Design of Cognitively Accessible Web Pages

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***Abstract*—Considering the design of universally designed interfaces for static and dynamic web pages, this work focuses on the group of users with cognitive/intellectual disabilities, while simultaneously accounting for the needs of users with motor and sensory deficits. A number of specific inclusive techniques are applied to the login mechanism of a web service in the course of the redesign of this site. The techniques evolve, i.e. are tested, validated, and refined, over a series of implementation iterations and subsequent evaluation, involving personas and scenario testing, an expert panel, and user testing. The testing shows that the web service's resulting login mechanism is much more universally accessible than today's solution. Generically applyable, universal design principles are derived for a number of intellectual deficits, such as problems with linguistics (text and language), learning and problem solving, orientation, focus and attention span, memory, and visual comprehension.**

Keywords-Cognitive disabilities; intellectual deficits; impairment; deficiencies; accessibility; e-inclusion; universal design; user experience; web pages.

I. Introduction

Accessible web sites and online services is a topic of high concern for industry, public actors, and research likewise. However, people with sensory deficits are typically in focus here, while motor and cognitive impairments often are given less attention. This article concentrates on the latter, sometimes also referred to as intellectual deficiencies, extending the work presented in [1].

There is a strong rationale to address the topic of cognitively accessible web pages. In 2006, roughly 22 million people in the United States were counted to have cognitive disabilities due to various reasons [2], while world-wide estimates for 2008 range as high as 400 million people [3]. These numbers include the intellectual challenges typically encountered by a number of elderly people with various degrees of severity.

The starting point for the project described in this article was a case provided by the Norwegian public services provider Altinn [4], involving a redesign of their site [5]. One of the requirements for the new design and the new functionality was to accommodate for people with cognitive challenges. A detailed survey of all requests to Altinn's help desk had revealed that 33% of the users had problems with the login process [6], and the service provider considered it a strategic goal to reduce the number of help requests by developing a new page design and an improved service architecture.

The paper is organized as follows. After an introduction to relevant cognitive impairments (Section II), a brief review (Section III) of related and previous work summarizes other research, points at gaps to fill, and names this work's contributions towards these goals. Next, the status quo of the current solution is detailed (Section IV) before the development method is explained (Section V). This is followed by the listing of generic design principles with a subsection for each considered cognitive impairment (Section VI). This also includes a discussion of the benefits for other user groups as well (Section VII). After that, the prototype is presented (Section VIII), with a special section on instruction videos (Section IX). Finally, there is a general discussion regarding the consequences of this work's findings (Section X) before the final conclusion is drawn.

II. Cognitive impairments

Cognitive impairments can be defined as "(the) substantial limitation of one's capability to think, including conceptualizing, planning, sequencing thoughts and action, remembering, interpreting subtle social cues, and manipulating numbers and symbols" [2] and can appear at any age. Causes for these impairments include prenatal fatal influences, injuries, and mental illnesses. Basically, a person with cognitive challenges has over-the-average difficulty succeeding with one or more types of mental tasks.

There are several ways to classify cognitive disabilities. In the context of this research it seems appropriate to distinguish between a clinical-diagnostic and a functional approach. Clinical diagnoses of cognitive disabilities include

- autism,
- Down Syndrome,
- traumatic brain injury (TBI),
- dementia,
- dyslexia,
- dyscalculi, and
- learning difficulties in general [7].

Clinical diagnoses are of course helpful and necessary from a medical perspective, but for the purpose of accessibility, classifying cognitive disabilities by functional disability is more useful. Functional disabilities ignore the medial and behavioral causes of the disability and instead focus on the resulting abilities and challenges [7], [8]. It is also worth mentioning that, naturally, any impairment can have various degrees of severity, ranging from mild variants to extreme cases. This vast range makes the universal design of web pages very challenging, and it is obvious that even the most cautious design cannot cope with all variants of impairments that exist.

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By looking at the aforementioned survey, areas of difficulty with the previous solution could be identified. E.g., 27% of the calls to Altinn's help desk were related to finding the right service, and 33% of all users had problems with the login routine [6]. The close inspection of data also allowed to classify user groups according to a particular deficit. For instance, the cognitive requirement needed to find the proper service is the ability to orientate in a website.

The following listing of impairments was identified as relevant to represent the target group of users with cognitive deficits.

- Linguistic (text and language)
- Learning and problem solving
- Orientation
- Focus and attention span
- Memory
- Visual comprehension

One of the most important objectives of the project was to derive a number of principles for good web design concerning these given target groups. This process started with a review of related work.

III. Previous and related work, and this article's contributions

Works related to the topic of this project include an early version of this paper which has been presented previously with preliminary results [1].

In the design guidelines for web design for impaired users, i.e., without a specific focus on the cognitively disabled, [9] give a large number of detailed design instructions. [10] derive a set of cognitive user characteristics based on neuroscience; however, the work lacks concrete design suggestions. While the [11] provides an exhaustive and detailed listing with concrete design principles, it remains unclear how these are justified with regard to the particular cognitive impairments considered. The same applies to the work by [12], even though this work is not equally detailed. Next, [13] presents a great number of design suggestion with a considerable amount of detail, and [7] lists a set of concrete design guidelines in a tabular format and marks them as "applies to" with regard to four major areas of cognitive challenge. On the downside, both documents lack the justification for why particular guidelines are derived. [14], [15] discuss cognitive accessibility with regard to concrete examples and list some derived practical design suggestions. The listings appear to be far from complete, though. And last but not least, parts of the WCAG 1.0 [16] and 2.0 [17] specifications cover measures for cognitive impairments, but only to a limited degree [18], [11], [14].

In contrast to the aforementioned research, the contribution of the present work is to derive generic design principles/guidelines for people with cognitive deficits from concrete examples, and by means of testing and user studies. Moreover, each guideline is associated and hence classified with regard to a specific impairment. Also, in contrast to the cited works, the focus here includes orientation problems as well, as they seem to be very common (27%) with the given (Altinn) case.

IV. Current solution

Figure 1 shows a screenshot of the current login solution at the time of writing, which was the starting point for the development of the inclusive design. It illustrates several problematic areas, including those discussed below.

1) The grayed-out area on top shows inaccessible functionality, is irrelevant in the given setting, and does thus not help users to focus on the login process below in a satisfactory manner.
2) The user has to choose the preferred login method out of a list of options on the middle left, such as password, PIN code from mobile phone, and smart-card. There may be too many list items to read for users with reading deficits.
3) The little icon, which is placed after each list item, and which symbolizes the security level of each login method, is likely to confuse non-technical users and those with problem solving challenges. It may further be problematic for individuals with visual comprehension deficits.
4) The main login part on the middle right of the page consists of the fields for user input such as social security number and password, and changes according to the choice of login method on the left. The resulting two-column layout of the page may be too complex to understand for users with focus problems, and it might also be problematic to those with attention span challenges.

Also the screenshot of the "My page" shown in Figure 2, at which the user arrives after the login procedure, shows a page with a number of issues, including the following.

1) The page structure is rather complex and not easily comprehensible. It is not straight forward to understand why a particular piece of content is relevant for the user to reach her goals, and how this content relates to other content on the page. This is likely to confuse particularly users with orientation problems and learning difficulties.
2) There is too much information to process, and there is a lot to read for the user to understand the page structure. This might be problematic especially concerning people with dyslexia.

By way of conclusion, it appears the technical possibilities are in the center of today's solution. Content is grayed out because it is a "cool" design effect, too many login methods are presented because — among other reasons — they are technically possible, the security level is shown, even though it is only of interest to the minority of users, and parts of the page are dynamically altered because it is technically possible to embed all parts of one task in the same page. What is needed is a solution which puts the human and his and her needs into the center.

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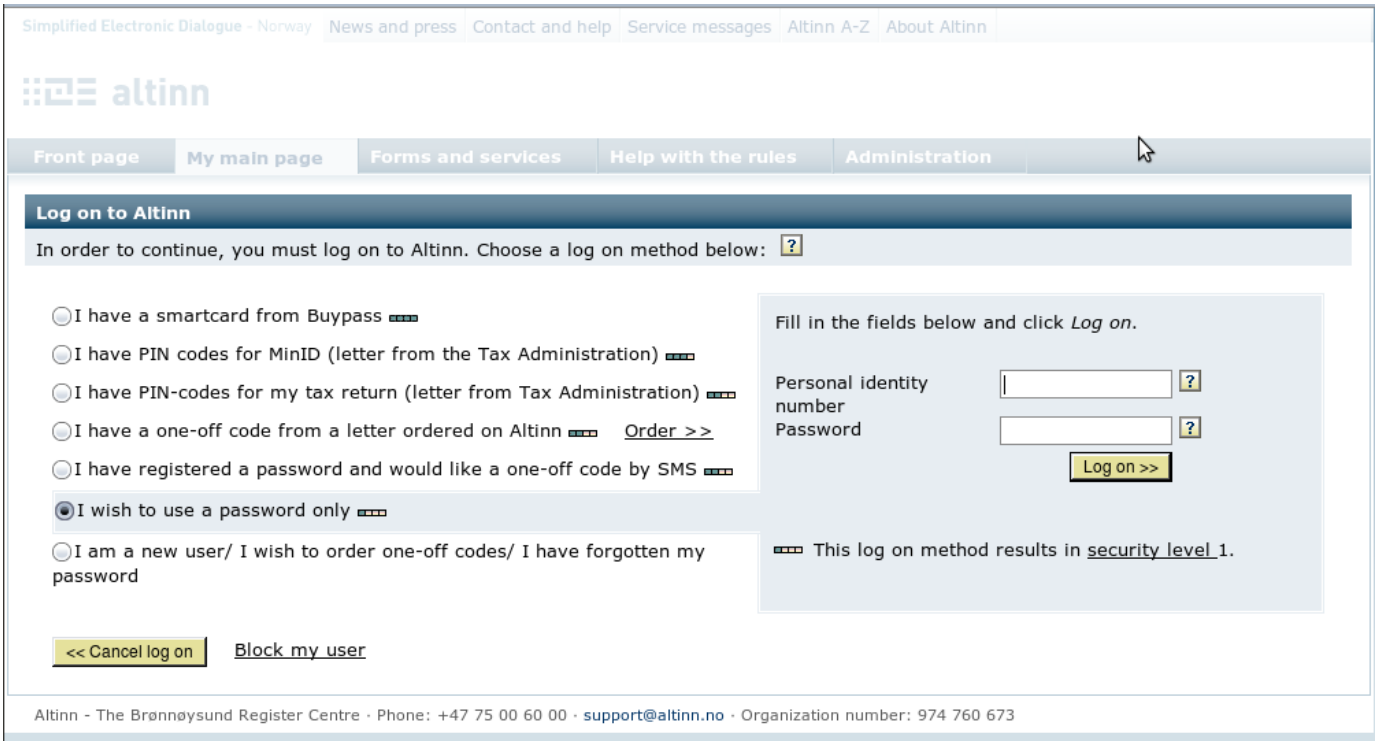

Figure 1. Screenshot of the current login solution

V. Methodology

Among the objectives of the project were to build a prototype for a new login solution with improved design and functionality as compared to the current solution as specified in Section IV. Another goal was to derive generic guidelines concerning the design of web pages with regard to people with intellectual impairments. It is simultaneously stressed that the developed solution also accounts for the needs of individuals with mobility and sensory deficits, as the user interface meets the requirements of the WCAG 2.0 Recommendation Level AA.

The design guidelines were formulated as hypotheses, implemented in the prototype, and tested for verification. The guidelines are naturally influenced by the results of user testing in other previous projects of our research team. The implementation was refined in several iterative cycles to reflect the feed-back from each evaluation phase.

There were multiple types of evaluation: First, different persona profiles helped to speed up the implementation and testing in the beginning of the development process. The fictive characters, six in total, were given appropriate properties to cover the spectrum of impairments of the target groups, such as “has concentration difficulties”, “poor memorizing abilities”, etc. They were associated with scenarios, allowing simple and cheap cognitive walk-throughs by means of role plays and methods like “thinking aloud”.

Second, when the prototype had reached a certain degree of maturity, the evaluation was conducted by a panel consisting of experts in accessibility, e-inclusion, and universal design. The experts were presented walk-throughs while discussing all aspects of the implementation and were able to provide the latest feed-back from their research areas.

Third, while getting close to the prototype’s completion, a minor user study with eight users representing the cognitive target groups was carried out. The users had various cognitive challenges, such as minor dementia, reading and writing difficulties, focus problems, etc. The number of users was bound by budget limitations. We believe, however, that viewed as a complement to the personas and expert evaluation, the size of the user study is reasonable.

Finally, all design recommendations were collected in an online best-practices tutorial [19]. As the financing institutions of the projects limited the target to the Norwegian market, the tutorial currently comes in Norwegian only, but an English translation is planned in the long-term. Besides topics addressing

- universal design,
- legal matters,
- cognition,
- on system planning, specification, implementation, and evaluation,
- related recommendations, specifications, standards, and standardization organizations,
- useful links and tools,
- glossary, and
- literature

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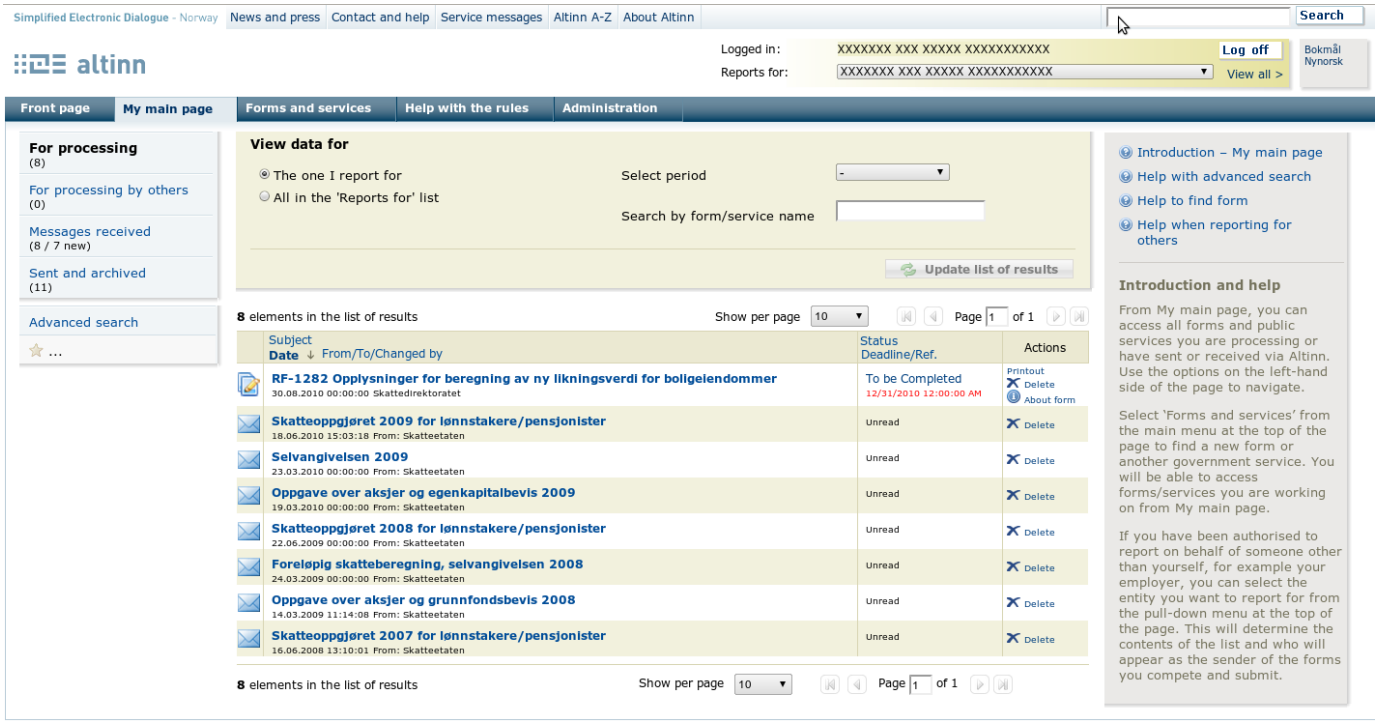

Figure 2. Screenshot of Altinn's "My page" (partly in Norwegian)

the tutorial also lists the design guidelines with practical examples in Hyper-Text Markup Language (HTML), Cascading Style Sheets (CSS) and JavaScript.

VI. Design Recommendations

The following sections detail the identified design principles or guidelines. They are meant as recommendations and "best practice". Neither of the principles below are listed in any specific order. It is noted that a design measure for a particular functional area may be in conflict with measures from different functional areas, and it therefore happens in some cases that opposite measures for different functional areas have to be balanced against each other.

A. Text and language

Linguistic problems are difficulties with writing and in particular reading larger amounts of text. A dyslectic may represent this user group. There are no recent statistics, but numbers for Norway from 2005 indicate that approximately 1/3 of the population have moderate to serious reading and writing challenges [20], while other sources talk about 15-20% of the population [21].

The following non-exclusive listing of design principles accommodates linguistic problems.

- Short paragraphs with a reasonable amount of text
- Text in columns with a limited number of characters per line. Concurrent research is yet inconclusive concerning the optimum line length for highest comprehension [22], but we believe that 60–100 characters is a reasonable number.
- Short and concise sentences
- Avoidance of non-literal text, such as allegories, metaphors, slang, and colloquialism
- Avoidance of technical expressions and expert talk
- As few abbreviations and acronyms as possible, and all with proper explanation
- Use of short or non-compound words in languages were single words can be assembled to longer words (such as Norwegian and German)
- Enhancement of semantics by high-quality multimodal content, e.g., symbols/icons, graphics/images, audio, video (depending on the context)
- Textual content structured in short and easily comprehensive logical units like paragraphs and lists, preferably with a heading in advance. Units easily separable from the remaining content
- Choice among several languages for both international and national sites
- Sufficiently long display of subtitles or help text in video to enable slow readers to capture everything. It is of advantage if the user can pause play-back, repeat a timed media sequence, or alter the play-back velocity.

B. Learning and problem solving & orientation

Some individuals lack the mental flexibility to process information and to apply knowledge in order to solve a given problem. Combined with a low mental endurance, this

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typically results in frustration and a user turning away from the task set out. After all, the vast majority of users seeks to get things done with the least possible effort [23] and thus expect things simply to work [24]. Many tasks which have to be solved, such as login, are viewed only as an impediment before the main objective beyond (for instance, filling out an electronic tax statement form) can be accomplished.

Orientation difficulties are part of this class of problems. To cope with these challenges, the design principles listed below should be followed.

- Standard compliant, working solutions, tested thoroughly and on a number of different platforms and user agents (e.g., browsers) to ensure compatibility
- Choice among several alternatives, such as login methods, to solve a task so that a user can pick the one she is most familiar with. However, the number of alternatives should be kept low, depending on the context.
- Multiple modalities for conveyance of content, and possibility to let the user decide upon the preferred modality. An example is to accompany an instruction video by showing a series of key frames from that video with textual description conveying the same message
- Show only content relevant in a given setting to ease orientation
- Common design conventions to make processes predictable, such as hovering effects for responsive user interfaces, known technologies like drop-downs to compact item listings, and for instance a top-bottom left-right ordering of information in terms of relevance for users with a Western background
- Consistent layout and functionality, to give a "learned once, apply everywhere" effect
- Information about the process, like "what" (description), "why" (reason) and "how" (clear instructions), as well as informative error messages and showing potential solutions to problems aim at supporting the process of solving a particular task
- Provision of not only links to help and contact information but also expert systems and demonstrations to make the user's threshold to seek help low enough, and to enable them to help themselves
- Help and demonstration as specific as possible
- Content in logical units which are easily distinguishable from each other
- Information about where in the hierarchy a user currently is, the so-called bread crumb trail
- Responsive user interface, with hints for content and functionality, such as so-called tooltips or other hovering effects on buttons, links, and other page elements, continuation dots for listing extracts, dynamic mouse pointer form depending on the underlying content, prefilled text input fields, etc.
- Classification of large amounts of data with regard to several criteria, with pointers for each classification, to let the user make the preferred mental connection
- Personalized content and functionality in terms of user profiles and sessions, which is essential for functionality like the user's "most used services", "services used last time", and "self-chosen services", as well as state of visit, in terms of data like recognized user name and date and time of last visit
- Ability to search the entire site in an intelligent manner in order to quickly find exactly the information or resource the user has been looking for, for those who prefer to search rather than to navigate
- A 2-step method concerning the user's approach to large quanta of information is often helpful, where a simplified view should be the default option, from which a link to the high-level, i.e., complex, view should be provided
- A personalized "latest news" section, giving service status information, and an update on changes since the last visit and on current important issues
- Avoidance of lengthy scrolling, rather provision of links to additional content
- Links leading to content on the same site should be opened in the same window/tab as the current page. The user should be informed before opening new windows or tabs with content on external sites

C. Focus and attention span

Attention span refers to the ability to focus on what is important at a particular point in time, and to be able to keep that focus during a longer time period. Similar aspects are one's concentration ability and distractibility.

The design principles identified to accommodate attention span deficits include the following items.

- Only content relevant in a given context, in particular no display of grayed out, irrelevant content
- Use of static page elements, and avoidance of flashing and scrolling elements
- Visual cues to draw the user's attention, such as highlighting the active input field
- Larger processes split up into smaller logical chunks, each of which can be solved with a low attention span
- Consistent layout and page structure in order not to distract the user
- Modifications of the page after it has finished loading not too far away from the center of the page to gain the user's attention
- Avoidance of long durations of timed media, such as an audio clip or a video

D. Memory

Memory difficulties in general denotes the user's ability to recall what has been learned over time. Any memorizing type can be affected, such as working memory, and short-term and long-term memory. Important design principles accounting for these challenges are listed subsequently.

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- Larger processes split up into several logical units/tasks, each of which as brief and simple as possible, according to the Divide-and-Conquer principle
- Reminders concerning the overall context (e.g., "You want to fill out a tax form"), and explanation of the particular context ("Therefore you have to login")
- Information about the progress for a particular task, possibly giving it a title as well ("Step 1 of 2: Login method"), and proper instructions for what has currently to be done, ("Choose how to login") and what the requirements are ("You will need ...")
- Easy navigation within the process in order to give the user the possibility to go to arbitrary parts of it and to acquire information herself, for example by means of navigation buttons, tabs, or a breadcrumb trail
- Sufficiently short play-back of timed media, depending on the content

E. Visual comprehension

Some cognitive impairments cause difficulties in processing visual information. This demands for the following non-exclusive list of design principles.

- Use of several modalities to convey a particular message, leaving it to the user to choose the form that best fits her needs. Typical examples of modality sets are {text, still image/graphic} and {text, audio/voice}
- Complementing of still images with offering animations or video, and vice versa, i.e., offering the modality sets {text, graphic, image animation} and {text, still image, slide show, video}
- Voice accompanying a video for improved understanding ability, as voice accompanying the visuals in a video decreases the time needed for understanding
- Presentation of video content (and accompanying voice) in a sufficiently calm manner to give users the time to process the information given
- Screencasts showing a small region of interest instead of the entire screen to allow users to differentiate between the video and the actual page

For a discussion of instructions videos, it is referred to Section IX.

VII. Benefits for other user groups

Despite the fact that measures for different intellectual deficits sometimes have to be balanced against each other, in general not only a particular target group benefits from certain design principles but rather the vast majority of users.

For instance, the set of design principles for an individual with visual impairments greatly overlaps with the sets for those with language and text difficulties and for those with visual comprehension deficiencies. Next, the group of computer novices shares a considerable number of design measures with users known to have learning and problem solving deficits. Computer novices are likely to have a limited amount of web skills for problem solving and at the same time are untrained regarding the specific problem. This leads to situations where a user is overwhelmed by the technological challenge and therefore lacks the ability to keep the overview, and to focus on what is important in the process.

Tired users typically lack the ability to concentrate over longer periods of time, so they can be categorized as having attention span impairments. Another example is elderly people who sometimes suffer from loss of short-term memory and may have poor concentration skills. This is a compound functional problem consisting of memory and attention span deficits. Finally, even expert users and people with good web skills may be facing challenges when they — being in a new situation — are untrained for a particular task.

To sum up, the majority of design principles for a user group with intellectual impairments helps other user groups as well, and they often are useful for almost any user. This result is consistent with other recent research [25]. After all, a user's cognitive abilities vary over time and typically depend on a particular situation. For instance, consider the situation of a car driver who must not let the eyes off the traffic. Any text message must thus be read out loud to him, which corresponds to the impairment blindness.

VIII. Prototype

The final login prototype comprises a number of pages, including pages covering various login methods, a new portal page, a personalized "My Page", and a page demonstrating screencast technology. A screenshot of the first step during the login process is shown in Figure 3.

All pages and all page elements were checked (manually) throughout the design process against all parts of the design guidelines to ensure the inclusive result. And as already mentioned, there were several iterative cycles in which the requirements specification and consequently the page design were improved by the feedback from the evaluation phases.

It can be seen that all points of criticism, as expressed in Section IV, have been addressed.

1) Only relevant content is shown.
2) The list of options has to been cut down from 7 options to 4, while the remaining alternatives are "hidden" in a drop-down element
3) The security icon has been removed entirely; instead, a link to more exhaustive security information is provided (in the right-hand "assistance" box). Also, the status bar (on top of the page) displays security information, such as 'insecure connection'
4) The login process has been split up into 2 steps/pages (of which only the first is shown in Figure 3); one where the login method has to be chosen, and another one with the main login part (which depends on the choice in step 1)

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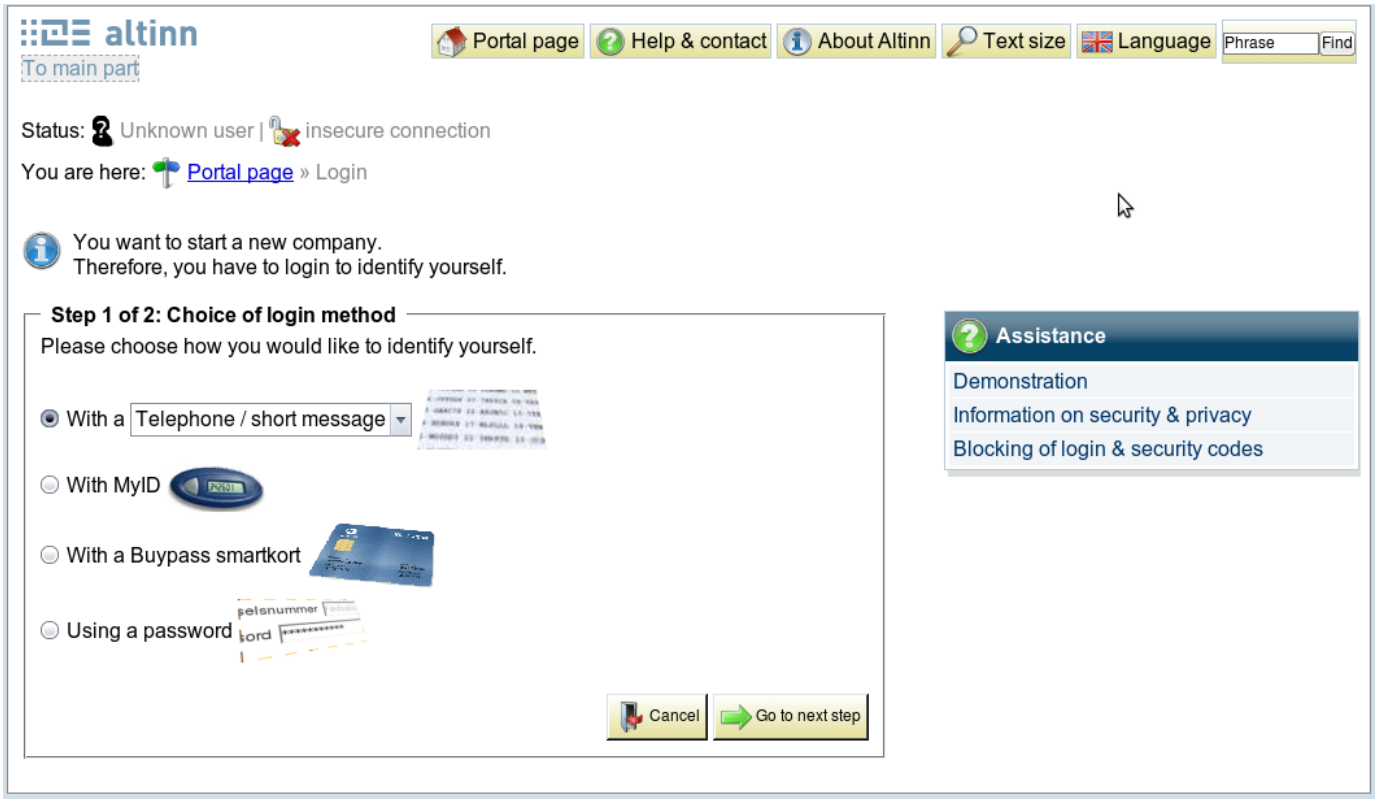

Figure 3. Screenshot of the prototype's first step out of two of the login process

The example illustrates also a number of other design principles as well, such as the use of symbols/icons for fast comprehension, buttons for quick navigation, easily separable blocks of content, etc. User with orientation difficulties in addition to low vision will benefit from a fluid/flexible page layout where the page elements stay approximately in place compared to each other when zooming into the page, i.e., when increasing font and image dimensions. This is also an advantage when the user has a screen with only small dimensions available. Figure 4 shows a combination of both implications.

The prototype also includes a user-specific personalized page which matches the "My page" of today's solution as mentioned in Section IV. A screenshot of this page is given in Figure 5. In the prototype, we have addressed all issues encountered previously, including the following.

1) Now there is a "clean" and simple page structure with blocks of content which are easily distinguishable.
2) All content irrelevant in the given context has been removed. Each content block is summarized by a concise title. Icons are additionally used to convey the meaning of associated text.

IX. Instruction Videos

During the building of the prototype, there was a high focus on multimodality to improve user interface and experience of the old solution. This involved in particular the use of instruction videos or so-called screencasts, where an example user shows and tells how to solve certain problems, e.g., the task of logging in, by means of screen and voice recordings. Various versions of screencasts were tested in several development cycles with hearing impaired / deaf and in particular elderly individuals in a subproject [26], and the design principles found regarding cognitive deficits are the following.

- Subtitles and boxes with help texts not to far off the screen's middle to catch the user's attention, and easily distinguishable from the video content
- Marker / colored area around the cursor to draw the user's focus
- Particular regions of interest marked with for instance red color
- The page with the screencast opening in the same tab/window, and links for navigating back from the screencasts

A number of other principles, e.g., "textual" (Section VI-A) for text and subtitles, "memory" (Section VI-D) for length of the video, and "visual" (Section VI-E) for the region of interest apply as well for screencasts. Other principles found mainly address the needs of people with sensory (visual) deficits. They are listed here for completion purposes.

- Yellow foreground on black background gives the best visibility of text and image objects
- Offering of a variety of voice presentation concerning a

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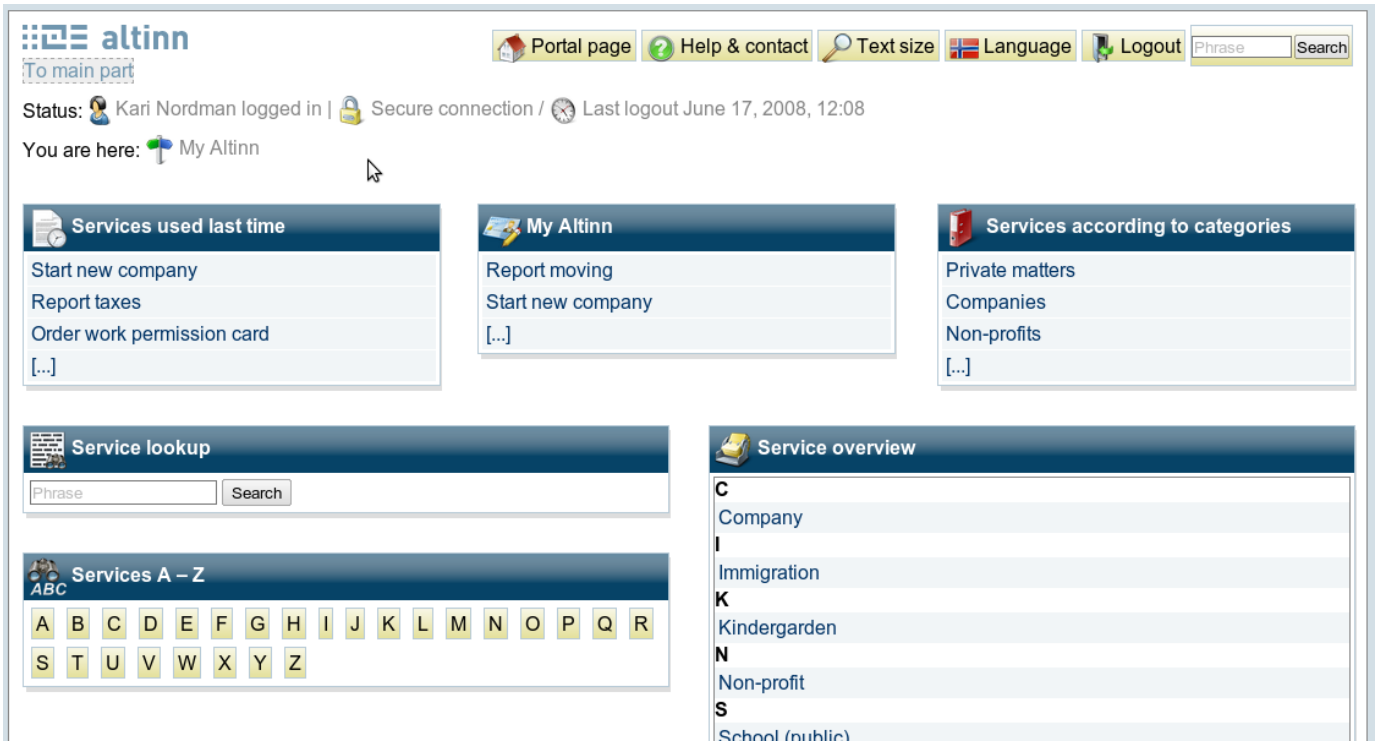

Figure 5. Screenshot of the prototype's personalized "My page"

speaker's gender, pronunciation, and dialect

Another important finding is that the majority of users had problems interacting with the (Flash) media player. I.e., a large number of users was unable to play a video, stop it, replay it if needed, invoke and leave again full-screen mode, etc. One conclusion is that the controls of the media player remain to be hinders in particular for people with cognitive challenges. As the focus of the implementation was on open technologies like international web standards, it has been viewed as outside the scope of the project to modify the proprietary code of Adobe's Flash media player.

X. Discussion

Concerning the development of static and dynamic web pages, the remedy is to consider intellectual impairments throughout the entire design chain for the system to be built, consisting of

- requirements formulation,
- system architecture and design,
- implementation and integration, and
- testing, evaluation, and verification.

The aim must be to build cognitively accessible solutions, to give users the possibility to participate in the technological progress, and to achieve a stronger market impact of the product or service.

Next, the complexity and heterogeneity of the group labelled cognitively impaired must not be underestimated. As we have seen, cognitive impairments can arise in several ways, and they can affect many aspects of human function. However, some impairments affect only some functions, not others. This has consequences for the design of ICT for these groups. We find that our results correspond with [27] who underscores in a survey of the research in the field, that "one size does not fit all". For example, the principle of simplicity can be recommended on a general level, as we know from other research that most users disapprove complex web pages. However, when applied to specific groups in specific contexts, we will find that a feature or interface solution that one user may find simple, would be too difficult for another. Accordingly, we must avoid defining "simplicity" in general terms and instead understand it in terms of the cognitive skills and capabilities of the actual user and user groups.

Likewise, when it comes to practical interface design, "most users do better with wider interfaces, but some may do better with narrower interfaces" [27]. We must therefore be careful in the formulation of design recommendations to account for the diversity all user groups. This is particularly pertinent for the development of universally designed solutions where there must be an increased focus on utilizing the potential for developing flexible, personalized, and customized solutions. Successful solutions of the future must be adapted to the individual needs and capabilities of each single user. Actual accessibility and usability cannot be reduced to specific features and interface affordances. Our list of recommended design principles is hence not exhaustive and must be applied within an appropriate framework that provides individualization and personalization.

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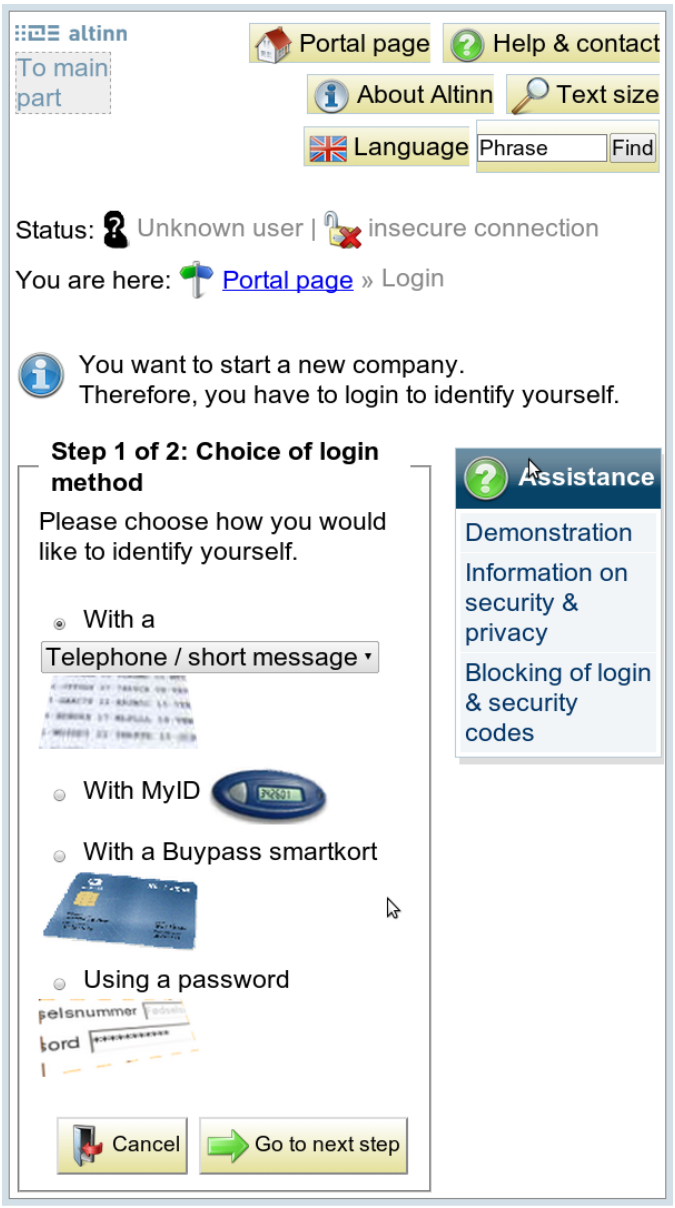

Figure 4. Screenshot of the prototype's login process with narrow page dimensions and a zoom factor of ca. 150%

XI. Conclusion and Outlook

The login process of an existing website has been made more accessible and usable concerning users with intellectual deficiencies, and in particular with linguistic, learning and problem solving, focus and attention span, memory, and visual-comprehension challenges in mind. Additionally, and in contrast to other work, the topic orientation problems has been addressed.

A number of generic accessibility principles was derived for each deficiency, and these principles were implemented in the improved login solution. This work aims hence at basing the heuristics and educated guesses typically given in the literature on concrete examples. The prototype has undergone several iterations with various testing, including personas, experts, and user feedback. The final testing results show that the prototype provides a solution which suits the needs of the target group much better than today's solution.

Concerning future work, future international standards/recommendations should reflect the knowledge about cognitive deficits and technical remedies regarding static and dynamic web pages in their technical recommendations.

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