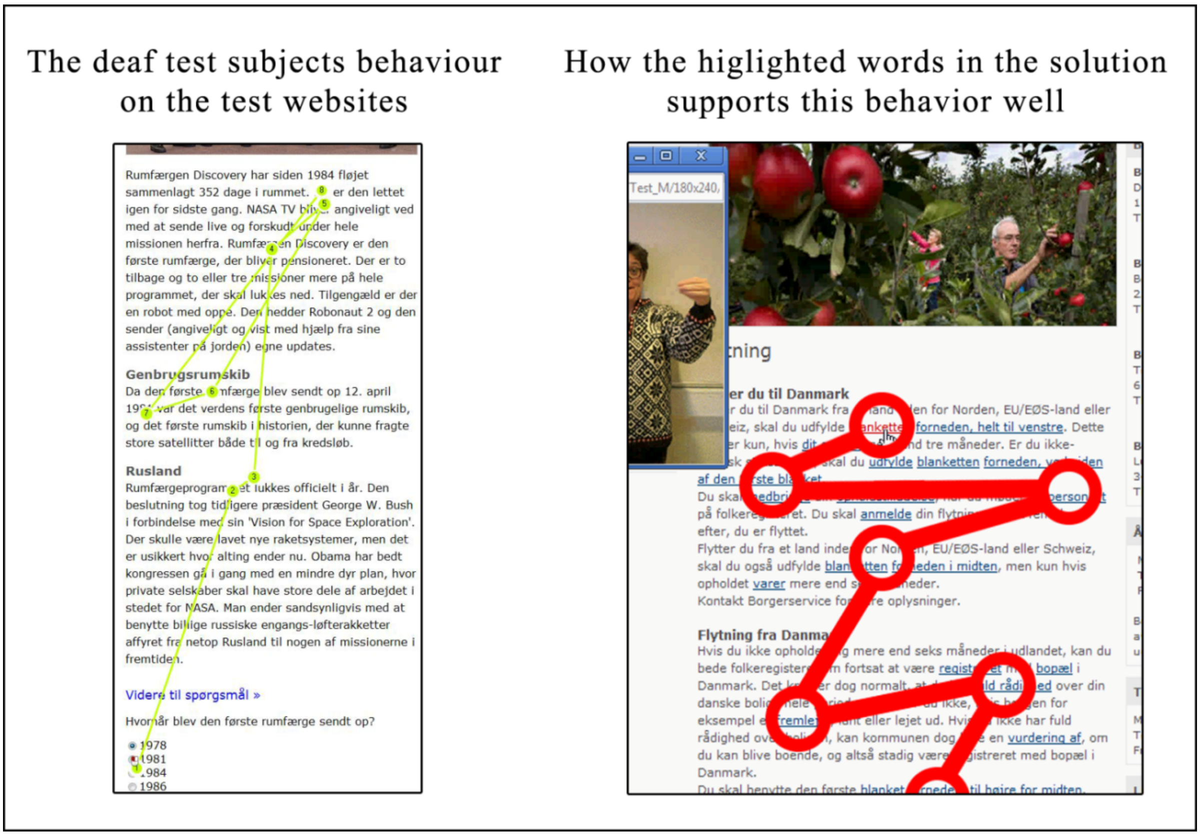


Figure 27: This figure illustrates how the search and match strategy corresponds to the use of the HTML-prototype

That the reading behavior of the deaf test subjects is supported by the mentioned solution does not give the whole picture as to why the solution works well. Firstly, the difficult words in the solution are translated into the deaf people's own language, sign language. This eliminates any problems the individual deaf person would have with understanding a word written in a language, which to certain degree is foreign to them (e.g. Danish or English). Secondly: according to Banks et al. deaf people have a tendency to remember isolated fragments of information and details of concepts more than the relation between them.

It is estimated that the empirical and theoretical foundation have been found for the why the solution from the previous project works well.

IX.b: Conclusion

This project took outset in the goal that an empirical and theoretical foundation should be found why a solution developed in a previous project worked well. The solution was a simulation of a sign language dictionary embedded in a browser as a help for deaf people on the Internet.
Through a theoretical investigation six reading strategies was derived from the works of Andrews and Mason. From Delgardo and González the Internet search strategy of *search and match* was found to be used frequently by deaf people on the Internet. The 8th strategy of *pictures* on the Internet was found via Jakob Nielsen. From these strategies the reading behavior of deaf people on the Internet could be identified.
A between subjects design experiment was initiated with a group of deaf test subjects and a control group of hearing test subjects. Both groups interacted with three fictitious websites, while their reading strategies were recorded via an eye tracker and some reading strategies were derived from asking the test subjects afterwards. The results of the experiment revealed that there was a clear difference in preferred strategy usage between the two groups. The strategy of *search and match* turned out to be one of the preferred strategies of the deaf test subjects.
This result goes hand in hand with the goal of this project. The experiment revealed that deaf people typically scan websites for words, which are central to the content of the website (e.g. *search and match*). In the solution made in the previous project it was simulated that a sign language dictionary would be embedded in a browser. The difficult and important words were highlighted in order to signal that they were important and that they could be translated into sign language with the click of a mouse button, which would bring up a translation of the word into sign language in a pop-up window. That the deaf test subjects primarily uses the *search and match* strategy on websites gives the sign language solution from the previous project an empirical and theoretical foundation, since deaf people generally look for the central words in ordinary websites. This behavior in deaf people is supported by the very design of the solution from the previous project.

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Attachments

Attachment I: Reading Levels of the Test Subjects

Deaf test subjects:

Table 6: The reading level of the deaf subjects

Test subject #	Text reading	Vocabulary test	Word reading	Overall score
1	17	15	6	38
2	9	13	4	26
3	10	15	6	31
4	14	13	11	39
5	12	11	7	30
6	NA*	NA	NA	NA
7	11	9	6	26
8	9	15	6	30

* The exact reading level of deaf test subject number six was not known, since he had not been tested. But according to his teacher he had a poor reading level. [Schmidt, 2010]

Table 7: The definition of the scores in the reading test taken by the deaf subjects

Overall score	Reading level
Below 36	Poor reading level
Between 36 and 44	Insufficient reading level
Above 45	Good reading level

Control group of hearing test subjects:

Table 8: The reading level of the hearing subjects

Test subject #	Text reading	Vocabulary test	Word reading	Overall score
1	22	27	24	73
2	22	34	21	77
3	38	28	28	94
4	35	32	29	96

5	24	33	36	93
6	26	18	26	70
7	29	30	17	76
8	27	29	25	81

Table 9: The definition of the scores in the reading test taken by the hearing subjects

Test	Score	Level
Text reading	0 – 30	Insufficient
Text reading	31 – 41	Sufficient
Vocabulary test	0 – 15	Insufficient
Vocabulary test	16 – 37	Sufficient
Word reading	0 – 10	Insufficient
Word reading	11 – 38	Sufficient

In accordance to the Danish ministry of education a person is estimated to be a good reader if he or she receives the level of “Sufficient” (corresponding to an A in these types of reading tests) in at least two out of the three tests [Undervisningsministeriet, 2008]. All of the hearing test subjects, which participated in the experiment had a score which ranked them as good readers.

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Attachment II: Description of Eye Tracking

The Tobii x120 eye tracker used in this project uses infrared light to detect the gaze direction of the test subjects in accordance to the screen. This is done by mounting an array of infrared light diodes around two infrared cameras in the eye tracker. The infrared light saturates the face of the test subject. The eyes reflect most of the infrared light. The skin absorbs most infrared light it is exposed to. The use of infrared light also has the advantage that it does not irritate or distract the test person during an experiment, as visible light would do. [Tobii a, 2011] [Penzo, 2005]

Figure 28: The eye tracker

The reflected infrared light from the eyes is easily designable from the background via the infrared cameras, due to its high level of brightness in contrast to the low level of brightness in the rest of the test subject's face. Changes in the reflection of the infrared light are detected by the infrared cameras. This is then converted by powerful algorithms in the eye tracker software to the end product: the position of a person's gaze on the computer screen. [Tobii a, 2011] [Penzo, 2005]

The main data, which the eye tracker collects, are fixations. A fixation happens when the eye is relative still for a certain amount of milliseconds on a certain point, such as pictures and text. The output data can come in two forms, if the areas on the screen are designated as Areas Of Interest: fixation length and fixation count. Fixation length is the length of all the fixations measured in the designated area. Fixation count is the number of fixations counted in the designated area. [Tobii a, 2011] [Penzo, 2005]

There are certain parameters and nuisance variables, which need to be taken into account when using an eye tracker for data acquisition. Since the test subject can freely move his or her head then there can arise certain situations where the eye tracker will and cannot track the gaze. If the test person looks away from the infrared light emitted against the subject then the eye tracker can lose track of the subject's eyes and valuable data can be lost. These nuisance variables can be overcome by proper and precise instructions to test subjects and the correct calibration of the eye tracker.

Attachment III: Datasheet of The Tobii x120 Eye Tracker

Table 10: The specifications of the Tobii x120 eye tracker [Tobii b] [Tobii c]

Tobii Model:	X120
Data Rate:	60 or 120 Hz
Accuracy:	Typical 0.5 degrees
Drift:	Typical 0.1 degrees
Spatial resolution:	Typical 0.3 degrees
Head movement error:	Typical 0.2 degrees
Head movement box:	30 x 22 cm at 70 cm
Tracking distance:	50 - 80 cm
Max gaze angles:	35 degrees
Top head-motion speed:	25 cm/ second
Latency:	Maximum 33 ms
Blink tracking recovery:	Maximum 8 ms
Time to tracking recovery:	Typical 3 ms
Weight (excluding case):	Ca. 3 kg
Eye tracking technique:	Both right and dark pupil tracking
Eye tracking server	Embedded
Connectors	LAN, power

Specification of technical terms

- **Data rate:** Number of sampled gaze points per second. The TobiiT/X series Eye Trackers have a stable data-rate of 60 Hz or 120 Hz; that is 60 or 120 gaze data points per second are collected for each eye. [Tobii b, 2011]
- **Accuracy:** The typical difference between the Measured Gaze Direction and the Actual Gaze Direction at different parts of the screen for a person positioned at the centre of the eye tracking box. This does not include drift effects and compensation errors from larger head movements. The accuracy of the Tobii eye trackers varies depending on external conditions such as lighting, quality of the calibrations, and individual eye characteristics. [Tobii b, 2011]

- **Drift:** Change in accuracy due to change in lighting. The specified value relates to complete inversion of screen color, e.g from black to white without recalibration in between. [Tobii b, 2011]
- **Spatial resolution:** The term “spatial resolution”, or “noise”, denotes the frame-to-frame variation of the measured gaze point. [Tobii b, 2011]
- **Head movement error:** Decrease of accuracy at the edges of the eye-tracking box as compared to the centre where the calibration was done. This includes head translations sideways as well as movement back and forth and up and down. The value is an average of the two types of translations. [Tobii b, 2011]
- **Head movement box:** Measures the box (height x width in cm) where at least one of the eyes is within the field of view of the eye tracker (the present value was measured at 70 cm distance from the sensor). [Tobii b, 2011]
- **Tracking distance:** The distances to the sensor within which the eye tracker is able to detect at least one of the eyes. [Tobii b, 2011]
- **Max gaze angles:** Maximum gaze angle that the eye tracker can detect at least one pupil. The angle is calculated from the centre of the sensor. [Tobii b, 2011]
- **Top head-motion speed:** The maximum speed that a user can move the head at which the eye tracker is able to still find at least one pupil. [Tobii b, 2011]
- **Latency:** Is calculated from the time when an image was shot to when a valid gaze point is delivered to an eye tracking application there is a certain delay. This delay is caused both by sensor hardware and by the computation of the eye tracking software algorithms. Since the timestamp is set at exposure, such delay does not affect the accuracy of the timestamp. [Tobii b, 2011]
- **Blink tracking recovery:** Blinking is the involuntary act of shutting and opening the eyelids. During each blink the eyelid blocks the pupil and cornea from the illuminator resulting in missing eye position data points. This measure represents the typical time the eye tracker takes to resume tracking when the eyelids are open again. During an eye blink tracking recovery is almost instantaneous. [Tobii b, 2011]
- **Time to tracking recovery:** An eye tracker working in a natural user environment may occasionally lose track of the eyes of the user, for example, when the user completely turns away from the tracker. This measure represents the typical time from complete tracking failure to when the eye tracker finds the eyes again. [Tobii b, 2011]
- **Eye tracking technique:** The Tobii Eye Trackers use two different techniques to determine eye position: 1. Bright pupil eye tracking, where an illuminator is placed close to the optical axis of the imaging device, and causes the pupil to appear lit up (this is the same phenomenon that causes red eyes in photos). And 2. Dark pupil eye tracking where the illuminator is placed away from the optical axis causing the pupil to appear black. [Tobii b, 2011]
- **Eye tracking server:** Gaze data calculations are performed by firmware embedded in the eye tracker. Different applications can be connected as clients to the eye tracker system over a LAN connector to gather eye gaze data and other data in real-time and to perform calibrations and other actions. [Tobii b, 2011]

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Attachment IV: Declaration of Consent

Produkt- og design psykologi, gruppe 1076
Dato: XX.XX.XXXX

Jeg bekræfter hermed som testperson, at:

- Jeg har forstået den givne information vedrørende forsøget og indvilliger i at medvirke i forsøget.
- Jeg har forstået, at jeg har ret til at forlade forsøget på et hvert givent tidspunkt, uden yderligere forklaring.
- Jeg er indforstået med, at mine læsefærdigheder bliver testet og vil blive brugt anonymt i forbindelse med datahandling.
- Renskrevne citater og observationer fra forsøget og svar på stillede spørgsmål må blive brugt anonymt i den efterfølgende artikel.
- Jeg giver tilladelse til, at renskrevne citater, observationer samt eventuelle billeder taget fra forsøgsopstillingen og spørgsmålene må videregives til vejleder og censorer i forbindelse med projekteksamen og anvendes hertil. Ydermere at denne information må videregives til tredjepart efter skriftlig tilladelse fra forsøgslederen.

Dit navn vil blive hemmeligholdt overfor både offentligheden og Aalborg Universitet.

Testpersonen navn: ____

Underskrift: ____

Forsøgsleders navn: ____

Underskrift: ____

Attachment V: Datasheets

Table 11: Assembled data for all test subjects in the easy task

sub	re	ahead	back	pic	ident	search	niv	type	age	answer
d1	5	0	8	10	24	18	b	d	30	w
d2	4	0	3	4	20	20	c	d	52	w
d3	7	0	6	8	35	25	c	d	42	w
d4	7	0	4	4	14	14	b	d	37	w
d5	1	0	1	7	12	7	c	d	33	w
d6	3	0	8	2	11	9	c	d	31	w
d7	1	0	9	7	15	14	c	d	29	w
d8	1	0	0	5	9	9	c	d	38	w
h1	3	0	20	2	12	10	a	h	25	r
h2	4	0	13	4	13	15	a	h	61	w
h3	4	0	9	2	11	8	a	h	26	r
h4	3	0	14	3	12	10	a	h	21	r
h5	3	0	29	6	9	15	a	h	31	r
h6	1	0	10	0	6	9	a	h	27	r
h7	1	0	10	3	9	7	a	h	29	r
h8	6	0	19	2	13	15	a	h	27	r

Table 12: Assembled data for all the test subjects in the medium task

sub	re	ahead	back	pic	ident	search	niv	type	age	answer
d1	3	0	6	7	23	16	b	d	30	w
d2	5	0	8	5	11	13	c	d	52	w
d3	2	1	5	4	15	13	c	d	42	r
d4	1	2	11	4	20	16	b	d	37	r
d5	1	0	0	3	12	9	c	d	33	r
d6	2	3	6	4	11	13	c	d	31	w
d7	1	0	3	4	15	10	c	d	29	r
d8	0	0	3	11	25	28	c	d	38	r
h1	0	0	16	1	8	8	a	h	25	w
h2	0	2	19	4	23	9	a	h	61	r
h3	0	2	7	4	11	5	a	h	26	r
h4	4	1	15	3	6	8	a	h	21	w
h5	3	0	25	5	16	16	a	h	31	w
h6	0	0	18	2	4	4	a	h	27	r
h7	3	2	5	5	7	6	a	h	29	r
h8	1	3	12	1	6	7	a	h	27	r

Table 13: Assembled data for the test subject in the hard task

sub	re	ahead	back	pic	ident	search	niv	type	age	answer
d1	5	0	9	3	11	19	b	d	30	w
d2	7	0	5	3	17	16	c	d	52	r
d3	11	5	17	1	9	12	c	d	42	w
d4	2	2	8	1	8	9	b	d	37	w
d5	0	0	1	1	9	18	c	d	33	w
d6	3	1	8	1	8	15	c	d	31	w
d7	2	0	1	3	15	8	c	d	29	w
d8	1	0	1	2	16	18	c	d	38	w
h1	3	4	18	1	6	9	a	h	25	r
h2	2	4	28	0	7	15	a	h	61	r
h3	4	4	10	3	20	2	a	h	26	r
h4	1	2	19	1	5	6	a	h	21	w
h5	3	0	35	0	5	10	a	h	31	r
h6	1	0	19	0	2	8	a	h	27	r
h7	0	0	12	2	5	7	a	h	29	r
h8	4	2	36	1	13	13	a	h	27	r

Attachment VI: The Written presentation to the Deaf Test Subjects

Dine læsestrategier bliver testet.

Du skal læse noget tekst på nogle hjemmesider.

Efter hver side skal du svare på nogle spørgsmål.

Dette sker tre gange.